ABSTRACT THESIS: Rising temperatures cause significant global impacts, which, if not contained in a short time, can lead to serious dangers for the city and its inhabitants, especially in warm temperate climates. In particular, heat islands and heat waves are among the most dangerous extreme phenomena, and different design actions can affect mitigation and adaptation to them differently.
This research identifies strategies and actions that, in the short term, can mitigate the occurrence and impacts of heat waves and islands on the existing residential stock in warm temperate climates, selecting the most efficient and effective ones.
To this end, this thesis is developed with an experimental analytical approach based on a literature analysis and experimentation through simulations. The literature analysis allows for identifying the drivers that have the most significant influence on heat islands and heat waves, how morphology influences the aforementioned phenomena, and the possibilities of formulating a model to summarise their behaviour. On this basis, the author identifies the significant dangers that heat islands and heat waves can bring to the existing stock, the physical indicators that most influence their occurrence, and associates a set of indicators for each danger. Integrated with the literature, the analysis of best practices identifies mitigation and adaptation actions. The association to each hazard of a set of solutions capable of decreasing the onset of the extreme phenomena studied and the selection of the most effective and efficient actions allows the experimental part to be undertaken, where, through simulations with UWG generator, a method is identified for evaluating the effectiveness of the various actions selected. In this way, it is possible to identify the efficiency level as the technology and the morphology of the building change, while keeping the location and climatic conditions constant. Finally, the thesis is verified on three different pilot cases.
The research identifies the main hazards in the city brought by heat islands and heat waves, the actions capable of decreasing the occurrence of each hazard, and the effectiveness and efficiency levels of each technological solution. Furthermore, the thesis studies indoor and outdoor effectiveness and efficiency variations by varying the morphology and keeping the location constant. Finally, this research identifies a method, through the simulation of microclimates with the UWG generator, which can be used in any context to evaluate the effectiveness of individual actions or systems of actions concerning heat islands and heat waves.
This study shows that at the outdoor level, the effectiveness of an action in the exact location, but placed in a morphologically different environment, presents slightly different levels of effectiveness. Conversely, when the location varies, even though it is in the same climatic zone, the level of effectiveness changes strongly. Indoors, effectiveness levels vary strongly depending on morphology, even in the exact location, and are influenced by the composition of buildings.

DOTTORANDO Federica Nava
PhD Pianificazione, Design, Tecnologia dell'Architettura

Innovative and integrated energetic and bioclimatic strategies for adapting existing contexts to climate change and extreme events, aiming to mitigate the environmental impact

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INDEX

PART I LITERATURE REVIEW

CHAPTER 1.0 INTRODUCTION AND FRAMEWORK

p. 15 1.0.1 Research content

p. 18 1.0.2 Identification of thesis topic

p. 20 1.0.3 Research questions and goals

p. 24 1.0.4 Methodology

CHAPTER 1.1 LITERATURE REVIEW

p. 34 1.1.1 Research Background: A global response to climate change. Rising temperatures in warm temperate climates

p. 34 Summary

p. 34 Introduction

p. 35 Method of conducting research

p.36 Data interpretation

p. 40 1.1.2 Heat islands in warm temperate climates

p.40 Summary

p.40 Introduction

p.41 Method of conducting research

p. 46 Analytical summary of the Literature review

p.52 1.1.3 Heat waves in warm temperate climates

p.52 Summary

p.52 Introduction

p.53 Method of conducting research

p.58 Analytical summary of the Literature review

p.64 1.1.4 Microclimate and Urban Morphology

p. 64 Summary

p.65 Introduction

p.66 Method of conducting research

p.68 Analytical summary of the Literature review

p. 74 1.1.5 Simulation models

p.74 Summary

p.74 Introduction

p.76 Materials and method

p.79 Results

p.84 Discussion

p. 87 1.1.6 Research object and definition of urban environmental problems. Adaptation to phenomena due to islands and heat waves

p.87 Summary

p.87 Introduction

p.89 Method of conducting research

p.91 Results and discussion

PART II EXECUTION OF THE RESEARCH

CHAPTER 2 2.1 HAZARDS EVALUATION ON EXISTING STOCK RELATED TO URBAN HEAT ISLANDS AND HEAT WAVES

p.122 Inotrduction

p. 123 2.1.1 Hazards evaluation of existing built stock

p.123 Summary

p. 123 Introduction

p.124 Ways of conducting research

p.132 Results and discussion

p.140 2.1.2 Evaluation of the factors influencing heat island and heat waves

p.140 Summary

p.140 Introduction

p.141 Ways of conducting research

p.146 Conclusions

p.148 2.1.3 Association to each hazard a set of indicators capable of decreasing its occurrence

p.148 Summary

p.148 Introduction

p.149 Way of conducting research

p.156 Discussion and conclusion

p.161 2.1.4 Comfort index

p.161 Summary

p.161 Introduction

p.162 Way of conducting research

p.165 Conclusions

CHAPTER 2.2 TECHNOLOGICAL ANALYSIS AND EVALUATION OF INTEGRATED SOLUTIONS FOR URBAN HEAT ISLAND AND HEAT WAVE ADAPTATION

p.178 2.2.1 Case studies' analysis

p.180 Introduction

p.181 Way of conducting research

p.268 Results and discussion

CHAPTER 2.3 IDENTIFICATION OF ACTIONS FOR ADAPTATION TO HEAT ISLANDS AND HEAT VAWES

p.274 2.3.1 Analysis of the actions

p.274 Summary

p.274 Introduction

p.279 Way of conducting the research

p.404 Results and discussion

CHAPTER 2.4 2.4 CONSTRUCTION OF A MODEL TO DEFINE THE EFFECTIVENESS OF THE SOLUTIONS EXAMINED
p. 432 2.4.1 The UWG model: modules and parameters (identification of morphological parameters, buildings and elements)
p.432 Introduction
p.434 Materials and methodology

PART III OUTCOMES
CHAPTER 3.1 3.1 A SUPPORT TOOL
p.449 3.1.1 Development of a support tool to evaluate the effectiveness
p.450 Introduction
p. 451 Tool construction
p.486 Outlines and conclusions

PART IV EVALUATION OF THE TECHNOLOGIES EFFECTIVENESS ON PILOT CASES

CHAPTER 4.1 4.1 VERIFICATION ON PILOT CASES
p.499 4.1.0 Verification on pilot cases
p.500 Introduction
p.504 Methodology
p.508 4.1.1 The Westside neighborhood, San Antonio, Texas, USA
p.511 Climatic Analysis
p.516 Analysis of services and morphotypes
p.521 Surfaces analysis
p.524 Vegetation Analysis
p.528 Exposition analysis
p.530 Analysis of case studies and individualization of the actions
p.540 Model setting
p.564 Masterplan and results
p.566 4.1.2 The Quarticciolo neighborhood, Rome, Italy
p.566 Contextualisation in the urban fabric
p.571 Climatic analysis
p.574 Welfare and services analysis
p.577 Historical analysis
p.582 Morpho-typological analysis
p.585 Geology and Hydrogeology
p.588 Surface and vegetation analysis
p.594 Exposition analysis
p.596 Similar case studies, SWOT and objective individualization

p.608 Model setting
p.654 Solutions analysed and masterplan
p. 656 4.1.3 The Shuangta neigborhood, Suzhou, China
p.656 Contextualization in the urban fabric
p.661 Climate analysis
p.664 Historical analysis
p.671 Relation between Suzhou's history and the site
p.672 Morpho-typological analysis
p.677 Services analysis
p.677 Surface and vegetation analysis
p.681 Similar case studies, SWOT and objective individualization
p.690 Exposition analysis
p.706 Solutions analysed and masterplan
p.728 4.1.4 Results and discussion

PART V CONCLUSION

CHAPTER 5.1 5.1 RESULTS. CONCLUSIONS AND DISCUSSION
p.740 5.1.1 Results
p.742 5.1.2 Conclusion and discussion
p.742 Conclusions
p.748 Limitations and future developments

PART VI

APPENDIX
A.1 Hazard analysis on the existing residential stock
A.2 Analysis of documentation for the identification of short-term objectives and hazard KPIs
A.3 Symulation setting
Setting part 2
Setting part 3
Setting part 4
Setting part 5
A.4 Data that Ladybug presets

A.5 Glossary
References

PART 1

Introduction and literature review

CHAPTER 1.0

1.0| INTRODUCTION AND FRAMEWORK

ABSTRACT

Rising temperatures cause significant impacts globally, increasing extreme phenomena affecting natural and artificial systems and further exacerbating the effects of climate change. The topic is vast, so this chapter outlines how the research is conducted and is divided into four paragraphs. The first illustrates the general contents, the second the thesis questions, the third the objectives, and the fourth illustrates and explains the workflow and method characterising this research.
In this way, it is possible to understand in which thematic area the thesis is positioned, the disciplinary fields it involves, the gaps in the literature it intends to fill, the innovativeness, the questions it answers, the general and specific objectives and the method by which this research is carried out.
The importance of this initial part lies in framing the thesis in specific areas, questions, and objectives to make its innovativeness and the coherence of its steps explicit. These, in particular, are set out in paragraph four, which illustrates the methodology and contains a workflow where the locations in the chapters of the individual parts that make up the research are explicit. The paragraph on methodology only illustrates the logical steps, which are explained in more detail each time. To show a clearer congruence, a small summary workflow is repeated at the beginning of each chapter, highlighting the specific points that the chapter deals with and the outcomes. The method is always straightforward.
This research should be read as one of the results born from the author's work and research experiences at the D*epartment of Planning Design and Architecture Technology,* section of *Environmental Technological Design,* at the *University of Rome' la Sapienza'*, at the *School of Architecture and Planning at the University of Texas at San Antonio,* at the *Research Laboratory GSA (Geometry Structure Architecture) ENSA Paris Malaquais* and at the *School of Design of Xi'an Jiaotong-Liverpool University,* where the author was hosted as a visiting PhD student.

Innovative and integrated energetic and bioclimatic strategies for adapting existing contexts to climate change and extreme events, aiming to mitigate the environmental impact
p. 14

1.0.1|Research content

The thesis title is: "*Innovative and Integrated Bioclimatic and Energy Strategies for Adapting Existing Contexts to Climate Change and Extreme Events to Mitigate the Environmental Impact.*"
Its aims include elaborating decarbonisation strategies and actions to mitigate urban heat island phenomena and ensure the adaptation of the existing context in warm temperate climates to extreme events related to increasing temperatures—heatwaves and urban heat islands. The thesis objects are the existing, consolidated neighbourhoods (at a larger scale) and existing buildings (at a smaller scale).
The central theme of the thesis belongs to the Technology of Architecture (disciplinary sector CEAR-08/C) but also presents interdisciplinary exchanges with the existing context's topic (disciplinary sector CEAR-11/B) and with engineering sectors such as Systems for Energy and Environment (disciplinary sector IIND-06/B) and with Technical Environmental Physics (disciplinary sector IIND-07/B). These interdisciplinary exchanges have led to numerous research projects and publications during the PhD.
The thesis research is aimed at researchers, professionals, and public administrations. It offers decision-making support for adapting to climate change and mitigating the impact of extreme events on urban and peri-urban areas, which is concerned with the UN's 2030 targets.
The innovative thesis' elements focus on the time responsiveness that actions and project strategies must respect according to the European Commission's 2030 objectives: producing 27% of energy from renewable sources and reducing greenhouse gas emissions (Kutty et al., 2023) and carbon neutrality in 2050. Payback times have a strong influence on stakeholders' decisions and the effectiveness of the solutions themselves. Another element of originality consists in the integrated definition of bioclimatic and energy solutions, taking only the extreme phenomena linked to the increase in temperature in warm temperate climate zones as the field of interest. In particular, the phenomena investigated con-

sist of the widespread rise in average temperatures, the heat wave phenomenon, and heat islands in the city. Finally, the analysis and subsequent application on a global level, through application cases located in different parts of the world, thus considering different building strategies and history but similar climatic situations and risks, constitutes a further original element of the thesis.
The work is divided into four parts, which are strongly interconnected from a logical-methodological point of view but can also be consulted separately.
The first part of the research is analytical and is represented by Chapter 1.0, "Introduction and Framework", and Chapter 1.1 ", Literature Review". This part provides a framework of reference in national and international contexts.
Paragraphs 1.1.2 and 1.1.3 describe the actions taken and a specific framework of risks and vulnerabilities arising from the extreme phenomena under consideration.
Paragraph 1.1.4 illustrates the relation between the climate and the context.
Paragraph 1.1.5 includes a panoramic view of the most important tools for simulating the impact of climatic conditions on the urban context. It illustrates the research's objective and urban problems related to global warming.
Chapters 2.1, 2.2, 2.3, and 2.4 articulate the second part of the thesis. Chapter 2.1 illustrates hazards related to urban heat islands and heat waves that could affect existing stock, the main KPI about these phenomena, and the association of each hazard with a set of KPIs that can affect it. Chapter 2.2 consists of a literature review of the technologies used in best practices – existing neighbourhoods affected by urban heat islands during the hottest period of the year and heat waves. Chapter 2.3 analyses the technologies and actions found in the case studies and the literature review, qualitatively evaluating the time of responsiveness and their effectiveness. Finally, chapter 2.4 elaborates on a tool to assess quantitatively the effectiveness of the previously analysed technologies. The international case studies identify solutions and best practices from urban districts that, after requalification, increase energy efficiency and bioclimatic response. This work is preparatory to the third part. Chapter 3.1 utilises a UWG model to simulate microclimates and evaluate KPIs. The fourth part consists of verifying the focused technologies through three pilot cases located in three different world regions, in places with the same climate zone. These

paragraphs consist of the experimental application of active and passive solutions in the urban context on three case studies represented by consolidated neighbourhoods located in three different parts of the world in the same climate zone: the Westside, a neighbourhood located in the city of San Antonio, in the United States (TX), in Shuangta, Souzhou in China and Quarticciolo, in Italy.

1.0.2| Identification of thesis topic

Anthropogenic greenhouse gas emissions caused significant global impacts, including an increased greenhouse effect, climatic changes, and increased toxic substances in the air. These caused an average temperature increase of about 1.0 °C compared to pre-industrial levels. Anthropogenic global warming is estimated to grow by 0.2°C per decade, caused by past and current emissions that the atmosphere has failed to absorb. (Intergovernmental Panel of Climate Change -IPCC-, 2023).
A temperature rise is considered 'Unsafe' as it leads to an increase in sea level, rate, and peak warming, causing extreme phenomena such as heat islands and heat waves, loss of biodiversity and resources, increased vulnerability, heavy rainfall and drought, and risks to health, livelihoods and food security (Intergovernmental Panel of Climate Change -IPCC-, 2023).
Although emissions of climate-altering gases have been reduced by 32% from 1990 levels by the end of 2020, this is not enough to stop the rise in temperatures, as the speed at which the atmosphere and earth absorb climate-altering gases is slower than the speed of emissions. Warming due to anthropogenic emissions from the pre-industrial period will persist for centuries or millennia. It will continue to cause further long-term changes in the climate system (Environmental Energy Agency -EEA-, 2022; Intergovernmental Panel of Climate Change -IPCC-, 2023). In terms of energy efficiency, the EU also succeeded. The COVID-19 pandemic played an essential role: lockdowns, travel restrictions, and the closing of national borders led to a drastic but temporary 5% decrease in consumption by 2021. To achieve the target of a 55% reduction by 2030, compared to 1990 levels, it is necessary to decrease 134 $MtCO_2$ per year (Environmental Energy Agency -EEA-, 2022, p. 18).
On the other hand, in the renewable energy sector, the EU reached a level of 22% utilisation. The most significant shares are in electricity consumption and, to a lesser extent, in heating and cooling. The current target for 2030 is to exploit 32% of energy sources

from renewables (Environmental Energy Agency -EEA-, 2022, p. 18).

As cities are responsible for almost 75 % of global consumption, action should be taken to mitigate consumption and increase adaptation (Environmental Energy Agency -EEA-, 2022, p. 12). Furthermore, long-term population flow trends show that cities will be home to an ever higher proportion of the world's population in the future, increasing energy demand and soil consumption (Fondazione per lo Sviluppo Sostenibile; Ecomondo; Stati Generali della Green Economy, 2004; World Economic Forum, 2022, p. 3). Today, soil is a limited and valuable resource as it is the basis for producing food, fuels, and fibres. Soil sealing is the leading cause of degradation in Europe because it increases the risk of flooding, contributes to climate change, causes the loss of agricultural and fertile land and natural and semi-natural areas, and contributes to the destruction of the landscape. In addition to losing productive functions, soil sealing wipes out the soil's ability to absorb CO_2, impacting biodiversity and social enjoyment (European Commission, 2013). Soil contains embedded carbon: by carrying out new construction, thus removing the surface layer of the soil, part of the organic carbon stock is released as a greenhouse gas due to mineralisation (European Commission, 2013). For these reasons, the thesis focuses on existing stock. As Losasso says in his book *Architettura, Città e territorio verso la Green Economy,* ‹‹Mass retrofitting applied to the existing building stock is a valid opportunity to integrate technical and design, active and passive solutions, in a multi-scalar (building-neighbourhood-city) perspective, to reduce environmental impacts during the life of buildings. Intervening with retrofitting actions allows local energy generation from renewable sources, energy demand management (through monitoring systems and intuitive user interfaces), distribution and exchange between prosumers through Smart grids, and local collaboration mechanisms (such as recovering waste heat from production and tertiary activities to meet residential thermal needs)›› (Losasso, Davoli, & Leone, 2017).

Table I: Thesis questions

1.0.3| Research questions and goals

Table 1 explicates the thesis questions. They are divided into questions whose answer depends on a study of the literature as the identification of actions and systems of actions that enable effective, short-term intervention on the existing in warm temperate climates to cope with heat waves and heat islands and others whose answer presupposes a more experimental development-such as the search for a mode of intervention in bioclimatic and energy to adapt the existing consolidated residential stock to rising temperatures and mitigate their impacts in warm temperate climates; such as the identification of the most beneficial actions according to the time-effectiveness of the response.

Literature	What actions and systems enable **effective, short-term intervention** in existing, warm temperate climates to cope with heat waves and heat islands?	
Experimental development	**How** can bioclimatic and energy interventions adapt the consolidated residential landscape to rising temperatures and mitigate their impacts in warm temperate climates	**How** do we select technologies according to the **time/response effectiveness ratio?**

Table I.

The research aims to provide a framework for responding to heat waves and heat islands in a climate change context.
Specific objectives consist of:

- Developing strategies, systems, and actions in the bioclimatic and energy fields to adapt the existing and established residential stock to extreme phenomena due to increased temperatures in warm temperate climates.
- The definition of an analytical and methodological framework that can provide bioclimatic and energy strategies, systems,

actions, and devices to mitigate and adapt the existing consolidated residential stock to extreme events due to rising temperatures in warm temperate climates, with short response times that can meet the goals of the 2030 agenda.

The body of the thesis is divided into two parts: the first consists of a literature review on the topics covered in the research, and the second combines information to answer the elaborated questions. In particular, a state-of-the-art analysis of the hazards brought by rising temperatures, heat islands and heat waves is necessary to answer the first and second questions. In this way, it is possible to identify the risks of the city 1.1.1. Par 1.1.2 and 1.1.3 provide a greater understanding of the attended phenomena. Studying extreme phenomena allows their decomposition into main drivers and factors causing urban heat islands and heat waves. From this, it is possible to derive the physical parameters that significantly influence the decrease of the extreme phenomena, par 2.2.1. In parallel, the analysis of best practices, par. 2.2 - existing highly energy-intensive neighbourhoods that, as a result of redevelopment measures, have decreased energy demand, increased the level of adaptation to urban heat islands and heat waves, and mitigated the occurrence of the latter - provide a picture of the actions taken, which integrated with the literature analysis, allows the development of a system of strategies and technologies for mitigation and adaptation to islands and heat waves. The analysis of each technology, par. 2.3.1 provides insight into the modes of operation, areas of application, parameters on which the technologies most affect, response times, level of maintenance required, and installation times. This analysis allows answering the third question qualitatively, par. 2.3.2. The identification of a system of microclimate simulation and environmental analysis allows the identification of a way to evaluate the effectiveness of actions, providing qualitative-quantitative information, par. 1.1.5, 2.4.1, 3.1, and associating with each hazard a set of indicators that most affect it, par. 2.1.3. Verification of the results obtained on pilot cases allows further validation, chap. 4.

The outcomes of this thesis consist of defining the KPIs that affect islands and heat waves. Another outcome is identifying possible hazards on existing stock due to urban heat islands and heat waves. The thesis also defines sets of the most effective and efficient indicators and actions against the hazards found in cities and identifies a list of best practices. Developing a framework for identifying action sets for mitigating and adapting to urban heat islands and heat waves represents another outcome.

Figure 1.

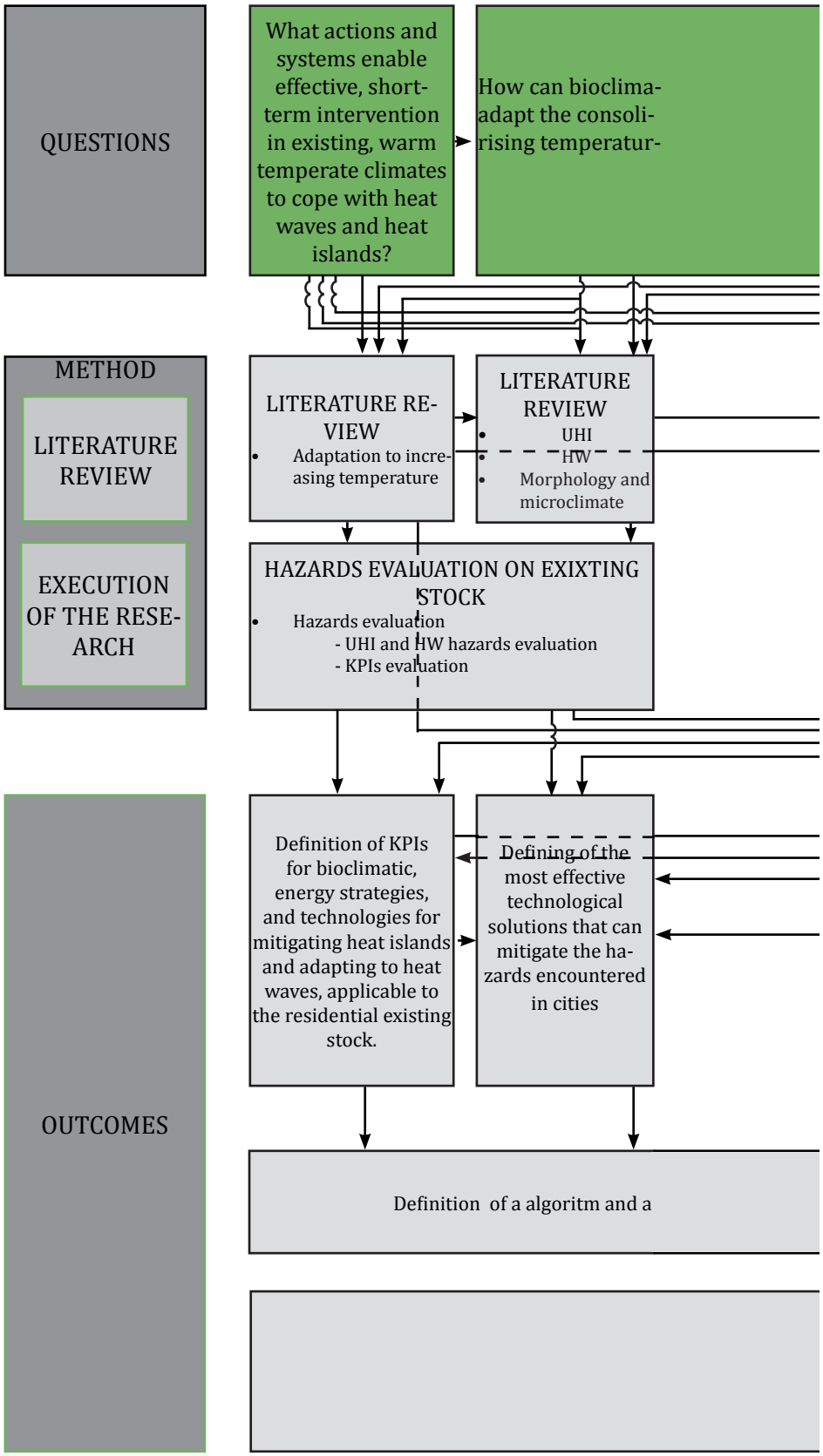
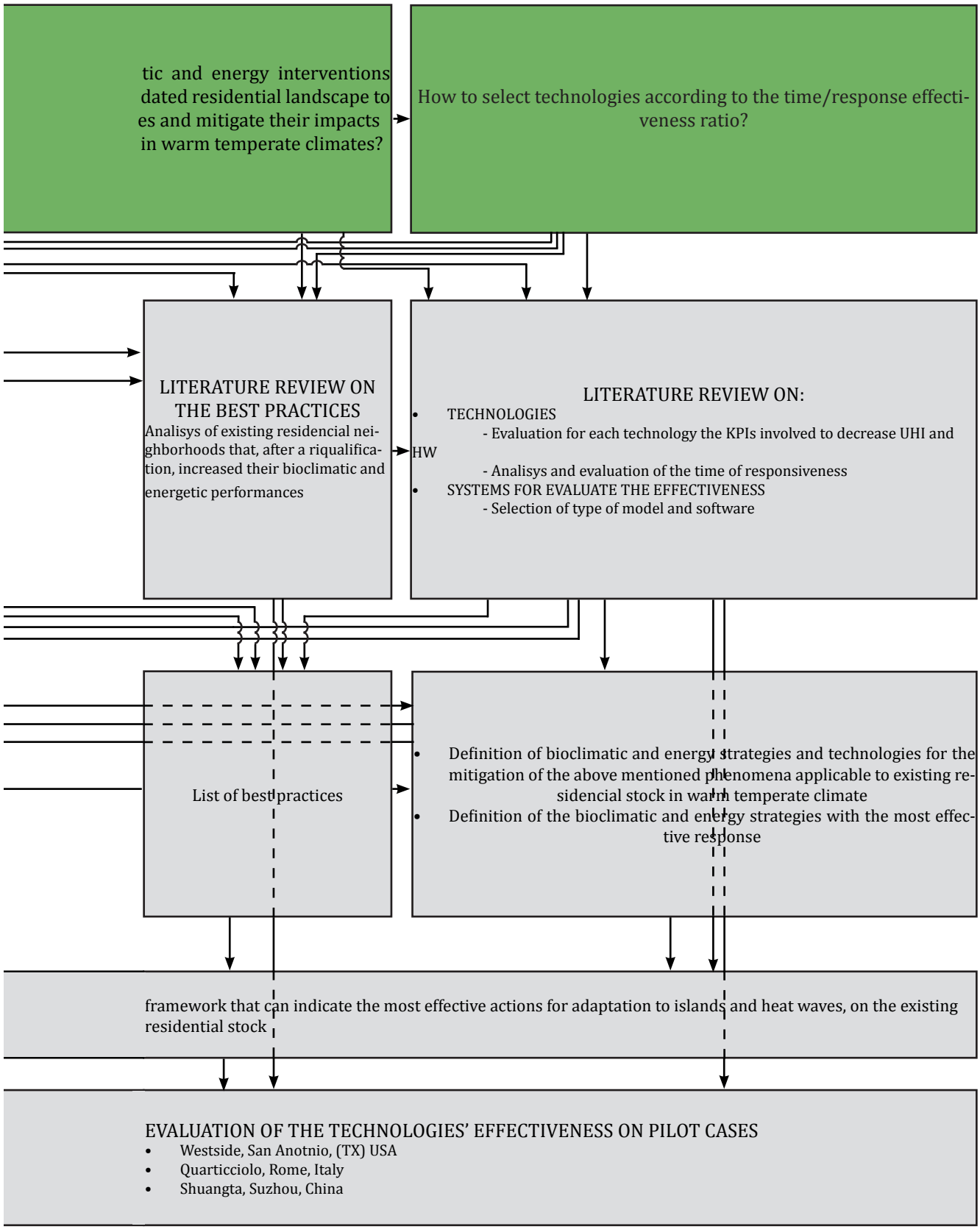


Figure 1. The matrix is the basis of this thesis's development methodology. Author's elaboration


tic and energy interventions
dated residential landscape to
es and mitigate their impacts
in warm temperate climates?
How to select technologies according to the time/response effecti-
veness ratio?
LITERATURE REVIEW ON
THE BEST PRACTICES
Analisys of existing residencial nei-
ghborhoods that, after a riqualifica-
tion, increased their bioclimatic and
energetic performances
LITERATURE REVIEW ON:
TECHNOLOGIES
- Evaluation for each technology the KPIs involved to decrease UHI and
HW
- Analisys and evaluation of the time of responsiveness
SYSTEMS FOR EVALUATE THE EFFECTIVENESS
- Selection of type of model and software
List of best practices
Definition of bioclimatic and energy strategies and technologies for the
mitigation of the above mentioned phenomena applicable to existing re-
sidencial stock in warm temperate climate
Definition of the bioclimatic and energy strategies with the most effec-
tive response
framework that can indicate the most effective actions for adaptation to islands and heat waves, on the existing
residential stock
EVALUATION OF THE TECHNOLOGIES' EFFECTIVENESS ON PILOT CASES
Westside, San Anotnio, (TX) USA
Quarticciolo, Rome, Italy
Shuangta, Suzhou, China

1.0.4| Methodology:

Methodology.

The author approached the problem based on the widely used definition of risk as the product of vulnerability, exposure and hazard (Intergovernmental Panel of Climate Change -IPCC-, 2023). A hazard is defined as any condition that can lead to harm. Exposure refers to any condition that increases the probability of a hazardous condition occurring, while vulnerability, in this thesis, refers to the ability of the built environment to respond to hazards. From an analysis of heat islands and heat waves, the author derived the significant hazards in the city and the indicators that have the most significant influence on the phenomenon. In parallel, an analysis of best practices identifies strategies and actions to decrease vulnerability to heat islands and heat waves. The literature and case studies are necessary for deriving a set of actions and technologies. Thanks to these, it is possible to identify the most effective technologies which greatly influence mitigation and adaptation to extreme phenomena at urban and building levels. The author then associates each hazard with actions that can decrease its occurrence by acting on the indicators. A study on the available assessment methods to assess efficiency allows the development of a framework for selecting the most effective and fastest actions to mitigate and adapt the existing UHI and HW. Finally, the author tests the proposed framework on three pilot cases.
The first phase includes the literature review, which forms the basis for the subsequent phases. The literature review focuses on rising temperatures in warm temperate climates, heat islands during warm periods of the year - when this phenomenon can have the most important impacts - and heat waves, in warm temperate climates. The object of the research and the functioning of extreme phenomena are explained here.
Following the study of the phenomenon, Chapter 1.1.4 analyses how islands and heat waves affect the existing stock. The parameters of the influence of the existing stock on the extreme phenomena considered are made explicit here.
Step 1.1.5 involves analysing tools for evaluating the effectiveness

of various actions in consolidated cities. This chapter examines the available tools through a literature review, including analysing and comparing various software.
Then, step 1.1.6 individualises, based on the literature, energy and bioclimatic strategies as the most effective ways to reduce the influence of UW and UHI in the existing residential stock.
The second phase represents the development of the research, and it is divided into four sub-phases:
Interpreting the literature review on extreme phenomena related to rising temperatures on the existing residential stock.
This phase consists of three steps: an evaluation of the hazards on the existing stock, the extrapolation of indicators found in the previous chapter, which can diminish their occurrence, and Chapter 2.1.1. 2.1.2 and 2.1.3. Step 2.2 analyses best practices: For this purpose, existing neighbourhoods that present problems of heat islands and heat waves and which, following redevelopment, have mitigated the effects and occurrence of extreme heat islands and heat wave phenomena are selected. In Chapter 2.3.1, the research collects actions applicable to the existing built stock. Technologies presented in best practices and others from the literature review are used. In this way, the author individuates various bioclimatic and energy actions that decrease the occurrence and strength of the extreme phenomena considered. This part is divided into two further sub-phases that characterise the better technologies. Chapter 2.3.1 deals with analysing actions. In particular, installation, return period, decommissioning, and maintenance times are made explicit.
The various technologies are selected according to their effectiveness in indoor and outdoor environments based on the previous literature review on bioclimatic and energy actions that can decrease extreme urban heat islands and the incidence of heat wave phenomena.
At this stage, a set of technologies that can decrease the probability of occurrence is individualised for each hazard. Then, four technological solutions are identified as the most effective. Their effectiveness is then simulated by forming a model that evaluates the key performance indicators under initial conditions, without any technology, and one following the application of the identified technologies, outdoors and indoors.
Step 2.4 aims to develop a model that represents the microclimate,

simplifying the complexity of the relationship between urban heat islands, heat waves, and the existing residential stock. The model's composition aligns with the literature review part—step 1.1.5. A comparison of the different models shows that Ladybug Tools, as a Grasshopper plug-in, is the best for this research. Ladybug Tools is a collection of open-source software for environmental design.
Although these plug-ins are directly connected to Grasshopper, they can also communicate with AutoCAD, GIS, or other simulation engines. Ladybug allows studies on solar radiation, time of day, and comfort. This software is based on creating a 'sky matrix' file consisting of geographical location, time zone, data from a weather station, and hourly diffuse and direct radiation values. On this basis, the model is built, adding buildings and vegetation-characterising materials (Evola et al., 2020; Bazafkan, 2017; Giannelli et al., 2022; McNeel et al., 2010). As a parametric plug-in, it allows users to customise workflows for specific design problems and evaluate the effects of multiple parameters, such as geometries, material properties, climates and urban form, quickly and iteratively within a familiar design platform and at a scale not possible in empirical/physical studies. This characteristic is essential to develop strong feedback in the design process and link data to design. The study showed that the Ladybug Tool is a valid method to simulate temperature, relative humidity, UTCI comfort index, and indoor and outdoor mean radiant temperature in the early stages of the design process, where quick feedback is essential. The tool has been validated by numerous studies, including (Elrefai & Nikolopoulou, 2023; Elwy et al., 2018; Evola et al., 2020; Lopez-Cabeza et al., 2022). In particular, experiments in Basel (Switzerland), Toulouse (France), and Singapore validated the UWG calculation model used in this thesis. (Bueno, Norford, Hidalgo, & Pigeon, 2013; Bueno, Roth, Norford, & Li, 2014; Rotach, et al., 2005; Street, Reinhart, Norford, & Ochsendorf, 2013; Masson, et al., 2008; Salvati, La città contemporanea in clima mediterraneo: isola di calore, morfologia e sostenibilità, 2016). Step 3 consists of evaluating the effectiveness of the technologies selected in step 2.3 by using the UWG calculation and controlling how it changes, changing the morphology and the urban conditions.
Phase 4 concerns the verification of three pilot cases. In particular, the three neighbourhoods analysed, according to Wladimir Köppen's classification (see section 1.1.1), enjoy the same climatic conditions.

Following the assessment of effectiveness as morphology varies within the same climate zone (section 2.4), it is noteworthy to observe the varying effectiveness values achieved by the actions in the presence of different techniques, historical architectural elements, and minor climatic differences. Despite these differences, the three neighbourhoods share aspects in common that make them comparable, such as the same climate zone, the affordable and popular housing that characterises them, and the period of construction, which spans between 1800 and 1900.

As can be seen from Fig. 2, each chapter represents a necessary step to elaborating the various outcomes—the key performance indicators, the best practices, the matrix of adaptation to the dangers posed by islands and heat waves on cities, the most effective technologies, pilot cases—and the tool, the final output of the research.

Figure 2.

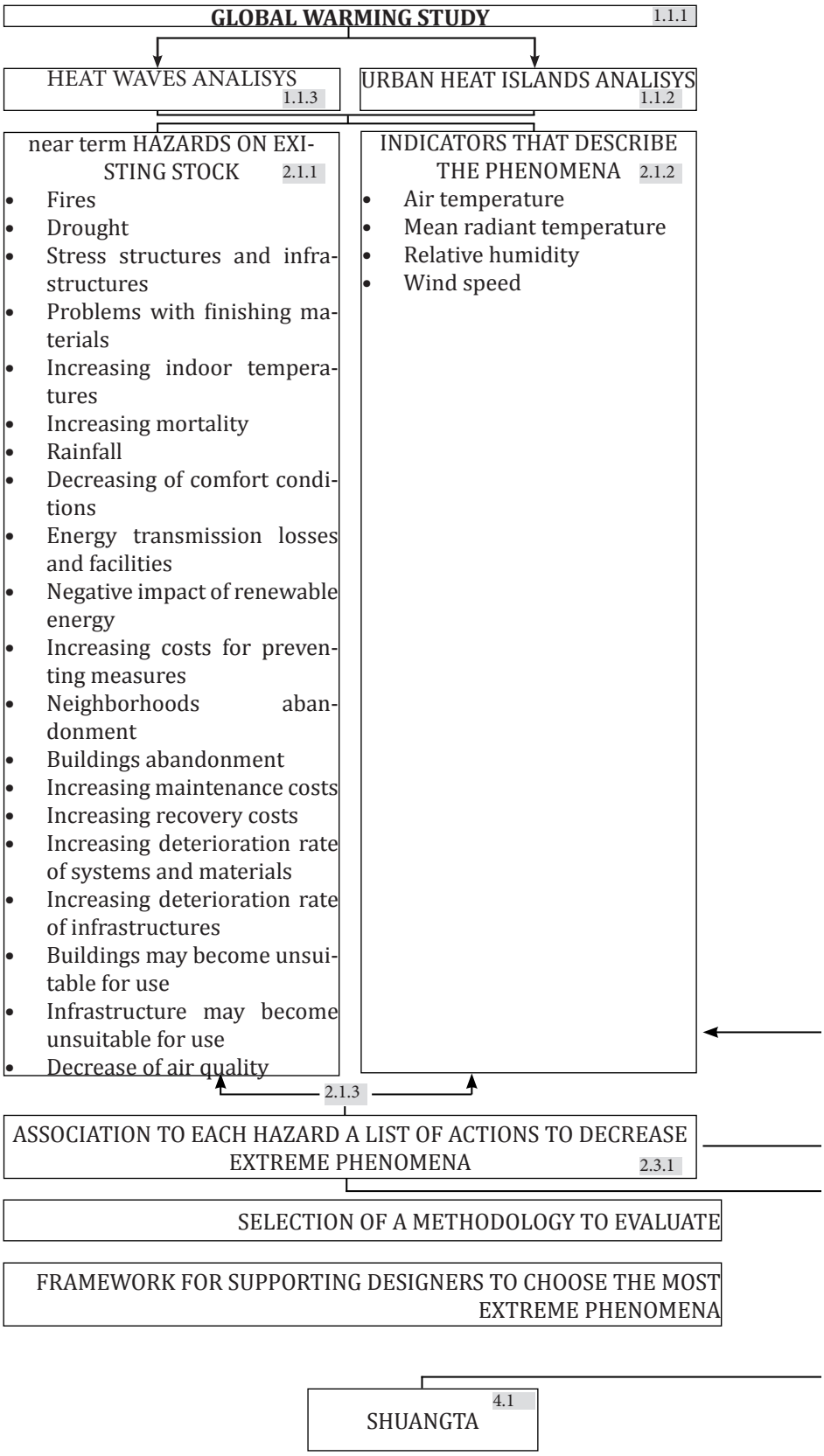
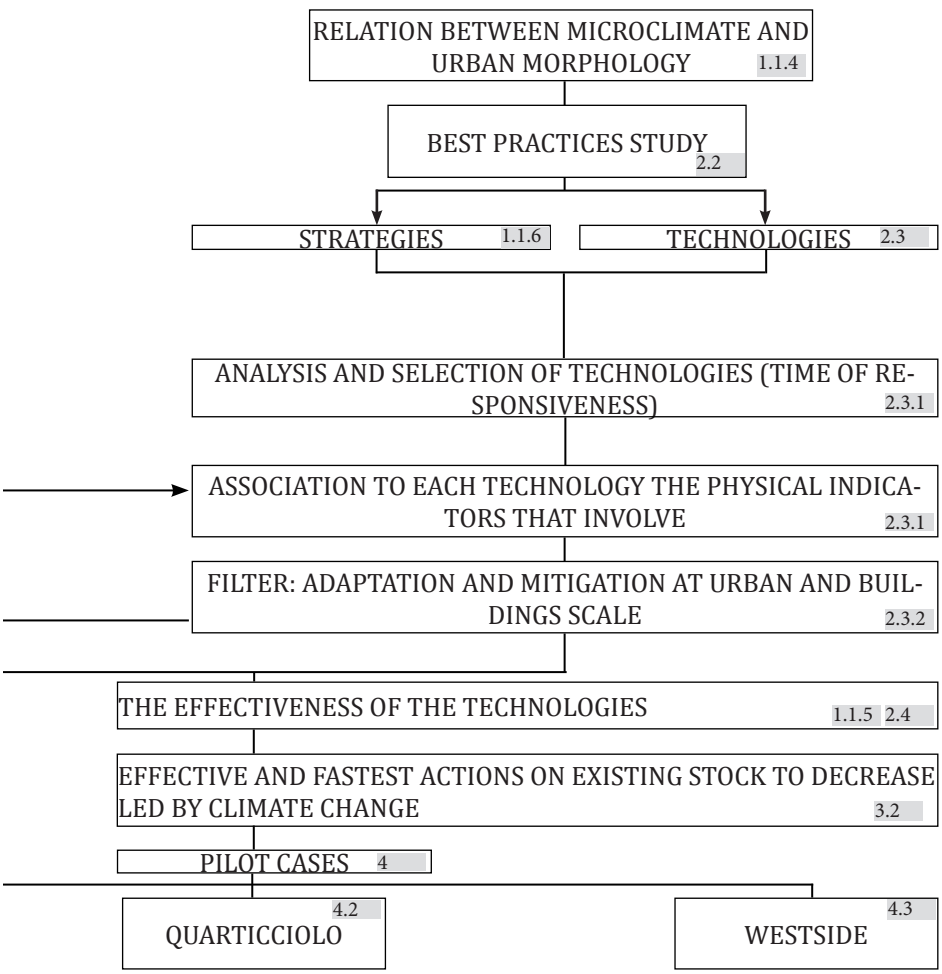


Figure 2. Thesis workflow: The parts within the boxes represent the parts of the research where a literature review was carried out, while those within the rhombuses represent a part of the research where previously found data is reworked. The numbers in grey refer to the chapters of the thesis. Author's elaboration

THESIS WORKFLOW



1.0.5| References:

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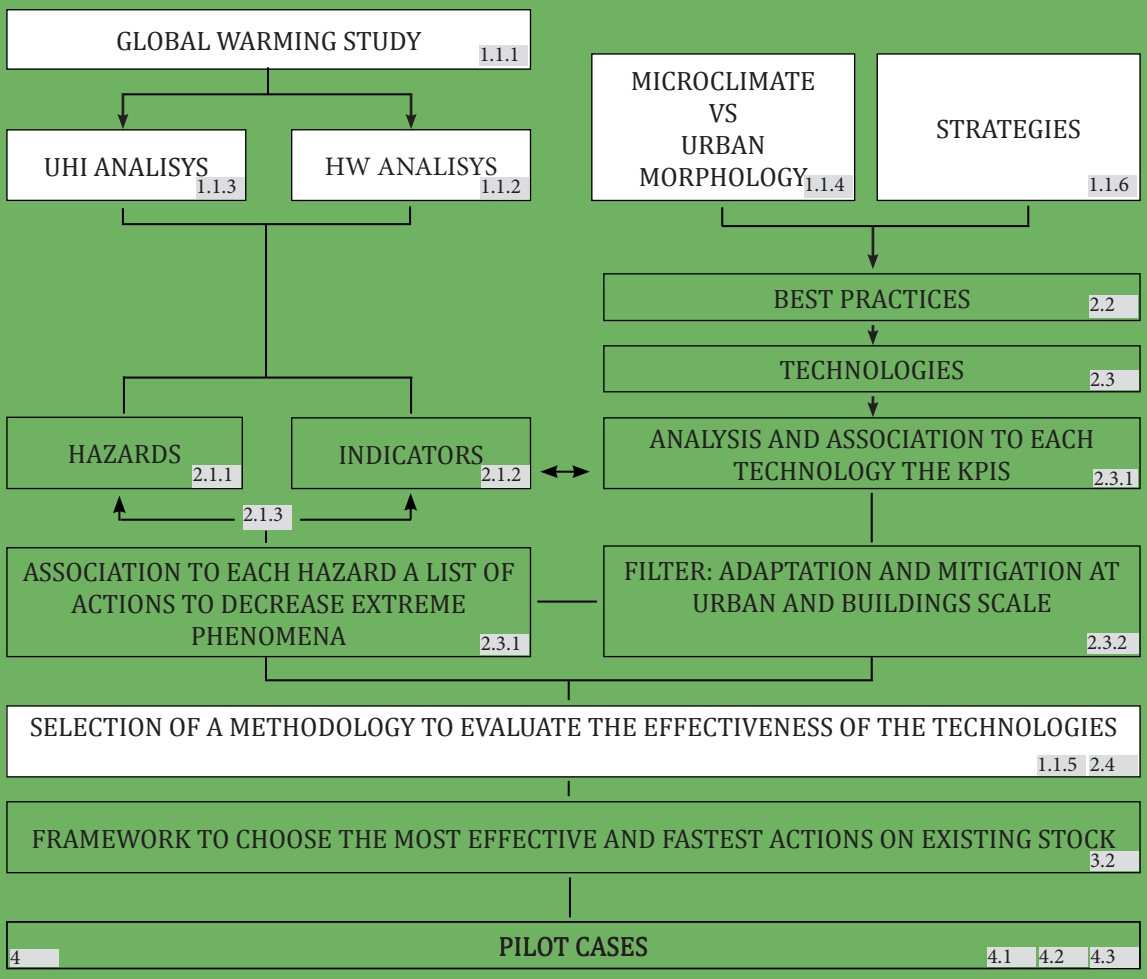
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CHAPTER 1.1

1.1| LITERATURE REVIEW

ABSTRACT
The research aims to identify the most effective and efficient strategies to cope with heat islands and heat waves on the existing residential stock. Different and complex topics are analysed: islands and heat waves, urban morphology, the approach and strategies to adapt the existing built environment and mitigate the causes, and the best tools to evaluate the effectiveness of the actions. For this reason, the chapter is divided into thematic paragraphs and for each topic considered, develops a literature review that represents the basis of the research.
The research approach is analytical: for each topic, a literature review is carried out and lays the foundations for the execution phase, which corresponds to parts 2 and 3 of the thesis. The narrative literature reviews start with skimming documents from various search platforms, such as Scopus and Science Direct. The selection is expanded by adding texts, articles, and conference proceedings studied in other research but relevant to the topics in question.
The literature review chapter is divided into the following paragraphs: the first analyses the global phenomenon of rising temperatures and demonstrates, based on the scientific literature, that heat islands and heat waves are among the most dangerous extreme phenomena for existing buildings. The second and third sections analyse the extreme phenomena of islands and heat waves, identifying their definition, behaviour and characteristics. The fourth analysis examines how urban morphology influences the phenomena above and illustrates various indices contributing to understanding the impact. The fifth part aims to identify the best tool for evaluating effectiveness within a built fabric. Based on the literature, the last section of the chapter demonstrates that the best methods for mitigation and adaptation to heat islands and heat waves are using energy efficiency and bioclimatic strategies. The variety of topics involves different areas that are sometimes outside architecture, such as climatology. This has been not easy, as understanding the phenomenon has taken a long time. Despite this, analysing existing literature makes it possible to identify and develop an unambiguous theoretical framework, bringing together different perspectives, theories and models.
The analysis shows that the extreme phenomena considered are very complex and that heat waves, in particular, depend mainly on climatic phenomena and natural cycles, which are difficult for man to control in the short-time, and to a smaller extent on land use, on which man can intervene. In contrast, humans can more easily manage the causes of increased urban heat waves. Through the use of energy efficiency and bioclimatic strategies, it is possible to control their effects and mitigate their triggers. Urban morphology and land use play a key role in this. In particular, professionals and researchers can use various simulation tools to identify the most effective actions, and the Ladybug tool is among the best.

KEYPLAN



Outcomes of this chapter:

Provide a solid **basis** on which to set up the research. In particular, the literature review aims to:

- Identify the **most dangerous phenomena and risks** related to rising temperatures on existing built stock (1.1.1)
- Explain the major causes of the occurrence or increase of **heat islands and heat waves** (1.1.2, 1.1.3)
- Understand the relationships between **microclimate and urban morphology** (1.1.4)
- Investigate what is the best **tool for evaluating the effectiveness** of technologies (1.1.5)
- Investigate what are the **best ways to mitigate and adapt** the existing built stock to heat islands and heat waves (1.1.6)

1.1.1| Research Background: A global response to climate change. Rising temperatures in warm temperate climates.

Summary.

Global warming brings numerous environmental and human hazards, making it necessary to take early action on the existing stock. This section aims to understand the most dangerous extreme phenomena linked to rising temperatures in warm temperate climates concerning the existing residential stock.
The approach consists of a literature review of warming temperatures, contextualised in warm temperate climates and the possible extreme phenomena.
This work specifically outlined the characteristics and risks associated with rising temperatures in warm temperate climates by highlighting the significant extreme phenomena that rising temperatures can bring.

Introduction.

To date, one of the most critical global challenges is to find solutions to the environmental climate crisis. The IPCC (International Panel on Climate Change) found that human activities cause an average temperature increase of about 1.0 °C and continue to rise, reaching a 1.5 °C increase. Rising temperatures are causing severe global climate imbalances with a consequent change in climates and habitats: territories that were previously considered to enjoy warm temperate climates, such as the entire Mediterranean belt, are becoming warmer and warmer, posing serious risks to natural and anthropogenic systems (Intergovernmental Panel of Climate Change -IPCC-, 2023). In particular, the warm temperate belt, which has always been the cradle of civilisation, will undergo enormous changes and heavy impacts. The territories with this type of climate can be identified through the climate classification formulated by Wladimir Köppen, later updated by his collaborators and successors, as it is still widely used in various areas. Over

the years, the map has been modified due to ongoing temperature changes and the increased sensitivity of detectors[1].
In this context of climate change, anthropogenic global warming plays a key role: it is increasing by 0.2 °C per decade. Reversing the upward trend in emissions is impossible: climate-altering gases take time to be absorbed by the ecosystem, which is less fast than the rate at which harmful gases are emitted, despite efforts by today's governments to decrease their production. Therefore, speed and action in the short term are paramount in combating the rise in global temperature.
According to the Global Risks Perception survey, carried out by the World Economic Forum, the risk most likely to occur according to participants' perceptions is caused by extreme weather conditions (as many as 66% of voters said that) (World Economic Forum -WEF-, 2024)[2]. When asked to estimate the severity of impact after two years, extreme events related to rising temperatures take second place. At ten years, they again take first place, followed by a critical change to earth systems, biodiversity loss, ecosystem collapse and natural resource shortage, all of which are risks that are nonetheless related to climate change. In its 2023 climate change report, the IPCC identified the short-term hazards and risks of rising temperatures.
This part of the research aims to better understand the problems and consequences by identifying connections and interconnections between hazards associated with rising temperatures in warm temperate climates and inhabited settings.

Method of conducting research.

This part aims to define hazards produced by rising temperatures in population centres. The research methodology is divided into two phases: the first phase consists of a narrative analysis of the literature on hazards related to rising temperatures. In the second phase, connections and interconnections are identified, along with the various hazards found, and schematised graphically.

In the first phase, research is carried out on the dangers of climate change to the environment. The reports of the most important organisations, such as the IPCC (International Energy Agency), EEA (European Environmental Agency), IEA (International Energy

1. For example, Cfa or Csa marked territories are mostly a part of the Italian peninsula. The first letter, "C," refers to temperature and indicates a warm temperate climate, where the temperature of the hottest month is consistently above 10°C and the temperature of the coldest month is consistently below 18°C.
The second letter refers to precipitation. In this case, the "f" indicates the absence of a dry period. Other classifications disagree with this approach and indicate Italy as a summer drought period (Peel et al., 2007). The last reading, "a," indicates a very high temperature in the summer season, which is consistently above 22 °C.

2. The Global Risks Perception Survey (GRPS) has been conducted for nearly two decades and is the World Economic Forum's primary source of global risk data. This year's GRPS collected the most important views on the evolving global risk landscape from 1,490 experts from academia, business, government, the international community, and civil society. "Global risk" refers to the possibility of an event or condition that would negatively impact a significant portion of global GDP, population or natural resources if it were to occur.

Agency), WEF (World Economic Forum), and WMO (World Meteorological Organisation), are analysed. Scientific articles and conference proceedings are also analysed to ensure relevance. In this sense, documents in English and Italian are selected on the Scopus and Science Direct platform that had among their keywords' temperature increase', 'effects', ' global warming', ' extreme events', ' existing neighbourhoods' and their combinations. Skimming the specifically analysed documents is carried out by reading the abstracts and the entire texts.
The second phase involves analysing the documentation and reflecting on connections and interconnections between the various hazards. Following this analysis, a summary chart enabled an understanding of which phenomena are driving forces.

Data interpretation.

The detected risks scheme (Fig. 3) shows a deep interdependence between causes and effects. From this interpretation of the data, derived from the study and analysis of climate change reports such as the (Intergovernmental Panel of Climate Change -IPCC-, 2023) and IEA (International Energy Agency -IEA-, 2022), it emerges that some phenomena cause more hazards than others: in particular, heat islands and heat waves are among the phenomena that lead to more hazardous effects on humans and the environment. Heat islands, which in the winter period increase the feeling of comfort within cities (D'Olimpio, 2023), in summer cause increased vulnerability, dryness of the land, droughts, risks to human health, increased risk of wildfires, loss of biodiversity, and decreased welfare levels. Likewise, heat waves are also hazardous because they contribute to rising sea levels, a general decrease in development levels, a general increase in vulnerability for natural and artificial systems, heavy rainfall or drought events, loss of biodiversity, risks to human health, and increased risk of wildfires. Increased pollutants are also a hazardous phenomenon, leading to increased levels of vulnerability for natural and anthropogenic systems, bringing serious risks to human health. Finally, the melting of glaciers by rising temperatures is causing sea levels to rise, resulting in a loss of coastal resources. This means the loss of many sea-facing population centres, many types of habitats and

animal and plant species, and the loss of usable land. The literature shows various hazards due to islands and heat waves. The following paragraphs of the research focus on these phenomena to investigate their leading causes and how they influence population centres.

Figure 3.

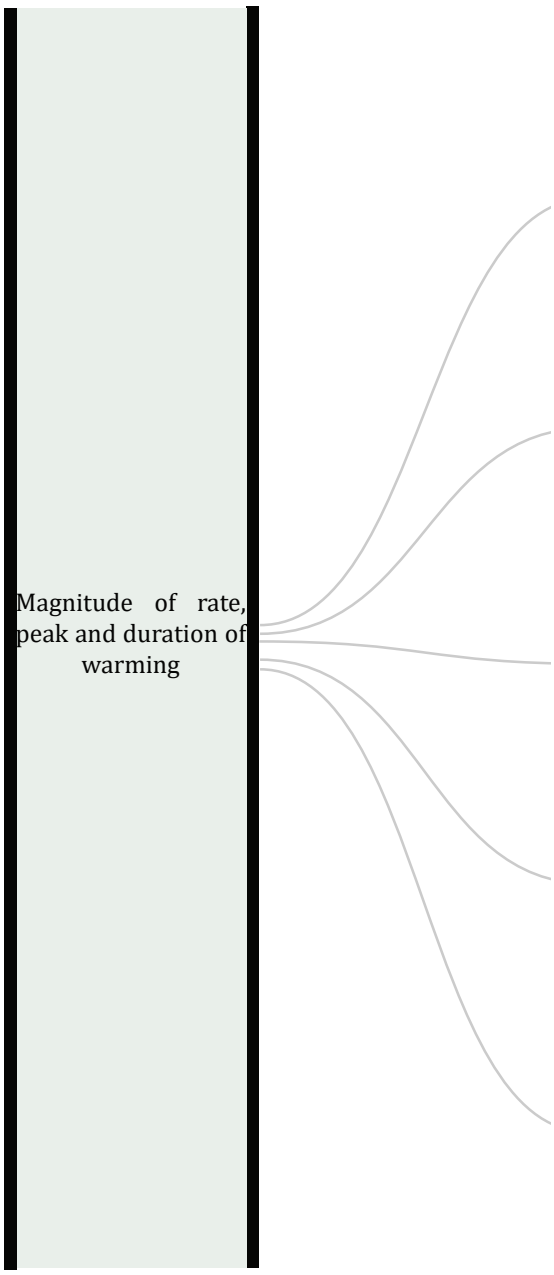
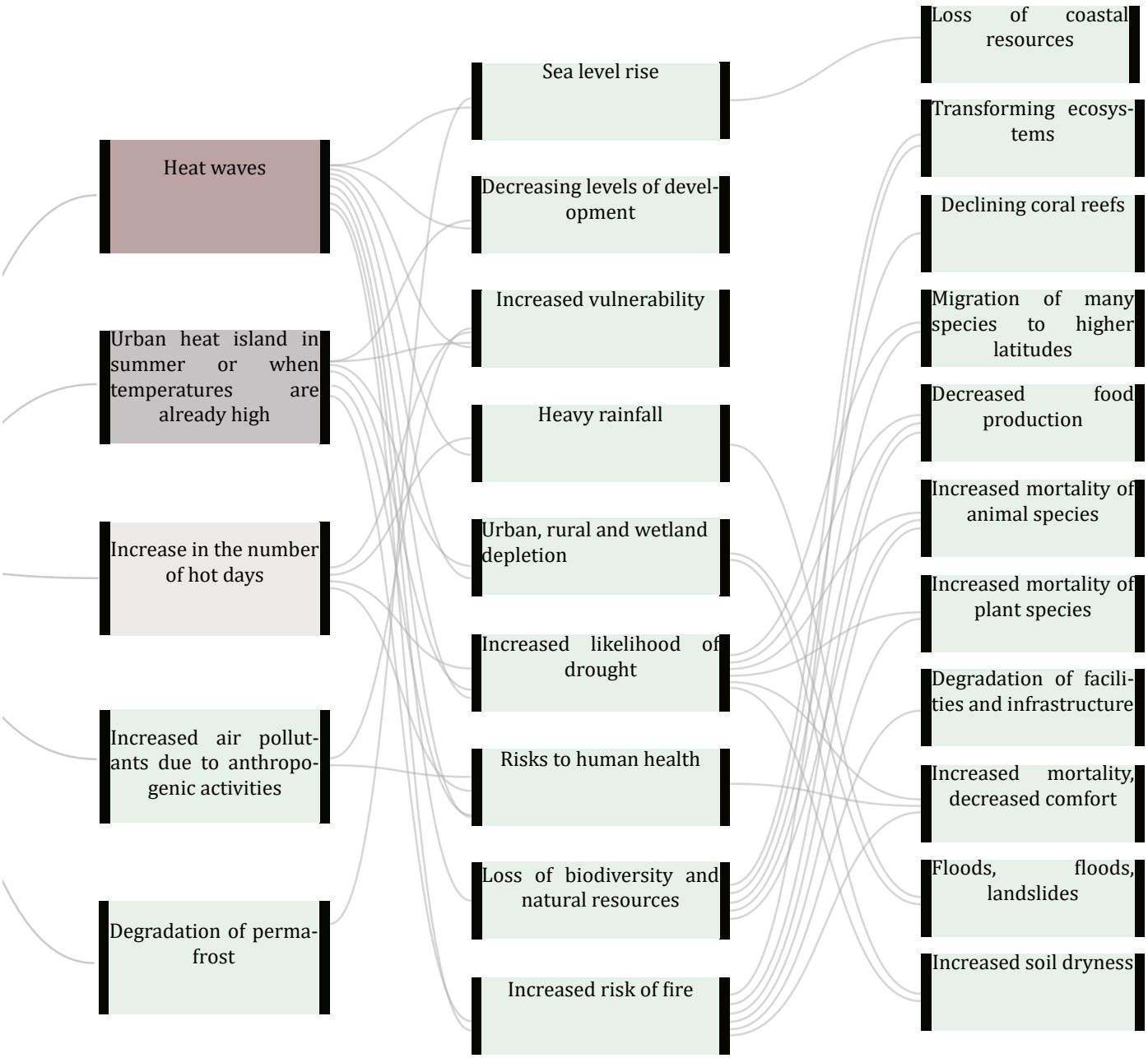


Figure 3. Causes and effects of rising temperatures on the existing stock according to IPCC data. The phenomena in red and grey have more interconnections than others and can increase the occurrence of more dangers. As can be seen, heat waves and heat islands pose many dangers globally. Author's elaboration.


Heat waves
Urban heat island in summer or when temperatures are already high
Increase in the number of hot days
Increased air pollutants due to anthropogenic activities
Degradation of permafrost
Sea level rise
Decreasing levels of development
Increased vulnerability
Heavy rainfall
Urban, rural and wetland depletion
Increased likelihood of drought
Risks to human health
Loss of biodiversity and natural resources
Increased risk of fire
Loss of coastal resources
Transforming ecosystems
Declining coral reefs
Migration of many species to higher latitudes
Decreased food production
Increased mortality of animal species
Increased mortality of plant species
Degradation of facilities and infrastructure
Increased mortality, decreased comfort
Floods, floods, landslides
Increased soil dryness

1.1.2| Heat islands in warm temperate climates

Summary.

Heat islands that develop in warmer seasons are one phenomenon that poses dangers to the city and its inhabitants.
An analysis of the relevant literature identifies the main characteristics and drivers governing the phenomenon, helping to understand what actions are most appropriate to decrease its occurrence and impacts on the urban fabric.

Introduction.

This part of the thesis investigates the characteristics of heat islands to identify the major drivers on which they depend.
Heat island in presence of already high-temperature levels, such as warm seasons, is an phenomenon that poses dangers to the city. This phenomenon is complex, depending on various factors and their combinations, and can occur at different scales (M. Imran et al., 2021).
Heat islands occur within urban centres. About 80% of the population in Italy lives within urban centres, but the statistical analysis and studies affirm that this data is increasing (EUROSTAT, 2020). During the cold season, the heat island phenomenon is not considered as problematic as it can help to reduce the temperature difference between the outdoor and indoor environment. On the contrary, during the summer season, it can be dangerous as it involves thermo-climatic criticalities related to temperature levels in the urban environment, potentially causing damage to structures, infrastructure, human health and the natural environment (D'Olimpio, 2022).
The urban heat island phenomenon has been known since ancient times. Horace (65-8 B.C.) and Seneca (4 B.C.-65 A.D.) wrote that heavier air in urban areas persists than in natural areas. Later, in 1800, Luke Howard observed temperature alterations between

natural and artificial environments and formalised the concept of an "urban heat island." In the mid-19th century, G. Luigi de Bartolomeis stated, "In the winter season, the coldness usually is greater in the low plains surrounding the city of Turin than on the astronomic observatory of the Academy... In the cities, the temperature rises more than in the countryside and in the soft lands, covered with grasses and plants, since in the former the direct heat is combined with the reflected heat of the sun's rays reflected from the walls, floors, floating gas and the numerous concourse of the population, as is the case in the city of Turin. In contrast, in the latter, there is more concentration than reflection of sun rays, and the same plants and trees absorb a large part of the heat." (D'Olimpio, 2022; de Bartolomeis, 1840-47).
The research is structured on this basis and takes a bottom-up approach. In particular, it includes an analysis of the relevant literature, extrapolating characteristics, and analysing the main drivers governing the phenomenon.
In this way, a framework of causes and effects governing heat islands can be set up based on the literature. In architectural technology, the focus is more on the impact of a particular phenomenon. On the contrary, studying the root causes, thus entering the field of climatology and physics, is fundamental because it allows us to act upstream of the problem, increasing the effectiveness of the strategies adopted. This step is functional for identifying the parameters that greatly influence the identified extreme phenomena.
Below is the research method and an analytical summary of the literature review.

Method of conducting research.

This part of the research is carried out in two distinct phases. The first phase consists of a literature review of urban heat islands in warm temperate contexts. The second phase aims to render the information gathered in the literature graphically. Figure 4 shows a graphic diagram summarising how the author conducted this research.

Figure 4.

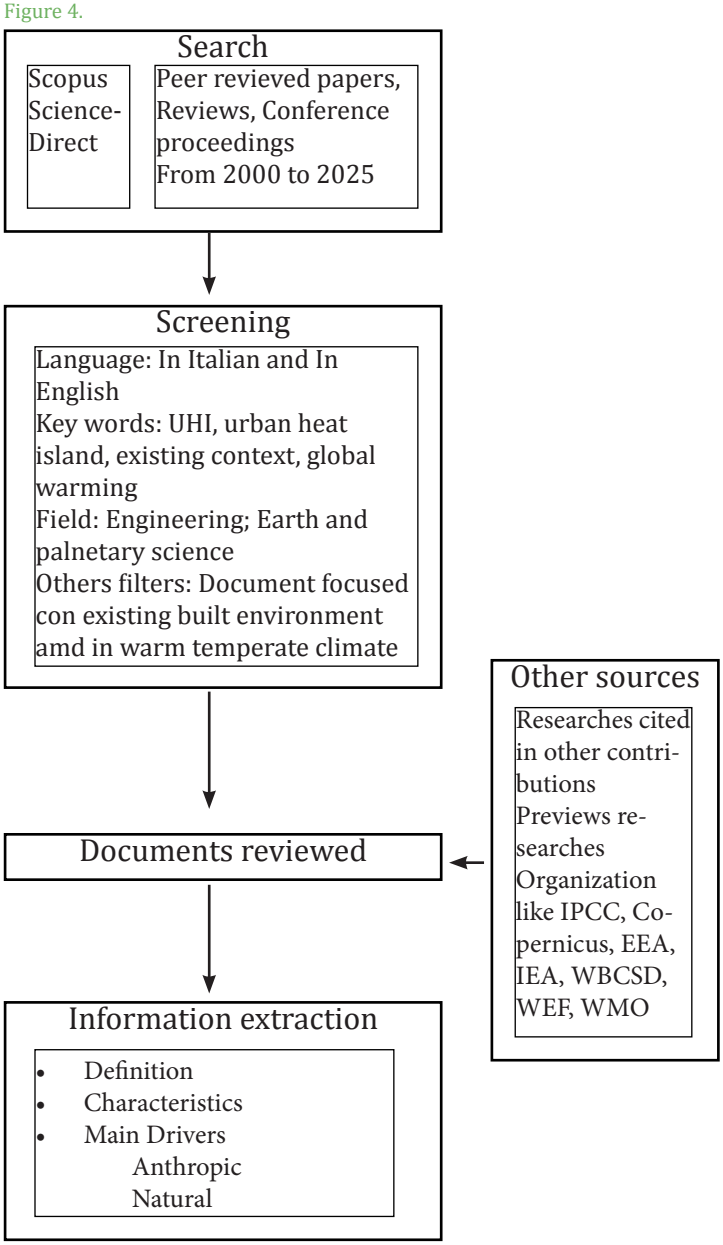


Figure 4. Graphic representation of par. 1.1.2 methodology. Author's elaboration

The first phase, conducted on the ScienceDirect and Scopus platforms, consists of individualising papers that analyse the phenomenon to identify the definition, characteristics, and causes that influence the phenomenon. The documents analysed are in Italian and English and have a time range from 2000 to 2025. The keywords used are UHI, urban heat islands, existing context, global warming and their combinations in engineering and earth and planetary science. The literature base increases with the addition of papers studied for other research that, however, exhaustively analyse the topic and from organisations that monitor the phenomenon worldwide, such as the IPCC (International Panel of Climate Change), Copernicus, EEA (European Environment Agency), IEA (International Energy Agency), WBSCSD (World Business Council for Sustainable Development), WEF (World Economic Forum), WMO (World meteorological organisation). After careful selection from the literature, around fifty contributions that specifically explain the phenomenon and analyse its causes and effects are identified. Each document is analysed in detail to extrapolate the information on heat islands.

The second phase of the research aimed to rework the information to build a graphic representation of the phenomenon's characteristics, the major drivers, and the interrelationships between them. Analysing the literature in the first part allows us to break down the phenomenon according to the significant triggering factors and indicate what factors impact the occurrence or recurrence of heat islands. Therefore, the elaborated scheme comprises a column on the left with influencing factors and subsequent columns where the sub-factors mainly affect the heat island, see Fig. 5.

Figure 5.

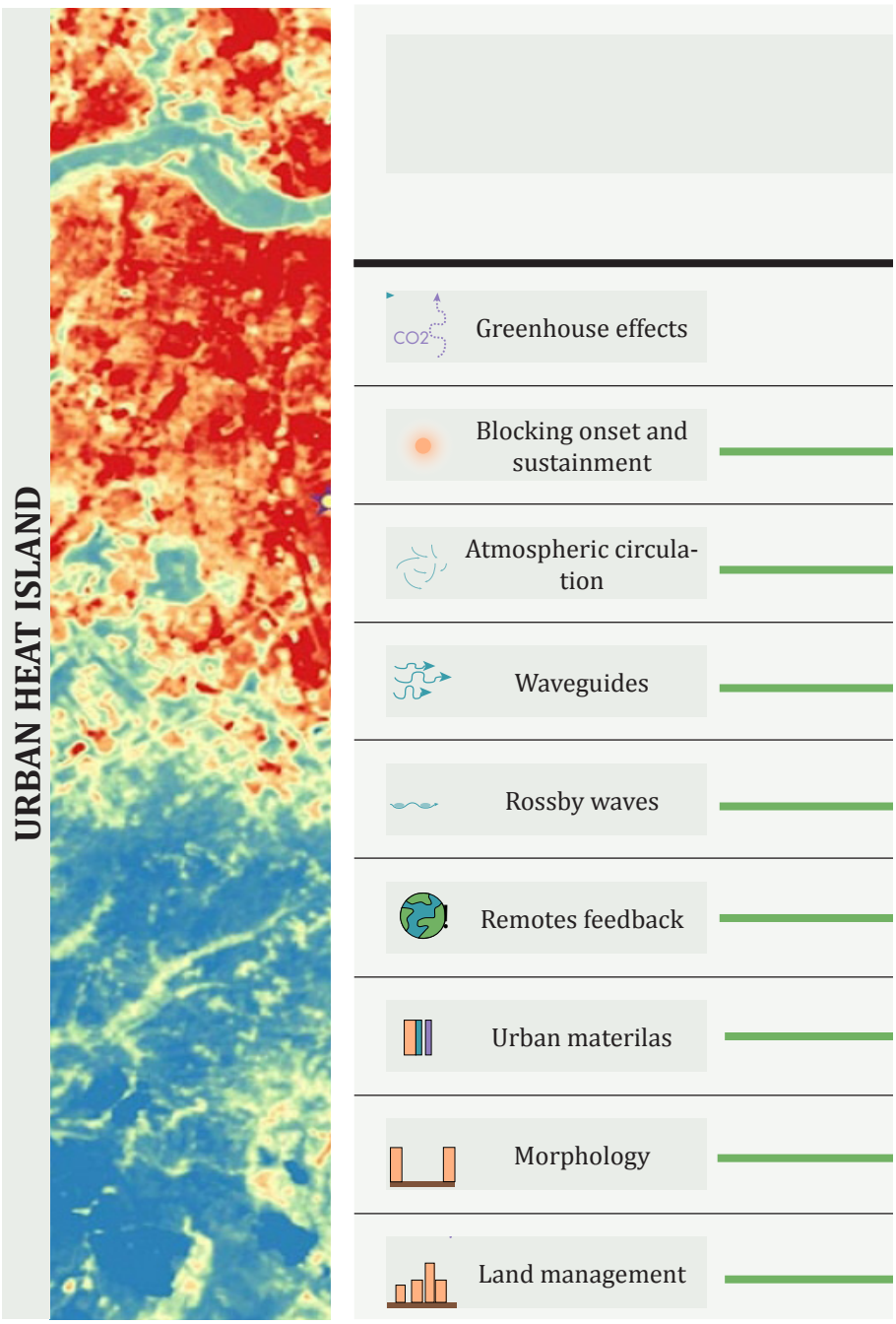


Figure 5. Schematic representation of the causes of heat island occurrence. These are broken down and analysed according to individual characteristics. The analysis indicates whether the causes are due to human or environmental factors, whether they occur unexpectedly or not, at what scale they act - microscale, mesoscale or macroscale, how long they affect the analysed phenomenon and what physical parameters they involve. Author's elaboration

Factors			
Anticyclone conditions →	Solar radiation		
Cloud cover	Wind	Humidity	Solar radiation
Cloud cover	Wind	Humidity	
Cloud cover	Wind	Humidity	Solar radiation
Cloud cover	Wind	Humidity	Solar radiation
Buildings materials	Infrastructure materials		
Sky cover factor	H/L	Urban geometry	
Permeable surfaces	Draining systems	Soil moisture	Vegetation state

Analytical summary of the LR

According to (Lai & Cheng, 2009; Miller, 2018; O'Malley, Piroozfar, fARR, & Pomponi, 2015; Kolokotroni & Giridharan, 2008; Giannopoulou et al., 2011) the urban heat island effect (UHI) is defined as a difference in temperature between an urban centre (which has the highest temperature) and outlying regions (with lower temperatures), with the most considerable intensity - Δ T - 3-5 hours after sunset. Research has indicated that the UHI effect occurs most frequently in calm and weak wind conditions, with a cloudless sky. Heat islands can be classified according to spatial classes: at the neighbourhood scale, the UHI of a block is described as the difference in temperatures within the city and referred to as the micro-scale; at the local/regional scale, the UHI identifies the temperature change across the entire urban and suburban area. At this scale, local geographic and climatic conditions influence the UHI (M. Imran et al., 2021)
The leading **causes** that produce or increase the heat island effect are as follows:

- **Anthropogenic heat:** Heat emission can occur through various human activities. These activities consist in the sum of the total energy used by vehicles, building operating air conditioning systems, industrial plants and processes-infrastructure, and urban activities, with energy-intensive buildings and traffic volume (Issa Shammas & Imran, 2021; Kleerekoper, van Esch, & Baldiri Salcedo, 2012; M. Imran et al., 2021; O'Malley, Piroozfar, fARR, & Pomponi, 2015); in addition, the presence of pollutants in the atmosphere absorbs and re-emits longwave radiation into the urban environment, exacerbating the phenomenon (Kleerekoper, van Esch, & Baldiri Salcedo, 2012).
- Intense **land use:** the presence of significant thermal masses and the ability of buildings to retain heat contribute to the occurrence of heat islands (O'Malley, Piroozfar, fARR, & Pomponi, 2015; M. Imran et al., 2021; O'Malley, Piroozfar, fARR, & Pomponi, 2015; Issa Shammas & Imran, 2021; D'Olimpio, 2023). In particular, material properties have a significant influence on the occurrence of heat islands:

- Thermal emissivity: measures the ability of a surface to dissipate heat or emit longwave (infrared) radiation (it is a radiative property of a material) (M. Imran et al., 2021; O'Malley, Pi-

roozfar, fARR, & Pomponi, 2015; Issa Shammas & Imran, 2021).

- Increased heat storage by building materials with sizeable thermal admittance. Furthermore, cities have a larger surface area than rural areas to store more heat (Kleerekoper, van Esch, & Baldiri Salcedo, 2012).

- Absorption of sun shortwave radiation in low albedo (reflection) materials and reflected by multiple reflections between buildings and street surfaces (Kleerekoper, van Esch, & Baldiri Salcedo, 2012; Issa Shammas & Imran, 2021).

- **Morphology** and size of cities also influence the UHI phenomenon: various research has shown that temperature differences between air and building surfaces vary up to 20-30 °C during the day in summer and 5-10 °C at night in winter. Researchers also found that the temperature differences between roofs and ambient air vary between 14-25 °C during the day (M. Imran et al., 2021). In particular, urban geometry is one of the causes: this results in multiple reflections and absorption of shortwave radiation due to lower albedo than in the rural environment (Tong, et al., 2018; Issa Shammas & Imran, 2021; D'Olimpio, 2023). Increasing the height of buildings and reducing the width of streets could reduce daytime temperatures but increase them at night. Urban geometry also has an influence on wind, solar radiation, air humidity and water balance (Rizwan, Dennis, & Liu, 2008; Issa Shammas & Imran, 2021; O'Malley, Piroozfar, fARR, & Pomponi, 2015; O'Malley, Piroozfar, fARR, & Pomponi, 2015). In addition, in the presence of Urban streets canyon effects, the loss of longwave radiation decreases the heat island effect overnight (O'Malley, Piroozfar, fARR, & Pomponi, 2015).

- **Reduction of vegetation and permeability** in urban areas (M. Imran et al., 2021; O'Malley, Piroozfar, fARR, & Pomponi, 2015; D'Olimpio, 2023) a significant portion of net radiation is converted into energy during evapotranspiration and photosynthesis processes when an area is covered by vegetation (Wong & Yu, 2005; Issa Shammas & Imran, 2021). Within an area of vegetation, energy is mainly divided into latent heat fluxes and remaining as sensible heat fluxes. This phenomenon promotes a decrease in air temperature with energy division depending primarily on the flow of available moistu-

re from the soil, surface, and atmosphere (McPherson, 1994; Issa Shammas & Imran, 2021). Ambient air cools during the process of evapotranspiration. A greater loss of naturally vegetated surfaces results in more significant cold loss in urban areas. Evaporation from urban areas decreases due to "impervious surfaces", less permeable materials, and less vegetation than in rural areas. As a result, more energy is converted into sensible heat and less into latent heat (Kleerekoper, van Esch, & Baldiri Salcedo, 2012).

- **Weather conditions and climate** are challenging to control: the presence of wind and cloud flows reduces the occurrence and intensity of UHI. Wind reduces UHI through cold air from rural to urban areas. Clouds provide natural insulation that absorbs and re-emits infrared radiation. This absorption slows the radiative cooling process at night and reduces temperature differences between urban and rural areas. Anticyclonic weather conditions increase the outgoing longwave radiation in the nighttime radiative amount, providing undisturbed solar radiation that is favourable for the development of UHI (M. Imran et al., 2021). Obstruction of the sky by buildings results in a decreased longwave radiative heat loss from street canyons. The obstructing surfaces intercept the heat and absorb or radiate back to the urban tissue (Kleerekoper, van Esch, & Baldiri Salcedo, 2012). Reducing wind speed decreases the turbulent heat transport within streets (Kleerekoper, van Esch, & Baldiri Salcedo, 2012).

The **characteristics** peculiar to heat islands are:
The heat island occurs more at night than during the day due to heat release from the constituent materials of the city (Issa Shammas & Imran, 2021). Heat islands can be decomposed into:

- Surface heat island: The urban canopy layer (UCL) consists of the air between urban buildings, from the ground to the rooftops and tree canopies.
- Atmospheric heat island: The second layer is located directly above the first and is called the urban boundary layer (UBL); it starts from the tree canopies and roofs of buildings to where the city no longer influences the atmosphere. The roughness in cities promotes the development of an urban boundary layer (UBL).

- Features or properties in the urban canopy layer (UCL) and urban boundary layer (UBL) could cause positive thermal anomalies due to energy alteration (Issa Shammas & Imran, 2021).

The UHI has also been shown to have linear growth with a logarithmic increase in population (Zhang, Wang, Shen, & Da, 2009).

Specific local and regional conditions strongly influence the urban heat island. It develops best under anticyclonic conditions, while the heat island minimally rises under low-pressure conditions. Low wind speed and clear sky conditions favour the occurrence of this phenomenon. In contrast, high wind speed is associated with very low levels of heat island (Mihalakakou, Santamouris, & Helmis, 2002; Santamorius, 2015). Significant UHI intensities are reported for relatively cloudy conditions but under very low wind speeds (Kim & Baik, 2004; Santamorius, 2015). The threshold wind speed above which UHI tends to decrease substantially is a function of city size and other local characteristics. Studies attest that these thresholds are between 4 and 11 m/s (Park, 1986; Santamorius, 2015).

Most of the existing experiments report that urban heat islands are better developed during the warm period of the year (Morris, Simmonds, & Plummer, 2001; Santamorius, 2015). However, in geographic zones characterised by dry and humid periods, the phenomenon is better developed during the dry season, which may not coincide with summer (Y. & Jong-Jin, 2005; Santamorius, 2015). As it concerns its daily variation, literature affirms that the maximum intensity is observed during clear and calm nights (Tereshchenko & Filonov, 2001; Santamorius, 2015) and it takes its maximum of 3–5 hours after sunset (Oke, Boundary Layer Climates, 2002; Santamorius, 2015).
The weakest heat island phenomena appear in spring and summer, while the most substantial phenomena appear in autumn. Strong UHI effects occur between 6 a.m. and 9 p.m. and decrease for 2-3 hours until midnight (Oke, Boundary Layer Climates, 2002).

Many studies report the association between heat island phenomena and pollution: rising temperatures in urban areas are associated with the formation of secondary pollutants such as

ozone (O_3). In addition, UHI effects influence the level of pollutants such as NOx and O_3 during the day and at night.
The phenomenon of UHI is associated with air circulation in cities. The mobilisation of breezes in the town increases the diffusion of pollutants.

Finally, the heat island phenomenon is 1.2-1.4 °C greater during nights, where heat wave phenomena are also present (Oke, Boundary Layer Climates, 2002).

Ultimately, as emerges from the literature and as shown in Figure 5, heat islands are governed by both natural climatic factors (greenhouse effects, blocking onset and sustainment, atmospheric circulation, waveguides, Rossby waves, remotes feedbacks) and anthropogenic factors such as the constituent materials of urban centres, morphology and land use. Analysis of the scientific literature shows that heat islands during the hottest time of the year lead to the occurrence of numerous risks at the environmental level, at the urban level, at the economic level and on the individual.

At the environmental level, according to data collected by IPCC (International Panel of Climate Change -IPCC-, 2001), the associated risks include a rise in ground ozone levels, increased levels of pollution in the air, and a significant alteration in precipitation patterns with the onset of extreme events such as floods. At the urban level, there could be a significant increase in surface and air temperatures, connected with a consequent increase in energy consumption, possibly affecting the economy. Other risks associated with the occurrence of heat islands relate to increased soil dryness and decreased air quality within cities (Rosenfeld, et al., 1995).

Finally, the health risks consist of decreased thermic comfort. This causes severe imbalances, especially in vulnerable groups of people, leading to cerebrovascular and cardiorespiratory disorders, cardiovascular stress, reduced blood viscosity, increased risk of thrombosis, mental disorders, and potential increases in crime (Patz, Campbell-Lendrum, Holloway, & Foley, 2005).

1.1.3| Heat waves in warm temperate climates

Summary.

As indicated in the previous paragraphs, heat waves are one extreme phenomenon that, with increasing average temperatures, are growing in duration and intensity.
Reviewing the literature makes it possible to identify the causes of the phenomenon and how humans can act on these to mitigate their impacts and increase the adaptation process.
A visual representation indicates the phenomenon's primary and secondary causes and interrelationships.
The impacts of this phenomenon, generated mainly by natural drivers, can be intensified with specific human behaviours, increasing the risk. Through this research, it is possible to understand what behaviours can mitigate the impacts and adapt the context to the occurrence of heat waves.

Introduction.

This part of the thesis aims to understand the characteristics of heat waves, the main factors that cause them, their interrelationships, and the drivers governing the phenomenon.
Heat waves are one extreme phenomenon that, with increasing average temperatures, are growing in duration and intensity. Human activities can exacerbate complex climatic-environmental interrelationships that generate the phenomenon.
Since ancient times, humans have been interested in weather and climate phenomena since survival depended on them (Mariani, 2017). Since time immemorial, the climate has undergone upheavals, colder or warmer periods, which have occurred over time. These natural phenomena have led animal and plant species to adapt to the changing climate. The Anthropocene, through greenhouse gas emissions and reckless land use, has led to disruptions in the climate balance, causing intense and rapid extreme pheno-

mena, including heat waves, which have lately increased in intensity and frequency (Abbass et al., 2022). Since 1880, when global records began, the summer of 2023 was the hottest: the temperature reached 0.23 °C higher than any other summer ever recorded (ANSA, 2024). According to the World Climate Research Program (WCRP), heat waves represent one of the most significant extreme events related to climate change (Barriopedro, García-Herrera, Ordóñez, Miralles, & Salcedo-Sanz, 2023). In addition, heat wave is often associated with air stagnation, exacerbating respiratory problems in urban areas (Barriopedro, García-Herrera, Ordóñez, Miralles, & Salcedo-Sanz, 2023).
The research is approached from the bottom up, based on an analysis of the state of the art in the field.
This analysis is fundamental to the development of this thesis, as understanding the characteristics of the phenomenon and studying it is the basis for identifying more effective strategies that can surgically decrease its occurrence and impacts. Many contributions approach the problem by listing various actions that act on the effects of heat waves on the city. In contrast, this contribution approaches the problem at its root, identifying the causes and the physical and climatic interrelationships. In this way, impacts can be tackled more effectively, and future heatwaves can be discouraged as much as possible by acting on the primary factors causing the phenomenon.
The methodology of conducting the thesis and its results are summarized below.

Method of conducting research.

This part of the research is carried out in two distinct phases. The first phase consists of a literature review on the topic. The second phase consists of the reworking and graphical rendering of the information gathered from the literature. Figure 6 shows a graphic diagram summarising how this research was conducted.

Figure 6.

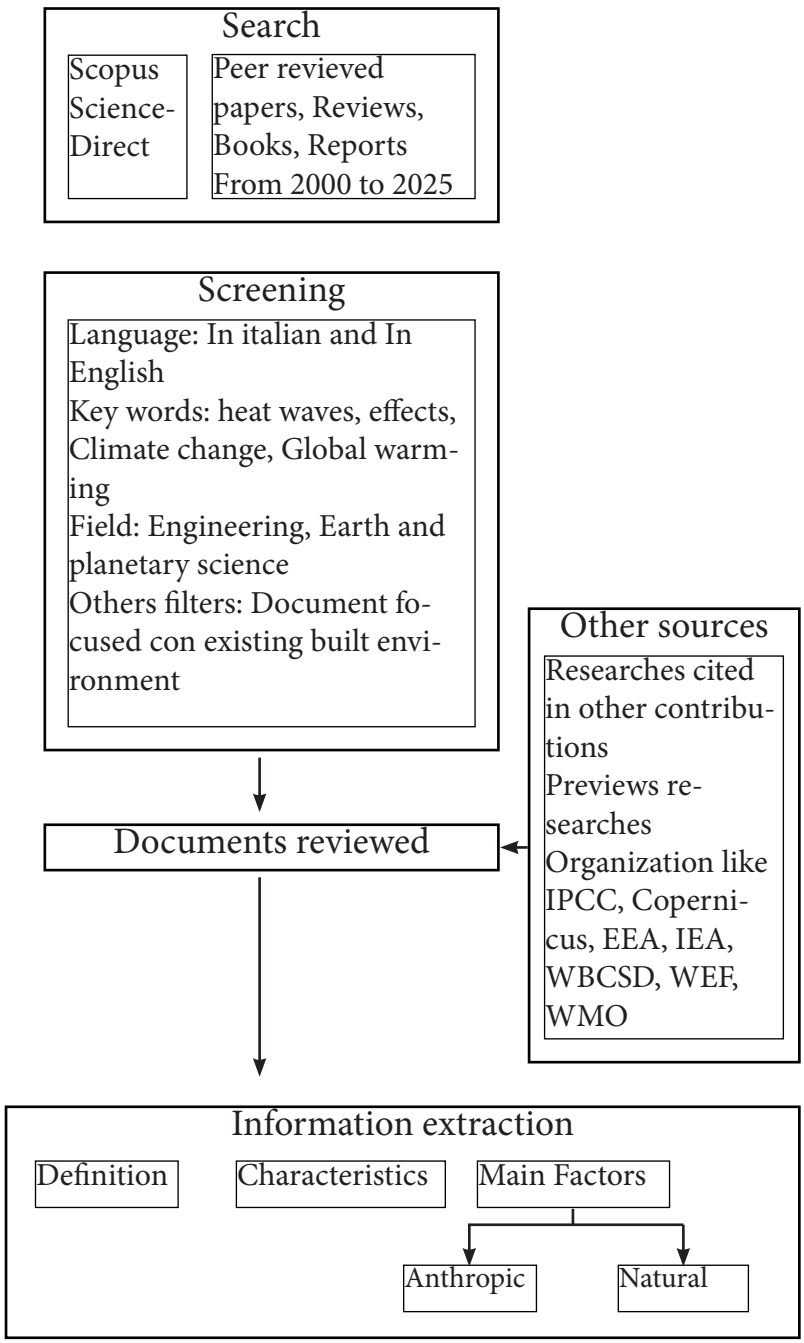


Figure 6. Workflow of literature review on heat waves. Author's elaboration

The first phase consists of a literature review on the subject under consideration to understand the definition of a heat wave, its characteristics, and the physical phenomena that cause it. Articles in both Italian and English from 2000 to 2025 are considered. The keywords used are heat wave, effects, existing context, and global warming combined. Other papers on the subject, studied in the context of other research, help understand the phenomenon. In addition, reports written by organisations that study the phenomenon, such as the IPCC (International Panel of Climate Change), Copernicus, EEA (European Environment Agency), IEA (International Energy Agency), WBSCSD (World Business Council for Sustainable Development), WEF (World Economic Forum), WMO (World Meteorological Organisation) are important sources of information and are therefore added to the analysis. Furthermore, suppose an article refers to a specific aspect of the phenomenon or has interesting repercussions or connections to the built fabric, cited in other contributions. In that case, it is added to the essential documents of this thesis phase. All these documents undergo an initial screening, whereby documents not relevant to the study of the phenomenon are eliminated. The documents analysed in detail and used in this part of the thesis are around fifty.
The second step is to process the collected information into a graph, visible in Figure 7. The significant factors causing or increasing the heat wave are in the first column on the left. Natural factors are highlighted in green. The columns on the right show the sub-factors caused by climatic phenomena or human action that, in particular, increase the occurrence, duration, intensity, and effects of heat waves. The arrows indicate the connection between the various phenomena.

Figure 7.

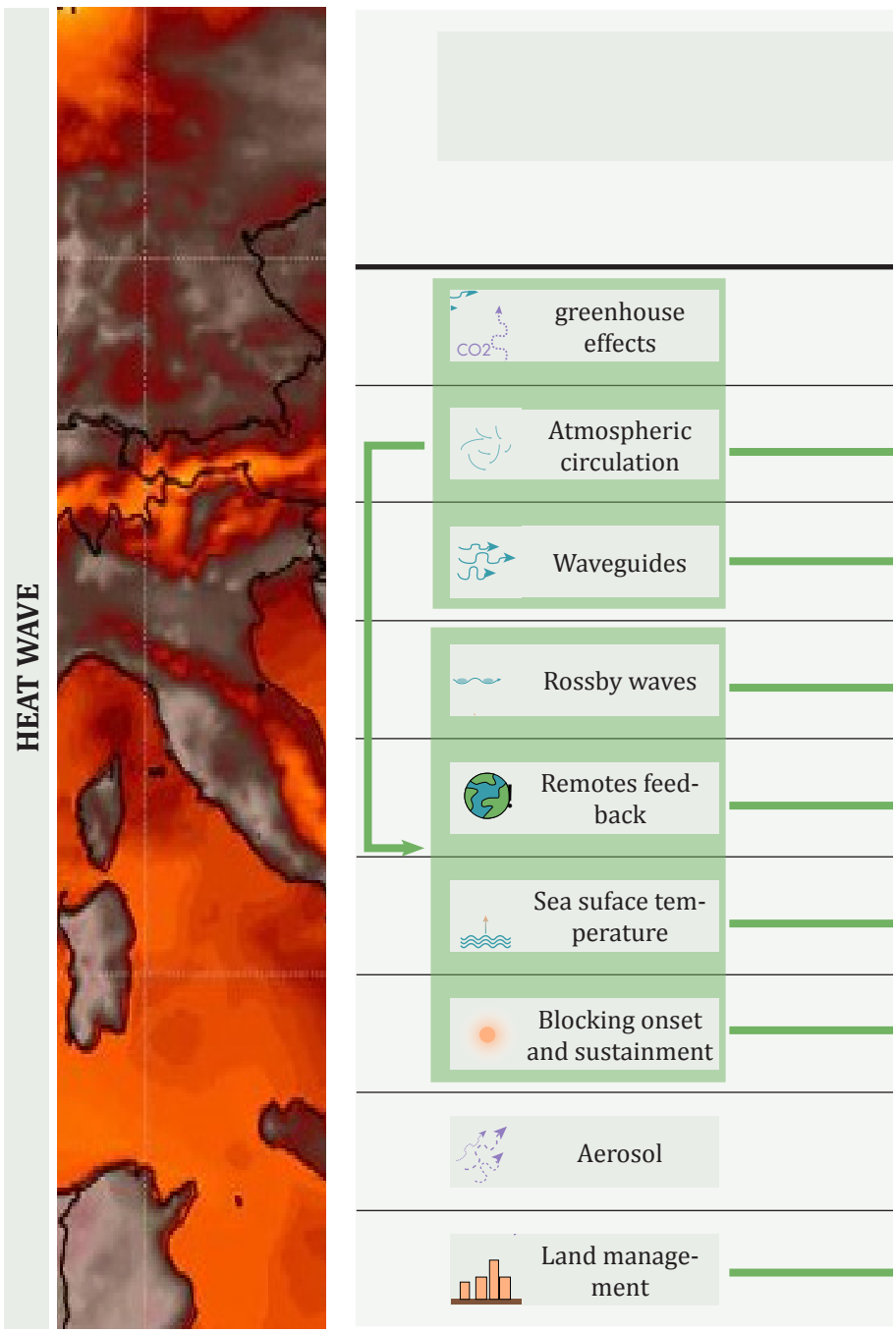


Figure 7. Schematic representation of the causes for the occurrence of heat waves. These are broken down according to individual characteristics and analysed. The analysis indicates whether the causes are due to human or environmental factors, whether they occur abruptly or not, at what scale they act - microscale, mesoscale or macroscale - how long they affect the phenomenon analysed and what physical parameters they involve. Author's elaboration.

Factors				
→	Wind	Humidity	Solar radiation	
→	Wind	Humidity	Solar radiation	
→	Wind	Humidity	Solar radiation	
→	Wind	Humidity	Energy fluxes	Solar radiation
→	Wind	Thermal energy		
→	Anticyclone conditions →	Solar radiation		
→	Permeable surfaces	Draining systems	Soil moisture	Vegetation state

Analytical summary of the LR.

There are various definitions of a heat wave. Regarding the reference climatic period, according to Perkins-Kirkpatrick & Lewis (2020), a heat wave occurs upon the persistence of at least six consecutive days in which T_{max} is greater than the 90th percentile for that particular day.
(Frich et al., 2002) define the above phenomenon as a period of at least five days of exceptionally hot and possibly humid weather, during which the average maximum temperature is exceeded by at least 5°C.
Arnetoli defines the heat wave phenomenon or "warm spell" as a persistent period of exceptional heat with maximum temperatures exceeding the period's maximum by 90 to 95 per cent. This phenomenon occurs on a large scale—regional or continental—and is caused by high-pressure atmospheric systems forming a blockade over large areas, persisting even for many days (Arnetoli, 2021).
The IPCC defines this extreme phenomenon as abnormal heat, often relative to a temperature threshold, lasting from 2 days to months (IPCC: Annexe VII: Glossary, 2021).
The physical causes governing the occurrence of heat waves are as follows:

- Heat waves at lower latitudes can be related to the **stationing of systems** for a shorter or longer period. In contrast, at mid-latitudes, heat waves are caused by dynamical adjustments at the level of the upper layer of the troposphere that give rise to **Rossby waves**[3] (Trenberth et al., 1998), which improve heat wave phenomena. Rossby waves consist of phenomena caused by increased Coriolis parameter[4] with latitude and the conservation of angular momentum. This type of wave consists of inertial oscillations around an "equilibrium point" given by geostrophic balance[5]. This type of wave and its associated phenomena represent one of the principal means by which atmospheric circulation and heat exchanges occur all over the Earth's surface.
- Meteorological phenomena can foster heat waves, such as abnormal conditions in remote climatic components or **anticyclonic areas**: a stationary system with an abnormally high centre of pressure that remains in the same position for longer than the expected period. Most often, this is due to the presence of "blockages" caused by a division of wind fluxes in the

3. Rossky waves owe their name to Swedish physicist Carl-Gustav Arvid Rossby, who first identified them in the atmosphere and explained them in 1939. From a meteorological point of view, the Rossby wave is one of the main factors responsible for the formation of anticyclonic and cyclonic zones.

4. Coriolis parameter takes into account of the effect of the earth's rotation on bodies (D'Ercole, 2018).

5. Geostrophic balancing: a situation in which the pressure forces are exactly balanced by the Coriolis force

upper atmosphere, which can last for many days (Barriopedro, García-Herrera, Ordóñez, Miralles, & Salcedo-Sanz, 2023).

- From relationships with **soil type**:

- When soil moisture decreases, heat waves are more likely to occur.

- For heat waves to occur, the previous winter and spring must have been dry; this condition causes the soil to dry out. The dryness of the soil amplifies the "blockage of wind flows," exacerbating the phenomenon (Durre, Wallace, & Lettenmaier, 2000).

- **Rising sea temperature,** a phenomenon that occurs mainly in tropical climates, is related to the release of latent heat and, thus, from a physical point of view, affects the increase of heat waves. Internal components of the long-memory climate system (ocean, cryosphere) also influence HW over various time scales, promoting atmospheric teleconnections and anomalous heat/humidity fluxes that cause remote interactions with regional processes (Barriopedro, García-Herrera, Ordóñez, Miralles, & Salcedo-Sanz, 2023; Trenberth et al., 1998; Ferranti & Viterbo, 2006).
- **Anthropogenic forcings:** Humans can intervene at different levels in the occurrence of the heat wave phenomenon:

- Globally: Through an increase in the concentration of **greenhouse gases** in the atmosphere and the aerosol effect thus, the earth's energy balance on the upper layer of the atmosphere is altered through stagnation of the long-wave thermal radiation emitted by the planet, resulting in continued global warming (Kasoar et al., 2018; Samset et al., 2018; Westervelt et al., 2018,Arias et al., 2021, Mondal et al., 2021; Sicard et al., 2022; Barriopedro, García-Herrera, Ordóñez, Miralles, & Salcedo-Sanz, 2023).

- Regionally: Dry soil can increase heat waves through land use and land cover, affecting climate through biogeophysical processes and biophysical effects in atmospheric and terrestrial energy and water flows (Jia et al., 2019). Balance of radiative and nonradiative effects controls the Earth's surface temperature: Deforestation can cause radiative cooling by increasing surface albedo and nonradiative warming by reducing evaporative cooling and turbulent air motions. Environmental dryness conditions have increased since 2003, up to 40% by increasing soil dryness and promoting heat absorption by vertical surfaces (Fischer, Seneviratne, Lu¨thi, & Scha¨r, 2007; Stefanon, D'Andrea, & Drobinski, 2012). Soil influences these phenomena through water availa-

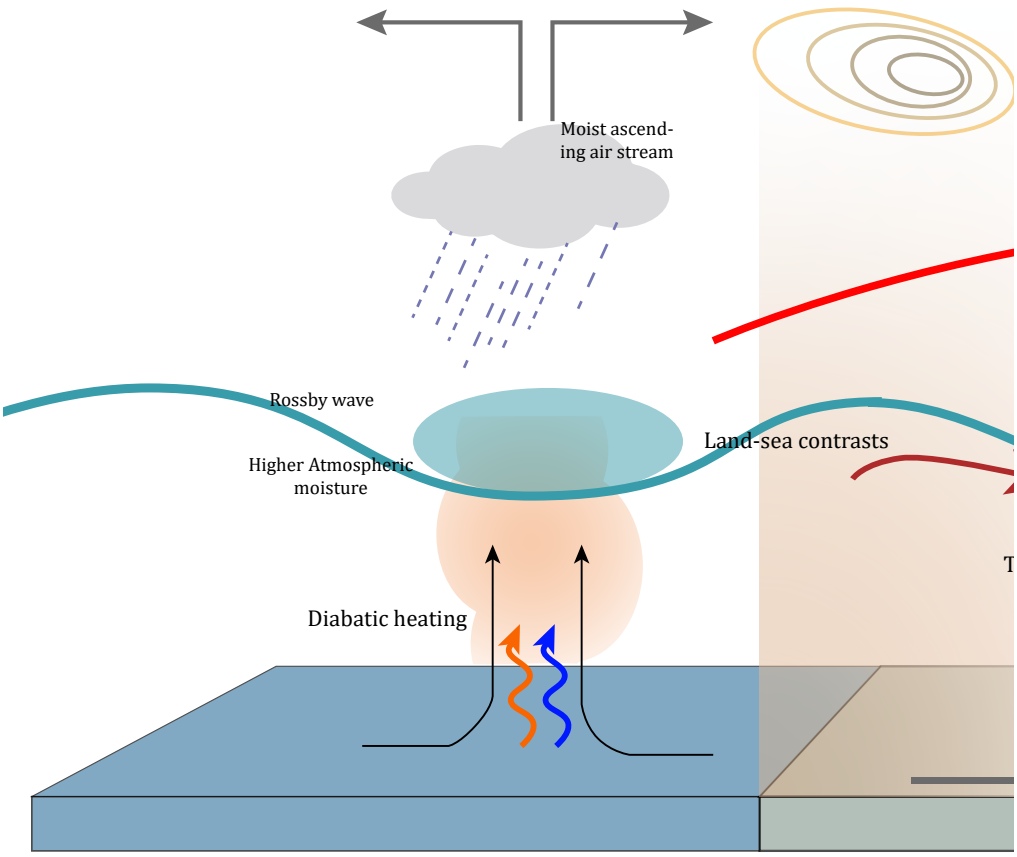
bility, snow cover, and albedo. These factors cause asymmetric changes in maximum and minimum temperatures and different seasonal responses (Y. Li et al., 2015; Barriopedro, García-Herrera, Ordóñez, Miralles, & Salcedo-Sanz, 2023). Several studies found that, at the European level, soil moisture depletion increases summer temperature variability and amplifies the intensity and probably the duration of HWs in both observational datasets and models of different complexity (Fischer et al., 2007; Hirschi et al., 2014; Lorenz et al., 2010; Miralles et al., 2014; B. Mueller & Seneviratne, 2014; Suarez-Gutierrez et al., 2020; Wehrli et al., 2019; Barriopedro, García-Herrera, Ordóñez, Miralles, & Salcedo-Sanz, 2023). Increased dryness in the soil and the consequent lowering of evaporative cooling, caused by the lack of rainfall in the preceding months, results in increased plant transpiration due to early greening in spring (Ma et al., 2016) or increased atmospheric demand (Vicente-Serrano et al., 2020). In particular, the influence of soil moisture, mediated by transpiration, depends on complex plant dynamics and physiological responses among plant species. Soil dryness can modify atmospheric circulation through diabatic effects on thermal column expansion, upper-level divergence, or intensification of thermal minima (Haarsma et al., 2009; Koster et al., 2016; Sato & Nakamura, 2019; Teng & Branstator, 2019; Vautard et al., 2007; Zampieri et al., 2009). In turn, these phenomena can influence precipitation (Ardilouze et al., 2020; Guillod et al., 2015; Taylor et al., 2012; Barriopedro, García-Herrera, Ordóñez, Miralles, & Salcedo-Sanz, 2023).

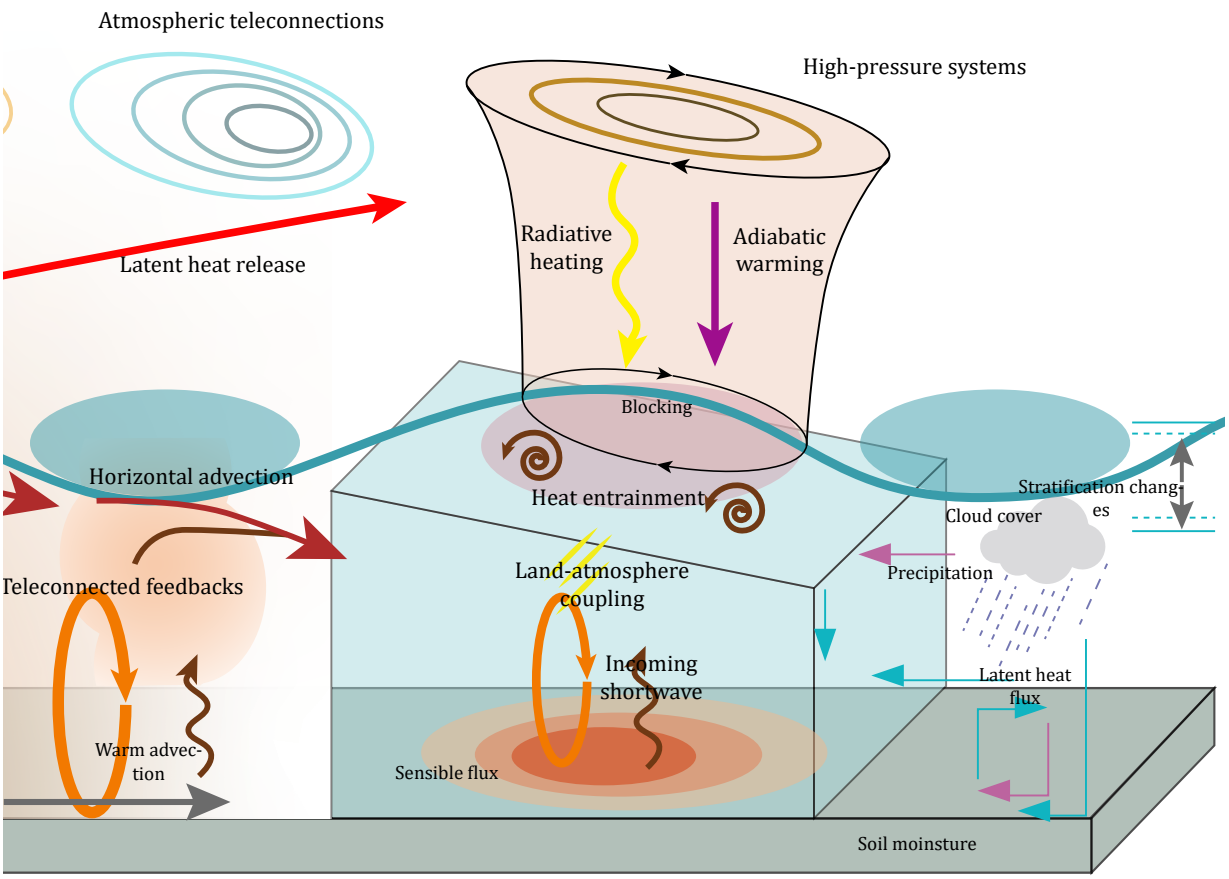
- The heat wave phenomenon can be exacerbated by heat accumulation over several days, causing further soil depletion (Miralles et al., 2014; Barriopedro, García-Herrera, Ordóñez, Miralles, & Salcedo-Sanz, 2023). Deep atmospheric boundary layers during the day modulate the entrainment of warm, dry air, which is stored in the residual layers at night and re-enters the boundary layer during the next diurnal cycle, or it can be transported by ventilative flows (Quinting & Reeder, 2017; Schumacher et al., 2019; Zschenderlein et al., 2019). This phenomenon is called “teleconnection feedback” and can lead to the “self-propagation” of events. Thus, the transport of diabatic warming from upwind regions that experience land-atmosphere feedback can instigate similar feedback and exacerbate droughts and HW in downstream locations (Miralles et al., 2019; Schumacher et al., 2019; Schumacher, Keune, Dirmeyer,

& Miralles, 2022). Figure 8 illustrates the mechanisms behind the phenomenon.

Figure 8. A schematic representation of how heat waves form. Author's representation based on (Domeisen, et al., 2022; Barriopedro et al., 2023)

Figure 8.




Atmospheric teleconnections
High-pressure systems
Latent heat release
Radiative heating
Adiabatic warming
Blocking
Horizontal advection
Heat entrainment
Stratification changes
Cloud cover
Teleconnected feedbacks
Land-atmosphere coupling
Precipitation
Incoming shortwave
Latent heat flux
Warm advection
Sensible flux
Soil moinsture

1.1.4| Microclimate and Urban Morphology

Summary.

Heat islands and heat waves cause extensive damage to existing buildings. At the same time, the characteristics of the built environment influence the aforementioned phenomena. This part of the research aims to understand the relationship between the built environment and heat islands and heat waves by identifying the morphological indices that significantly influence the phenomena considered. Acting on the triggering or aggravating factors makes it possible to mitigate impacts and adapt to the context.
To this end, a narrative analysis of the scientific literature was necessary, combining documents found through a search on the various platforms with others found in previous research but inherent to the theme. Following the retrieval of the information, these are reordered and reworked to obtain a precise picture of the characteristics specific to the urban context that have the most significant impact on the extreme phenomena linked to the increase in temperature mentioned above.
This analysis clearly shows that urban morphology, shape ratios, materials, and surface types are fundamental parameters for controlling the causes and effects of heat islands and heat waves.
The research limits correspond to the presence of multiple indices, some very similar to each other, others the same but with different names, and others still not applicable to warm temperate contexts as they are developed for other climate types. In this paragraph, based on the scientific literature, an attempt is made to give an order and to indicate the most critical indices that influence the phenomena of islands and heat waves on existing residential buildings in warm temperate climates.

Introduction.

The urban heat island and excessive energy use are now a significant threat to the safety and sustainability of cities. Buildings are responsible for much of the global energy demand, about 40 per cent of final energy use, of which 50 per cent is due to air conditioning and climate control systems (Intergovernmental Panel of Climate Change -IPCC-, 2023; Housing Europe, 2021; Elmarakby & Elkadi, 2024).

The built fabric plays a vital role in interacting with humans and the environment (Lucarelli, Mandaglio, & Mussarella, 2020). The surrounding environment affects human well-being and happiness, closing the symbiotic and interdependent circle (Krekel & MacKerron, 2020). Identifying indices that affect rising temperatures in existing neighbourhoods could increase awareness and adaptation behaviours by positively impacting decreased risk to natural systems. By encouraging the adaptation of existing architecture to increasing temperatures, the built environment acts as a mediator between anthropogenic and natural systems, establishing a stable balance between the Earth and humans (Ulber & Mahall, 2019).

Before the advent of climate control systems, the symbiotic link between the artificial and the natural was extremely present: form, construction methods, and materials depended on environmental factors. Today, the thesis developed by (Ottone et al., 2019) that the urban theories of the 1800s, with Camillo Sitte (Sitte, 1981), Rem Koolhaas (Koolhaas, 2006) and Bernardo Secchi (Secchi, 2009), consider urban form as a design whose responsible is the urban planner, increasingly estranged from the environmental surrounding context, turns out to be correct. In this way, a whole series of modifications became necessary to change the architectural landscape by transforming the great urban utopias through recovery and reuse and by mending the link between the city and its context (Claudi De Saint Mihiel, 2020; De Saint Mihiel, 2016).

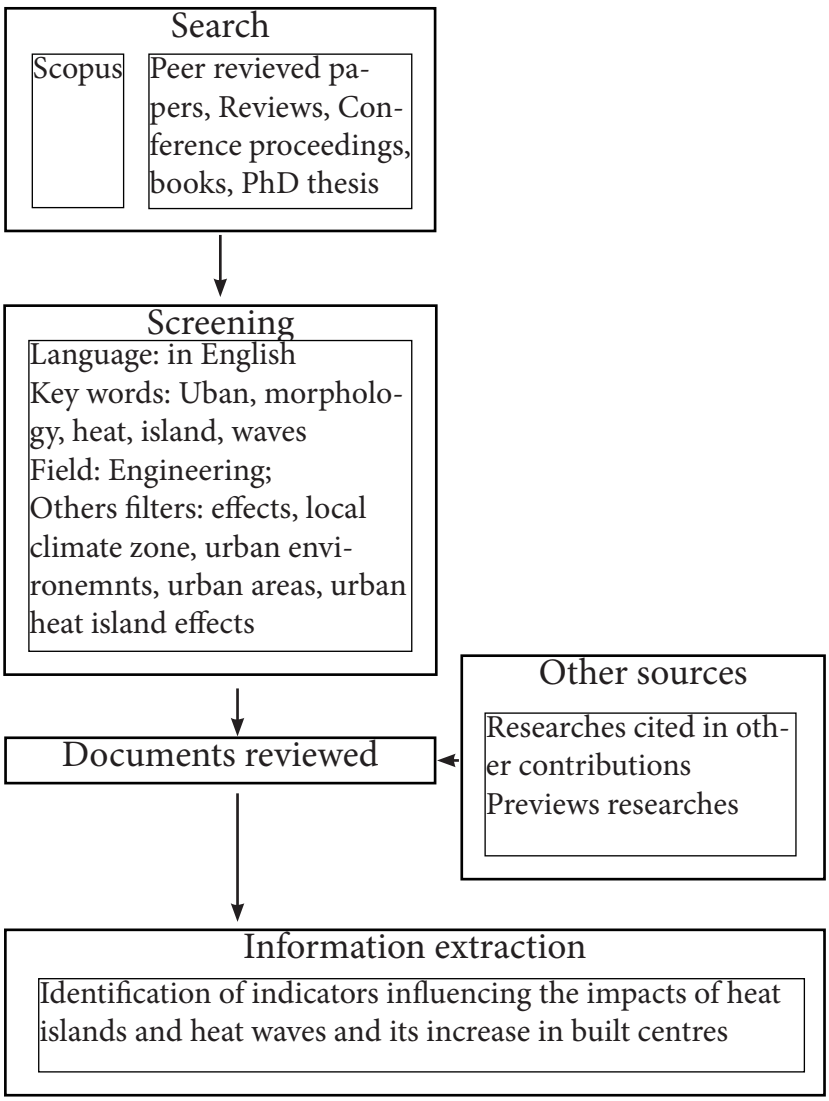
By analysing historic Italian and European traditional cities in terms of adaptability, we can find an intelligent relationship between urban forms and the natural environment, helping to re-establish a harmonious link between city, nature and people in today's urban design. In traditional cities, especially Italian ones, people's comfort is based on the combination of bioclimatic systems inside and outside the building, materials that instinctively help the functioning of these, and urban regulation systems. After a long development and evolution, these cities have achieved their present form.
As a function of ongoing climate change, the theories that light, temperature, pressure, and humidity represent architecture's new "building blocks" are increasingly finding acceptance. In this context, as (Scuderi, 2014) and (Tucci, 2018) said, climate change has always occurred on Earth. It determined the evolution of society, cities, and landscapes, readjusting and reshaping the built environment according to the new arrangements.
Studies on heat island intensity as a function of urban geometry are contradictory and not very generalisable because they are conducted in different climatic contexts and focus on a single morphological parameter. This section aims to systematically identify indices and measurement methods to quantify the effects of heat islands and heat waves on the existing built context. The various documents consulted often only refer to a few of these. Instead, at this stage of the thesis, a complete overview of the tools available allows us to increase the level of comprehension of the phenomenon, the impacts it causes, where to intervene and how to make strategic choices that are more focused on mitigating and adapting the phenomena studied.

Method of conducting research.

The research methodology is divided into two phases: the first consists of a literature analysis, and the second of reworking the information. Figure 9 summarises the method used graphically.

Figure 9.Graphic representation of 1.1.4 paragraph methodology. Author's elaboration

Figure 9.



The first phase is characterised by an analysis of the literature concerning the topic: the relationship between the built fabric, rising temperatures and related extreme phenomena. Initially, the author investigates the topic through the Scopus platform. The keywords used are density, built form, urban morphology, urban heat island, heat waves, global warming and their combinations. The contributions found are filtered, taking only those in English and only from engineering field. From this group of papers, those most pertinent to the research – concerning the relation between morphology and microclimate of the built environment - are selected. Papers previously consulted for other sections of the thesis or other research investigating the influence of morphology on the urban microclimate are included in the group of documents. Following a skimming, the research is based on around forty documents, including books, articles in scientific journals, doctoral theses and conference proceedings. In this phase, all the parameters within the city that influence the increase in heat islands and the impacts of heat waves are identified.
The second phase of the research consists of reworking the information found on how the built environment influences the microclimate. The most important factors within the urban fabric that affect heat islands and heat waves are explicit and summarised below in 'Results and Discussion'.

Results and discussion.

Among the most widely used indicators in the literature is the Sky View Factor or urban canyon verticality ratio, which is insufficient to describe the wide range of urban forms encountered in cities in the Mediterranean area. In dense and compact urban configurations, the proportion of urban canyons results in multiple reflections of incident radiation, "radiative trapping," leading to more absorption of radiation, promoting overheating of surfaces and thus of the air (Salvati, 2016). The urban canyon that has been widely used to study the relationship between the heat island and the shape of the city turns out to be reductive since the density of the buildings causes contrasting effects, which must be adequately studied depending on the reference climate. The following are the leading indicators that influence heat islands and heat wave impacts within built-up areas:

- Topographic indicators:

- Elevation: As the temperature decreases, it rises in elevation along the slope of relief (0.65 °C per 100 m) (Gerundo, 2018).

- Average height of buildings: the average height of the buildings in the area under analysis. This parameter coincides with the height of the urban canopy layer, the layer closest to the ground, when calculating heat island influence (Gerundo, 2018).

- Land cover ratio (LCR) is the ratio of the covered area of building bodies. This ratio influences the radiative exchange of city surfaces by increasing temperature (Gerundo, 2018).

- Building density (BD), or building index, represents the ratio between the volume V of the n buildings in the area under analysis (Gerundo, 2018).

- Non-permeable surface Rate: represents the ratio between the impermeable surface and the total surface in the area under analysis. The increase in impermeable surfaces leads to an increase in the danger of rainwater runoff, which, unable to infiltrate the soil, washes away following the slope of the land (Gerundo, 2018). Other sources, such as (Bianco, 2020), identify the same parameter as the Biotope Area Factor (BAF) about soil permeability. From the point of view of calculation, the latter turns out to be slightly more precise because while the first parameter divides between permeable and non-permeable surfaces, the second one, BAF, is based on the classification of the materials constituting the urban fabric through a permeability coefficient. Similar to these values, the runoff is a function of the permeability of the surfaces constituting the existing.

- Reduction of building impact: (Rie) The R.I.E. index is an algorithm that calculates a building's or buildable area's capacity to adequately manage rainwater. The index can vary from 0 to 10 (with an open upper range), and the higher the score obtained, the better the response in terms of improvement (Bassolino, 2020).

- Urban Aspect ratio: represents the ratio between the height of two facing building curtains (Gerundo, 2018; Erell, 2008). Based on this principle, , different classifications of street canyons have been proposed, distinguishing between suburban aspect ratio (for H/W values between 0.1-0.5), urban aspect ratio or avenue (H/W = 0.5-2), and high rise aspect ratio or deep canyon (H/W >2), (Piringer e Joffre, 2005; Alberti & Guerri, Urban Aspect Ratio, 2020).

- Sky view factor: represents the portion of the sky visi-

ble from a given point at ground level. The parameter expresses in terms of percentage the ratio between the radiation received or emitted on a flat surface and the radiation emitted or received from within the radiating hemisphere (Gerundo, 2018) (Alberti & Guerri, Sky View Factor (SVF), 2020).

- Frontal area density (FAD) measures frontal area per unit of horizontal area and per unit of height increment. (Gerundo, 2018).

- Form ratio: includes all components of the building envelope that separate the closed spaces from the external environment. The more compact a building is, the better its bioclimatic and energy behaviour will be (Gerundo, 2018).

- Albedo: is a dimensionless index measuring the quantity and quality of incident solar energy reflected within a surface. It varies between 0 – white and 1 – black surfaces (Bassolino, 2020, p. 189-192).

• Urban green descriptive parameters

- Green area ratio: The area covered by urban green to the area under analysis is represented by the green area ratio (Gerundo, 2018).

- Normalized difference vegetation index: The NDVI index makes it possible to characterise the presence, vigour, phenological stages and stress conditions (phytopathology, water stress) of vegetation, being related to the anatomical structure of leaves, their shape and density and concentration of chemical pigments. NDVI varies, therefore, between -1 and +1. In general, if there is much more reflected radiation in the near-infrared than in the visible wavelengths, then it is likely that the vegetation present at a point is more dense (e.g., a forest). In that case, NDVI will tend to give positive values (0.3 ÷ 0.8), while negative values characterise the case of clouds and snow (Gerundo, 2018), (Di Pietro, Iamonico, & Strumia, 2020).

- Leaf area index (LAI): The LAI is a parameter used in forestry and defined as half the leaf interception area per unit of surface area (Chen, Black, 1992). From a dimensional point of view, it is expressed in square meters of foliage per square meter of soil (m^2/m^2) (Gerundo, 2018).

In order to take the above parameters into account, a preliminary analysis of the tissues undergoing redevelopment and adaptation is necessary, taking into consideration various morphological pa-

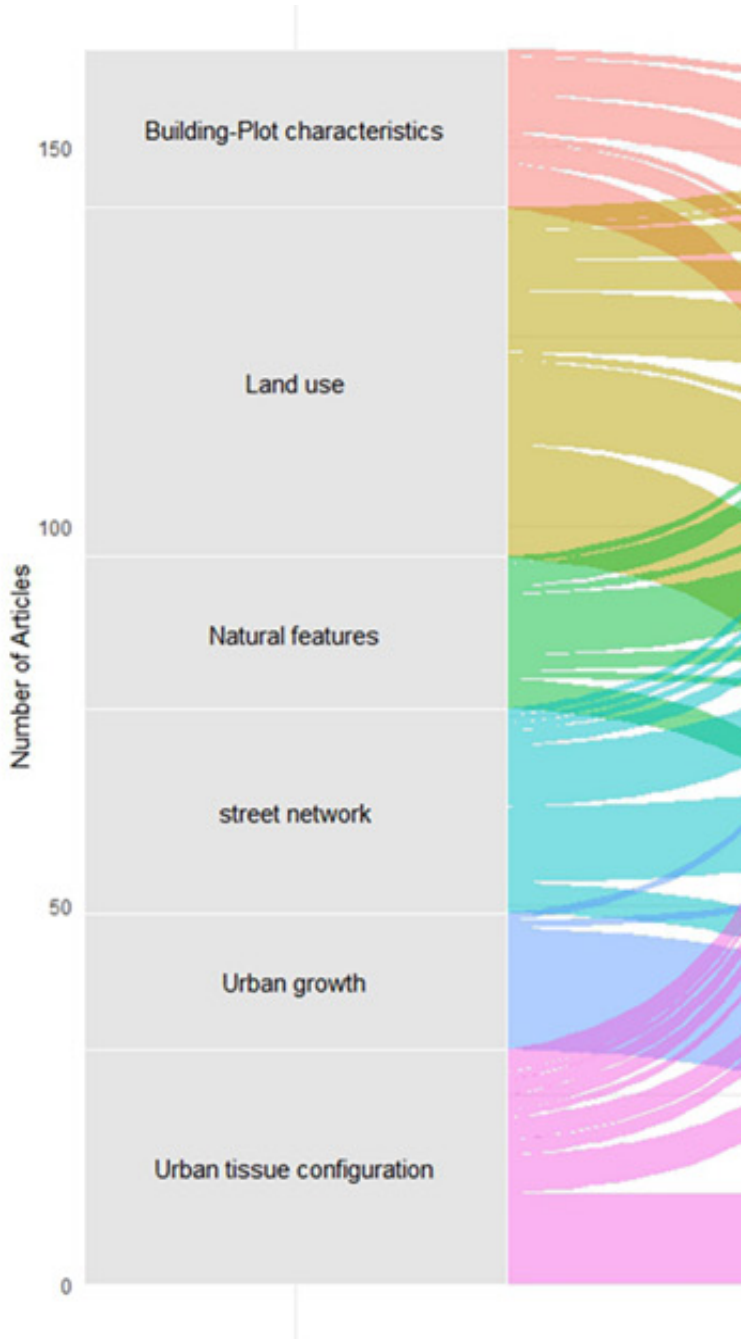
rameters such as the built-up area, the road network, vegetation, building height, shape and density (Kotharkar et al., 2023), (Liu et al., 2023) (Zhang et al., 2023, p.6). Of particular interest is the summary provided by Zhang in *Spatial measures and methods in sustainable urban morphology: A systematic review*, Fig. 10, where, on page 6, he identifies sustainable outcomes for different aspects of urban morphology based on an analysis of the literature.

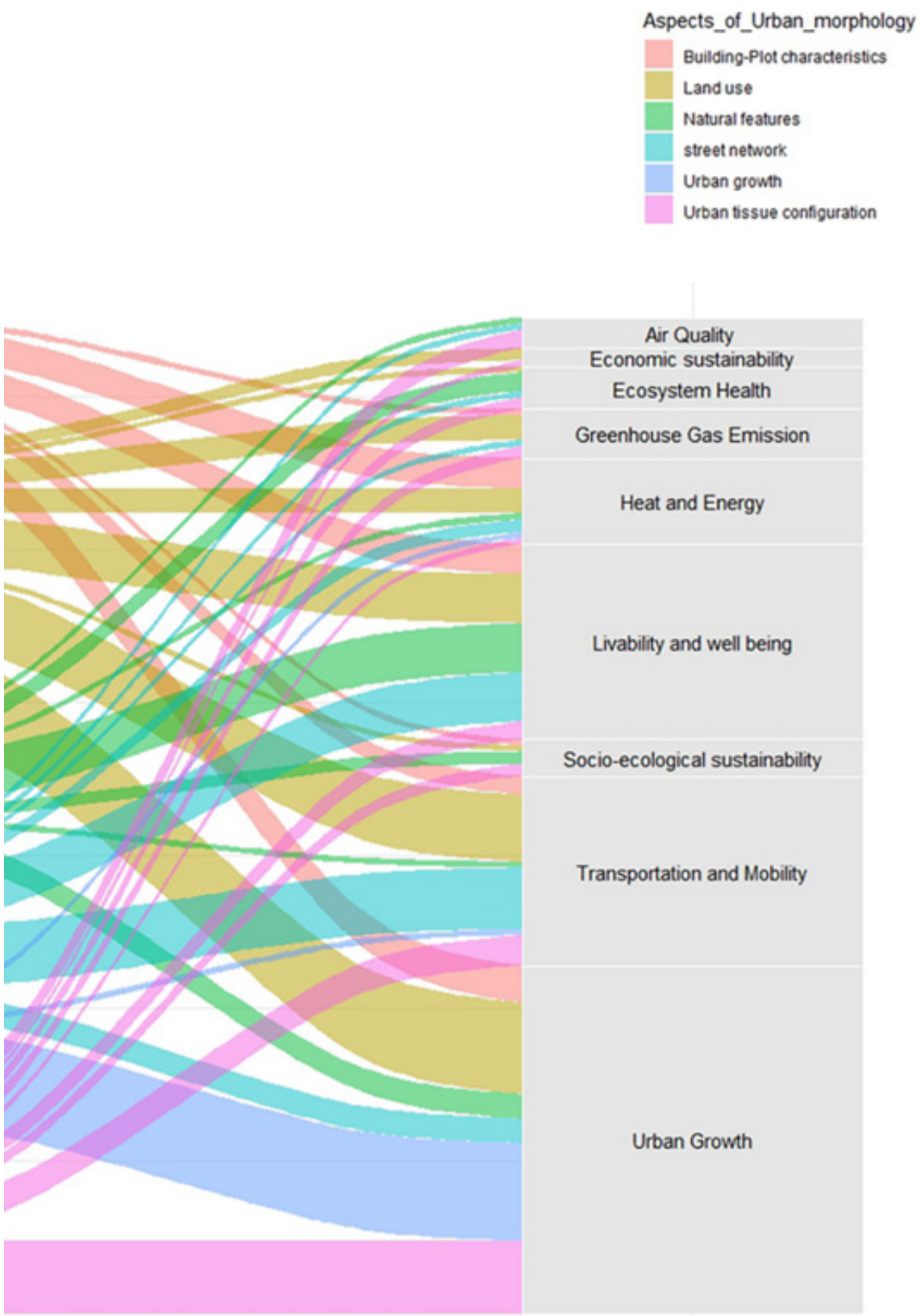
Oke conducted one of the earliest studies linking heat islands and urban geometry (Oke, 1981). In 1981, Oke theorised an analytical relationship between heat islands and morphology through a logarithmic relationship between the increase in UHI and the Sky View Factor.
Many contributions observed increased air temperature and heat island intensity in densely built-up areas with less vegetation. This happens because the morphology and thermo-radiative characteristics of urban surfaces change the energy balance, leading to an increase in net radiation as well as important changes in the ventilation as the shape of the city changes (Álvarez, 2013; Stewart & Oke, 2012; Salvati, 2016; Salvati, Coch, et al., 2017; Da Silva Lopes & Hora, 2024; Dorer et al., 2013; Elmarakby & Elkadi, 2024; Karimimoshaver et al., 2021; Kotharkar et al., 2023; Ottone et al., 2019; Salvati et al., n.d.; Urițescu et al., 2019, 2019; Zhang et al., 2023).
As Gehl states (Gehl, 2017), the form and interrelationships between cities and the microclimate, the presence of open spaces, green areas, and places to meet and share, strongly influence the psychophysical and cognitive well-being of inhabitants, contributing to an increase in the level of adaptation[6].
Today, to decrease the advance of extreme events related to rising temperatures, it is essential to act on the built fabric through urban regeneration actions to transform the existing fabric from a wound in the ecosystem to an integral part of it, acting in symbiosis with the surrounding environment and becoming a part of its metabolism (Morin, 2007).

6. Studies in psychology suggest that being exposed to green environments improves mental well-being: reduction of stress, increase of positive emotions, cognitive restoration, increase of self-regulation effects, encouragement of physical exercise, social interaction and longevity, decrease of air and noise pollution (Krekel & MacKerron, 2020).

Figure 10.

Figure 10. Sankey diagram of sustainable outcomes with different aspects of urban morphology. The width of the ribbons represents the number of articles (ntot = 89) (Zhang et al., 2023).




Aspects_of_Urban_morphology
Building-Plot characteristics
Land use
Natural features
street network
Urban growth
Urban tissue configuration
Air Quality
Economic sustainability
Ecosystem Health
Greenhouse Gas Emission
Heat and Energy
Livability and well being
Socio-ecological sustainability
Transportation and Mobility
Urban Growth

1.1.5| Simulation models

Summary.

Global warming, caused by anthropogenic emissions, requires rapid interventions on the existing residential stock that can stem the damage and meet the UN's 2030 and 2050 targets. Therefore, assessing the efficiency of different technological solutions to extreme phenomena due to rising temperatures is an important issue.
To address this part of the thesis, the author used an analytical-experimental approach to the problem, evaluating different environmental analysis tools on the urban fabric. In this way, it is possible to establish an analytical framework for comparing different software and to identify the most suitable for evaluating the efficiency of technological solutions applied to the existing. Among the wide availability of tools dealing with environmental analysis, Ladybug Tools is one of the most valid tools for evaluating the effectiveness of bioclimatic and energy actions applied to existing buildings. However, it has some limitations in the modelling of specific technological solutions.

Introduction.

This section aims to identify a tool for evaluating the effectiveness of bioclimatic and energy technology actions on the existing residential stock to improve adaptation and mitigate the impacts of heat waves and heat islands. The issue involves evaluating technological solutions' effectiveness and efficiency[7] in a given context.
To date, the importance of an architectural design responsive to the boundary conditions of a given place (climate, context, morphology, materials used) has driven developers to improve calculators and tools for evaluating the effectiveness and responsiveness of design strategies to the context in which they settle. However, due to the dynamic nature of the urban environment, it is difficult to

7. "Efficiency" refers explicitly to technological actions aimed at sustainability, but no univocal definition has been found. However, Figge et al. (2014) suggest that the term "eco-efficiency" means the "ratio between the value created and the resources used or the impacts created." "Eco-efficiency strategies focus on maintaining or increasing the value of economic output while reducing the impact of economic activity on ecological systems. Zero-emission, as the ultimate extension of eco-efficiency, aims to provide maximum economic value with zero negative ecological impact, a true decoupling of the relationship between economy and ecology" (Mair & Martí, 2006). Figge distinguishes two basic strategies for eco-efficiency: reduction and substitution. "reducing resource use per unit of value created increases eco-efficiency. Alternatively, companies can aim to replace the most harmful substances with less harmful ones per unit of value created to increase eco-efficiency.

identify one simulation tool for all types of contexts (Naboni et al., 2017). For this purpose, algorithms formulated for consultation by specialists such as physicists were simplified and explicitly formulated for the context of this study. Various researchers developed software programs for building-city interactions to simulate urban microclimates that can give information on MRT (mean radiant temperature) surface temperature: the radiant temperature represents a key parameter for describing extreme phenomena related to rising temperatures (Barriopedro et al., 2023) and key parameters affecting the well-being of individuals (Kamel, 2021a).
In 2017, Emanuele Naboni compared the most widely used software for environmental analysis on buildings to better understand their differences (Naboni et al., 2017). The evaluated software included CitySim Pro, ENVI-met, HoneyBee, Ladybug tools, and Autodesk CFD. Other comparisons have been carried out by (Giannelli et al., 2022; Badino et al., 2021; Naboni et al., 2017), including in the evaluation software such as GRASS GIS, ArcGIS, and SimStadt. Also, the research to identify a plan to mitigate and adapt the city of Singapore against heat islands compares multiple simulation software to qualitatively and quantitatively assess outdoor thermal comfort (Pignatta et al., 2018).
This part of the research comprises a literature review concerning the characteristics of the most commonly used tools for conducting environmental analyses. Subsequently, a comparison and analysis contribute to selecting the most suitable tool to assess bioclimatic and energy technologies applied to existing buildings.
Identifying a tool that can give quantitative indications, referring to KPIS, on the effectiveness of technological actions applied to the existing infrastructure for adaptation and mitigation to extreme events caused by the increase in temperature allows for the reinforcement of the evaluation of the effectiveness carried out through the literature review.
The methodology used and the results are detailed below. These are articulated in the identified instruments' comparison, analysis, and discussion.

Materials and method.

The methodology consists of two steps: identifying suitable instruments for an efficiency evaluation and selecting the most suitable instrument for the present research. Figure 11 outlines how this part of the thesis is conducted.

Figure 11.

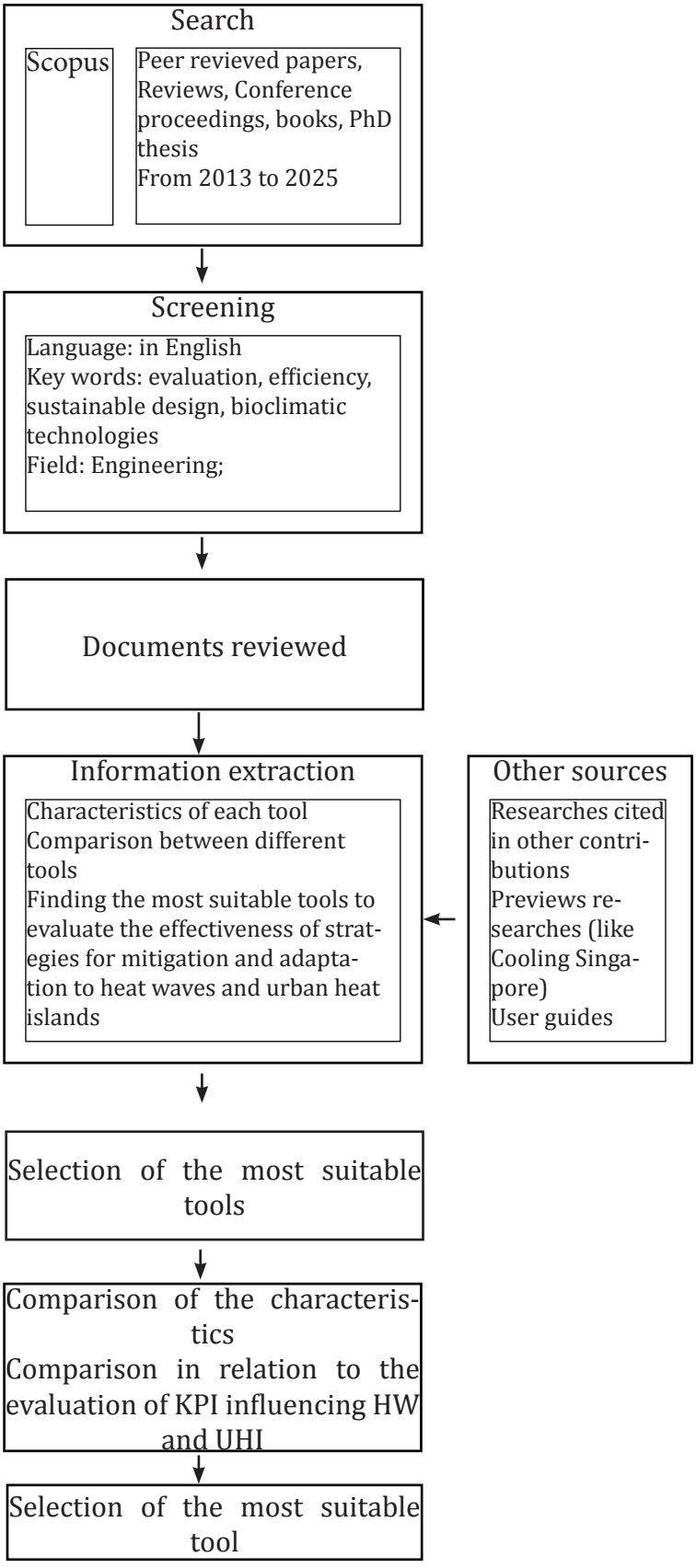


Figure 11. Outline the way research was conducted concerning para. 1.1.5. Author's elaboration

In particular, the first step consists of state-of-the-art research on existing, user-friendly software that performs environmental analyses. The research is conducted through the Scopus platform. Following an initial analysis of a wide range of documents, fifty-seven contributions have been selected, ranging from 2013 to 2024. The keywords used are *evaluation, efficiency, sustainable design, bioclimatic technologies* and their combinations. Subsequently, adding other, older contents was necessary as they were quoted within the articles as initial sources through which the various environmental analysis tools were developed. Finally, looking at the user guides of the most likely tools was also necessary.
The second part consists of a selection, from among the tools available on the market, of those that best meet the efficiency evaluation objectives. Specifically, the research compares three software tools, ENVImet, CitySim, and Ladybug, plugged into Grasshopper. These tools are selected because, according to the literature, they are the most suitable for evaluating the response of user-friendly strategies and actions in architectural and engineering fields to increase adaptation levels and mitigate against heat islands and heat waves. From the interpolation between the needs to assess both outdoor and indoor conditions and to have quantifiable KPIS, a choice of software has been made. The selection consists of two stages:

- In the first phase, the three tools have been compared generically by identifying the operating engine, merits, and shortcomings (see tab. II in the results). This comparison provides a basic overview of the software.
- In the second phase, the three tools have been compared in a way that is more responsive to the requirements of this research: in a table, the author checks, based on the previously analysed literature, whether the software performs indoor and outdoor simulations, whether they assess temperature, air humidity, average radiant air velocity temperature and whether they carry out assessments of individual comfort (a parameter not strictly related to the research, but of interest to evaluate effectiveness). The results of the research can be seen in the Table. III in the discussion part of this paragraph.

Results.

	ENVI-MET	Ladybug tools	Citysim Pro
Function	It is a holistic microclimate model system designed to simulate the surface-plant-air interaction in an urban environment.	It is a collection of computer applications that support environmental design.	CitySim Pro is a command-line solver for simulating buildings' energy demand and supply for space conditioning. It specifies the input buildings' characteristics and the climate file.
Simulation engine	CFD (Computational Fluid Dynamics Model)	Energyplus, Open Studio	GUI/shell scripts GUI only (for data import/conversion)
Strengths	It considers the hemisphere's geometric characteristics: each vector is weighted by a factor of the angle of incidence relative to the surface	Freeware	Freeware
	Cool surfaces in shaded areas indirectly reduce the radiated surface temperatures and vice versa.	Accurate characterisation of the model	Flexibility in importing the model (from SketchUp, as .dxf, or as a Rhino model)
	It takes into account the interaction of vegetation with the microclimate.	Possibility of parametrisation.	
	It can be a plug-in for GIS platforms, SketchUp, and Grasshopper software.	Possibility of taking into account both indoor and outdoor conditions.	
		It evaluates multiple design iterations with high spatial and temporal resolution in shorter times.	

Table II. Comparison of ENVImet software, CitySim, and Ladybug tools.

	ENVI-MET	Ladybug tools	Citysim Pro
Weaknesses	Overestimate the global radiation.	The amount of heat emitted and stored in materials is not considered.	It provides just outdoor conditions and indoor temperature.
	It can take into account just the outdoor conditions: it is not possible to evaluate indoor conditions.	it provides an estimate of evapotranspiration based on the ratio between vegetation cover and albedo (UWG).	
	Very long simulation time.	It does not provide fluid dynamic evaluation unless using Butterfly.	Very long simulation time.
	Approximate geometry model.		

Table III.

Comparing different simulation models was possible by analysing scientific literature, including reviews and application cases, and consulting the guides for each tool.

Ladybug Tools provides a suite of plugins for Grasshopper, a visual programming language for Rhino, which enables designers to conduct environmental analysis and simulations for architectural design. Ladybug, Honeybee, Dragonfly and Butterfly are all components of the Ladybug Tools suite for Grasshopper: Ladybug deals with environmental analysis, including that of natural lighting and solar radiation; Honeybee handles building energy simulation, from heat load calculations to energy sustainability assessments; Dragonfly focuses on data visualisation and analysis; and Butterfly specialises in computational fluid dynamics for advanced airflow simulations (Zarcone, Nava, & Tucci, 2024). A microclimate generator consisting of four models is used for urban microclimate simulation (Bueno et al., 2014):

- RSM: a model based on energy equilibrium at the ground surface. A transient heat diffusion equation is solved using finite Element Analysis methodology to represent heat accumulation and release from the ground.
- VDM: Reads air temperatures and speed measured by the weather station and sensible heat fluxes calculated by the RSM. It calculates vertical air temperature profiles above the weather station by solving a heat diffusion equation. The USB model supplies it.
- UBL: The UBL model calculates air temperatures above the urban canopy from vertical air temperature profiles provided by the VDM and sensible heat fluxes provided by the RSM and

UC-BEM. The model uses an energy budget for a selected control volume within the urban boundary layer.

- UC-BEM: The UC-BEM calculates urban canyon air temperature and humidity from irradiance and precipitation data, air speed and humidity measured by the weather station, and air temperature above the urban canopy layer calculated by the UBL model. The Town Energy Balance (TEB) scheme, including the building energy model (Bueno et al., 2012), is the basis of the model (Le Bras & Masson, 2015).

The model's mode of operation consists of its division according to wind directions into four quadrants (north, west, south and east). At each time step of meteorological data (based on available observational data), the model identifies upwind and downwind neighbourhoods according to neighbourhood proximity and wind direction. The model calculates the average air boundary layer temperature for the first group (the upwind group) and passes it as the reference temperature to the second group. The second and third groups follow the same process. If the first group is empty for a specific wind direction, the next group containing the central neighbourhood becomes the first one. The model imposes no restrictions on the size of the different neighbourhoods. Therefore, the user should be aware that the model considers the reference air temperature for a particular neighbourhood to be that of the upwind neighbourhoods, regardless of size.

The energy performance of each building type is simulated separately and in parallel. All building types in a neighbourhood are affected by the same urban climate (that of the neighbourhood), and their effect on the urban climate is weighted according to the distribution of building use. The aim is to to estimate better the energy consumption of buildings at the urban scale and the sensible heat fluxes released into the environment (Bueno et al., 2012).

ENVI-met is designed to simulate surface-plant-air interactions and has been widely validated and used in recent years (Wang et al., 2016). ENVI-met performs detailed calculations of short-wave and long-wave radiation fluxes concerning shading, reflection, and radiation from building systems and vegetation and considers evapotranspiration and sensible heat flux from vegetation to air, including full simulation of all plant physical parameters (Perini et al., 2017). ENVI-met has a typical spatial resolution of 0.5 m to 10

m and a temporal resolution of 10 s. A simulation should be run for at least 6 hours to stabilise the fluid dynamic model. Therefore, researchers used to carry out 24-hour simulations. The optimal time to start a simulation is at night or dawn so that the simulation can follow the daily increase in solar radiation. ENVI-met requires an area input file with three-dimensional geometry and a configuration file with initialisation input parameters. The simulation does not consider anthropogenic heat emissions.

CITYSIM CitySim is initially developed as a linear command solver to simulate the energy demand and supply of conditioned space in buildings by specifying building characteristics and a climate file. The software has been developed and tested at the Solar Energy and Building Physics Laboratory (LESO-PB) of EPFL (l'école Polythechnique Fédérale de Lausanne). Following satisfactory results, the energy consulting firm Kaemco developed a graphical, user-friendly software interface still under development (Citysim Pro) (Mutani G. , Coccolo, kampf, & Bilardo, 2018). The definition of the building envelope, which includes three surface types, articulates the operation: floors, walls and roofs, each with a homogeneous temperature. A four-node model can represent a building's thermal zone, in which all components, including light materials in a room (air and furniture), floors, the envelope, and fixtures, are represented by nodes, which interact with each other. Indoor and outdoor air temperatures, window conductance, infiltration/ventilation of fixtures, internal convective gains, heating and cooling loads, surfaces, floor and ground temperatures, internal convection coefficient, light flux transmitted by glazing, and convection coefficients of external wall and roof surfaces are parameters that are part of the calculation. In addition, radiant and convective exchanges influence the temperature calculations by determining sources in the energy balance of thermal nodes, which depend on absorbed incident light flux and infrared energy exchange (Mutani, Coccolo, & Bilardo, 2014).
The Building Energy Simulation Test (BESTEST) validates the software. The U.S. National Renewable Energy Laboratory, the International Energy Agency, and the U.S. Department of Energy developed this evaluation method. The approach compares a candidate program against a set of reference programs representing the state of the art in building simulation on a series of reference test cases (Emmanuel & Jérôme, 2015)

The chosen software must meet the needs related to the fact that it can quickly perform many simulations, using quantifiable indicators and evaluating indoor and outdoor environments. All three simulation models are validated (Alsaad et al., 2022; Emmanuel & Jérôme, n.d.; Salvati et al., 2019) and represent good options for evaluating how technological solutions respond to changing context as a function of adaptation and mitigation to islands and heat waves.

Discussion.

ENVImet presents a fluid dynamic simulation model for developing microclimate models for interacting with the urban environment, surfaces, plants, and air. Although it features very long simulations, uses approximate geometry, and takes into account the outdoor environment, it has many strengths, including precise calculation of interactions between vegetation and microclimate, consideration of hemisphere characteristics factor, weighted by the earth's angle of incidence, and the fact that it could be a plug-in of other software.

Ladybug tools use simulation engines such as Energy Plus and Open Studio. Among its weaknesses is that it cannot estimate unless Butterfly uses the effect of ventilation within the neighbourhood, which is a more approximate estimate than ENVImet for vegetation modelling. It does not consider the amount of heat stored and emitted by surfaces. On the contrary, among its strengths, we need to consider accurate model construction, fast simulation time, parameterisation, and evaluation of the indoor and outdoor environment, coupled with the fact that it is possible to download and use it free of charge.

CitySim is also free software that allows very accurate simulations and the possibility of importing geometries from numerous software (Sketchup, Rhino, Autocad). Among its outputs, it also calculates energy production from photovoltaics and heat and cooling demand. In contrast, weaknesses include the inability to calculate any indoor and outdoor well-being index and any parameter in the indoor environment other than temperature.

As shown in Table IV, Ladybug tools, although they do not perform fluid dynamic simulations and do not calculate ventilation inside the built-up area, best meet the objectives of the simulation speed and evaluation of indoor and outdoor KPIS.

Table IV

MOST IMPORTANT PHYSISCAL FACTORS CONNECTED WITH HW AND UHI		ENVI-MET	Ladybug tools	Citysim Pro
Air temperature	Indoor		√	√
	Outdoor	√	√	√
UR%	Indoor		√	
	Outdoor	√	√	√
mrt	Indoor		√	
	Outdoor	√	√	√
Wind speed	Indoor			
	Outdoor	√		√
Comfort	Indoor		√	
	Outdoor	√	√	√

Table III. CitySim, Ladybug tools, and ENVImet software comparison according to the characteristics sought in the above research.

Using Ladybug Tools, it is possible to evaluate, through KPIS, the variations between data from a weather station and those from microclimate modelling within a neighbourhood as the different technological solutions analysed change. The decision to use Ladybug tool is based on the desire to carry out simulations in the same parametric modelling environment (Rhinoceros/Grasshopper), allowing the simultaneous evaluation of various parameters and scales of analysis and the automatic calculation of the effects on the phenomena considered concerning changes in different input parameters (Fig. 13).

Figure 13

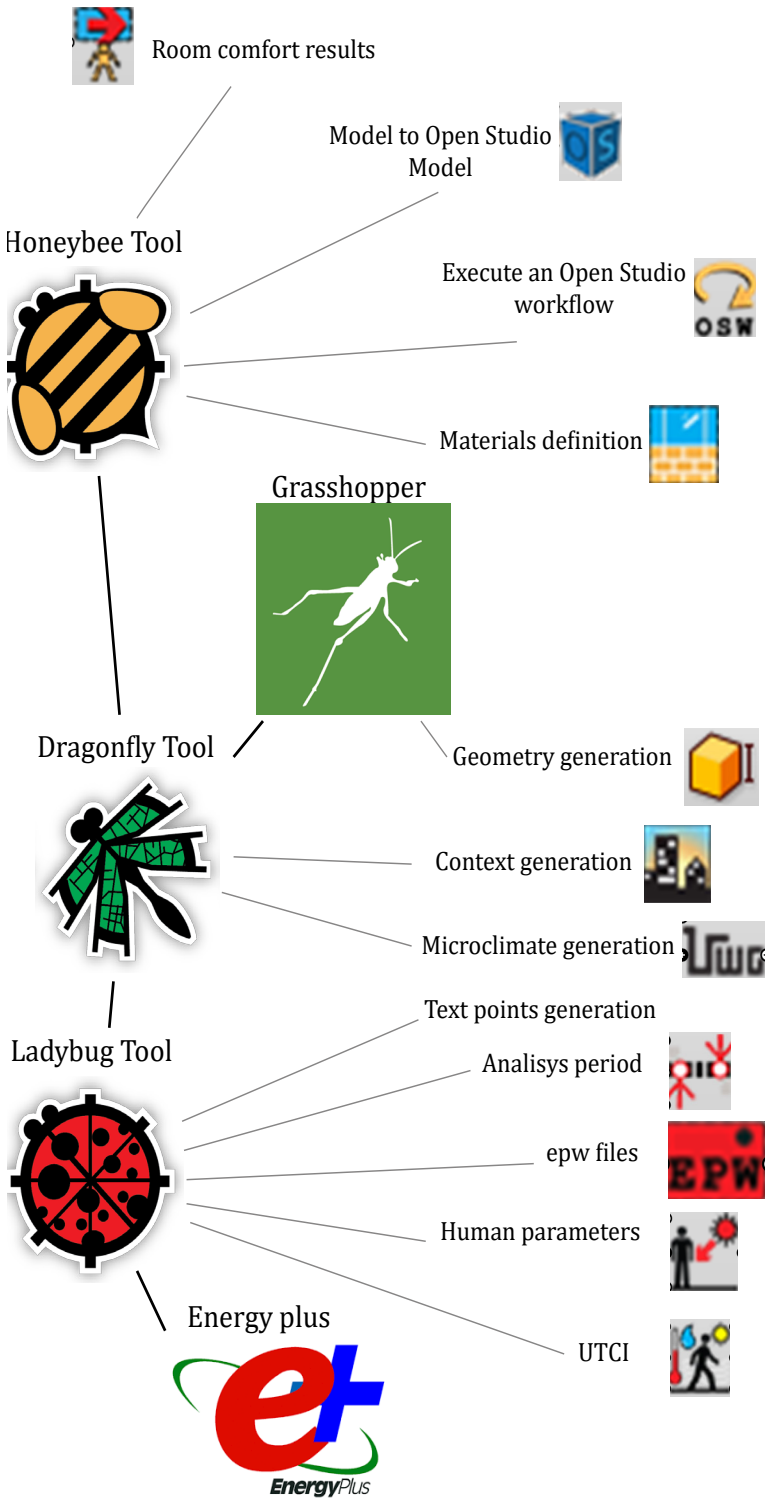


Figure 13. Map of Ladybug tools main ones and used. (Zarcone, Nava, & Tucci, 2024)

1.1.6| Research object and definition of urban environmental problems. Adaptation to phenomena due to islands and heat waves.

Summary.

Warming temperatures strongly impact the existing built stock. At the same time, the shape and materials of population centres increase various dangerous phenomena due to rising temperatures. Effective and efficient solutions are necessary. This chapter identifies the best ways to act on the existing fabric to decrease impacts from heat islands and heat waves.
The methodology used consists of two steps. The first is a literature review of today's methods to reduce the aforementioned phenomena, including a literature review and an example of best practices. The second is a review of solutions adopted in the past that are useful for understanding methods to decrease temperature without active cooling systems.
This part of the thesis illustrates the need to take bioclimatic and energy actions on the existing to improve the behaviour of structures and infrastructure, improving comfort levels. Some methods used in the past are still valid, and some represent best practices from which to take examples. The chapter outlines some of the best approaches found in the literature.

Introduction.

One of the most important global challenges is finding solutions to the climate-environmental crisis. While previously there was talk about the possible risks, focusing on the future, that the crisis would bring, now some risks, as rising temperatures and related phenomena have occurred, so it is necessary to undertake changes that have results in terms of adaptation and, as far as possible, mitigation of the phenomena.
An economy based on energy conservation and efficiency in the architectural field, the encouragement of the use of energy from

renewable sources, and the protection of resources would allow for greater competitiveness, also from an economic point of view, guaranteeing the achievement of the cornerstones of the circular economy (Stati Generali della Green Economy; Fondazione per lo sviluppo sostenibile, Ecomondo, 2020). The issue is not easy to analyse as it is linked to other emergencies, such as the scarcity of energy resources resulting from the conflicts affecting the planet, which entail chain effects (energy supply modes, transportation, raw materials, economics and geopolitics).

As cities are responsible for nearly 70 per cent of global consumption, (European Environmental Agency, 2020) states that measures and actions ad hoc can mitigate consumption and increase adaptation. Furthermore, long-term population flow trends show that in the future, cities will be home to an increasing proportion of the world's population, increasing energy demand even more (World Economic Forum, 2022). Despite important achievements, the civil sector, particularly the residential one, is responsible for 45 per cent of final energy consumption and 17.5 per cent of direct pollutant emissions in Italy. It is, therefore, necessary to intervene with more appropriate technologies and solutions and more streamlined tools and procedures.

In this sense, new construction interventions are highly discouraged as they would increase the rate of embodied carbon deriving from new materials, causing it to grow exponentially for demolition interventions and subsequent new construction[8]. Moreover, regarding housing availability, Italy has the highest rate of vacant and available buildings (Housing Europe, 2021). However, experts estimate that more than 1.2 million new buildings will rise in the next ten years. On the contrary, it is advisable to act on the existing fabric, in particular on neighbourhoods in the process of degradation or abandonment, on the suburbs, a fascinating landscape from an architectural point of view, public housing complexes are built by big names in architecture, following specific design, architectural and social strands (Gallo & Romano, 2018). Furthermore, these neighbourhoods, built in the late 1800s and early 1900s, did not enjoy active climate control systems and already exhibited inherent bioclimatic behaviours. A requalification of these contexts, through the encouragement of such behaviours, leads to a decrease in energy consumption, an increase in the feeling of well-being, a decrease in expenses, and an enhancement of social, historical, and architectural heritage.

8. In addition to direct energy consumption due to active plant systems, there is indirect energy, i.e., related to the production of the materials that make up buildings. This energy is called "grey energy" or embodied energy; similarly, the sum of indirect climate-changing gas emissions related to the components of a building is called embodied carbon (embodied carbon) (Asdrubali & Grazineschi, 2022).

Method of conducting research.

This part of the research consists of two phases:
The first is a literature review regarding mitigating extreme phenomena and adapting the existing residential stock. This phase is characterised by a Scopus-based literature review and carried out using the following keywords: adaptation, mitigation, and global warming. The selected articles, only in English and in the field of engineering, are open access and also include within them the following filters: *climate change, sustainable development, buildings, sustainability, urban planning, urban area, thermal comfort, renewable energy sources, heat island, built environment, building, building stock*. This base is expanded by including contributions found in other research and by consultation with some protocols that refer to the same themes, such as LEED and Passivehaus. Past building strategies are also consulted at this stage, using various books to understand how to mitigate the effects of excessive heat and increase adaptation without active air conditioning systems. From this basis, it assesses that addressing the problem with a bioclimatic and energy efficiency approach would decrease emissions and expenditures and increase levels of mitigation and adaptation to heat waves and heat islands.
The second phase consists of searching for best practices: plans concerning bioclimatic and energy solutions applied in the present, such as the adaptation plan developed for the city of Paris, the centre of Amsterdam, or Singapore, represent a fundamental step in understanding the approach used and the methodology to tackle the problem. In particular, the plan for Singapore provides a straightforward methodology for analysing the area and actions. Figure 14 schematically represents the steps taken to understand how to approach the problem of adaptation and mitigation from islands and heat waves on the existing residential stock.
The following section details the results.

Figure 14.

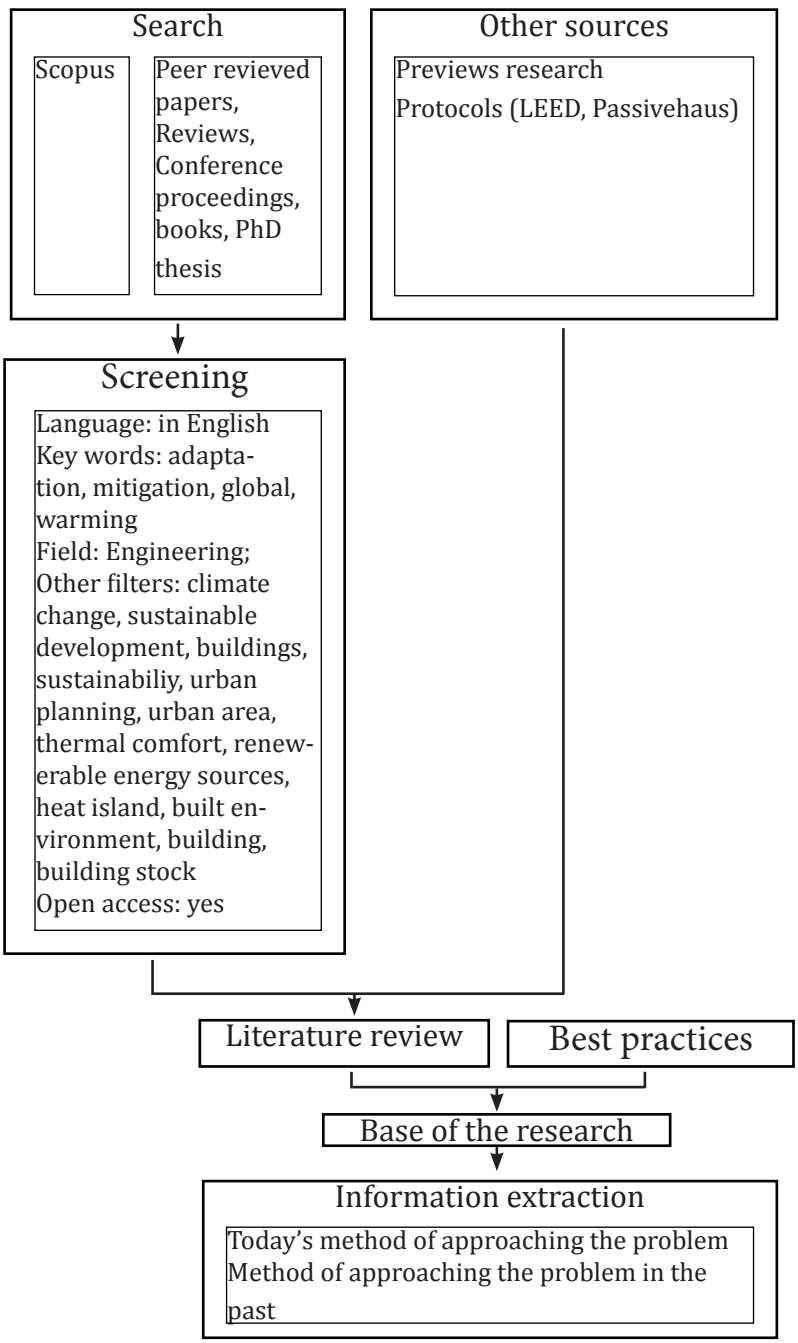


Figure 14. The scheme represents the method used to increase levels of adaptation and mitigation from heat islands and heat waves on existing residential stock—author's elaboration.

Results and discussion.

1. Bioclimatic requalification and energy efficiency:

Although V. Olgyay[9] and B. Givoni[10] first coined the term 'bioclimatic approach' in architecture, special attention to the relationship between nature, architecture, and the ecosystem has always been present in the building methods of the past, fig. 15. Offspring of this relationship are solutions such as the wind chimneys built in Arab countries, trulli that evacuate hot air through the roof, and dwellings carved into the rock that exploited thermal inertia, developed in Italy, Spain and America - a significant site is Mesa Verde (USA), the Chinese Yao Dong dwellings and others (May, 2014).

9. Victor Olgyay was an architect, a planner, and one of the first researchers in bioclimatic architecture. Until 1970, he was an associate professor at the School of Architecture and Urban Planning at Princeton University. His first article, " The Temperate House" (1951), showed his interest in this topic. Other academic productions followed this paper, such as "Bioclimatic Approach to Architecture" and "To Pave to Bioclimate Control and Orientation to Meet Requirements" (1954). Later, due to the global energy crisis of the 1970s, interest in the work of this researcher (and his brother Aladar, who was working on similar issues) grew even more among scholars of the subject.

10. Baruch Givoni was an Israeli architect specialized in bioclimatic design. One of his most famous writings is "Man Climate and Architecture" (Elsevier, Amsterdam), from 1969, in which he explores issues concerning energy and buildings, the atmosphere, urban climate, and solar energy.

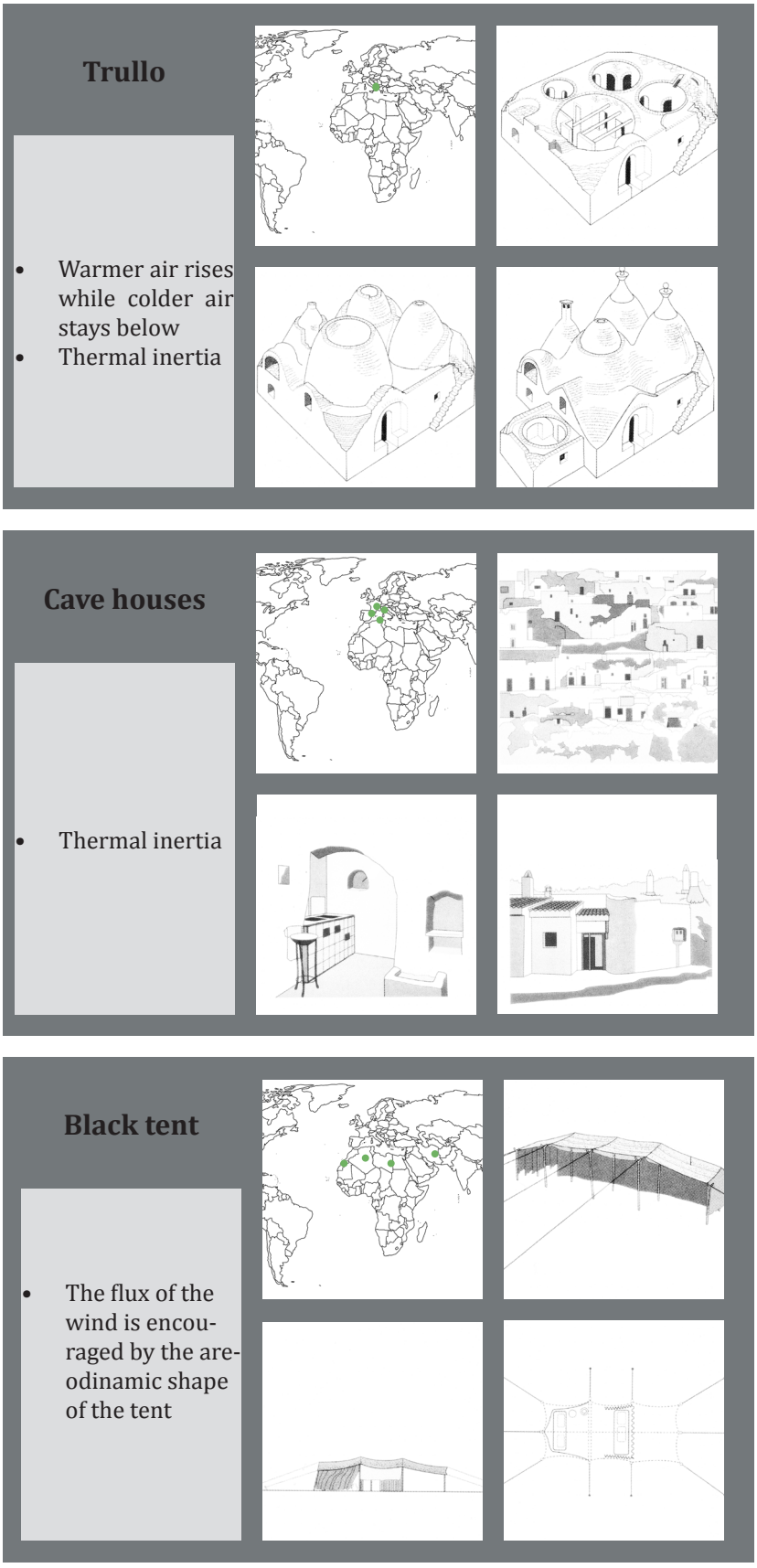
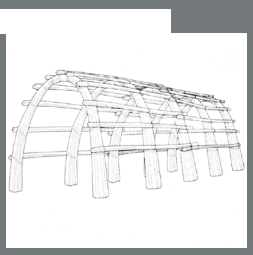
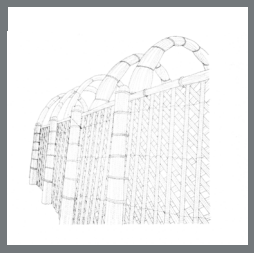
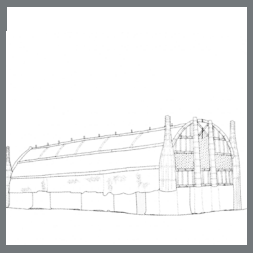


Figure 15. Bioclimatic solutions in the spontaneous architecture – Author's elaboration based on (May, 2014)

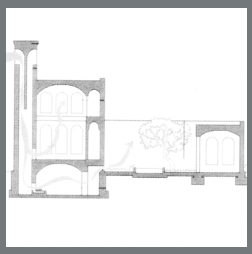
The Reed House of the Marsh Arabs

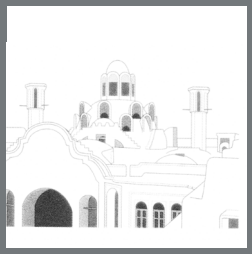
- Between one reed and the next, there is a layer of air that allows the wind to penetrate inside

Court house and wind towers

- Wind tower and porches increase the ventilation indoor and air renewal



Chinese Yao dong

- Thermal inertia

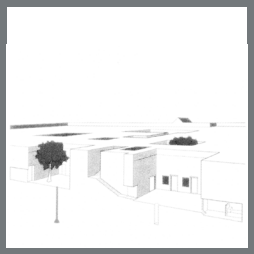
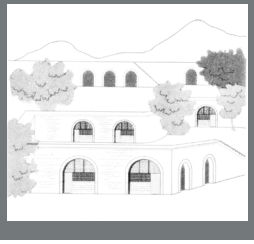
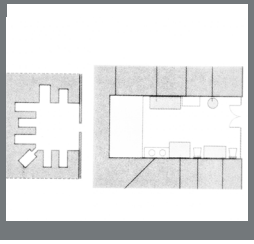





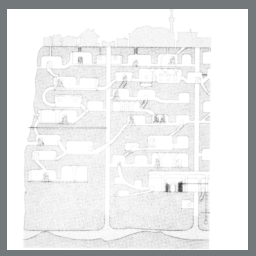
Figure 15.

Innovative and integrated energetic and bioclimatic strategies for adapting existing contexts to climate change and extreme events, aiming to mitigate the environmental impact
p. 94

Inhabited caves in Cappadocia

- Thermal inertia

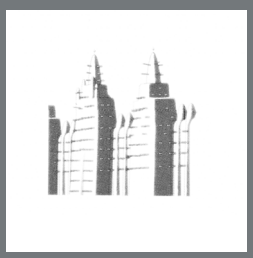
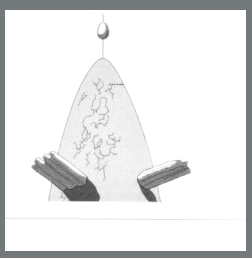





The Great Mosque of Djenne

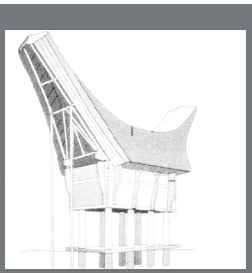
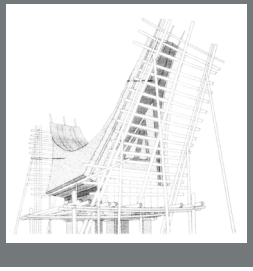
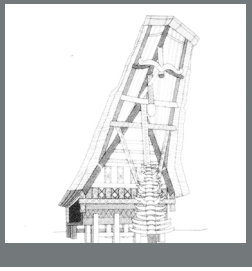
- Thermal inertia - given by bricks and mud plaster
- palm branches minimise cracks ceramic downspouts direct water away from the building



Toraja's Tongkonan

- Warmer air rises while colder air stays below
- Wooden piling defends against rainfall

In his 'De Architettura', Vitruvius has already touched on the best way to orient buildings or the choice of healthy locations to build (Cecafosso & D'Olimpio, 2020). The characteristics of the bioclimatic approach in construction, summarising what V. Cecafosso and D. D'Olimpio have enunciated, are articulated in the environmental and climatic study of the project site and its interactions. It is, therefore, essential to have a biological investigation, on the one hand, that defines human sensations and an energy one that defines the consumption of the buildings. This investigation aims to set up architectural and non-architectural solutions to improve positive climatic characteristics and mitigate disadvantageous or problematic ones (Cecafosso & D'Olimpio, 2020). These strategies mainly consist of encouraging active technological solutions on the one hand and passive bioclimatic building behaviour on the other. Bioclimatic architecture and energy efficiency today cannot be disjointed as they are now part of the same theme, and the result is not divisible: bioclimatic design can lead to decreased energy consumption (Claudi De Saint Mihiel & Thiebat, 2023; Cecafosso & D'Olimpio, 2020).

'Energy efficiency is defined as the ability of a physical system to achieve a given result using the least amount of energy compared to other less efficient systems, increasing its efficiency and consequently achieving energy savings, lower costs and increased environmental benefits' (Cumo, Piras, & Sforzini, 2019). As long as there were no space heating or cooling systems, it was customary to keep in mind the passive behaviour of the building to ensure thermo-hygrometric well-being. From the early 1900s, the first radiators began to be developed for space heating during the winter, not caring about cooling in the summer and considering heat as a 'thing to bear'. As heating systems developed and became more commonplace in homes, the minimum standards of comfort also changed. According to the various editions of the Italian Engineer's Handbook, it appears that professionals should calibrate the systems to maintain an indoor temperature of 16°C; later, the limit was moved to 18°C and grew (Colombo, 1944). The last law for dimensioning systems stipulated an indoor temperature of no more than 26 °C. From these figures, it is clear that, since the early 20th century, immoderate use of active heating systems has reached indoor temperatures in winter that require too high an energy expenditure. It was not until 1976 that the first law on the consumption of buildings was issued in Italy: 'norms for the

containment of energy consumption for thermal uses in buildings' (particularly in Article 3) (Norme per il contenimento del consumo energetico per usi termici negli edifici, 1976). From that moment, energy consumption started to be the object of attention. This fact can also be seen from a social anthropological point of view, for example, in the change of clothing from the early 1900s to the present day: if, in the past, there was a clear difference between winter and summer clothing (under the shirt it was customary to wear a woollen sweater), this is no longer the case today. Just think of men's '4-season' clothin[11].

1.1 Energy and Bioclimatic Requalification: Economic aspects.

Economic reasons support the thesis that mitigation and adaptation are the cornerstones of future development, technological development that allows a decrease in consumption postulates, consequently, economic and energy savings. In a time of scarcity of energy resources, theoretical contributions rule out the possibility of "long-term" energy shortages and postulate the emergence of a future, uncertain "backstop technology" (Nordhaus, 1973)[12] that can replace today's exhaustible source technologies.
At the same time, promoting research on new renewable source technologies would divert resources from consumption and capital accumulation (D'Alessandro, Luzzati, & Morroni, 2010, p. 532). Renewable energy research involves upfront but short-term costs for future growth and gains (D'Alessandro, Luzzati, & Morroni, 2010, p. 533). Many economists have complained that having continuous economic and social growth as a goal implies enormous costs from natural resource depletion and pollution. Moreover, GDP, which has always been a fundamental parameter for quantifying a country's well-being, does not reflect its actual well-being but represents a small part of a much larger system (Barro & Sala-i-Martin, 1998)[13]. This single parameter cannot consider social relations, security, cultural and environmental heritage and only partially considers aspects such as quality of services, health, education and training. Studies have emphasised the need to decouple welfare from economic production. Since the Industrial Revolution, fossil fuels were the basis of the economy. Numerous studies have pointed out that using renewable energy alone is not enough. A reduction in consumption growth would also be necessary (D'A-

11. A discussion with Professor Emanuele Habib, DIAEE Associate Professor Department of Astronautical, Electrical and Energy Engineering - Technical Physics area, was the basis of the reflection regarding the change in lifestyles resulting from the appearance of heating systems. This comparison shows that excess heat was not considered a problem in the past. On the contrary, with the spread of heating systems, the indoor temperature of buildings rose higher and higher. This behaviour also affected lifestyles and fashion.

12. Energy resources are essential for the existence of markets and their consumption extends over a very long period. This creates a dependency between the resource and the market. But since the availability of future resources and technologies is uncertain, so too is the path of energy consumption (Nordhaus, 1973).

13. ISTAT has identified 12 indicators of well-being grouped into twelve domains of well-being, namely: health, education and training, work and life-time balance, economic well-being, social relations, politics and institutions, security, subjective well-being, landscape and cultural heritage, environment, innovation, research and creativity, and quality of services (Istituto Nazionale di Statistica (ISTAT), 2022)

lessandro, Luzzati, & Morroni, 2010, p. 538)
That is why the issues of the bioclimatic and energy levels in buildings cannot be treated separately. On the one hand, in the energy field, it is important to develop innovative, active technologies. In contrast, studying the morphological characteristics of buildings and the environment in the bioclimatic field is essential to take up existing passive technologies, increase their effectiveness, and, where possible, set up new passive solutions. If buildings did not architecturally behave bioclimatically, they would consume much more. However, bioclimatic strategies alone cannot always ensure thermo-hygrometric well-being, so active technologies should couple it.
The manifesto of the Green Economy[14] (UNEP, 2008) strongly reflects environmental and technological design issues. It is also linked to the interconnection between bioclimate and energy efficiency approaches. It encourages the protection of natural and cultural capital. Capital preservation refers to promoting beauty and architectural quality while safeguarding the identity of places, cultural uses, jobs, and traditions. "The enhancement of heritage through actions of urban regeneration as an important driver of a possible Green Economy, rehabilitation and reuse as a necessary promotion of new housing supply to attract renewed users/repopulation, and energy efficiency as a fundamental element of economic savings in the management of heritage must constitute the elements of reflection on how to transfer 'global' theorisations into the multiple local realities" (Antonini & Tucci, 2017).
In Italy and Europe, since the crisis of 2008, there has been a contraction of urban growth that has given rise to the appearance of abandoned and degraded areas, "in the real estate market, the trend of prices and rents is strongly influenced by the characteristics of the area in which the property insists, and the possible existence of areas of degradation in proximity has negative effects on demand for that area" (Mattarocci, 2018). These effects trigger negative dynamics that can worsen over time: the depopulation of areas and extreme events that would lead to further degradation (floods or extreme drought phenomena), lower demand, and exacerbate the phenomenon. All these aspects point to the importance and urgency of acting in such contexts. On the contrary, efficient residential systems, the quality of buildings and infrastructure, orderly and efficient land use, and attractive and functional cities are key parameters for balanced growth of jobs and market op-

14. Green Economy: an initiative promoted by the United Nations Environment Program to address the climate, ecological-environmental, social and economic-financial crisis. "A Global Green New Deal" project outlines sustainable developments, considering several objectives: "revitalizing the world economy and creating new jobs; tackling the climate crisis by promoting investments, both private and public, in the development of clean technologies and green infrastructure, particularly in support of energy efficiency, renewable energy development and natural resource conservation" (UNEP, 2008).

portunities (Antonini & Tucci, 2017; Mastrolonardo et al., 2018).

1.2 Bioclimatic and energetic requalification, protection and conservation

From the conservation point of view, a joint action of bioclimatic and energy redevelopment would trigger building behaviours by encouraging adaptation in the face of extreme phenomena and mitigating the negative impacts of built-up areas. The world of historical/architectural heritage conservation and resource and environmental conservation can no longer be separated, as they are interdependent. Today, it is necessary to review the relationship between the conservation of matter and energy (Pianezze, 2012). Today, the two topics are separated, dealt with in different degree courses, and used completely different methods. Even in the workplace, few companies today deal with both topics. In reality, the focus on land conservation and architectural heritage is one big thread and represents one of the most important challenges of contemporary life. As far back as 1849, John Ruskin stated that 'the earth is ours for the taking, it is not our possession' (Ruskin, 1981)[15].

With the Amsterdam Declaration in 1975, the concept of 'integrated conservation' formally appeared for the first time. It was echoed in the Brundtland Report[16] of 1987 (Carbonara, 1997, p. 166) that affirmed: 'Sustainable development meets the needs of the present without compromising the ability of future generations to meet their own needs' (Commissione mondiale sull'ambiente e lo sviluppo -WCED-, 1987). At the same time, the issues of restoring environmental quality and sustainability were debated at length during the 1970s and 1980s in much the same way that conservation issues were debated. Acting through a multidisciplinary approach, taking 'resource' in its broadest meaning (i.e. any limited asset that is a source of wealth), each of the constituent elements of a system (la Repubblica, 2022) can provide the proper range of applications.

As far back as 2009, the Federal Office of Energy and the Federal Commission for Historic Monuments affirmed the need to treat natural and artificial resources as a unicum with the same objective of 'supporting sustainable development' by reducing energy consumption and covering needs through renewable energy sources.

15. John Ruskin (1819/1900) was a leading exponent of what is commonly called "romantic restoration." Initially he was an art critic, following travels in Europe, he became increasingly interested in architecture and the subject of Restoration, which he interpreted with a well-rounded meaning: it is necessary to preserve not only works of art or artefacts but also in the environment around us and nature. His reflections on the "imprint of time on the work" add value to the sublimated beauty. According to the critic, sublimity is not the degradation itself but the fact that this assimilates architecture into nature's work. Returning to a natural state does not impoverish but enhances beauty. Moreover, Ruskin challenges the criteria for valuing architectural heritage development in Europe because they lead to the loss of irreplaceable values, money cannot identify the loss of wealth, and the loss of a non-renewable resource.

16. Brundtland Report is a document published in 1987 in which the concept of sustainable development was introduced. Although there is no overt mention of the environment, there is an apparent reference to people's well-being and environmental quality. Thus, it formulates an ethical principle underlying eco-sustainability: responsibility, from present to future generations, for maintaining environmental and resource balance (Commissione mondiale sull'ambiente e lo

sviluppo -WCED-, 1987)

The need to conserve energy resources and existing artefacts with intrinsic historical, architectural and cultural values is justifiable and pursues the same objective of supporting sustainable development. The Office indicates a procedure for action on buildings, paying particular attention to the definition and protection of historically relevant parts of the building and the assessment of energy consumption (Ufficio federale dell'energia; Commissione federale dei monumenti storici, 2009). At this point, if one delves into the more specific issues of conservation, a question may arise: Is it permissible to correct technologies that have proven inadequate and defective?

This question is also entirely pertinent for architectural technologists who work on structures that bear witness to history, culture, and tradition, albeit in the modern and contemporary historical periods. In this case, however, as Brandi teaches, functionality is very much present in these buildings, which cannot be considered objects of applied art. Neighbourhoods from the fascist era, for example, which are of great historical and architectural importance, represent great testimonies but, at the same time, are 'alive' and still in use. On the contrary, in these cases, it is appropriate to intervene to prevent the spread of physical and anthropic degradation phenomena. In this case too, therefore, it is necessary to critically articulate interventions on a case-by-case basis, 'by evaluating everything with artistic sensitivity and a lively historical sense, to achieve a scientifically correct..., "aesthetically" appreciable result' (Carbonara, 1997, p. 581-594) and at the same time reducing the impact the asset has on the environment. Within the scope of a project, the specialist bodies must carefully weigh up the interests of energy modernisation of buildings, building protection and use with the owners to find appropriate solutions together (Ufficio federale dell'energia; Ufficio federale dei monumenti storici, 2009).

Several adaptation plans have been formulated at the urban level (e.g., Paris, London, Singapore), which are examples of the application of environmental architecture to the existing fabric. The one drawn up for Singapore is one of the most complete and comprehensive, and has provided the basis for developing pilot cases.

1. Cooling Singapore's best practice

Among the best practices analysed, the Cooling Singapore research is one of the most important: a study to adapt the city of Singapore to rising temperatures. The plan, implemented in 2020, aims to develop strategies and actions for the city to mitigate extreme phenomena related to rising temperatures, primarily due to heat islands. It consists of various research and publications, from analysing climatic and meteorological conditions (Acero et al., 2020) to defining the efficiency of various technological solutions applied to the city (Ruefenacht et al., 2020).
The plan consists of an in-depth study of the Singapore area to adapt and mitigate extreme events caused by rising temperatures. Specifically, the research takes human comfort (PET) as a benchmark. The plan focuses on the efficiency of technological solutions applied to the context. This research can extrapolate the methodology used for Singapore, how the context and tools were analysed, and how the outputs were applied and defined.
The reports that make up the Cooling Singapore research compare different tools for assessing the efficiency of strategies and actions in the context, from simulation software to environmental indices to how to conduct a context analysis to identify vulnerabilities in an area, incentivising processes of adaptation and mitigation to rising temperatures. In contrast, specific results cannot be taken universally for granted, as actions and strategies are tested specifically for the Singapore context.
Through an analysis of climate variables at different urban sites in Singapore, it is possible to quantify the impact of different urban elements and strategies on local climate variables and outdoor comfort. For this purpose, sensors at 4-5 sites simultaneously measured temperature, wind speed and direction, relative humidity, and soil temperature (Acero et al., 2020).
Studies are also conducted on traffic, anthropogenic heat, and the distribution of heat fluxes from city buildings, which define key research terms. Another section of the Cooling Singapore research illustrates design strategies, the most important guidelines for mitigating heat-related effects, and recommendations for a specific city area to increase outdoor thermal comfort. The assessment focuses on the statistically hottest time of the year, which, in this case, is in April, between 11 a.m. and 4 p.m. (Ruefenacht et al., 2020). The research also provides a catalogue with over 80 ac-

tions to incentivise heat island mitigation and adaptation, broken down by type and in tabs. This report is important because the proposed solutions can be applied to the city under study and climate contexts similar to Singapore's (Ruefenacht & Acero, 2017). An excursus on different tools could highlight their heterogeneity and provide an overview of the main components, inputs and outputs (Li & Aydt, 2020; Adelia et al., 2020).

Finally, the research provides a simplified guide that combines the main simulation tools that can evaluate the impact of different mitigation strategies in the local context of Singapore and elsewhere in reducing urban heat islands (UHI) and improving outdoor thermal comfort. The paper provides a list and brief description of 24 simulation tools available or under development, as shown in Figure 16. This paper is important for the present research because it provides the background material for comparing different tools for assessing the impacts of rising temperatures in cities. The 24 simulation tools are divided into three computational model categories. The researchers can use the following tools to understand different aspects of the UHI phenomenon and its comfort: a) Microscale, b) Mesoscale, and c) Supporting tools. The guide's content was gathered mainly through a literature review based on current scientific articles that study and use modelling software to assess the impact of mitigation strategies on UHI and outdoor thermal comfort, focusing on Singapore and tropical regions (Pignatta et al., 2018).

Figure 16 a.



MATRIX FOR MICROSCALE TOOLS	AVAILIBILITY OF SUPPORT					DATA	TARGET USERS					GUI
	Developer services	Website	Academic Papers	Forums	Guide and manuals	Internal database	Urban Designer	Researchers & Scientist	Engineer & Architects	Governmental agencies	Students	
ENVI-met	x	x	x	x	x	x	x	x			x	x
OpenFOAM	x	x	x	x	x	x	x	x	x		x	
PSI-BOIL			x					x	x			
ANSYS Fluent	x	x	x	x	x	x		x	x			
COMSOL	x	x	x	x	x	x		x	x			x
City Sim		x	x				x	x	x			
QUEST			x			x	x		x	x		x
UM-MIST			x			x	x			x		
STEVE			x				x	x	x	x		
RAYMAN		x	x	x				x		x	x	x
PHOENICS	x	x	x		x		x	x	x	x	x	x
IES	x	x	x		x	x		x		x		x
SOLWEIG	x	x	x		x		x	x	x	x	x	x
GrBEST		x	x				x	x	x			x
CEA		x	x		x	x	x	x	x			x
i-Tree Eco		x	x	x	x	x	x	x	x			x

Figure 16 a, b, c. Summary matrix of the properties of simulation tools

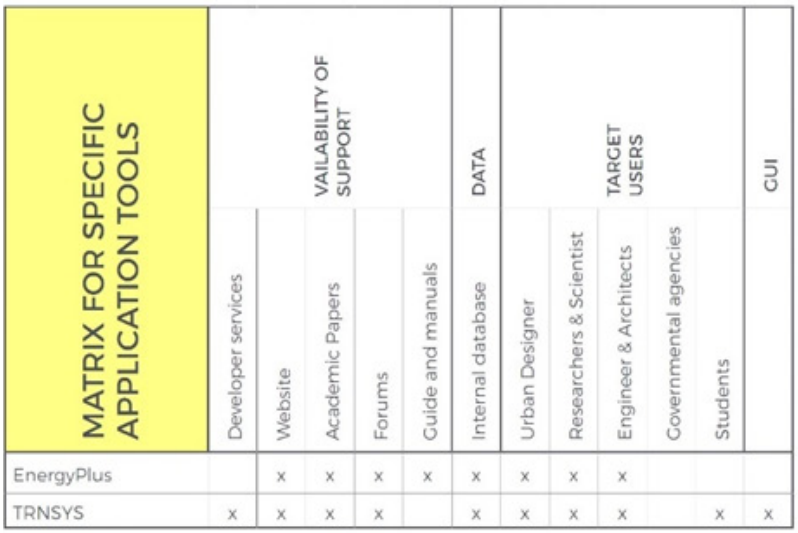
×	×		×	×	×	×	×				×					Low	COMPUTATIONAL RESOURCES
		×							×	×		×	×		×	Medium	
								×						×		High	
×		×	×		×		×	×	×	×					×	Climatology	SECTOR OF APPLICATION
							×	×	×	×	×					Urban Design	
	×															Energy	
×	×	×	×		×	×			×			×	×	×		Open source	AVAILABILITY
				×							×	×				Commercial with license	
							×	×	×							Limited availability	
							×	×	×		×	×	×	×	×		CFB BASED
				×													TRIAL VERSION
	×		×		×		×	×	×			×	×	×	×	Deterministic	CONCEPT
			×		×					×	×					Stochastic	
×	×	×	×	×	×		×	×	×	×	×	×	×	×	×		VALIDATED
×	×	×	×	×	×		×	×	×	×	×	×		×			GRAPHICAL POST-PROCESSING

Figure 16 b.

MATRIX FOR MICROSCALE TOOLS	AVAILIBILITY OF SUPPORT					DATA	TARGET USERS					GUI
	Developer services	Website	Academic Papers	Forums	Guide and manuals	Internal database	Urban Designer	Researchers & Scientist	Engineer & Architects	Governmental agencies	Students	
ENVI-met	x	x	x	x	x	x	x	x			x	x
OpenFOAM	x	x	x	x	x	x	x	x	x		x	
PSI-BOIL			x					x	x			
ANSYS Fluent	x	x	x	x	x	x		x	x			
COMSOL	x	x	x	x	x	x		x	x			x
City Sim		x	x				x	x	x			
QUEST			x			x	x		x	x		x
UM-MIST			x			x	x			x		
STEVE			x				x	x	x	x		
RAYMAN		x	x	x				x		x	x	x
PHOENICS	x	x	x		x		x	x	x	x	x	x
IES	x	x	x		x	x		x		x		x
SOLWEIG	x	x	x		x		x	x	x	x	x	x
GrBEST		x	x				x	x	x			x
CEA		x	x		x	x	x	x	x			x
i Tree Eco		x	x	x	x	x	x	x	x			x

COMPUTATIONAL RESOURCES			SECTOR OF APPLICATION			AVAILABILITY			CFB BASED	TRIAL VERSION	CONCEPT		VALIDATED	GRAPHICAL POST-PROCESSING
Low	Medium	High	Climatology	Urban Design	Energy	Open source	Commercial with license	Limited availability			Deterministic	Stochastic		
	x		x			x			x		x		x	
		x				x			x		x		x	x
	x					x			x		x		x	
	x						x		x		x		x	x
x				x			x		x			x	x	x
	x		x	x		x						x	x	x
	x		x	x				x	x		x		x	x
		x	x	x				x	x		x		x	x
x			x	x				x	x		x		x	x
x						x								
x			x			x					x	x	x	x
x							x			x			x	x
x			x			x					x	x	x	x
	x		x			x							x	x
x					x	x					x		x	x
x			x			x							x	x

Figure 16 c.



MATRIX FOR SPECIFIC APPLICATION TOOLS		VAILABILITY OF SUPPORT				DATA	TARGET USERS				GUI
	Developer services	Website	Academic Papers	Forums	Guide and manuals	Internal database	Urban Designer	Researchers & Scientist	Engineer & Architects	Governmental agencies	Students	
EnergyPlus		x	x	x	x	x	x	x	x			
TRNSYS	x	x	x	x		x	x	x	x		x	x

		COMPUTATIONAL RESOURCES		SECTOR OF APPLICATION			AVAILABILITY		CFB BASED	TRIAL VERSION	CONCEPT		VALIDATED	GRAPHICAL POST-PROCESSING
	Low	Medium	High	Climatology	Urban Design	Energy	Open source	Commercial with license	Limited availability			Deterministic	Stochastic		
		x				x	x			x				x	
			x	x		x		x			x	x	x	x	x

In conclusion, the above report is one of the most useful as it provides a compendium of the most important environmental simulation models for urban settings. This document is relevant because it shows ways different tools interact, proposes quantifiable KPIs and guidelines for evaluating the most efficient strategies applicable to Singapore and analyses its vulnerability. Including guidelines related to the speed of response of strategies, traceable in the document (Ruefenacht et al., 2020), allows the identification of the most efficient actions. Developing a support system for stakeholders (Chan, 2020; Chan et al., 2020) allows easy use of research products. Furthermore, defining more than 80 strategies applicable to the urban fabric further simplifies the choice. It divides the aforementioned by typology and describes their impacts on comfort and heat islands and the behaviour in tropical climates (Ruefenacht & Acero, 2017). Finally, studies on Singapore citizens and permanent residents' willingness to pay (Borzino et al., 2020) allow us to identify implementation preferences and how much they are willing to contribute to implementing new technologies within the city.

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PART 2

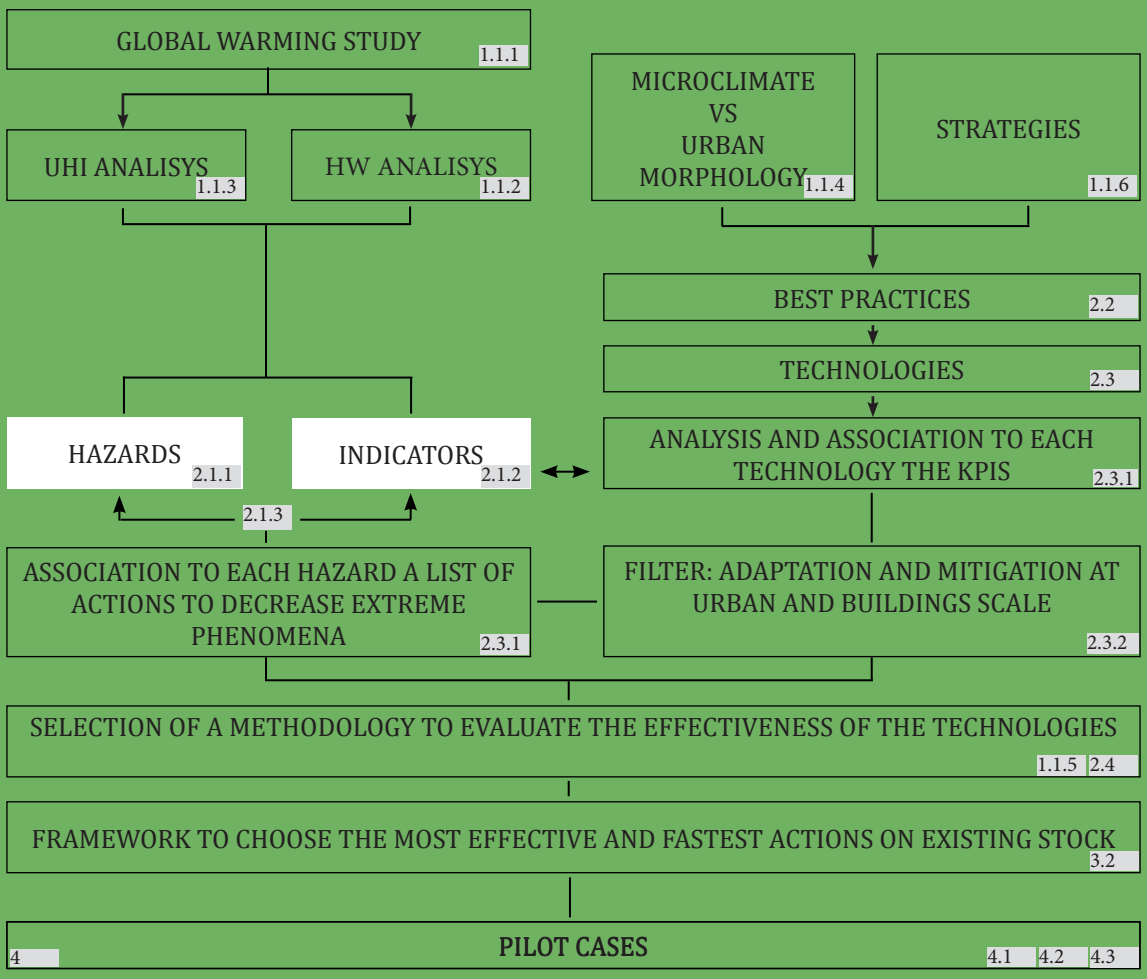
Execution of the research

CHAPTER 2.1

2.1| HAZARDS EVALUATION ON EXISTING STOCK

ABSTRACT
Increasing anthropogenic emissions cause global warming, generating various hazards in existing neighbourhoods, with consequences for anthropogenic and natural systems. Cities are responsible for more than 75% of emissions, so they must be the subjects of change. This study proposes a multi-criteria analysis to identify the hazards related to rising temperatures and the phenomena responsible for the most significant number of hazards in existing neighbourhoods. The approach used is analytical: the literature review allows the classification of phenomena related to rising temperatures and the definition and classification of hazards for existing neighbourhoods according to the 2030 UN goals.

KEYPLAN



Outcomes of this chapter:

- **Identifying** which **hazards**, heat islands, and heat waves increase their occurrence and intensity on existing built stock
- Identification of the **most significant physical indicators affecting islands and heat waves** (KPIs)
- Association with **each hazard of the physical indicators identified** in the previous paragraph, which in turn may influence the occurrence and intensity of the hazards

Introduction.

Central European and national research organisations have recently estimated that human activities have caused about 1.1 °C of global warming compared to pre-industrial levels. Between 2030 and 2052, the temperature increase could reach 1.5 °C. Reversing the trend is impossible: climate-altering gases take time to be absorbed by the ecosystem, which is less fast than the rate at which harmful gases are emitted, despite the efforts by today's governments to decrease their production. All of this causes severe imbalances in the global climate with a consequent change in local climates and habitats: territories previously considered to enjoy warm temperate climates, such as the entire Mediterranean belt, are becoming hotter and hotter, and so on, posing serious risks to natural and anthropogenic systems (Intergovernmental Panel of Climate Change -IPCC-, 2023). Global warming is an established and inexorable phenomenon, which in turn causes the onset of extreme phenomena such as severe floods, periods of drought, heat islands, heat waves, and sea level rise (Losasso et al., 2020). About 70% of emissions are estimated to be due to cities and buildings, where most of the world's population lives. This chapter focuses on the built fabric and the consequences of global warming. This part of the thesis aims to identify and analyse dangers and possible solutions to the 2030 targets set by the ONU[17].

This part of the research is divided into three parts. The first part aims to identify hazards related to the city, the second to assess indicators that may affect the phenomenon of rising temperatures, the third to associate each hazard with a set of indicators by which it may be affected and interventions that are feasible and take effect in a short time.

To this end, the contribution develops a multi-criteria analysis of the hazards related to a temperature increase above 1.5°C in the existing built fabric. It aims to understand in detail which phenomena they depend on, their characteristics, timing, and severity, and how we can act in the near term to decrease the risk. The goal is to stimulate adaptation processes and decrease the risks to anthropic and, consequently, natural systems.

17. In 2015, the UN set out 17 goals for sustainable development by 2030. These holistically affect the interdependent economic, social, cultural, energy and environmental spheres. In particular, these goals envisage a 40% reduction in greenhouse gases by that date to limit global warming to below 2 °C. They also envisage a more significant development of energy infrastructures and an increase in energy efficiency to achieve the more complex targets of an 85-90% reduction in emissions by 2050 compared to 2005.

2.1.1| Hazards, increased by the influence of urban heat islands and heat waves on existing built stock

Summary.

Heat islands and heat waves can cause hazards to existing built stock.
A literature review enabled the identification and analysis of these, serving as the basis for the subsequent part of the research concerning the formulation of goals and solutions that can act surgically to adapt to and mitigate heat islands and heat waves.

Introduction.

This part of the thesis elaborates on the material produced in the first part to find hazards in cities generated or increased by heat islands or heat waves.
As mentioned in the previous sections—1.1.1, 1.1.2, 1.1.3—the global temperature increases the occurrence of extreme phenomena such as heat islands and heat waves, which directly and indirectly affect anthropogenic and natural systems.
The World Meteorological Organisation (WMO) has already confirmed that the trend is increasing: On the 30th of January 2024, it recorded a new record temperature in continental Europe of 48.8 °C (World Meteorological Organization -WMO-, 2024). Cities and their inhabitants have a dual role concerning temperature increases: on the one hand, they are part of the cause, while on the other hand, they are strongly affected as this phenomenon causes discomfort and damage to structures and infrastructure (Intergovernmental Panel on Climate Change -IPCC-, 2023).
Hazards to cities are identified by integrating previous analyses of extreme phenomena and reviewing the literature concerning their short-term impacts on cities.
Many papers in the literature deal with mitigation and adaptation to extreme phenomena due to rising temperatures; in these papers, systematic identification of dangers in existing built stock

in a warm temperate climate is absent. Through this analysis, it is possible to understand the significant hazards and interrelationships and how phenomena influence each other.
The research's methodology, results, and analysis are described. The appendix includes a list of the hazards and the documents that discuss them.

Ways of conducting research.

The literature analysis carried out in the preceding paragraphs - see part 1 of the thesis - reveals numerous dangers to built-up areas. The methodology for conducting this part of the thesis consists of three steps.
The first phase consists of a literature review on the potential dangers caused by heat islands and heat waves on existing fabric. The search was conducted through the Scopus and ScienceDirect platforms and ranged from journal articles, monographs and books on adaptation to rising temperatures on existing fabric. In addition, the author also consulted reports written by various agencies[18]. The keywords used in this part of the research to obtain a screening of the documents are *urban heat island, heat waves, hazard, built environment, existing stock* and their combinations. From an initial screening, carried out by reading titles and abstracts of the documents, approximately sixty contributions emerge that specifically focus on the damage to the existing fabric from heat islands and heat waves. The appendix (A1, table IV and V) lists and identifies which contributions, mentions or analyses the hazards in the built environment[19]. Existing standards - such as LEED and Passivehaus[20]- are also considered. This phase is summarised in Figure 17 and allows the definition of possible hazards related to the city.

18. The most important agencies consulted are the Environmental Energy Agency (EEA), the International Energy Agency (IEA), the International Panel on Climate Change (IPCC), the ENEA, the World Business Council for Sustainable Development (WBCSD), the World Economic Forum (WEF), and the World Meteorological Organisation (WMO).

19. The data required for this contribution comes from institutions such as the International Panel on Climate Change (IPCC), the European Environmental Agency (EEA), ENEA, Eurostat, the International Energy Agency (IEA), the World Business Council for Sustainable Developme nt (WBCSD), the World Cities Report (WCR), the World Economic Forum (WEF), and the World Meteorological Organization (WMO).

20. The decision to analyse these certifications derives from the fact that the Passivehaus standard aims at the passive behaviour of buildings, i.e. zero consumption. The guidelines also include strategies for reducing extreme phenomena related to rising temperatures. LEED certification represents another best practice: through its organisation in requirements and credits, it presents a very precise scorecard with respect to sustainability issues in the built and unbuilt environment.

Figure 17.

Search	Scopus Science-Direct	Peer revieved papers, Monografies, Books, Reports From 2000 to 2024
Screening	Language: In Italian and in English Key words: urban heat islands, heat waves, hazards, built environment, existing stock Field: engineering, Architecture Others filters: Document focused con existing built environment	
Output	**Hazards find in the documents:** • Wildfires • Drought • Stress structures • Stress infrastructures • Problems with finishing materials • Increasing indoor temperature • Increasing mortality • Rainfall • Decreasing comfort condition • Loss of systems transmission • Negative impact of renewerable energy generation • Neigborhood abandonement • Buildings abandonement • Increasing energy costs • Increasing recovery costs • Increasing deterioration rate materials • Increasing deterioration rate infrastructures • Buildings may become unsuitable for use • Infrastructures may bacome unsuitable for use • Decreasing air quality	
Information extraction	Hazards on existing stock Definition of each hazards Analysis of each hazards	

Figure 17. The table explains how this research is conducted. Author's elaboration

Table V

Table V. The present table indicates, for each hazard, the set of documents where it is found.

Hazards on existing stock	N. of documents
Wildfires	1, 2, 3, 34, 41, 53
Drought	1, 3, 34, 41, 46, 48, 50, 53, 58, 65
stress of structures	5, 6, 7, 43, 44, 45, 46, 48, 49, 50, 51, 52, 57, 58, 62, 65
stress of infrastructures	5, 6, 7, 44, 46, 48, 49, 50, 51, 58, 66, 68
problems with finishing materials	3, 43, 46, 48, 50, 51, 52, 62, 65, 66
increasing indoor temperature	5, 8, 9, 10, 43, 44, 45, 46, 48, 50, 51, 52, 56, 57, 59, 62, 65
increasing mortality	11, 12, 13, 14, 15, 16, 5, 18, 19, 6, 9, 20, 33, 35, 36, 37, 39, 40, 46, 47, 48, 50, 51, 55, 57, 59, 61, 62. 64. 66. 69. 70
Rainfall	5, 6, 21, 1, 22, 41, 43, 46, 48, 50, 51, 65, 66
Decreasing of comfort conditions	11, 12, 23, 24, 7, 14, 15, 25, 26, 17, 6, 19, 8, 9, 27, 33, 35, 36, 37, 39, 40, 44, 46, 47, 48, 50, 51, 52, 55, 56, 57, 59, 61, 62, 64, 66, 69, 70
Energy transmission losses and facilities	28, 45, 46, 50, 51, 52, 61, 62, 65, 69, 70

Hazards on existing stock	N. of documents
Negative impact for renewer-able energies	3, 45, 48, 50, 51, 52, 62, 70
Increasing costs for preventing measures	24, 38, 46,50, 51, 52, 62, 70
Neighborhoods abandonement	3, 46, 49, 50, 51, 68
Buildings abandonement	3, 38, 49, 50, 51, 61, 68
increasing operational energy and costs	29, 30, 13, 15, 26, 8, 10, 38, 43, 44, 45, 46, 48, 49, 50, 51, 52, 62
Increasing recovery costs	24, 6, 38, 45, 46, 48, 49, 50, 51, 62
Increasing deterioration rate of systems and materials	3, 43, 46, 48, 49, 50, 51, 52, 62, 68
increasing deterioration rate of infrastructures	3, 6, 46, 48, 49, 50, 51, 68
buildings may became unsutable for use	3, 6, 44, 45, 46, 48, 49, 50, 51, 52, 62, 68
infrastrustures may became unsutable for use	3, 6, 44, 46, 48, 49, 50, 51, 68
Decrease of air quality	42, 1, 19, 26, 37, 36, 25, 34, 15, 28, 14, 23, 29, 32 , 33, 34, 35, 37, 39, 42, 43, 44, 45, 46, 48, 50, 51, 52, 60, 61, 62, 69, 70

The second phase consists of analysing each hazard according to parameters to ensure the achievement of the 2030 targets. The parameters are as follows:

- **Urgency:** They range from long-term, such as the abandonment of neighbourhoods due to rising temperatures, to medium-term, such as increased maintenance costs, to short-term or ongoing, such as the difficulty of materials dissipating heat due to thermal inertia. For example, the abandonment of buildings due to rising temperatures is a long-term hazard. In contrast, the difficulty of dissipating heat due to the thermal inertia of buildings is an ongoing hazard.
- **Speed: i**ndicates whether a hazard manifests itself suddenly or not. For example, the collapse of buildings is a sudden event, while the deterioration of infrastructure is not.
- **Interrelations and Correlations:** This parameter indicates the number of links and interrelations—made explicit in the matrix in Fig. 18—that each hazard has with the others. For example, the stress of structures and infrastructures has many correlations with other hazards, leading to the emergence of other hazards. In contrast, the increase in indoor temperature has few interrelations with other hazards.

The third step involves assigning a qualitative score to each hazard according to the parameters set out. The scoring follows the analysis and literature review.

Urgency: This parameter is divided into long-term, medium-term, and short-term hazards. Hazards that are happening nowadays are considered most urgent and are marked by a shorter grey stripe than the others, medium-term hazards by a longer one, and long-term hazards by a still longer one. For example, the decrease in air quality is now an established and ongoing phenomenon[21], marked by a long grey stripe. Conversely, the abandonment of neighbourhoods due to extreme phenomena caused by rising temperatures is a less urgent and longer-term phenomenon marked by a shorter stripe.

Speed: This parameter has two symbols, depending on whether the danger develops suddenly or not. For example, building collapse is a sudden phenomenon, as opposed to increased maintenance costs, which develop over a long period.

Interrelations and correlations: The scores given (represented by dots) are a function of the number of correlations between the analysed hazard and others. If a hazard has many connections,

21. According to the European Environment Agency's 2020 report, although air pollutant gases have decreased slightly and gradually since 2009, the levels are still too high to slow the global temperature increase, as the rate of greenhouse gas emissions is higher than the rate of absorption by the ecosystem (European Environment Agency., 2020a).

then the score is high. The fewer connections it has with other hazards, the lower the score. For example, the cost increase for preventive measures has a low score because it has few correlations with the other hazards.

Figure 18

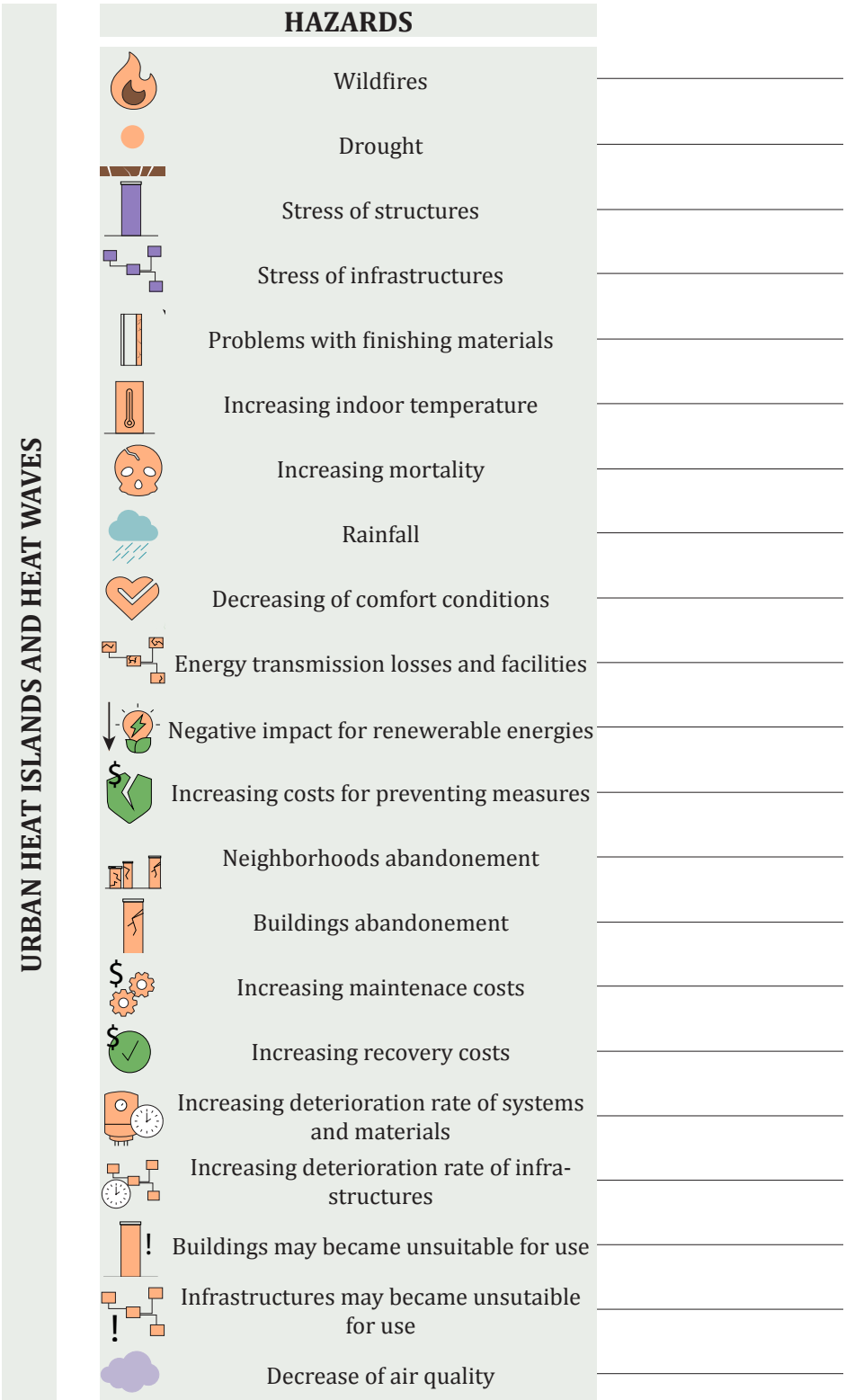


Figure 18. Identification of hazards and definition of each. Author's elaboration

DEFINITION

Presence of hot, dry winds. The presence of flammable material aggravates this phenomenon.

Dry soil reduces evaporative cooling.

This danger is due to thermal expansion in concrete, steel, insulating fibreglass, and building materials in general.

This danger is due to the thermal expansion of concrete, steel, and glass fibre insulation in infrastructure materials.

This danger is due to the increased rate of degradation of finishing elements caused by excessive heat and dryness in the environment or sudden rainfall. Ultraviolet rays consume the finishes of materials, affecting their durability.

The increase in the intensity, frequency and duration of the temperature rise makes the transmittance levels of structures insufficient to ensure indoor comfort.

The rise and persistence of above-average temperatures cause an increase in cardio-circulatory and respiratory problems that lead to increased mortality in the population groups most at risk.

Imbalances due to natural and anthropogenic factors causing sudden rainfall associated with heat waves.

The rise and persistence of above-average temperatures cause a decrease in the feeling of well-being due to changes in thermo-hygrometric conditions.

Energy losses increase by 1% when the ambient temperature increases by 3 °C in systems that already have losses of 8%.

Reduced efficiency of photovoltaic systems as the temperature increases, reducing the capacity of underground conductors—reduced current flows generated by hydropower due to water evaporation in reservoirs.

Increased danger from heat waves and heat islands leads to increased costs for preventive measures.

The increase in the intensity, frequency and duration of temperature rise caused by heat waves and heat islands encourages the abandonment of existing subdivisions and neighbourhoods that do not meet minimum welfare needs.

Increased danger from islands and heat waves causes faster degradation of structures and infrastructure, increasing maintenance costs.

Increased danger from urban heat islands and heat waves causes damage to structures and infrastructure, increasing restoration costs.

Increased danger from heat waves and urban heat islands causes damage to structures and infrastructure, increasing restoration costs.

The increase in the intensity, frequency and duration of the temperature rise caused by heat waves and urban heat islands speeds up the deterioration process of plants and materials.

The increase in the intensity, frequency and duration of the temperature rise caused by heat waves and urban heat islands speeds up the deterioration process of infrastructures.

The increase in intensity, frequency, and duration of temperature rise caused by heat waves and urban heat islands can result in performance that is no longer in line with the intended use of the buildings.

The increase in intensity, frequency, and duration of temperature rise caused by heat waves and urban heat islands can result in performance that is no longer in line with the intended use of the infrastructures.

Ventilative blockage causes stagnation of air, pollutants and a decrease in quality.

Results and discussion.

The matrix in Figure 18, explicates the dangers generated by rising temperatures, those that affect existing neighbourhoods, and the need to develop strategies that can act surgically.
An analysis of the literature shows that an increase in the danger of fire, a sudden phenomenon that can worsen by warm, dry wind flows and the presence of abandoned highly inflammable materials (as can sometimes occur in specific neighbourhoods), can also influence the incidence of other dangers on the inhabited fabric by causing more significant dryness of the soil - which in turn affects the degree of permeability of the same - can cause an increase in the stress of structures and infrastructures, can increase the danger of death, of the uninhabitable nature of structures or infrastructures, which can in turn lead to abandonment phenomena. From a maintenance point of view, this kind of danger can cause severe damage that increases restoration and maintenance costs.
The increase in drought phenomena, which, unlike fires, is not a sudden event but takes place as the days pass with no rainfall, reduces the evaporative cooling of the soil, triggering chain effects at both the meso-climatic and micro-climatic levels. In particular, at the meso-climatic level, excessive dryness of the soil during the winter and the previous spring reduces the probability of rainfall, triggering a vicious circle. At the microclimatic level, the persistence of days with no rainfall increases the likelihood of fires and power losses from various types of plants or infrastructure, including solar thermal and photovoltaics. For example, a decrease in the flow rate of rivers, lakes or aquifers may impact water infrastructure (Office of cyber and infrastructure analysis, 2015), causing a worsening of living conditions for inhabitants, even leading to the abandonment of buildings and neighbourhoods. Even at the maintenance level, the persistence of days with no rainfall affects restoration and prevention costs (such as the construction of water catchment basins).
Islands and heat waves also cause an increase in stress on structures from a static point of view: expansion caused by a very strong or long-lasting increase in temperatures can cause expansion of metal, concrete, and insulating materials of various kinds, which in the long run can affect the load-bearing capacity of buildings, causing an increase in maintenance and monitoring costs, also affecting finishing materials, increasing the temperature inside

structures and thus decreasing comfort levels.
An increased possibility of infrastructure stress, caused by a substantial increase in temperature or one that spreads over a long period, a danger that may manifest itself slowly and as extreme phenomena such as islands and heat waves become more critical, may lead to a decrease in the performance of infrastructure capacity, potentially also increasing the occurrence of fires, increasing the possible danger to adjacent structures, also affecting other components, such as finishing materials, causing energy losses in the transmission of systems and also affecting the life of the same and also affecting repair and maintenance costs.
One of the essential characteristics of finishing materials is that they protect the load-bearing part of the building and the underlying layers to ensure comfort and protect structures and infrastructure, in some cases forming a 'sacrifice' layer that can be restored to its original condition or replaced after maintenance. As the intensity and persistence of heat islands and heat waves increase, the durability of the finishing materials decreases over time. In the absence of maintenance work, this danger could also lead to problems in the load-bearing system of buildings and infrastructures, a possible increase in internal temperatures, a consequent decrease in comfort and an increase in the danger of mortality, especially for the weakest members of society. Degradation of finishing materials can cause malfunctions or a reduction in the lifespan of installations, causing a consequent increase in restoration, maintenance and operating costs.
The increase in outdoor temperatures consequently increases indoor temperatures. This phenomenon, which does not develop suddenly but depends on the climatic conditions and the transmittance of the envelopes, could make the structures unfit for use in the long run and, in the absence of maintenance, lead to their abandonment. The increase in indoor temperature strongly impacts human beings and health by decreasing the comfort level and increasing the risk of mortality.
Various studies highlight the close relationship between rising temperatures and the onset or aggravation of multiple diseases (Kleerekoper et al., 2012; Mohajerani et al., 2017; O'Malley et al., 2015; Patz et al., 2005). This danger affects weaker segments of the population, such as the elderly, children or the sick. However, it also strongly affects adults not affected by particular diseases by decreasing comfort and encouraging the growth rate of bacteria

and their vectors, such as mosquitoes, parasites, and ticks. Decreased air quality can contribute to increased mortality caused by rising temperatures and the spread of pathogens. In the long run, the increase in mortality caused by rising temperatures could lead to an increase in the abandonment of buildings and neighbourhoods if they cannot respond adequately to the needs for thermo-hygrometric comfort and room health.

In association with heat waves and imbalances caused by natural or anthropogenic factors, sudden rainfall events can occur. It is well established that with an average increase in temperature, rainfall events occur more intensely and concentratedly (Intergovernmental Panel of Climate Change -IPCC-, 2023). These events can impact structures and infrastructures, causing severe damage or the inability to use buildings or facilities. Concerning this, the cost and preventive measures increase considerably, along with the likelihood of buildings or entire urban areas being abandoned if the necessary safety conditions of the structures cannot be restored. Consequently, the risk of increased mortality is more significant.

Islands and heat waves strongly affect the use of buildings and infrastructure. Increased risk of wildfire and sudden rainfall are dangers associated with using buildings and infrastructure. Increased temperature inside buildings can cause difficulties in the use of facilities. Lack of maintenance or restoration following extreme events can also undermine use and decrease comfort. The decrease in the level of comfort within existing urban centres caused by an increase in heat islands and heat waves is a fact in a large number of studies as the increase in air temperature and especially the average radiant temperature, strongly affects the individual's feeling of comfort (Cheung & Hart, 2014; European Environment Agency., 2017; Kalkstein et al., 2008; Koppe et al., 2004; Portier et al., 2010; Santamouris, 2015). This danger is directly linked to increased mortality and rising temperatures inside buildings and infrastructure. A decrease in the comfort level may prevent the use of structures or facilities, increasing the risk of abandonment of buildings or urban compartments if the comfort level is too low or acceptable levels of safety cannot be restored.

It is a well-established phenomenon that air quality can be affected by ventilative blockages that may occur during heat waves, affecting the increase in bacterial growth rates and carrier vectors and favouring the stagnation of pollutants in the area. Sudden

wildfires can aggravate this danger and affect inhabitants' health and comfort.
Plants and infrastructures may experience a shorter service life in the presence of frequent and intense island and heat wave events compared to systems that do not experience temperature increases above seasonal averages for extended periods. This decrease in the duration also affects the structural stress by increasing the risk of potential fires in favourable weather conditions and system malfunctioning. Losses of transmission power are also linked to this danger. An increase in indoor temperature is a direct consequence, along with a decrease in comfort levels that can hurt health, encouraging the abandonment of buildings or compartments that cannot achieve acceptable levels of comfort and safety. In particular, according to (Nuruzzaman, 2015) and (Akbari et al., 2001), each 3 °C increase corresponds to a 1% energy loss for facilities that have already suffered energy losses. This figure is highly worrying, especially during the hot season when the already high temperature is further increased by extreme phenomena such as heat islands and heat waves.
The loss of plant power may cause stress on structures and infrastructures that can no longer guarantee minimum comfort conditions, thus increasing the danger of increased mortality. Problems with plant systems could also affect their service life, thereby increasing maintenance or repair work and the associated costs. An excessive increase in temperature also affects the efficiency of renewable source systems, such as photovoltaics, which are widely used within built-up areas, which may suffer a decrease in efficiency: as heat waves become more frequent and lead to remarkably high heat peaks, even during the night period, the systems do not have time to cool down, they are constrained to stress that decreases their efficiency. Rising temperatures also increase the demand for cooling, further increasing the strain on plants and infrastructure and affecting their ability to generate and transmit energy. A much more pronounced decrease in efficiency occurs in the presence of energy sources such as ventilation or hydropower (Cho, 2024; Intergovernmental Panel of Climate Change -IPCC-, 2023; Russo et al., 2022). The occurrence of this event on plants can cause a significant increase in internal temperature, significant transmission losses, and a shorter lifespan of plants and infrastructure.
From an economic point of view, the general increase in the cost of

preventive measures due to the growth in the frequency and intensity of heat waves and islands is directly related to other hazards that may arise in existing settlements, such as the likelihood of fires, prolonged periods of drought or heavy rainfall, and decreasing air quality, all of which may lead to additional costs for increasing safety and decreasing the risk to inhabitants, structures and infrastructure by increasing the level of adaptation.

Increasing islands and heat waves may encourage the abandonment of structures or compartments that do not meet the necessary parameters of safety or comfort. This risk may be exacerbated by increased rainfall or flooding or, conversely, by periods of drought or water scarcity that contribute to the failure of structures and infrastructure.

The growth in the hazards mentioned above, due to the rise in the occurrence and frequency of heat islands and heat waves, consequently increases the maintenance and repair costs of infrastructures, installations, and finishes. These dangers increased significantly due to rising air and surface temperatures and variable ventilation and humidity behaviour. From small to large scale, all systems involved have shorter life spans than under operating conditions where the climate is within seasonal averages.

The extreme phenomena mentioned cause, as explained, various damages to the anthropic and adjacent natural systems. An increase in the cost of repair work is expected: the increase in the frequency of fires, periods of drought, and sudden rains contribute to the increase in repair costs. The shorter life and stress of plants, structures and infrastructures also affect the duration and cost of repair and restoration to acceptable conditions of safety and comfort.

The analysis shows that the most significant short-term and ongoing dangers lie in the difficulty of materials to dissipate heat due to their thermal inertia, the increase in demand for air conditioning, and the decrease in air quality, which is an established phenomenon, especially in large industrial metropolises (European Environmental Agency, 2020).

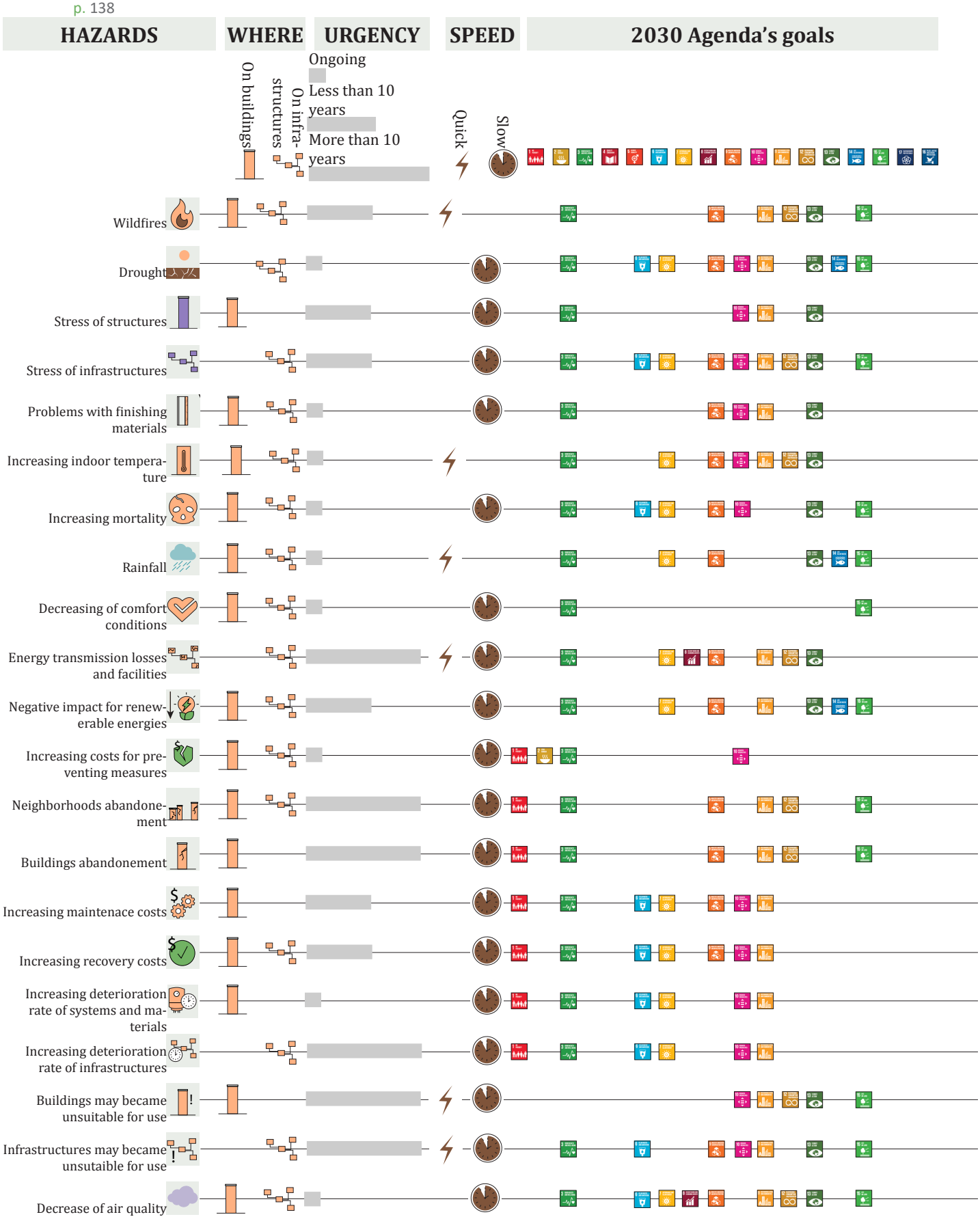
Sudden dangers include building collapses and physical and material infrastructure damage, such as transmission and distribution lines, transformers, and substations. Rising temperatures, fire outbreaks, or floods may also make buildings and infrastructure unfit for their functions.

The contribution aims to support engineers in analysing the bu-

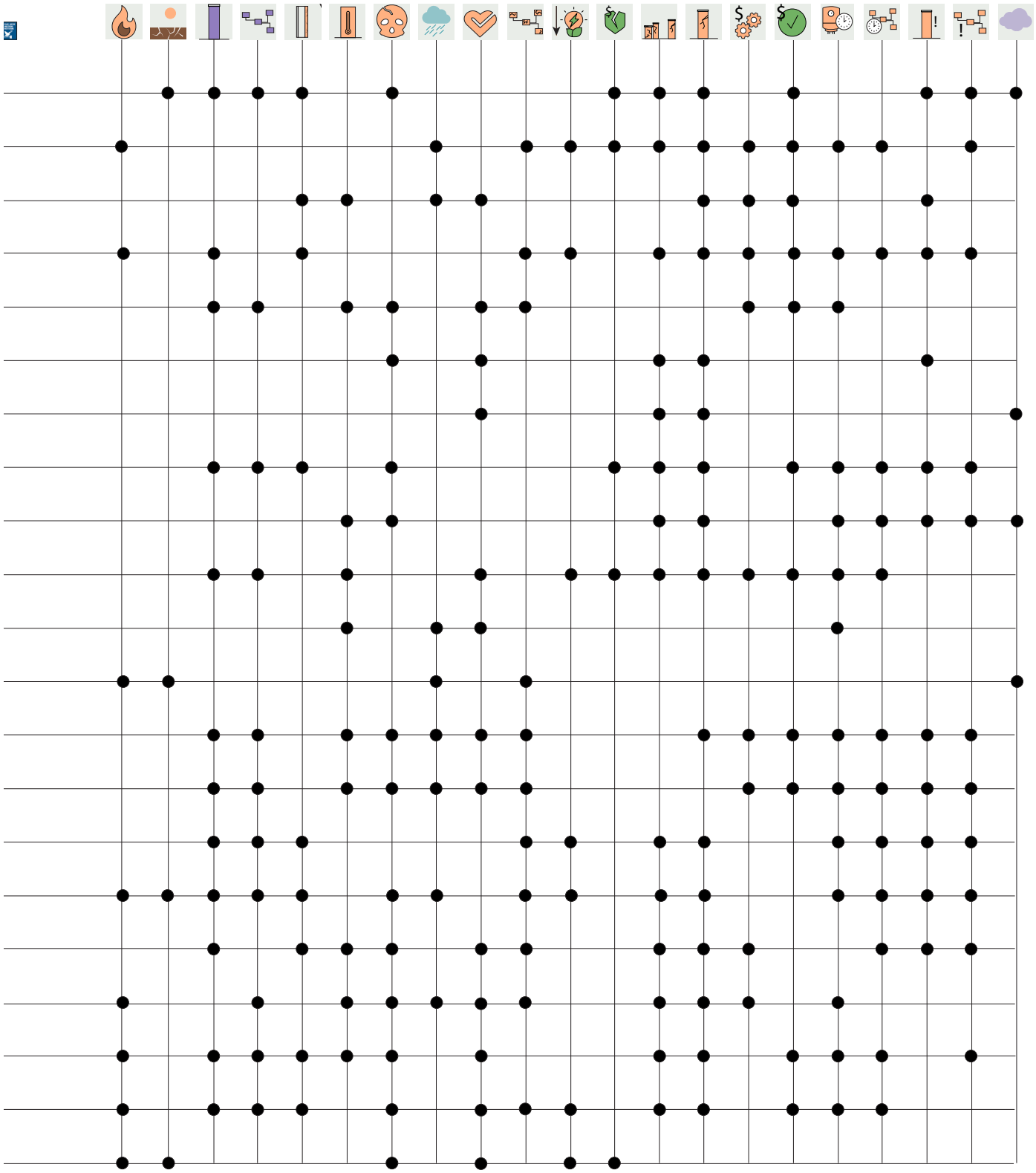
ilt environment to better understand possible risk scenarios and thus act more consciously. Examining the consequences of extreme phenomena makes it possible to define an in-depth cognitive framework that becomes the basis for an innovative methodological approach.

Figure 18. Hazards analysis matrix on the city. Author's elaboration

Innovative and integrated energetic and bioclimatic strategies for adapting existing contexts to climate change and extreme events, aiming to mitigate the environmental impact
p. 138



Interrelations



2.1.2| Evaluation of the factors influencing heat island and heat waves

Summary.

Key performance indicators allow us to identify actions to mitigate and adapt the existing context to extreme phenomena resulting from rising temperatures, particularly heat islands and heat waves.
The approach used in this part of the research is analytical and based on a literature review. This contribution is divided into three phases: the first consists of a decomposition of the causes and drivers of heat islands and heat waves, the second phase consists of an analysis of the factors and causes behind the two extreme phenomena, and the third phase consists of the decomposition into physical parameters describing them. The result is the development of a set of physical indicators that influence heat islands and heat waves, which are used to identify the most suitable solutions for decreasing each hazard and to assess the effectiveness of specific actions on the phenomena considered.

Introduction.

This part of the thesis aims to identify the most important physical factors influencing heat islands and heat waves. These two extreme phenomena are complex, generated by the interaction between different climatic phenomena, land use, and the influence of the sea, so tracing them back to precise physical factors is not trivial.
As mentioned in Sections 1.1.2 and 1.1.3, the continuous increase in temperature incentivises the frequency and intensity of these two phenomena, which are very different from each other. According to the definition provided by Perkins-Kirkpatrick & Lewis (2020), heat waves consist of the persistence of at least six consecutive days in which the T_{max} is greater than the 90^{th} percentile for that particular day, concerning the reference climatic period. Heat islands consist of the difference in temperature between an urban centre (which has the highest temperature) and outlying regions (with lower temperatures), with the broadest intensity - delta T - of 3-5 hours after sunset (Lai & Cheng, 2009; Miller, 2018; O'Malley, Piroozfar, fARR, & Pomponi, 2015; Kolokotroni & Giridharan, 2008; Giannopoulou et al., 2011; D'Olimpio, 2022). These phenomena that do not lead to particular hazards, in periods of extreme heat, such as the summer seasons, can, on the contrary, be hazardous and exacerbate natural and anthropogenic systems.
This part of the research involves analysing the characteristics of

the different factors that cause heat islands and heat waves based on the scientific literature. This allows us to understand the two phenomena better and trace the most important physical parameters that influence them.
In this way, it is possible to understand why and how specific human actions influence these phenomena or increase their impacts. This phase's validity involves tracing the most important factors influencing heat islands and heat waves to increase awareness among professionals and public administrations and intervene more precisely.
Below is the methodology for conducting this part of the research and the results obtained.

Ways of conducting research.

Key performance indicators must identify actions to mitigate and adapt the existing context to extreme phenomena resulting from rising temperatures, particularly heat islands and heat waves. The research is divided into three distinct steps.
The first step consists of analysing each cause and factor contributing to the increase in urban heat islands and heat waves into sub-factors and studying the influence each has on the others. This information is derived from a careful literature review—see sections 1.1.2 and 1.1.3.
The second stage of the research consists of analysing each cause and factor driving the heat islands and heat waves according to different parameters. The parameters are as follows:

- **Drivers:** indicate the causes that trigger the different phenomena influencing heat islands and heat waves. Drivers can be natural[22] or anthropic.
- **Speed:** indicates the speed of each factor: some can affect climate almost instantaneously, as is the case with atmospheric circulation, while others, such as greenhouse effects, affect climate more in the long term.
- **The field of action:** indicates the extent of the phenomenon's effects. They can have small-scale effects—if they involve only the territory adjacent to the phenomenon's triggering—medium-scale effects, or large-scale effects if they have worldwide repercussions on the climate.
- **Predictive in time scale:** indicates after how long the effects produced by the phenomena occur.

This phase allows for the different factors influencing the occurrence of heat islands and heat waves to be characterised.
Based on the previous study and analysis, the third phase extrapolates the most important physical indicators involved in each factor and cause. The research results are then graphically explained.

22. Anthropogenic phenomena can increase natural drivers. For example, climate-changing gas emissions increase the effect of Rossby waves (Barriopedro, García-Herrera, Ordóñez, Miralles, & Salcedo-Sanz, 2023)

Figure 19 a

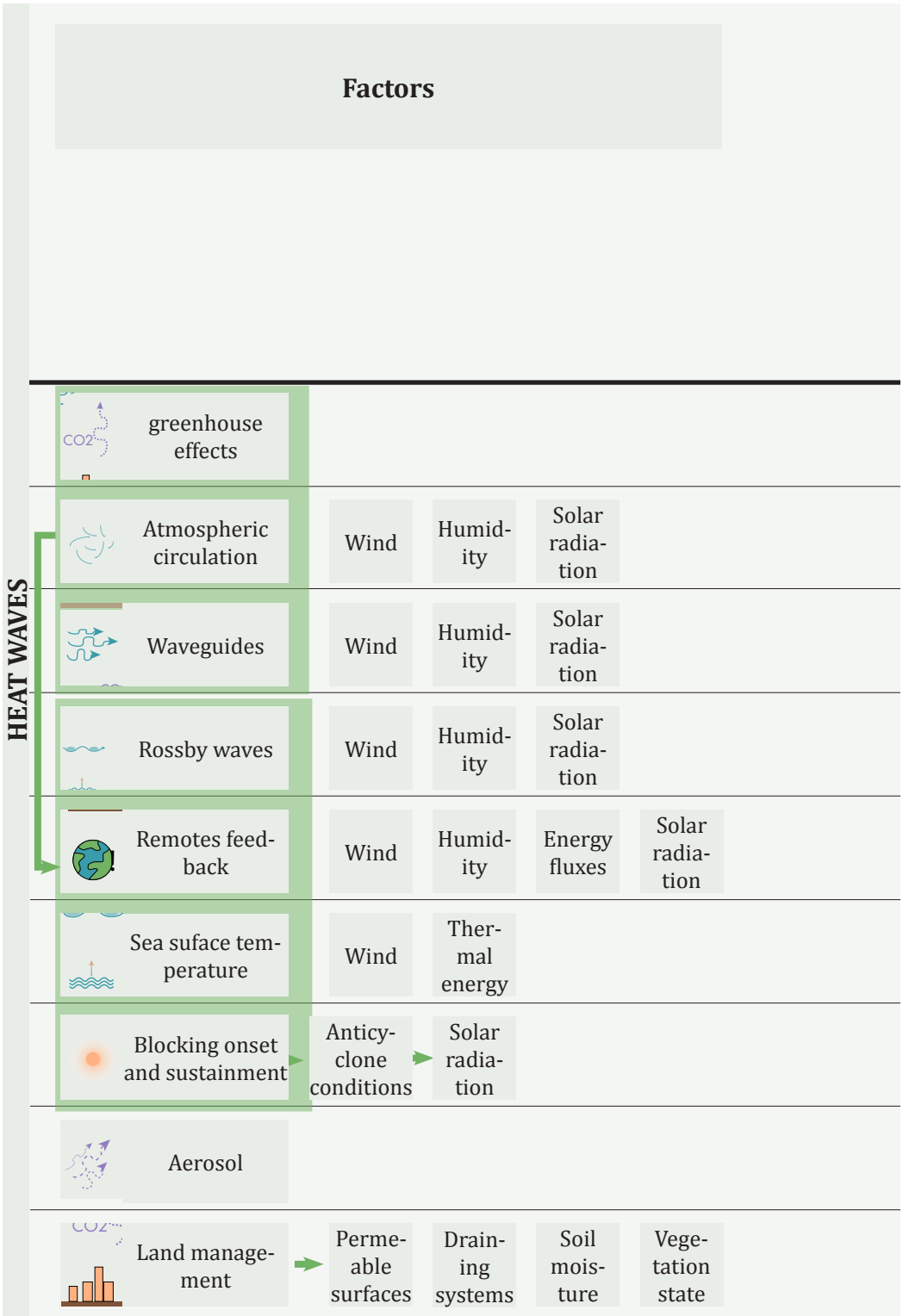
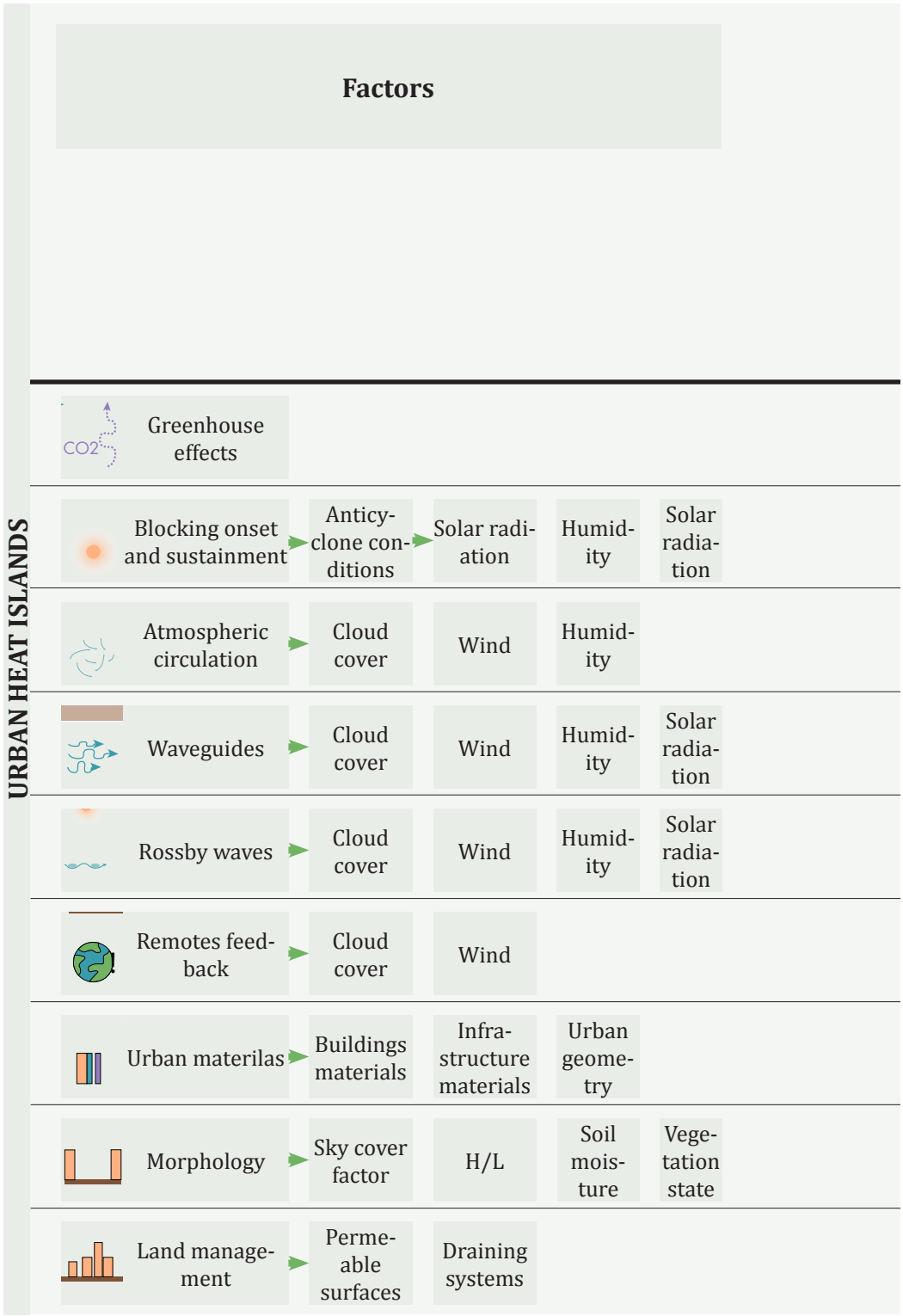


Figure 19 a, b. Diagrams representing the analysis and identification of indicators of the causes and factors influencing heat islands and heat waves. For the heat island diagram, the factors marked in green are not controlled by man; they are natural physical phenomena whose triggers may be anthropogenic. In contrast, green does not highlight human-controlled factors (such as land management and the aerosol effect). Author's elaboration

LEGEND:
UR%= relative humidity
T=air temperature
mrt= mean radiant temperature
ws=wind speed

Drivers	Speed	Field of action	Predic-tive on time scale	Indica-tors
Human drivers Natural drivers	Long term Istanta-neous	Micro Effects on microclimate Meso Effects on mesoclimate Macro Effects on macroclimate	Decennial effects 365 Yearly effects 365 Monthly effects 30 Weekly effects 7 Daily effects	UR%, **T**, mrt, ws
		Macro	365	UR%, **T**, mrt
		Macro		UR%, **T**, mrt
		Macro	30	UR%, **T**, ws
		Macro	7	**T**, ws
		Macro Meso Meso	365	**T**, ws
		Meso	30	**T**, ws
		Micro		**T**, UR%
		Micro	365	**T**, mrt
		Micro	30	UR%, mrt

Figure 19 b


Factors
URBAN HEAT ISLANDS
Greenhouse effects
Blocking onset and sustainment
Anticy-clone con-ditions
Solar radi-ation
Humid-ity
Solar radia-tion
Atmospheric circulation
Cloud cover
Wind
Humid-ity
Waveguides
Cloud cover
Wind
Humid-ity
Solar radia-tion
Rossby waves
Cloud cover
Wind
Humid-ity
Solar radia-tion
Remotes feed-back
Cloud cover
Wind
Urban materilas
Buildings materials
Infra-structure materials
Urban geome-try
Morphology
Sky cover factor
H/L
Soil mois-ture
Vege-tation state
Land manage-ment
Perme-able surfaces
Draining systems

Drivers	Speed	Field of action	Predic-tive on time scale	Indica-tors
Human drivers Natural drivers	Long term Istanta-neous	Micro Effects on microclimate Meso Effects on mesoclimate Macro Effects on macroclimate	Decennial effects Yearly effects Monthly effects Weekly effects Daily effects	UR%, **T**, mrt, ws
		Macro		UR%, **T**, mrt
		Micro		UR%, **T**,
		Macro		UR%, **T**, ws, mrt
		Macro		UR%, **T**, ws, mrt
		Macro		**T**, ws, mrt
		Macro Meso Meso		**T**, ws, mrt
		Micro		UR%, mrt
		Micro		UR%, **T**, ws, mrt
		Micro		UR%, mrt, **T**

Conclusions.

Regarding Fig. 19a, **heat waves** have the following characterisation:
Atmospheric circulation, waveguides, Rossby waves, remote feedback, and sea surface temperature can cause changes in ventilation. Environmental circulation, waveguides, Rossby waves and remote feedback can affect air humidity. Atmospheric circulation, waveguides, Rossby waves, remote feedback, blocking onset, and sustainment can cause changes in solar radiation. Remote feedback can cause or increase energy fluxes already present in the atmosphere. Blocking onset and sustainment can influence the advent of anticyclonic conditions. Finally, land management influences soil permeability, drainage systems and the presence of vegetation.
Greenhouse effects, the aerosol effect, and land use are triggered by anthropogenic action. In contrast, atmospheric circulation, waveguides, Rossby waves, and remote feedbacks have natural triggers.
Greenhouse effects, atmospheric circulation, waveguides, Rossby waves, and remote feedback influence heat waves at the macroscale; remote feedback and sea surface temperature have mesoscale effects while blocking onset and sustainment, and the aerosol effect and land use have microscale effects.

Fig. 19b states that greenhouse effects, blocking and onset sustainment, atmospheric circulation, waveguides, Rossby waves, remote feedbacks, urban materials, landforms, and land management affect **urban heat islands**. Cloud cover influences atmospheric circulation, waveguides, Rossby waves and remote feedback. Anticyclonic conditions and solar radiation underlie the increasing blocking onset and sustainment phenomena. Atmospheric circulation, waveguides, Rossby waves, and remote feedback increase and generally influence ventilation and humidity.
Buildings and infrastructure materials could affect the increase of urban heat islands.
The relation between the height of the buildings and the weight of the streets, the urban geometry, and the sky cover factor affects the morphology of the environment, influencing the phenomenon.
Last, permeable surfaces, vegetation, soil moisture, and draining systems affect land management and, consequently, the urban

heat island.
The anthropogenic activities increase greenhouse gas emissions, urban materials, morphology, and land management. Natural causes lead to blocking onset and sustainment, atmospheric circulation, waveguides, Rossby waves, and remote feedback.
Blocking onset sustainment, atmospheric circulation phenomena, urban materials, land management, and morphology have instantaneous consequences on urban heat islands.
Greenhouse effects, atmospheric circulation, waveguides, and Rossby waves act on the macroscale of the phenomenon. In particular, it is interesting to underline that remote feedback is a phenomenon that starts at the mesoscale, expands to the macroscale, triggering chain effects, and finishes again at the mesoscale. Blocking onset and sustainment, urban materials, morphology, and land management are elements that act at the microscale.
Greenhouse effects have affected urban heat islands for decades. The predictive time scale of remote feedback is about one year; waveguides act on the phenomenon monthly; Rossby waves have an incidence of weeks, and blocking onset and sustainment, atmospheric circulation, urban materials, morphology, and land use affect the daily urban heat island phenomenon.
Among the drivers that increase heat islands, air temperature, mean radiant temperature, and wind speed are the most important key performance indicators that can increase the urban heat island effect. Changes in air temperatures are driven by greenhouse effects, blocking onset sustainment, atmospheric circulation, waveguides, Rossby waves, remote feedback, morphology, and land management.
The relative humidity is modified by greenhouse effects, blocking onset sustainment, atmospheric circulation, waveguides, urban materials, morphology, and land management.
Atmospheric circulation, waveguides, Rossby waves, remote feedback, urban materials, morphology, and land management could affect the surface's mean radiant temperature changes.
Finally, wind speed affects atmospheric circulation, waveguides, Rossby waves, remote feedback and morphology.
The analysis shows that air temperature, wind speed, relative humidity, and mean radiant temperature are some of the most important factors because they affect almost all urban heat islands and heat wave-triggering phenomena.

2.1.3| Association to each hazard a set of physical indicators capable of decreasing its occurrence

Summary.

Previous research has revealed numerous potential hazards caused by heat islands and heat waves in existing centres. This section aims to associate each hazard with indicators capable of decreasing its occurrence. The indicators are the same as those identified for heat islands and heat waves, as the mentioned extreme phenomena cause previously identified hazards.
The approach is based on previous research, which is expanded and synthesised. In this way, a matrix that illustrates each hazard, suggestions for adaptation for cities, mitigation of the onset, and indicators that can influence it can be obtained.
The representation of the indicators and short-term objectives of the elaborated city is summarised graphically. It serves as a basis for the continuation of the work, evaluating the effectiveness and efficiency of various project actions regarding the identified hazards.

Introduction.

This section aims to identify quantifiable indicators and short-term objectives applicable to the existing residential stock that can decrease each hazard in the city and minimize its effects and occurrence.
The hazards driven by the increase in frequency and intensity of heat islands and heat waves are complex phenomena that depend on multiple factors. While the triggers may be unrelated to the problem, the likelihood of specific hazards within urban centres increases as the frequency and intensity of heat islands and heat waves increase (Intergovernmental Panel on Climate Change -IPCC-, 2023).
For example, alterations due to a rise in air temperature, ventilatory blockage, and changes in humidity concentration encourage the

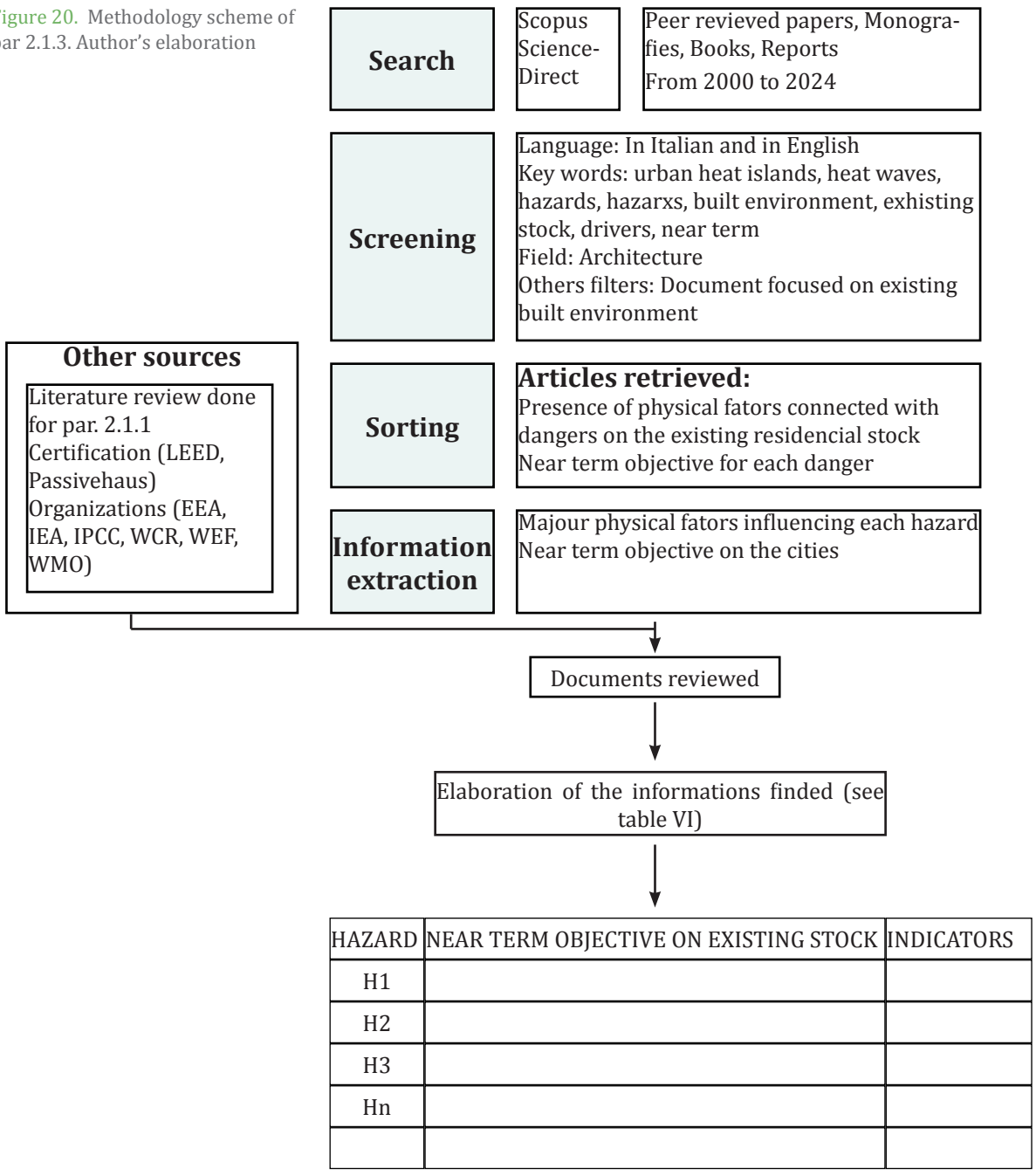
degradation of air quality within built-up areas (World Meteorological Organisation -WMO-, 2023).
For this reason, the study of each issue in the city, explicated in section 2.1.1, is necessary to understand which of the most critical parameters governing extreme phenomena—mean radiant temperature, air temperature, relative humidity, and wind speed—influences the hazards in city centres. In this way, it is possible to better understand each hazard and which parameter, related to islands and heat waves, it depends on the most.
Identifying indicators related to the global increase in temperature capable of decreasing each hazard's occurrence in the city is a very important factor for two reasons: the first consists of understanding the potential type of hazard in a given area and being able to act surgically to decrease its probability. The second is quickly and precisely responding to previously encountered problems in a given area.
The methodology for conducting the research and the results obtained are outlined below.

Way of conducting research.

The methodology for this part of the research is divided into two phases, as Figure 20 visually explains.

Figure 20

Figure 20. Methodology scheme of par 2.1.3. Author's elaboration



HAZARD	NEAR TERM OBJECTIVE ON EXISTING STOCK	INDICATORS
H1		
H2		
H3		
Hn		

In particular, the first phase builds on the literature study outlined in section 2.1.1. This part of the research consists of a breakdown of each hazard by going back to the primary causes, which, by influencing either the heat islands or the heat waves, affect the occurrence and intensity of the hazard considered. This part of the research is carried out through the analysis of the literature, carried out on the platform of Science Direct and Scopus, increasing the contributions found in section 2.1.1 and taking as keywords a combination of *heat island, heat waves, causes, drivers, indicators, and near-term*. After an initial skimming, approximately sixty contributions are considered. Each document consulted is analysed by identifying the topic, the hazards in the city, the KPIS (if any) and the short-term objectives of the city (if any). The entire analysis can be seen in the paragraph in Appendix A.2.
The second phase consists of a summary based on information found by formulating a matrix in which the short-term objective for the city and the key performance indicators that can decrease its occurrence are indicated for each hazard. Figure 20 shows the matrix representing the research's output.

Table VI. Analysis of documentation to identify short-term goals and physical factors influencing the hazards, increased by heat islands and heat waves on existing built stock.

Conclusions.

Figure 21

Figure 21. The matrix contains short-term hazards in cities and solutions and indicators influencing them. Author's elaboration

URBAN HEAT ISLANDS AND HEAT WAVES	HAZARDS that HW and UHI could increase on the built residencial stock	PHYSICAL FATOR INFLUENCING THE HAZARD
	Wildfires	Air speed Relative humidity
	Drought	Air speed Relative humidity
	Stress of structures	Air Temperature Mean radiant temperarature
	Stress of infrastructures	Air Temperature Mean radiant temperarature
	Problems with finishing materials	Relative humidity Mean radiant temperarature
	ncreasing indoor tempera-ture	Air speed Air Temperature
	Increasing mortality	Air Temperature Relative humidity Mean radiant temperarature Air speed
	Rainfall	Relative humidity Air speed
	Decreasing of comfort con-ditions	Air Temperature Relative humidity Mean radiant temperarature Air speed
	Energy transmission losses and facilities	Air Temperature Mean radiant temperarature Relative humidity
	Negative impact for renew-erable energies	Air Temperature Relative humidity Mean radiant temperarature

Figure 21

NEAR TERM OBJECTIVE
Addressing ventilative flows. Careful use of materials
Application of technologies and strategies that decrease soil dryness, such as draining and permeable surfaces
Use of materials and technologies with low albedo index, constant monitoring and maintenance
Use of materials and technologies with low albedo index, constant monitoring and maintenance
Use of resistant finishing elements, monitoraggio e manutenzione
Decreased soil and air temperature, increased outdoor ventilation and indoor cross-ventilation
Increased wetlands and shaded areas, use of cool materials, use of draining materials, use of specific wall thicknesses, increased surface reflectance, increased evapotranspiration, study of the shape of the city to direct ventilation flows, adoption of specific HW ratios
Decreased soil and air temperature, increased humidity, increased maintenance work
Increased wetlands and shaded areas, use of cool materials, use of draining materials, use of specific wall thicknesses, increased reflectance of surfaces, increased evapotranspiration, the study of the shape of the city - -to direct ventilation flows, adoption of specific HW ratios, air quality, presence of greenery
Increased wetlands and shaded areas, use of cool materials, use of draining materials, use of specific wall thicknesses, increased reflectance of surfaces, increased evapotranspiration, the study of the shape of the city - -to direct ventilation flows, adoption of specific HW ratios, air quality, presence of greenery
Increased wetlands and shaded areas, use of cool materials, use of draining materials, use of specific wall thicknesses, increased reflectance of surfaces, increased evapotranspiration, the study of the shape of the city -to direct ventilation flows, adoption of specific HW ratios, air quality, presence of greenery

Figure 21

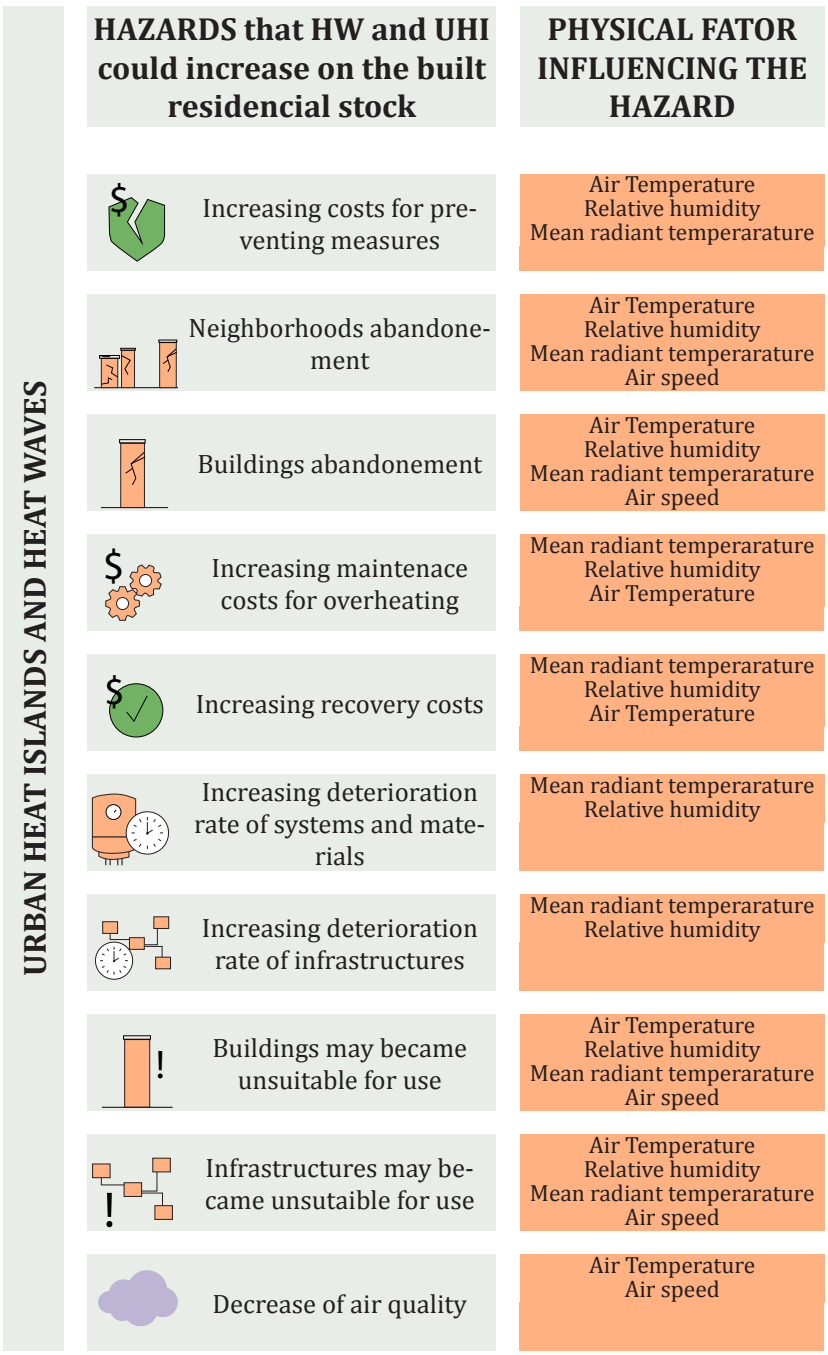

URBAN HEAT ISLANDS AND HEAT WAVES
HAZARDS that HW and UHI could increase on the built residencial stock
PHYSICAL FATOR INFLUENCING THE HAZARD
Increasing costs for preventing measures
Air Temperature
Relative humidity
Mean radiant temperarature
Neighborhoods abandonement
Air Temperature
Relative humidity
Mean radiant temperarature
Air speed
Buildings abandonement
Air Temperature
Relative humidity
Mean radiant temperarature
Air speed
Increasing maintenace costs for overheating
Mean radiant temperarature
Relative humidity
Air Temperature
Increasing recovery costs
Mean radiant temperarature
Relative humidity
Air Temperature
Increasing deterioration rate of systems and materials
Mean radiant temperarature
Relative humidity
Increasing deterioration rate of infrastructures
Mean radiant temperarature
Relative humidity
Buildings may became unsuitable for use
Air Temperature
Relative humidity
Mean radiant temperarature
Air speed
Infrastructures may became unsutaible for use
Air Temperature
Relative humidity
Mean radiant temperarature
Air speed
Decrease of air quality
Air Temperature
Air speed

Figure 21

NEAR TERM OBJECTIVE
Increase in wetlands and shaded areas, use of cool materials, use of draining materials, use of specific wall thicknesses, increase in surface reflectance, increase in evapotranspiration, study of the shape of the city to direct ventilation flows, adoption of specific HW ratios, air quality
Use of cool materials, draining materials, specific wall thicknesses, increased greenery, surface reflectance, evapo-transpiration, increased cross-ventilation, adoption of specific HW ratios, increased maintenance work
Decreased soil and air temperature, increased outdoor and indoor cross ventilation, increased air quality.
Use of materials and technologies that discourage heat island phenomena
Increasing shaded and humid areas, decreasing temperature and air quality, use of drainage pavement
Use of green infrastructure, drainage systems, water collection and reuse
Increasing shaded and humid areas, decreasing temperature and air quality, use of drainage pavement
Increasing building maintenance, management and renovation with strategies and technologies that improve energy efficiency and ensure bioclimatic behaviour. Using materials that are resistant to temperature rise and have high albedo values.
Increasing building maintenance, management and renovation with strategies and technologies that improve energy efficiency and ensure bioclimatic behaviour. Using materials that are resistant to temperature rise and have high albedo values.
Decrease in anthropogenic heat given by the total amount of energy used for vehicles, air conditioning systems, operation of buildings, plants and industrial processes

Discussion and conclusion.

This analysis reveals twenty-one potential hazards that islands and heat waves can pose to the existing residential fabric in warm temperate climates. The hazards concern the buildings that make up the built-up area, the infrastructure and the inhabitants,seepar. 2.1.1.

The analysis shows that the probability of fire occurrence and spread increases in the presence of ventilation flows that can 'walk' the flames with dry soil and surfaces. In this case, attention to the control of materials and the study and direction of ventilation flows could lower the level of danger from fires and, at the same time, promote the exploitation of ventilation to mitigate the occurrence of heat islands. Prolonged dry periods are also a danger closely related to ventilation humidity.

The presence of ventilation blockages influences the occurrence of longer or shorter periods of high pressure, fuelling the onset of heat wave phenomena in the following season - see section 1.1.3. In this case, it is essential to act on land use, using materials capable of absorbing water, such as various types of permeable and draining surfaces. Indeed, the increase in urban greenery, through evapotranspiration processes and soil water retention, favoured by the root system of plants, contributes to maintaining good humidity levels. According to various studies, including (Intergovernmental Panel of Climate Change -IPCC-, 2023), as the average temperature rises, the behaviour of rainfall tends to be concentrated in shorter time lapses but of much greater magnitude. In these cases, land use patterns are of fundamental importance: draining and permeable materials make flooding more difficult and favour water retention, discouraging the triggering of climatic phenomena that could cause heat islands or extreme events - see Section 1.1.3.

The decrease in air quality is a hazard influenced by the blockage of ventilation flows, which promotes stagnation, and the increase in air temperature, which causes an increase in the growth rate of bacteria and vectors. Furthermore, the increase in pollutant gases causes a radiation effect, which in turn contributes to the increase in temperature (Nuruzzaman, 2015). This type of hazard is strongly promoted by vehicle traffic, air conditioning systems installed in buildings and their operation in general. The promotion of soft mobility-based travel methods, the design of buildings and infra-

structures based on bioclimatic operation that limits their energy expenditure, and the use of energy-efficient systems and installations promote the maintenance of high air quality within urban centres. Decreased air quality also affects another danger from waves and heat islands: increased mortality. The factors favouring this increase depend on various climatic and local conditions: the absence of ventilation flows, a phenomenon often associated with heat wave events, climatic conditions that cause an increase in temperature and a change in humidity, and an increase in the average radiant temperature are factors that significantly affect the perception of human comfort. Regarding heat islands and heat waves, an integrated action is recommended, aimed at the use of different strategies based on blue infrastructures, the use of surfaces with a high albedo index, which is therefore not able to absorb heat, in the use of draining materials, in a design attentive to the transmittance values of the envelopes and in the use of various strategies that ensure the bioclimatic behaviour of the building - trombe-walls, bioclimatic atriums, ventilated facades or roofs - in increasing evapotranspiration through an increase in green infrastructures, in a careful morphological design, also aimed at managing ventilation flow and shading.
All these solutions increase comfort levels and decrease the danger of mortality. The comfort level also decreases due to increased indoor temperature, another danger related to heat islands and heat waves. This danger is directly related to the extreme phenomena studied due to the absence of ventilation and the increase in temperature. The increase in air temperature inside buildings can be mitigated by improving the bioclimatic behaviour of buildings, which could contribute to the creation of air pressure differences and thus to the emergence of ventilation flows, or shield from the sun's rays, or even increase the level of transmittance of the building. Concerning heat islands and heat waves, an integrated action is recommended, aimed at the use of different strategies based on blue infrastructures, the use of surfaces with a high albedo index, which is therefore not able to absorb heat, in the use of draining materials, in a design attentive to the transmittance values of the envelopes and in the use of various strategies that ensure the bioclimatic behaviour of the building - Trombe-walls, bioclimatic atriums, ventilated facades or roofs - in increasing evapotranspiration through an increase in green infrastructures, in a careful morphological design, also aimed at managing ventilation

flow and shading. The increase in air temperature inside buildings can be mitigated by improving the bioclimatic behaviour of buildings, which could contribute to the creation of air pressure differences and thus to the emergence of ventilation flows, or shielding from the sun's rays, or even increasing the transmittance level of envelopes. Decreasing the surface temperature and the presence of green infrastructure and permeable soil also contribute to decreasing the impact of islands and heat waves, thus decreasing the temperature at the indoor level.

Heat islands and heat waves also strongly affect buildings, plants and infrastructure. The finishing layer is particularly affected: radiation and heat conduction increased by the absence of ventilation contribute to an increase in the average radiant temperature and a decrease in the durability of materials.

In the presence of extreme phenomena due to the increase in temperature, it is advisable to study the most appropriate finishing materials, even characterising the elevations differently according to the different external conditions they have to cope with. Not only may finishing materials be damaged or their service life shortened, but also the load-bearing structures of buildings and infrastructure - see Section 2.1.1. The physical parameters that influence these hazards and depend on heat islands and heat waves are the increased air and surface temperatures, which could lead to infrastructure malfunctions or excessive expansion of component materials. Using materials that disincentivise heat absorption and constant monitoring of structures and maintenance would instantly decrease the occurrence of the aforementioned dangers. One of the most serious dangers that heat islands and heat waves could contribute is that structures could become unfit for use because they no longer meet safety, comfort, or both needs. This phenomenon can depend on rising temperatures and related extreme phenomena.

In this case, the literature recommends different types of action, indoors and outdoors, to improve energy efficiency and bioclimatic behaviour. The choice of materials used is also important to achieve adequate levels of transmittance and permeability. Periodic maintenance and monitoring are a part of the choice of materials to avoid potential damage to structures and infrastructure. Monitoring interventions, in particular, is important to control the rate of deterioration of materials and installations. This danger is highly influenced by rising surface temperatures and local climatic

conditions that may lead to periods of water shortages or decreased flow rates. This variability in the amount of water places an increased strain on installations and infrastructure.
Energy plants and infrastructures may also incur power or flow losses due to possible decreases in the flow rate or temperature increases that reduce efficiency (Nuruzzaman, 2015). Depending on the specific problem, it is appropriate to act differently.
For example, if the problem lies in the water supply, the construction of wetlands and reservoirs could mitigate the occurrence of the hazard. Conversely, if the problem lies in energy systems, then decreasing the surface temperature could help mitigate the onset of the hazard. In particular, excessive temperature increases also hurt renewable energy production - see section 2.1.1. This type of hazard is greatly influenced by the presence of precipitation, which affects water flow and air and surface temperatures, affecting the operation of various systems, including solar and photovoltaic. The use of an integrated mix of strategies contributes to the mitigation of this phenomenon. In particular, strategies to increase the indoor and outdoor bioclimatic behaviour of structures and infrastructures are of paramount importance.
The increased costs for organising preventive, monitoring, and remediation measures result from the enormous imbalances caused by heat islands and heat waves in the summer. The most cost-intensive factors associated with heat islands and heat waves are primarily related to the absence of rainfall events, which increase the dryness of the ground, affecting future heat waves (see Section 1.1.3) and water requirements.
Surface and air temperature are other factors influencing the extent and frequency of restoration monitoring and maintenance. In the absence of rainfall, it is recommended that green and blue strategies be used throughout the area to increase water collection or the soil's water content. For the second issue, a careful choice of materials is critical, combined with the presentation of shading systems and green infrastructure that protect against high air temperatures and sunlight. The use of cool surfaces can contribute.
In general, the analysis shows that the hazards influenced by a more significant number of key performance indicators are increased mortality, an increase in the rate of deterioration of structures and infrastructure, and the abandonment of buildings and neighbourhoods. The hazards that are influenced by a smaller number of key performance indicators are water shortages, infra-

structure stress, increase in indoor temperature, problems with finishing materials, sudden rainfall, energy transmission losses in distribution systems, increase in maintenance and recovery costs, increase in the speed of deterioration of facilities, structures and infrastructure, and decrease in air quality.
Hazards that are influenced by a smaller number of KPIs do not mean that they are less dangerous than those influenced by all the physical indicators that influence islands and heat waves: on the former, it is possible to focus attention on only one factor, acting more surgically, while on the latter it will be necessary to consider the whole range of physical parameters dependent on the above-mentioned extreme phenomena and to choose actions that act on several fronts.

2.1.4 | Comfort index

Summary.

There are many indices in the literature for assessing the individual's comfort.
Although this thesis is not concerned with comfort, it is interesting to investigate this aspect to understand how humans perceive rising temperatures and the extreme phenomena associated with them. Through an analysis of the literature, the most convenient one for research is identified to assess the feeling of comfort as temperatures rise and in hot climates. In addition to the indicators identified in the previous paragraphs, having an additional parameter for assessing people's comfort is fundamental in evaluating the effectiveness and efficiency of the actions applied to the existing building to increase adaptation and mitigation to islands and heat waves, increasing the validity of the results obtained.
Of the various indices analysed, the UTCI (Universal Thermal Climate Index) is the most responsive and comprehensive for evaluating increasing temperatures in hot climates.
Not all simulation tools calculate the UTCI and the other KPIS together. Therefore, it is necessary to evaluate the right simulation tool and consider as many parameters as possible.

Introduction.

Beyond identifying KPIS that influence heat islands and heat waves, identifying a parameter describing comfort would contribute to evaluating the effectiveness and efficiency of actions on the existing built stock. Although this is not the primary focus of this thesis, understanding how rising temperatures and associated extreme events, such as heat waves, are perceived would allow for greater control of many hazards related to human health and the occupation of spaces. This part of the thesis aims to identify a parameter that can describe individual comfort in cities as a function

of thermo-hygrometric well-being. The literature on comfort indices is vast. It is necessary to identify which is most appropriate for assessing the individual's comfort as a function of rising temperatures, and which can be valid indoors and outdoors.
Thermal indices are usually divided into three categories: linear equations, empirical indices based on regression models, and rational indices based on human energy exchange (Sehgal & Kumar, 2025). Of the first group are Wind Chill Index (WCI), Discomfort Index (DI), Humidex, Apparent Temperature (AT), Wet Bulb Globe Temperature (WBGT), Relative Strain Index (RSI) and Actual Temperature (ET). The thermal sensation, thermal sensation vote (TSV), actual sensation vote (ASV), and predicted mean vote (PMV) belong to the second group. Of the third group are Thermal Stress Index (ITS), COMFA, Perceived Temperature (PT), MENEX, Standard Effective Temperature (SET), Standard External Effective Temperature OUT_SET, Physiologically Equivalent Temperature (PET) and Universal Thermal Climate Index (UTCI) (Setaih et al., 2013; Sehgal & Kumar, 2025).
ASHRAE-552023 defines thermal sensation as "a subjective conscious expression of an occupant's thermal perception of the environment" (ANSI/ASHRAE Standard 55 , 2023). Gagge et al. 1967 described comfort as a "recognizable state of sensation" and stated that "it is usually associated with conditions that are pleasant and compatible with health and happiness; and discomfort with pain that is unpleasant (Gagge, Stolwijk, & Saltin, 1969; Y. Yang et al., 2024).
Analysing the state of the art allows for identifying data and information influencing an individual's comfort. Then, a comfort index is determined to evaluate the efficiency of various technologies on islands and heat waves.
The following explains the methodology of conducting the research and the results, which consist of an exposition of the factors influencing the feeling of comfort, an analysis of two comfort indices most commonly used in hot climates, and the rationale for the one selected.

Way of conducting research.

The methodology is based on literature analysis and presents a bottom-up approach. Two different research phases articulate the

method.
The first phase involves retrieving data and information influencing comfort concerning warm temperate climates. This phase is based on analysing the relevant scientific literature through Scopus and ScienceDirect channels. Following an initial skimming, the analysed papers consist of literature reviews on the subject from 2020 to 2025. The keywords used are *thermal comfort, comfort,* and *comfort indicators* and only papers about the engineering field are considered. In particular, the author took only those contributions that contextualise the topic within the city and focused on evaluation indices in hot contexts (see Fig. 21). By studying several sources cited within the consulted documents, it was possible to identify the writings of developers. Following identifying the articles, conference proceedings, and reviews that best corresponded to the needs of this research - the identification of a valid comfort index for high temperatures, indoors and outdoors - the author built up the basis of this part of the research.
The second phase involves the analysis of the comfort indices most commonly used to assess the impacts of rising temperatures. The PET index and the UTCI are the most commonly used in architecture and engineering to conduct preliminary studies. After analysing the two indices, the best comfort index to evaluate the effectiveness and efficiency of heat island and heat wave actions is selected. The choice is made based on analysing the state of the art.

Figure 22.

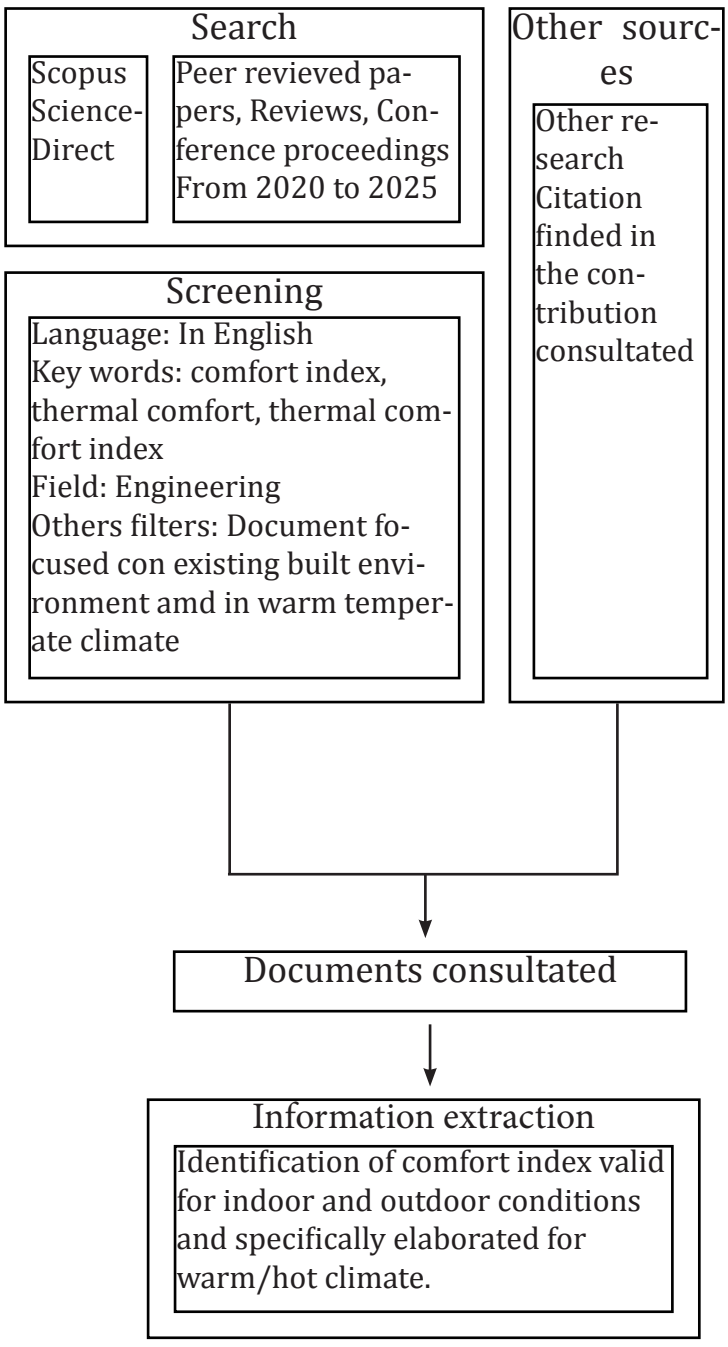
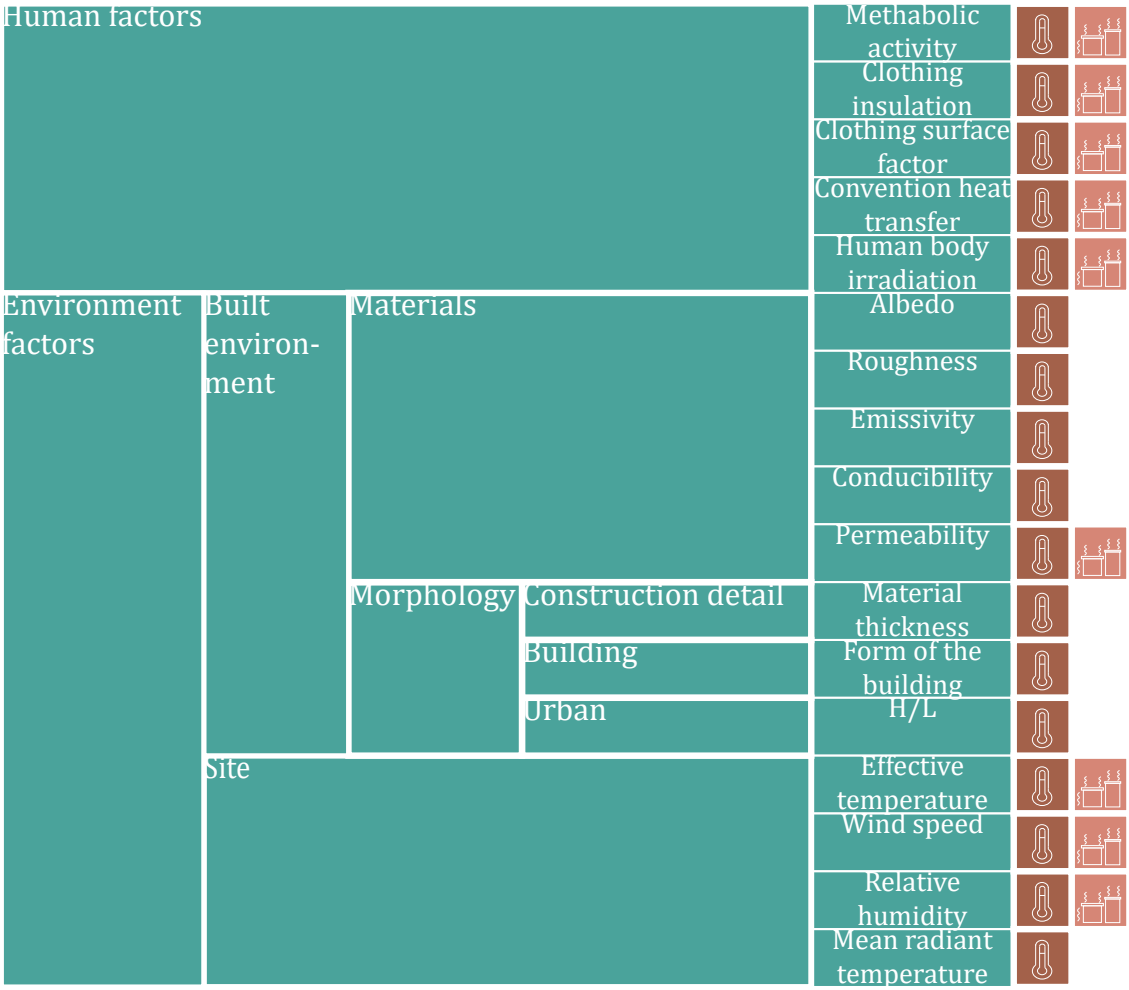


Figure 22. Workflow of the selection of the base document for evaluation of which comfort indicator is the most suitable for this research. Author's elaboration

Conclusions.

To calculate comfort, the average radiant temperature T_{mrt} is the most important parameter: MRT is the total of all shortwave and longwave radiation fluxes encountered by a human body (Sehgal & Kumar, 2025).
As shown in Figure 23, the literature shows that the factors affecting individual comfort depend on the individual's physical and psychophysical condition and environmental factors, divided between those arising from the built environment and those of the site. The parameters that depend on the built environment concern materials, urban morphology, buildings, and construction details.

Figure 23.


Human factors
Environment factors
Built environ-ment
Materials
Morphology
Construction detail
Building
Urban
Site
Methabolic activity
Clothing insulation
Clothing surface factor
Convention heat transfer
Human body irradiation
Albedo
Roughness
Emissivity
Conducibility
Permeability
Material thickness
Form of the building
H/L
Effective temperature
Wind speed
Relative humidity
Mean radiant temperature

At the microscale level, the PET and UTCI indices are the most widely used indices for assessing outdoor and indoor comfort (Zheng et al., 2025; Sehgal & Kumar, 2025). In particular:

- PET: Physicological Equivalent Temperature

$$M+W+R+C+E_D+E_{SW}+E_R+Q_{stock}=0$$

with:

	SYMBOL	UNIT
WORK	W	W
HUMAN BODY RADIANCE	R	W
CONVECTIVE FLUX	C	W
LATENT HEAT FLOW DUE TO THE EVAPORATION OF WATER INTO WATER VAPOUR THAT DIFFUSES THROUGH THE SKIN	E_D	W
SUM OF HEAT FLOWS TO HEAT AND HUMIDIFY THE INTAKE AIR	E_R	W
HEAT FLOW FROM SWEAT EVAPORATION	E_{SW}	W
STORED HEAT FLOWS	Q_{stock}	W

Figure 23. Parameters that affect comfort sensation. (Zarcone, Nava, & Tucci, 2024)

LEGEND: the following parameters can also influence:



Heat wave



Urban heat island

The reference values for the PET calculation are:

	SYMBOL	UNIT	VALUE
Wind speed	V_{ar}	m/s	0.1
Mean radiant tem-peature	t_r	°C	20
Air temperature	t_a	°C	20
Clothing insulation	I_{cl}	clo	0.9

- UTCI: Universal Thermal Comfort Index

$UTCI=3,21+(0,872*T_a)+(0,2459*MRT)-(2,5078*V_a)-(0,0176*RH)$

With:

$$MRT_{LW} = \left(\sum_{i=1}^{N} F_i * T_i^4\right)^{1/4} - 273,15$$

$$T_{sky} = \sqrt[4]{\frac{L_{sky}}{0,95 * \sigma}} - 273,15$$

$$MRT = MRT_{LW} * \left(1 - \frac{F_{sky}}{2}\right) + T_{sky} * \left(\frac{F_{sky}}{2}\right) + \frac{ERF}{h_r * f_{eff}}$$

with:

L_{sky} means horizontal infrared radiation intensity

σ symbolizes the Boltzmann constant, and it is usually set at 5,76E-08

h_r it is the radiant heat transfer coefficient, usually fixed at 6.012 W m-2 k-4

f_{eff} it is the fraction of the body surface exposed to diffuse radiation from the environment - 0,696

ERF: represents the energy flow absorbed by the human body; ERF=0,95*ERF_{solar}

$$ERF_{solar} = \left(0{,}5 f_{eff} f_{svv} \left(I_{diff} + I_{TH} R_{floor}\right) + \frac{A_p f_{bes} I_{dir}}{A_D}\right) T_{sol} \left(\alpha_{SW}/\alpha_{LW}\right)$$

(Kamel, 2021b)

The two indices differ in the human heat transfer model used to calculate the physiological response: PET is based on the two-node Munich Energy-balance Model for Individuals (MEMI), (Höppe, 1993). In contrast, the UTCI is based on a model developed by Fiala (Fiala et al., 2012). According to (D. Lai et al., 2020), in addition to using a more advanced transfer model, this index is more comprehensive than the PET: it has other improvements, such as the use of a self-adaptive clothing model and the use of the integrated physiological response (Bröde et al., 2012) as a criterion for comparing typical and real indoor environments (D. Lai et al., 2020). For these reasons, the UTCI index contributes to evaluating the effectiveness and efficiency of actions on the existing fabric in this research.

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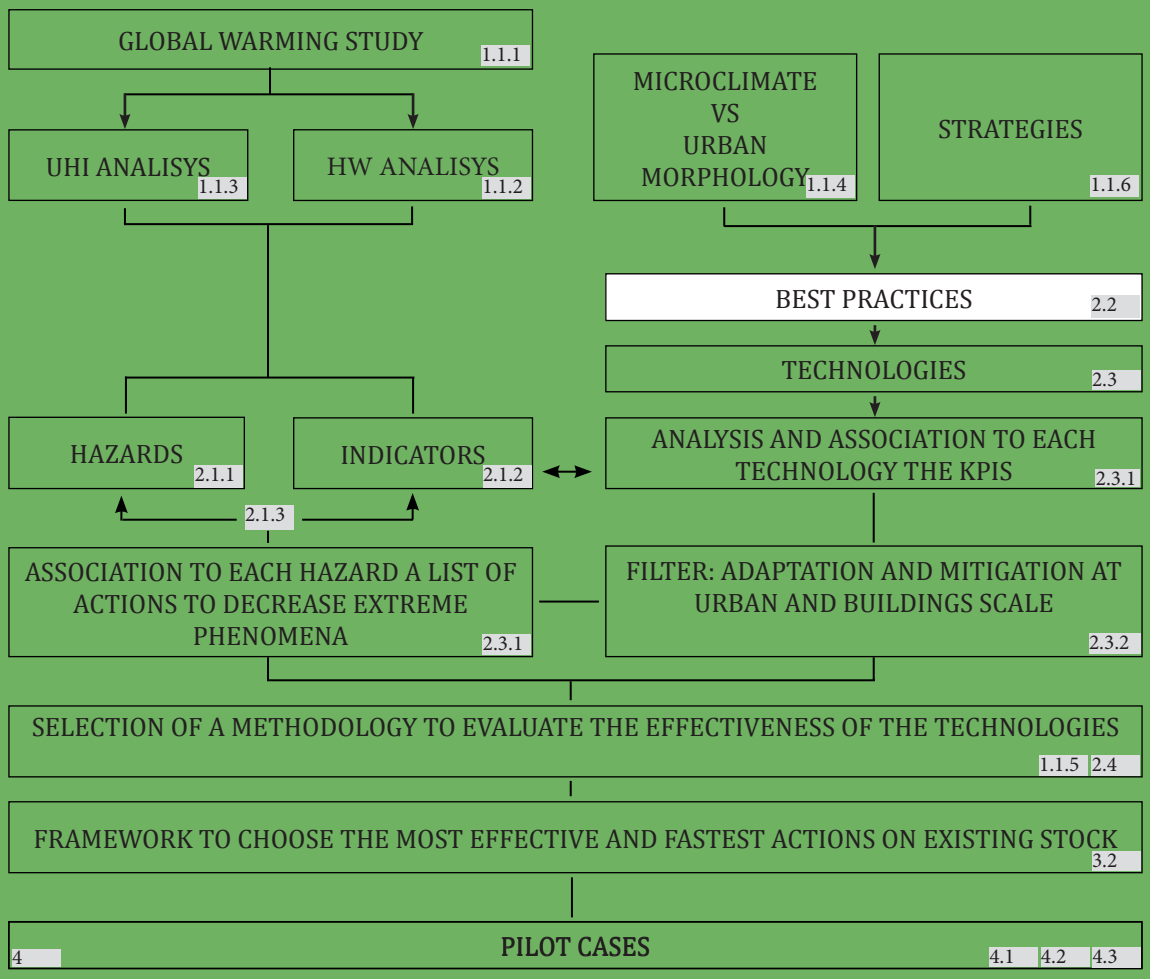
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CHAPTER 2.2

2.2| TECHNOLOGICAL ANALYSIS AND EVALUATION OF INTEGRATED SOLUTIONS FOR URBAN HEAT ISLAND AND HEAT WAVE ADAPTATION

ABSTRACT
Not all technological solutions aimed at achieving the sustainability goals set by the green economy allow for a decrease in the occurrence of heat islands and heat waves.
Through a collection of experiences across the planet, it is possible to select the most widely used actions and strategies to adapt and mitigate existing contexts to heat island phenomena and heat wave impacts.
When applied to existing contexts, this analysis can provide information on the most effective and efficient technologies for dealing with extreme phenomena due to rising temperatures.
The study is contextualised to the redevelopment of existing neighbourhoods built up to 2024.

KEYPLAN



Outcomes of this chapter:

- Selection of the the **most widely used actions** and strategies to adapt and mitigate existing contexts to heat island phenomena and heat wave impacts.

Introduction.

This part of the thesis aims to identify the most frequently used actions to adapt to and mitigate the occurrence of heat islands and the effects of heat waves.
Extreme phenomena related to rising temperatures, such as heat islands and heat waves, increase the vulnerability of built-up areas, impacting the health of people, buildings and the natural environment. In the literature, various thematic axes related to sustainability deal with different topics, such as a decrease in emissions, a decrease in consumption, recycling, and the reuse of resources. However, not all solutions aimed at sustainability and achieving the 2030 and 2050[23] agreements allow for a decrease in extreme events due to rising temperatures, which is the subject of this thesis. Furthermore, not all technological solutions are suitable for existing contexts. As already written in Section 1.1.6, the increase of urban land exceeds population growth by 50% by 2030, expecting an increase of 1.2 million square kilometres of new built-up area, causing a decrease in the supply of natural resources and an increase in energy consumption and greenhouse gas emissions (Tucci, Giampaoletti, Nava, & Tulelli, 2023).
Starting from the above theoretical assumptions, this research focuses on a careful and measured analysis of the actions used in case studies with similar characteristics to the topics covered in this thesis—requalification of existing neighbourhoods encountered by heat islands and heat wave events. Many neighbourhoods worldwide are sustainable or adopt principles to reduce consumption and pollution, belonging to C40 cities, following the aim of Net-Zero Challenging or referring to "100 Climate-Neutral cities by 2030 – by and for citizens".
This thesis deals with heat islands and heat waves within the existing built stock, so this research does not consider new construction. Instead, it focuses on the existing residential stock, characterised by a highly energy-intensive building stock that, following requalification actions, has significantly decreased its energy consumption, increased its bioclimatic behaviour and increased its comfort levels towards heat islands and heat waves. Therefore, the research's importance consists of an excursus of best practices focusing only on the existing built stock to mitigate and adapt to urban heat islands and heat waves.
Below is information on how the case studies were selected and

23. The 'European Climate Act sets a binding goal of EU climate neutrality by 2050 and a net internal reduction of greenhouse gas emissions of at least 55% compared to 1990 levels by 2030. The Emissions Trading Scheme (ETS) reform plans to increase the emission cut to at least 62% by 2030, compared to 2005. The same reform envisages a target of a 90% cut in emissions compared to 1990 levels by 2040 (Stati Generali della Green Economy; Fondazione per lo sviluppo sostenibile, Ecomondo, 2020).

analysed, as well as a summary and analysis of the results obtained.

Way of conducting research.

The research reviews case studies of neighbourhoods undergoing redevelopment whose objectives include heatwave adaptation, heat island mitigation, or both, to understand the strategies and actions most frequently used. The criteria for selecting case studies are:

- Existing energy-intensive neighbourhoods that have significantly reduced their consumption following redevelopment projects
- Redevelopment projects aimed at mitigating and adapting to heat islands and heat waves
- Neighbourhoods considered to be an established part of the city

This screening process has greatly reduced the number of examples considered. The selection includes both older best practices and more recent examples. The older cases are interesting for analysing the passive and bioclimatic solutions undertaken and for understanding how to use the existing morphology to increase such behaviours.
The analysis of the case studies is divided into two phases:
The first phase includes a literature study aimed at identifying districts built before 2025 and studying and analysing them. Other researchers in the department develop this part of the research, such as PRIN 2017's *"TECH-START—Key Enabling Technologies and Smart Environment in the Age of Green Economy. Convergent Innovation in the open space/building system for Climate Mitigation."*
An initial review revealed 21 case studies of districts that reflect the required characteristics - the result of redevelopment, whose objectives include adapting to and mitigating the impacts of heat islands and heat waves.
The second phase includes building a summary for each neighbourhood that clarifies the bioclimatic and energy actions undertaken. Each summary consists of four parts. The first part contains general information about the neighbourhood, including the location, designer, stakeholders, years of construction, size, and number of inhabitants. This part also indicates whether the neighbourhood

is concentrated around a central point of aggregation or not. The second part contains climatic-meteorological information, such as the number of sunny days, average temperatures, rainy days, frost, wind direction, and average wind speed. The third part summarises the district's history and the bioclimatic and energy strategies implemented to adapt to and mitigate the occurrence of heat islands and the impacts of heatwaves. The final section includes a summary outline of these actions and a bibliography.

This method enabled the identification of the most commonly used strategies and actions to mitigate and adapt to existing contexts affected by global warming, particularly in urban heat islands and heat waves. Below is an analysis of each district, along with an elaboration of the data through tables that compare the neighbourhood, highlighting which strategies and actions are taken for a specific area.

2.2| Technological evaluation analysis of integrated solutions for adaptation to extreme urban heat island and heat wave phenomena
p. 183

Circular Buiksloterham:

Informations:

Designer:	Metabolic, DEL VA Landscape Architects, Studioninedots, Frank Alsema, Peter Dortwegt, Saskia MUller (Amsterdam Smart City)
Stakeholders and owners:	De Alliantie, Waternet, Ontwikkelingsbedrijf Gemeente Amsterdam (OGA)
Designing year:	2014
Building year:	2014
Finish year:	In progress
Inhabitants:	45000
Dimension:	100ha

Collocation: Amsterdam, Netherlands



Neighborhood structure:



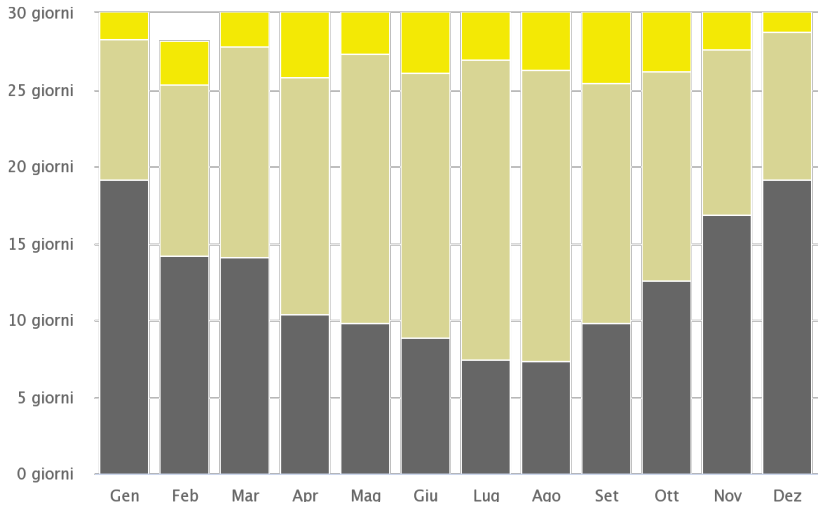
Pictures:



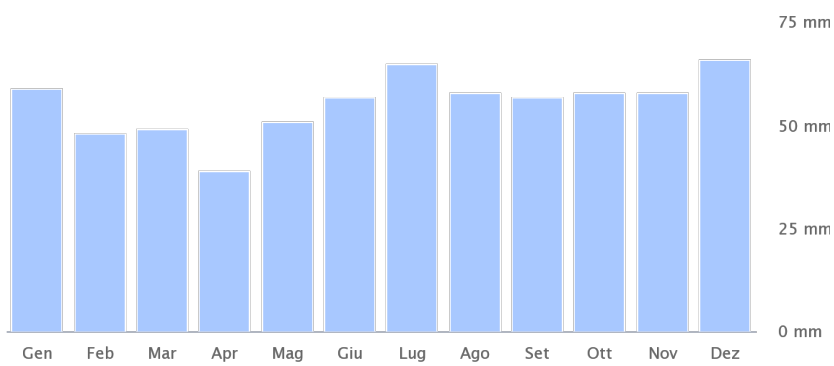


https://www.duurzaamgebouwd.nl/artikel/20090903-duurzaam-ontwerp-gezocht-voor-buiksloterham

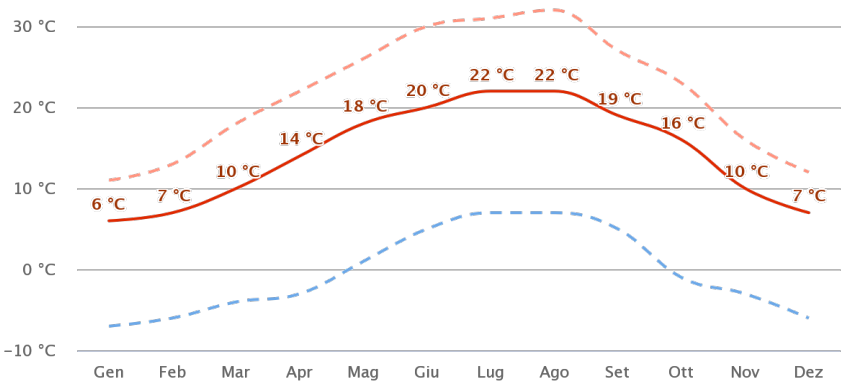
Climate conditions:



LEGEND:
Sunny days
Changeable weather
Cloudy
meteoblue.com



LEGEND:
Rainfall
meteoblue.com



LEGEND:
Warm days
Cold nights
Average maximum temperatures daily
meteoblue.com

GEN	FEB	MAR	APR	MAG	GIU	LUG	AGO	SET	OTT	NOV	DIC
SO	SO	OSO	NO	ONO	O	O	OSO	OSO	SSO	SSO	SSO
25	28	26	21	20	20	18	18	17	22	22	23
12	12	12	10	10	10	10	10	9	10	10	11

Wind speed and direction per month; meteoblue.com

Issues:

- **Abandoned area, formerly used as a dredging material depot.**

History:

Since 1886, the neighbourhood of Circular Buiksloterham has been used primarily for dredging material storage and agricultural activities. Around 1920, the first industries arose, taking advantage of the district's proximity to the river. The complex retained its industrial character until 1998, when the municipality of Amsterdam acquired the land that belonged to many industrial plants. Before the redevelopment, the neighbourhood had few public or green spaces and many brownfield sites that were empty or abandoned due to contaminants in the soil. Around 2014, a few significant industrial buildings and some light industrial functions (such as printing works) remained in the area. At that time, there were about 252 residents in the area. Despite its industrial past, Circular Buiksloterham is only five minutes away from the historic centre of Amsterdam. This left room for more flexibility in redevelopment because monumental buildings are absent, and the area has a low population density. The redevelopment started in 2014 and is still ongoing.

Actions:

All existing buildings have been retrofitted. The dwellings follow the Passivehaus standard of a 90 per cent reduction in heating energy demand. This allows a heating demand limit to be set at 15 kWh/m^2/year or 10 W/m^2 peak. The thermal insulation of the buildings is set at U=0.15 W/m^2k. The windows and door frames are well insulated to ensure thermal insulation and have low-emission glass, with argon or krypton in the cavity. The residential buildings have waste heat recovery systems from showers and wastewater (DWHR). All appliances do not exceed the energy requirement of 120 kWh/m^2 floor area per year. Exploiting indoor air flows transfers 75% of the waste air heat to incoming fresh air. All buildings are designed to have no thermal bridges. The energy demand of buildings corresponds to heating demand alone. Natural ventilation replaces active ventilation systems, lowering the energy demand by 290 million MJ. In terms of construction, the buildings are made of prefabricated elements, using separate, simple construction systems. The architects have designed complexes that can be easily dismantled, so that materials can be reused. Many buildings have blue and green roofs of different types: extensive and intensive types. Skylights maximise light penetration into interior spaces. LED lighting systems with automatic on/off sensors further reduce consumption. Installing 100 monitoring sensors allows a 30% reduction in total energy consumption. Niches for insect nesting, the design of migratory corridors, and the provision of habitats protect local fauna by improving their living conditions and maintaining high levels of biodiversity, ensuring the presence of bees, butterflies, dragonflies and endemic species threatened in Europe.

Summary:

Use of passive and bioclimatic solution
External coat Thermal break window Green Roof Green wall Angle-selective thermochromic materials

Improvement of the public transport system
Increasing the number of public transport stops Increased frequency of public transport

Use of active devices to harness energy sources
Solar thermal systems for hot water Photovoltaics systems Biomass digesters Heat recovery and storage systems Micro-wind turbines Hydrogen LED systems

Improving infrastructure for soft mobility
Cycle paths Car sharing/pooling

Ventilation control
Installation of openings inside buildings to promote pressure differences and thus ventilation

Setting up continuos monitoring systems
Home automation control and monitoring systems

La Duchére

Informations:

Designer: Gautier + Conquet

Stakeholders and owners: Grand Lyon Habitat

Designing year: 2000
Building year: 2001
Finish year: on going
Inhabitants: 12500 (5500 homes)
Dimension: 120ha

Collocation: Lyon, France

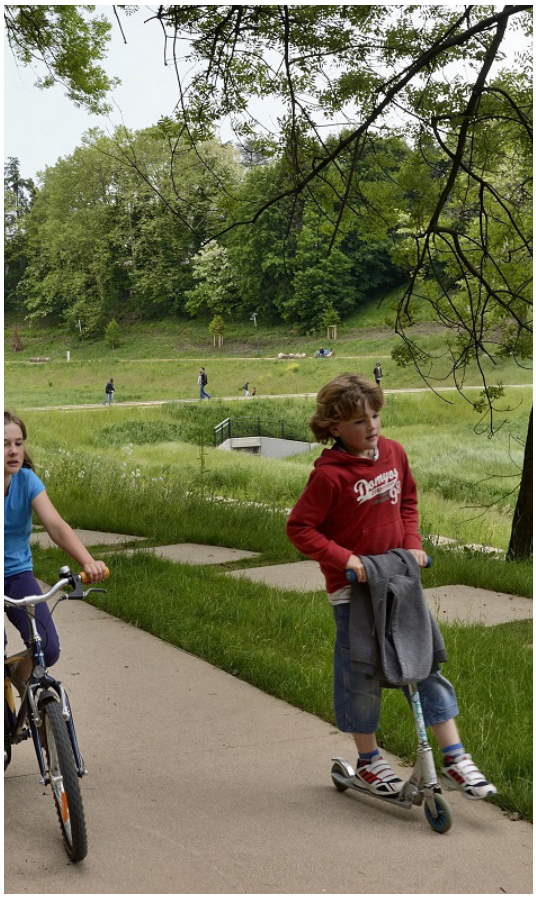


Neighborhood structure:



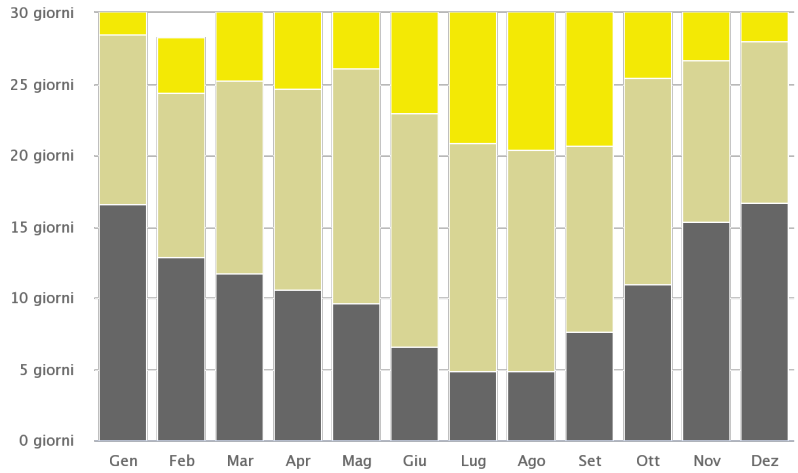
Pictures:



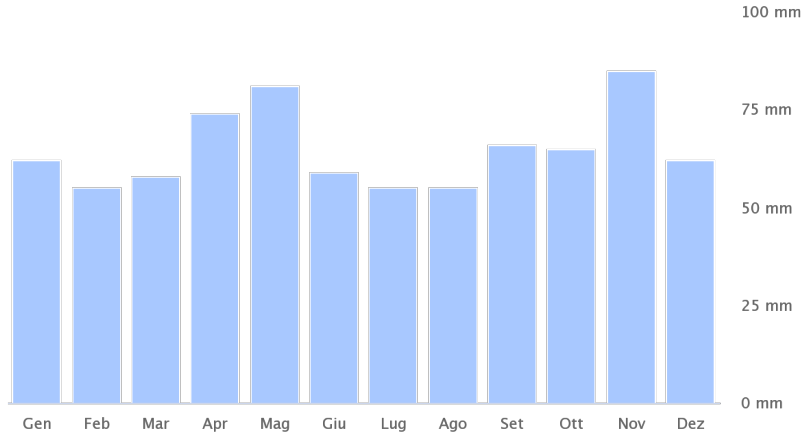


https://www.mrae.developpement-durable.gouv.fr/IMG/pdf/2022apara97_lasauvegarde_lyon_69.pdf

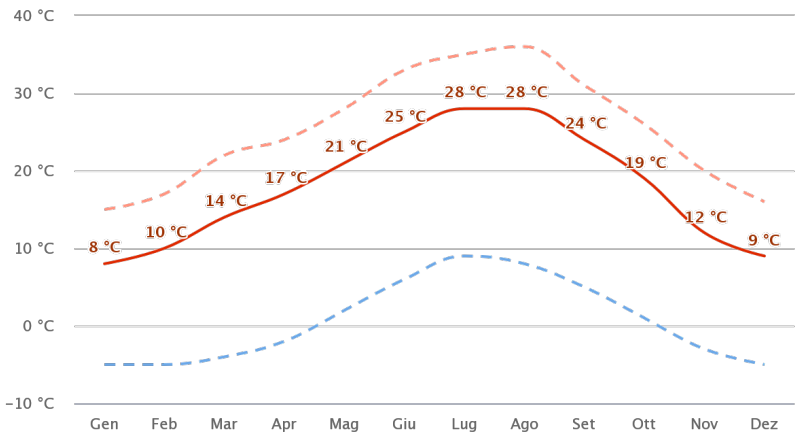
Climate conditions:



LEGEND:
Sunny days
Changeable weather
Cloudy
meteoblue.com



LEGEND:
Rainfall
meteoblue.com



LEGEND:
Warm days
Cold nights
Average maximum temperatures daily
meteoblue.com

GEN	FEB	MAR	APR	MAG	GIU	LUG	AGO	SET	OTT	NOV	DIC
ONO	NO	NNO	NO	NNO	NNO	N	N	NNO	SSO	S	SSO
10	11	10	11	9	9	9	9	8	10	10	10
4	4	4	4	4	4	4	4	4	3	4	3

Wind speed and direction per month; meteoblue.com

Issues:

- **Lack of planning at the territorial level**
- **Lack of design in built housing units without a precise architectural character**
- **Presence of heat island phenomena**
- **Circulation within the neighbourhood is difficult: dead-end streets, sometimes complicated pedestrian access**
- **Circulation within the neighbourhood is difficult: streets with alleys, old and poorly insulated buildings**
- **Non-diversified housing stock**
- **Underdeveloped public spaces**
- **Shopping centres in decline**

History:

The neighbourhood, which arose in the 1960s and was intended to house the working class, before the redevelopment work began in the 2000s, lacked a spatial plan and was characterised by housing units without a precise architectural character. Faced with the real estate crisis, Louis Pradel (mayor of Lyon) decided in 1958 to build a district with 5,300 houses on the hill of La Duchère, which had been occupied until then for agricultural and forestry purposes. The construction of La Duchère began with an overall master plan conceived by architects François-Régis Cottin and Frank Grimal. A series of housing units without any particular architectural character, some 5500, designed by architect François-Régis Cottin, were built on the site. In 1962, the first inhabitants began to settle. According to testimonies from 1972, the district was a place where social life and citizen participation in city affairs were strong. Around the 1980s, the district began to decline due to unsuitable urban planning, a high concentration of housing, social isolation, and the population's impoverishment. In particular, heat island phenomena increased discomfort, dead ends characterised the streets, and pedestrian access was complicated. Buildings within the neighbourhood were old and poorly insulated, public spaces were insufficient, and the shopping centre was in decline. In 2011, a major project was launched for the city to revitalise the district. From 2003 until 2021, the demolition of more than 1,700 social housing units and the reconstruction of 1,768 housing units, new businesses and office buildings took place. These redevelopments aim to improve the socio-economic image of the neighbourhood, which is considered 'sensitive' or 'difficult' thanks to funding from the ANRU (National Agency for Urban Redevelopment). In 2013, La Duchère obtained the eco-district label. It is the first in the Lyon metropolis. In 2016, a new project began on La Sauvegarde and Le Châteaux that sees the completion of the district's transformation. Then, in 2019, demolitions were carried out at La Sauvergarde, and in 2020, at Le Châteaux, the redevelopment of the entire complex was completed.

Actions:

The first action taken was defining a master plan, with a local road axis, Avenue Rosa Parks, and the redevelopment of the first two areas involved: La Sauvegarde and Le Château. These are selected within the new National Urban Renewal Programme (NPNRU) framework. The area is subject to the demolition of numerous dwellings, 1,500 dwellings, many cafés and small businesses. The project involves the construction of more than 1,500 new dwellings, including a large percentage of private dwellings, new social housing, an area with new businesses and several public facilities, including schools, a gymnasium and library, an athletics hall (Diagana Hall) and a party hall. La Duchère is involved in an energy programme affecting the city of Lyon.
The project in question is called European Transform. In particular, the actions undertaken include an increase of 70 MW of energy from wood for the entire city, an increase of 20 MW through photovoltaic systems and a further 20 MW of solar thermal energy, installed on buildings. In this way, a saving of 6000 tonnes CO_2/year is possible in the experimental phase.
In addition, there is a biomass-fuelled district heating network within the district. The presence of energy communities only allows a saving of 8% through the use of 'good behaviour' standards.
In order to reduce the phenomenon of heat islands, a pervasive

and articulated green system has been designed. It includes Parc du Vallon, which has been redeveloped, and new areas. The large avenue, Rosa Parks, and all the other streets are characterised by long rows of trees between the new buildings. There are numerous green areas and parks in the district. In addition to constructing new buildings, existing ones have undergone redevelopment to achieve the expected performance standards through reconfiguring the entire complex. In particular, to ensure adequate thermal and acoustic insulation, actions are undertaken on the opaque envelope, such as external insulation, and on the transparent envelope, such as installing thermal break window frames and galvanised sheet metal adjustable sunscreens. Significant insulation work was undertaken on basements and roofs, which, combined with replacing windows and doors and upgrading plant systems, allowed the individual building to be upgraded from class D to class B. The newly constructed buildings meet HQE (Haute Qualité Environnementale) standards. Thermoregulation systems are installed in the buildings to reduce electricity and water consumption. New buildings are low-consumption. Ventilation flow management has increased comfort in summer. In terms of green infrastructure, there is an extensive and articulated green infrastructure that includes the redeveloped Parc du Vallon and new areas. Long rows of trees characterise the large avenue, Rosa Parks, and all other streets, and among the new buildings, green areas and parks are numerous. In general, the redevelopment of 2.3 hectares of public space has led to a drastic decrease in the heat island phenomenon during the hottest time of the year.

Summary:

Use of passive and bioclimatic solution

External coat
Solar sharing

Use of active devices to harness energy sources

Solar thermal systems for hot water
Photovoltaics systems
Biomass digesters

Ventilation control

Morphological set-up of systems at neighbourhood level
Installation of openings inside buildings to promote pressure differences and thus ventilation
Urban canyon

Setting up continuos monitoring systems

Home automation control and monitoring systems

Use of green infrastructures

Parks
Tree lines
Pocket gardens
Green corridors
Arboreal backdrops

Use of blue infrastructures

Rain water collection and reuse

Improvement of the public transport systems

Presence of proximity services

Improving infrastructure for soft mobility

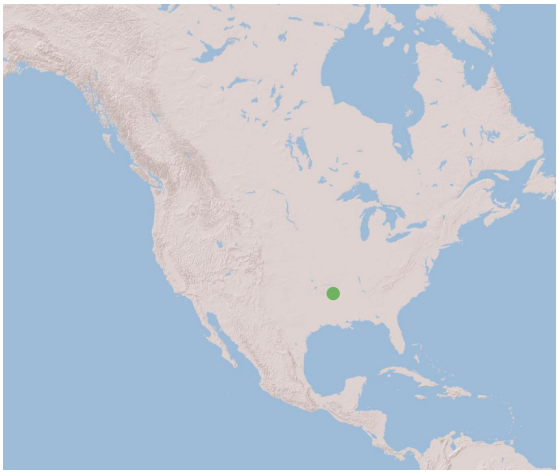
Footpaths
Cycle paths
Shading systems for cycle and pedestrian paths

Seaholm Ecodistrict

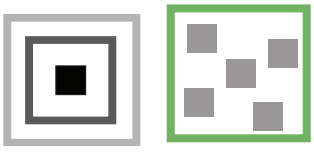
Informations:

Designer:	Gail Vittori, Pliny Fisk III
Stakeholders and owners:	City of Austin Office of Sustainability, Economic Development Department and Public Works Department, Austin Energy
Designing year:	2012
Building year:	2014
Finish year:	2017
Inhabitants:	2500
Dimension:	33ha

Collocation: Austin, TX, USA

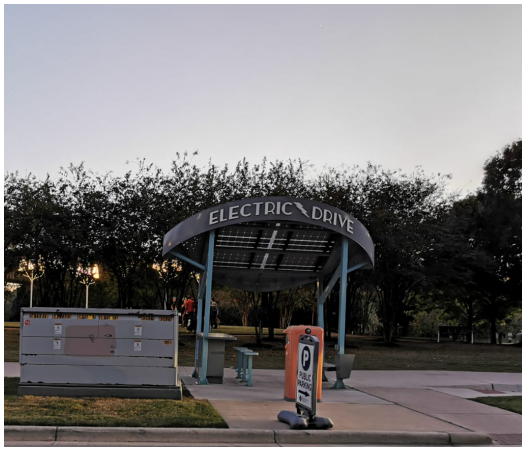


Neighborhood structure:



Pictures:

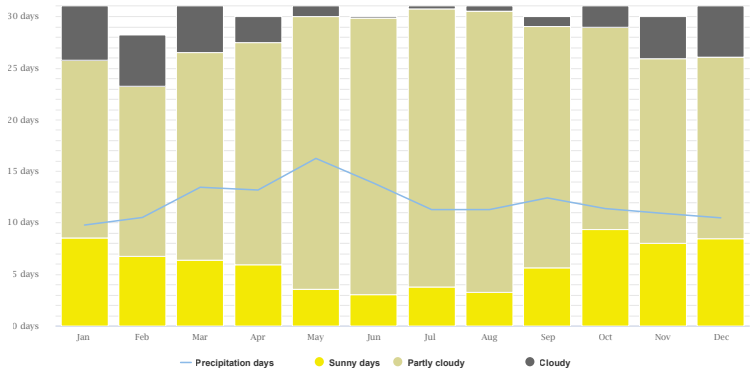






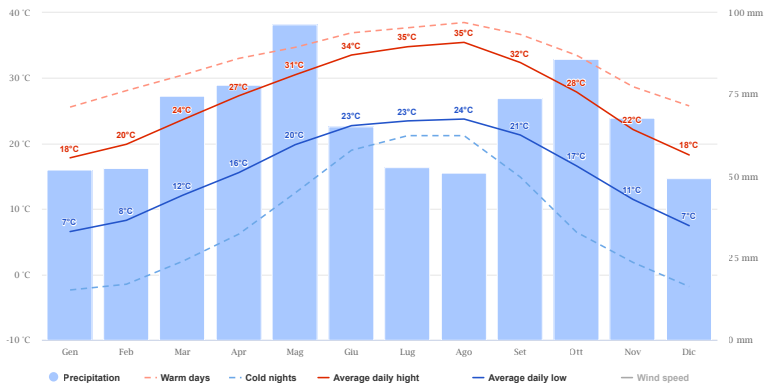
Pictures taken by the author of Seaholm Ecodistrict (2021)

Climate conditions:



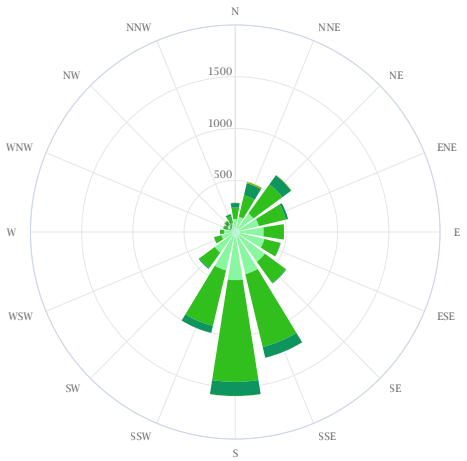
LEGEND:
Sunny days
Changeable weather
Cloudy
Precipitation days

meteoblue.com

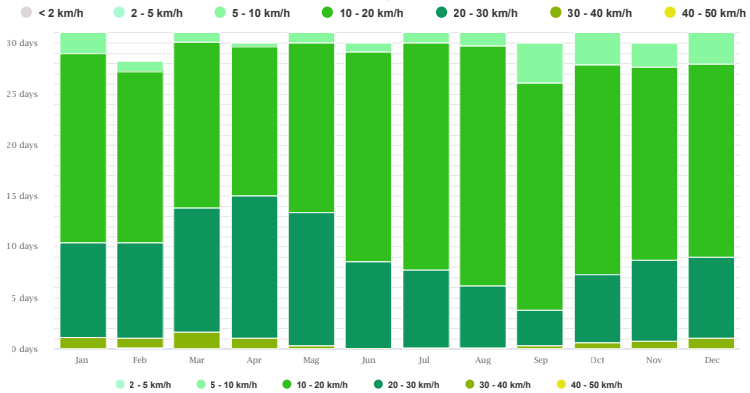


LEGEND:
Warm days
Cold nights
Average maximum temperatures daily
Rainfall

meteoblue.com



Wind speed and direction during the year; meteoblue.com



Wind speed and direction per month; meteoblue.com

Issues:

- **Seaholm was an abandoned and polluted former industrial site in the heart of Austin.**

History:

The Walter E. Seaholm power station, built between 1950 and 1958, is the first in Austin. It operated until 1989. The water treatment plant was opened in 1925, becoming one of the first water treatment plants in the world to adopt a new lime-based treatment developed at the University of Texas at Austin. Following the plant's decommissioning, the Seaholm area was a brownfield site encompassing eight city blocks. In 2012, the area was redeveloped into an environmentally sustainable centre to serve as a renewal backbone for the entire city of Austin. Design work began in 2001 when the city completed a master plan for the Seaholm district to redevelop and reuse the city's power plant area for integrated, mixed-use. The district is north of Lady Bird Lake, and the site enjoys a location that favours summer breezes. Being crossed by Shoal Creek bordering Lady Bird Lake, the area is rich in biodiversity and water resources. The area has become a social and meeting point. Planned improvements include a Central Library, the creation of a promenade along Cesar Chavez Avenue, a boutique hotel, 1475 multi-family housing units, and new office and retail space that will support up to 5000 workspaces.

Actions:

Rather than individual building energy planning, district energy planning has been carried out throughout the area. The use of microgrids allows greater flexibility in energy distribution. This allows pooling resources and storage capacity, resulting in more efficient and productive utilisation. In the area, photovoltaic and solar thermal systems are encouraged. In particular, there are micro-solar installations, including solar-powered kiosks and Scoofa solar tables. The solar kiosk Elettric Drive is a free charging installation opened in October 2016. Soofa solar benches are also installed in the district, providing power for charging phones, tablets and 100% solar-powered computer charging stations. The presence of installations powered by renewable energy sources has resulted in a 60 per cent reduction of energy in new buildings, an annual thermal energy production of 35.1 million kW/h. Geothermal heat generation allows a 75% reduction in total energy consumption, with a 51% reduction in greenhouse gases. The bioclimatic approach to design can be seen in the increase of LEED certifications within the district, the increase of surfaces with a high albedo index, the numerous presence of green roofs, the morphological optimisation according to solar orientation and natural light, the presence of triple-glazed thermal break windows with argon, the use of low consumption street lighting and LEDs, and the installation of daylight sensors - which increase lighting efficiency. In addition, the buildings are equipped with shading systems such as brise-soleil, louvres or screens. The green infrastructure is articulated through tree-lined avenues, parks, open spaces, green surfaces and roofs. The increase in vegetation is also aimed at retaining water, collecting and reusing rainwater stored in special cisterns. In this way, the green infrastructure can treat more than 36 million gallons of rainwater annually. Finally, Austin has developed an air quality protection programme for the city centre. An air quality improvement development programme is carried out throughout Austin. On the banks of Shola Creek, which runs through the district, the banks are being restored by improving drainage and establishing new habitats with native plantations.

Summary:

Use of passive and bioclimatic solution
Thermal break window Solar shading Green roof Green wall Cool roofs/cool pavements

Use of active devices to harness energy sources
District heating Solar thermal systems for hot water Photovoltaics systems Geothermal power LED systems

Use of green infrastructures
Tree lines Bioswales

Improving infrastructure for soft mobility
Footpaths Cycle paths

Setting up continuos monitoring systems
Home automation control and monitoring systems

Recovery and enhancement of the relationship with the acquatic/river environment
Artificial bank protection Use of the banks

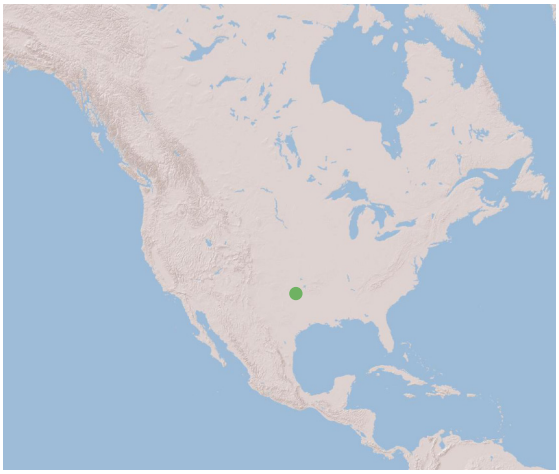
Use of blue infrastructures
Setting up wetlands

The Pearl

Informations:

Designer:	Lake|Flato Architects in collaboration with DHR Architects for Full goods Warehouse, RVK Architects for the lab office building at the Pearl Brewery, Brendan Wittstruck (for the lab office building)
Stakeholders and owners:	Silver Ventures
Designing year:	2001
Building year:	2009
Finish year:	On going
Inhabitants:	
Dimension:	350 houses and 150 hotel rooms
Cost:	$21.75 milion; apartments: $95/SF; office: $129/SF

Collocation: San Antonio, TX, USA



Neighborhood structure:



Pictures:



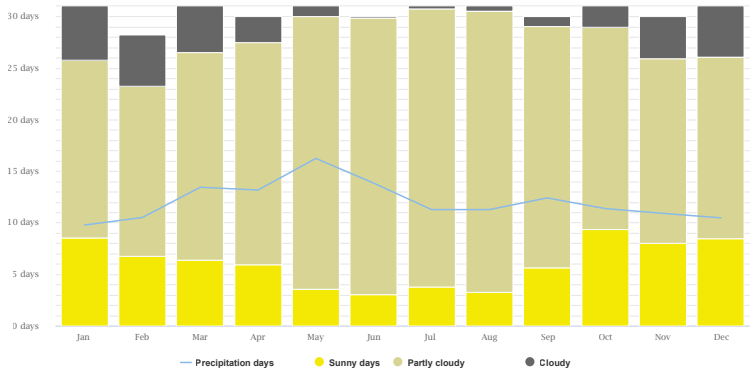
Pictures taken by the author of the Pearl (2021)





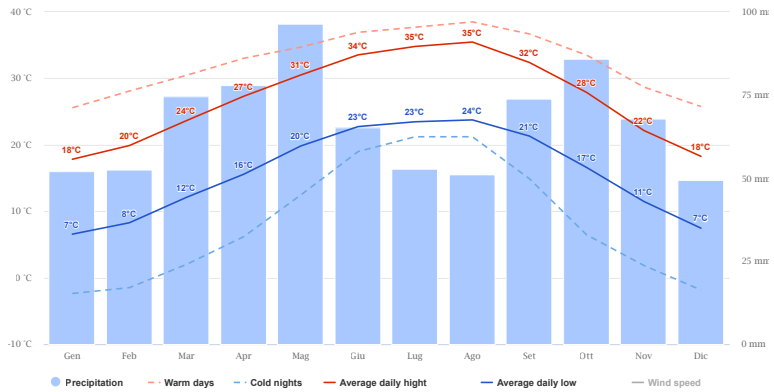


Climate conditions:



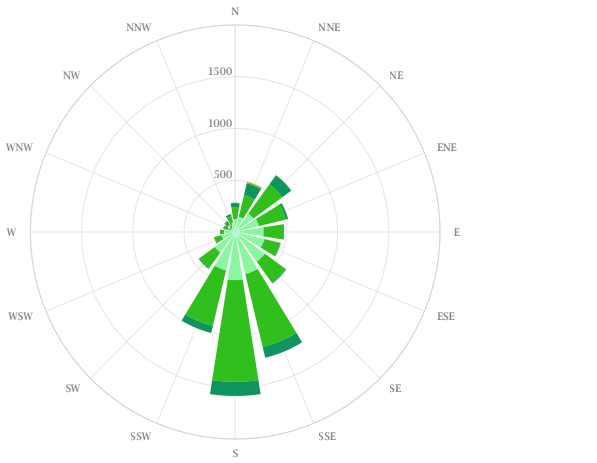
LEGEND:
- Sunny days
- Changeable weather
- Cloudy
- Precipitation days

meteoblue.com

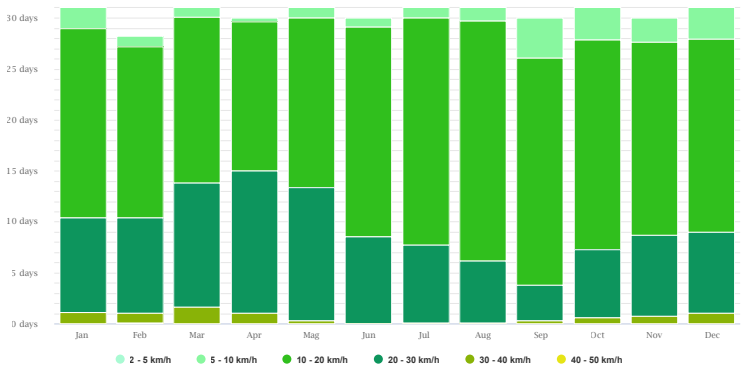


LEGEND:
- Warm days
- Cold nights
- Average maximum temperatures daily
- Rainfall

meteoblue.com



Wind speed and direction during the year; meteoblue.com



Issues:

- **Abandoned former brewery**
- **The site was a part of the city dying due to urban development.**

History:

The Pearl Brewery, built in 1889, closed in 2001. Initially built in 1893, the bottling department building fell into disrepair and caught fire on 9 September 2004. It was from this building that the redevelopment of the area started. The goal of the Pearl Brewery redevelopment was to create a sustainable live/work/study experience that maintained the identity of the historic brewery while radically repurposing key parts of the compound to accommodate new uses. Its spectrum of live/work spaces and restaurants ensures the site is occupied throughout the day, night, and weekends with various urban uses. The site has been transformed into a self-sufficient mixed-use village that accommodates residents, non-profit organisations, and local businesses to stimulate economic development. The area is entirely pedestrianised and respects the historical character of the buildings of which it is composed. Redevelopment work continued until 2007 and involved the adjacent Full Goods building. In 2009, the project also involved the San Antonio River by redeveloping the banks and providing pedestrian paths along the river. In 2010, a new building became the Culinary Institute of America. In 2012, a residential complex was built in the area, and in 2016, the former beer bottling department building became the new food hall of the neighbourhood.

Actions:

Several buildings within the district are LEED certified, such as Full Goods Warehouse. In particular, in this building, a photovoltaic system allows a production of 200 kW. In addition, the presence of a water heater, the control of lighting, the use of renewable energy sources, and the presence of high-efficiency minisplits for indoor air conditioning make the building self-sufficient. Outdoors, using passive strategies to save energy is favoured throughout the area. High-efficiency public lighting, morphological layouts aimed at exploiting natural light and indexing breezes, studying the orientation of the buildings, maximising building density, and reusing materials as objects of street furniture all contribute to the redevelopment and passive behaviour of the district. The area's historic character is preserved through timely and careful interventions that have not altered its aesthetics. The banks of the riverfront adjacent to the neighbourhood are being redeveloped through the construction of an adjacent wetland. Other actions undertaken within the district consist of reforestation using species native to the area and requiring little maintenance, the installation of humidity sensors next to the buildings to monitor the microclimate, the restoration of wetlands on the river banks, the installation of bioswales, water catchment basins and permeable surfaces. All these actions have contributed to increased drainage and decreased run-off.

Summary:

Use of passive and bioclimatic solution

Orientation

Use of active devices to harness energy sources

Photovoltaics systems
Energy efficient minisplit installation

Ventilation control

Morphological set-up of the system at neighbourhood level

Use of blue infrastructures

Rain water collection and reuse
Setting up wetlands

Improving infrastructure for soft mobility

Footpaths
Shading systems for cycle and pedestrian paths
Bicycle and/or pedestrian parking points

Control and increase of soil evapotranspiration

Permeable surfaces

Setting up continuous monitoring systems

Sensors to detect soil moisture
Home automation control and monitoring systems

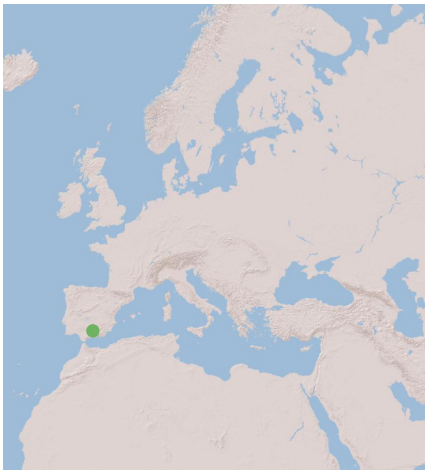
Recovery and enhancement of the relationship with the aquatic/river environment

Artificial bank protection
Use of the banks

Ecobarrio Trinitat Nova

Informations:

Collocation: Bancellon, Spain

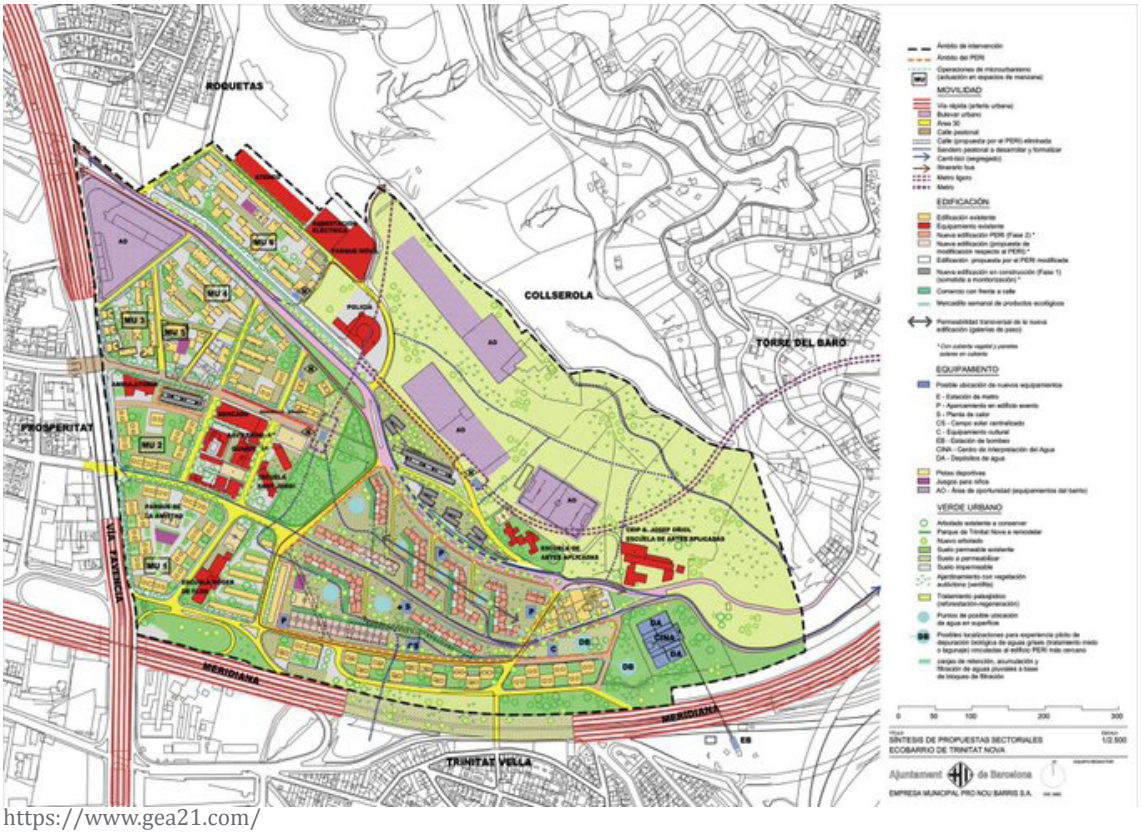


Designer:	**Technical team:** Atanasi Céspedes, Miquel Domingo, Carlos Verdaguer, Isabela Velázquez, **Designers and planners:** Manuel Ruisánchez (Fase 1), Carme Ribas e Pere Joan Ratvetllat (PERI)
Stakeholders and owners:	Generalitat de Catalunya, municipality of Barcellona, other companies involved in the project: AIGUASOL, ECOINSTITUT DE BARCELONA; CC60
Designing year:	2001
Building year:	2004
Finish year:	On going
Inhabitants:	891 dwellings
Dimension:	63834 mq
Cost:	17442986 € (grant 50%)

Pictures:

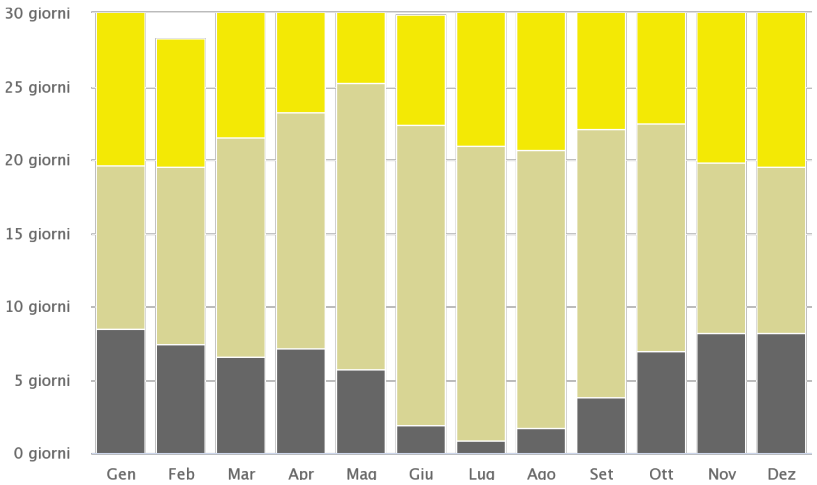
Neighborhood structure:



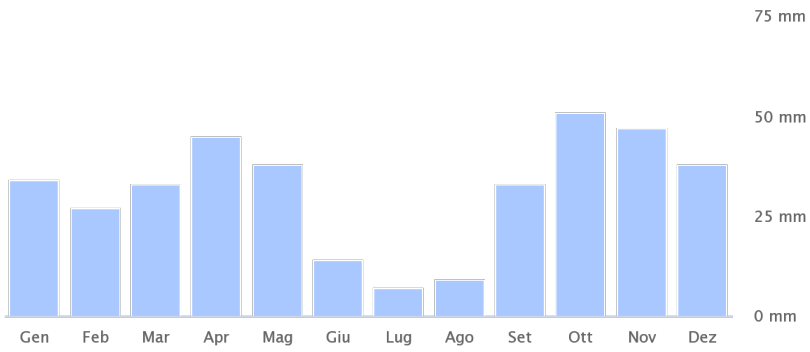


https://www.gea21.com/

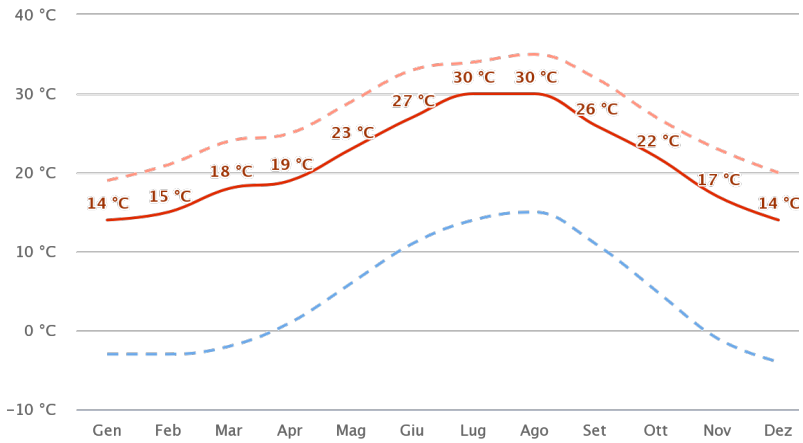
Climate conditions:



LEGEND:
Sunny days
Changeable weather
Cloudy
meteoblue.com



LEGEND:
Rainfall
meteoblue.com



LEGEND:
Warm days
Cold nights
Average maximum temperatures daily
meteoblue.com

GEN	FEB	MAR	APR	MAG	GIU	LUG	AGO	SET	OTT	NOV	DIC
N	SO	ESE	SE	SSE	S	SSE	SSE	SSE	SE	NE	ONO
5	5	6	6	5	6	6	5	5	5	6	6
3	3	4	4	4	4	4	4	4	3	3	3

Wind speed and direction per month; meteoblue.com

Issues:

- **Lack of planning**
- **Most of the buildings were built without the presence of projects**
- **Small houses made with poor-quality materials**
- **The neighbourhood does not offer any service or specific activity**
- **The road divides the neighbourhood from the rest of the city**
- **Aluminous problems**
- **Free spaces are dangerous**
- **Lack of a representative centre**
- **Extremely elderly population**
- **People who live in the area have a low education level and a high unemployment rate**

History:

Trinitat Nova is in northern Barcelona and belongs to the Municipal District of Nou Barris. In particular, the neighbourhood is on the southern slope of the Sierra de Collserola, bordered by two significant traces of the territory: the Avenida de La Meridiana and Ronda de Dalt, which physically separate it from other neighbourhoods. The neighbourhood was built in the decade of '50 to solve the social housing problem. In 1953, the construction of Trinitat began, and most of the buildings were built without a plan. The area lacked the minimum equipment (roads, infrastructure). The houses were small (the majority did not reach 50 square meters) and made of poor-quality materials. The physical decay of the neighbourhood started almost from the moment of its completion. The neighbourhood did not offer any service or specific facility. From a socioeconomic point of view, people who live in the area have a low education and a high unemployment rate compared to other districts of Barcelona. The presence of an aluminous problem led to developing a programmatic document, which, by establishing a priority intervention area, pushed for requalification actions. The concept of sustainability formed the basis of the planning for the neighbourhood's redevelopment. "Sustainability" on all scales of intervention, paying attention to the local context of material and energy flows and residents' quality of life regarding health, well-being and social coexistence. The principles of planning can be traced back to three basic lines.

- Insertion and interconnection with the city
- Model of "Eco-vicinity" through a focus on several key areas such as neighbourhood, participation and management, diversification of uses, public space as a place of city life, the city as an ecosystem, bioclimatic habitability and suitability, durability, recyclability and low impact
- Urban metabolism

Actions:

The neighbourhood has been redeveloped with a systematic and continuous improvement policy based on a balance between residential fabric, equipment, and leisure spaces. From the energy point of view, there are several photovoltaic systems within the district: the maximum annual energy yield of a photovoltaic panel in Barcelona is 10%. The annual solar output of a typical unit is 1.3 kWhe/Wp, with 125 Wp/m^2. In addition, small independent devices with a power of 5 kWp are installed within the district with 30-35 degrees of inclination and a southern orientation. The annual CO_2 emission saving is 623 kg CO_2eq/kWp. There are also various types of solar thermal systems in the area:

- EE-130 ACS system: listed as the minimum mandatory system. There are 1,170 m^2 in the district. This technology is intended to cover 60% of the DHW demand. This system, in total, provides 150 kW per typical building.
- System E-E, to cover 60 per cent of demand. The heat generated supplies a typical building with 200 kW.
- System E-I 225 m^2 of solar captors per building and system. Each capturer provides 24 kW.
- E-X System: total capture area is 2925 m^2 (325 m^2 per typical building) to cover 70% of the demand
- EBX-S System total capture area is 1575 m^2 (175 m^2 per typical building). The cogeneration capacity is 15 kWt with a 300 kWt boiler;

- EBX-CS System: total capture area is 2025 m^2 (225 m^2 per typical building). The stationery storage is 2000 m^2, and the cogeneration output is 150 kWt with a 300 kWt boiler.
- BBX system: The cogeneration power is 150 kWt, similar to the EBX system, and the total area is 2025 m^2 (225 m^2 per typical building).

These systems can reduce primary energy demand and CO_2 production by 45%.
There are also heat pumps for heating and electricity within the district.
The buildings making up the district are also equipped with an efficient system for collecting, treating and reusing wastewater from showers, washing machines, washbasins and bidets. This allows a drastic reduction in the consumption and reuse of water.
The buildings also have Trombe walls, face-change materials, and solar storage systems that contribute to bioclimatic behaviour. Double-glazed windows improve building insulation. The good orientation of buildings allows for good natural lighting and decreased lighting consumption. The design of openings to ensure cross ventilation allows a 43% reduction in cooling demand.
At the outdoor level, a policy of increasing and enhancing the green areas has been carried out: around Tamariu Street, there are new green spaces which, together with the existing Parque del Trinitat Nova and the Plaza del Reloj, constitute the green corridor towards Collserola. Throughout the area, there are various urban gardens. Finally, green areas are positioned on both sides of the Tamariu street to provide a pedestrian connection to other parts of the neighbourhood.

Summary:

Use of passive and bioclimatic solution

Thermal break window
Trombe-wall
Face-change materials

Use of active devices to harness energy sources

Solar thermal systems for hot water
Photovoltaics systems
Heat pumps
Cogeneration

Use of green infrastructures

Urban gardens

Use of blue infrastructures

Rain water collection and reuse
Setting up wetlands

Improvement of the public transport systems

Presence of proximity services

Improving infrastructure for soft mobility

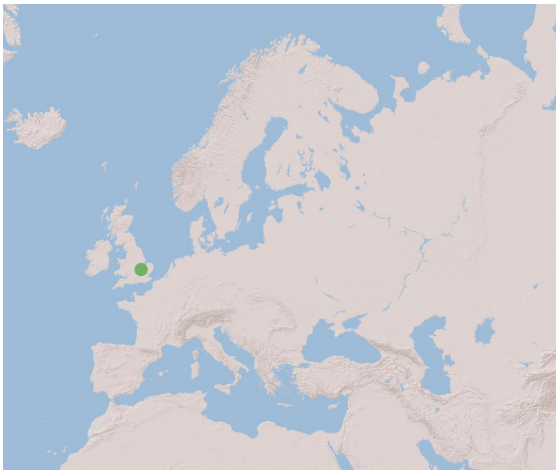
Footpaths
Garden squares

BedZED

Informations:

Designer:	Peaboy e Bioregional foundation, Bill Dunster Architects, Enjineers Arup
Stakeholders and owners:	The Peabody Trust
Designing year:	1997
Building year:	2000
Finish year:	2002
Inhabitants:	220 (with 100 homes)
Dimension:	3.5 ha

Collocation: London, UK



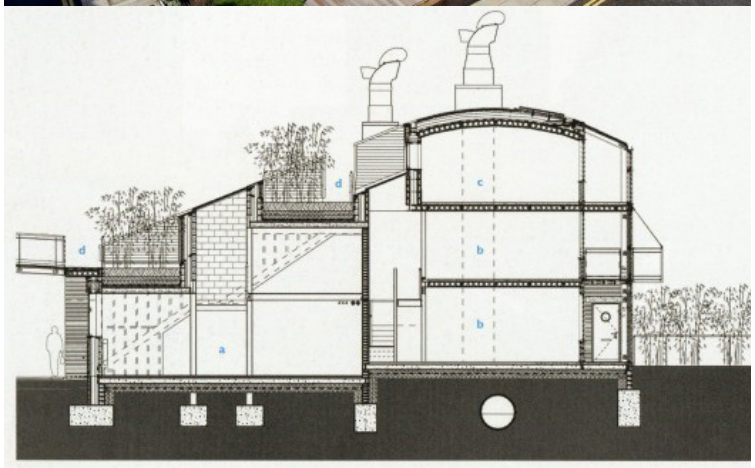
Neighborhood structure:



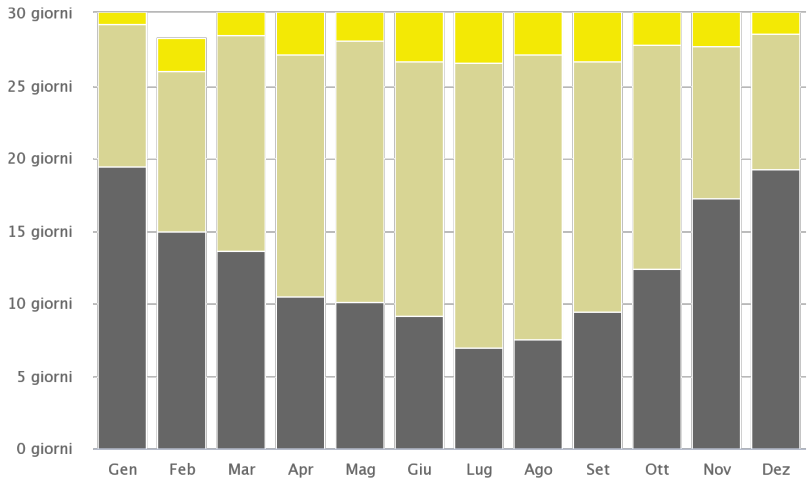
Pictures:



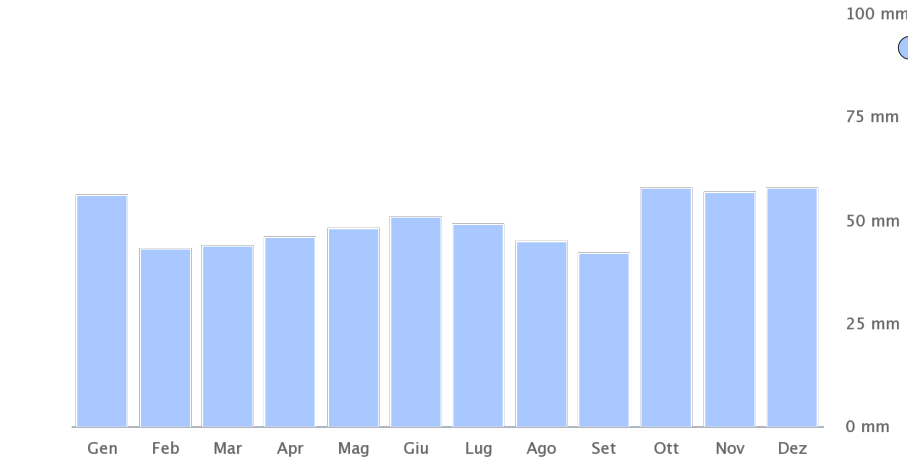
https://www.rinnovabili.it/



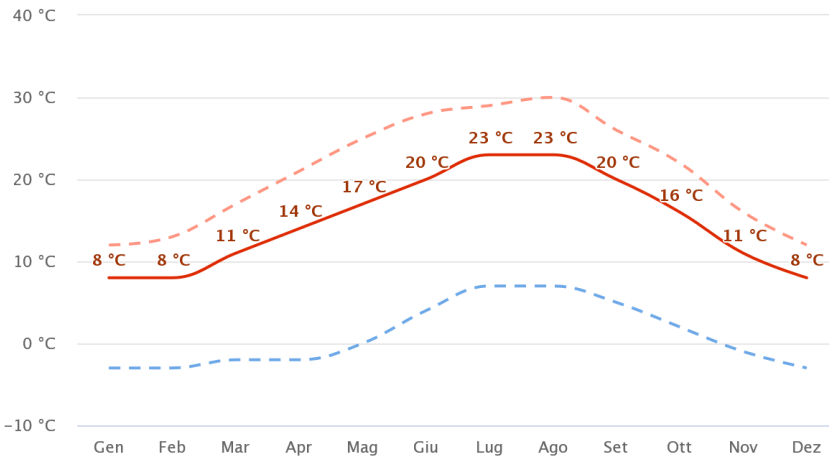
Climate conditions:



LEGEND:
Sunny days
Changeable weather
Cloudy
meteoblue.com



LEGEND:
Rainfall
meteoblue.com



LEGEND:
Warm days
Cold nights
Average maximum temperatures daily
meteoblue.com

GEN	FEB	MAR	APR	MAG	GIU	LUG	AGO	SET	OTT	NOV	DIC
OSO	OSO	OSO	OSO	OSO	OSO	OSO	OSO	OSO	OSO	SO	SO
13	14	15	14	14	14	13	13	10	11	12	12
5	5	5	4	5	4	5	5	4	4	4	5

Wind speed and direction per month; meteoblue.com

Issues:

- **The area was part of brown land in the south-east of the UK, once used for sewage sludge spreading**

History:

The zone was once used as a sewage sludge spreading area for the neighbouring Beddington farmland. In 1998, the London Borough of Sutton agreed to sell the plot of land to Peabody at slightly below full market value to promote sustainable development, with the idea of building new spaces that would provide many benefits to the city, including carbon reductions. Beddington Zero Energy Development (BedZED) is a carbon-neutral urban neighbourhood resulting from redeveloping a brownfield site in the south London suburb of Sutton. The neighbourhood is one of the first green developments in the UK designed to meet the energy requirements for a Nearly Zero Energy Building (NZEB). The promoter of this project is BioRegional Development, which is responsible for encouraging the market entry of sustainable practices. It has also proposed to the Peabody Trust, a leading London-based housing association for economic and social redevelopment, to take on the project. In collaboration with engineers Arup and Bioregional, Bill Dunster sought an opportunity to create a zero-fossil-fuel ecovillage. Peabody Trust, a London-based construction company, was recruited as the developer for the project. After selling the land to the Borough of Sutton in 1998, they moved on to the design phase. Construction began in 2000. BedZED was designed to use no fossil fuels and reduce climate-changing emissions while providing clean energy for residents.

Actions:

From an energy point of view, there is a 777 m^2 array of photovoltaic panels in the area, which produces 15% of the energy needs and provides energy to power zero-emission electric cars. In addition, there are microelectric turbines in the area. The district benefits from a small power station covering the remaining energy needs: the use of electricity in BedZED for domestic use amounts to 2,579 kWh per year, 45% less than in Sutton. The presence of micro wind turbines also significantly contributes to energy efficiency. Heat and electricity are supplied through a bio-powered Combined Heat and Power (CHP) plant. In conventional power generation, the heat energy generated by the conversion is lost, whereas with CHP technology, this heat can be utilised. The system consists of a woodchip burner installed at a CHP plant, resulting in a 55% lower electricity consumption for lighting, cooking and household appliances than the area average. The surplus produced by the plant is connected to the neighbourhood electricity grid to avoid energy waste. The woodchip burner works by pruning street trees.
The district heating network in the area consists of super-insulated pipes to minimise losses. Each building has a domestic hot water tank as a radiator. As a result, heating consumption is, on average, 81% lower than in neighbouring Sutton. From a bioclimatic point of view, optimising the shape of the buildings reduces the need for artificial lighting and heat loss. In particular, the eight building blocks have an east-west orientation with double glazing covering the entire south-facing vertical, increasing the penetration of sunlight into the rooms. The north-facing side consists of terraces and descending gardens to prevent shading. The orientation and planimetric distribution of the buildings make it possible to catch most of the solar radiation. The careful choice of materials for their transmittance and thermal inertia characteristics contributes to reducing consumption for cooling or heating. The buildings have air recycling systems with heat recuperators. The presence of large

windows allows adequate natural lighting. Energy storage systems are inside the buildings to save the surplus energy generated by photovoltaic systems. In addition, these enjoy large thermal masses on both vertical and horizontal enclosures through the presence of massive cast concrete and block slabs. In co-working areas, the necessary heat is provided by electronic devices that reuse waste energy.
Most buildings have "solar spaces" similar to winter gardens behind large south-facing facades. Homes and offices are equipped with energy-efficient, low-consumption lighting, appliances and meters for monitoring. A natural ventilation system provides indoor air exchange through windcatchers and wind chimneys on the roof.
The redevelopment activities include developing natural areas and biodiversity by planting native species and drought-resistant aromatic essences. All-access roads to the neighbourhood have native tree rows. In this way, the green infrastructure contributes to the absorption of CO_2, with species that need little maintenance as they are indigenous, increase psychophysical well-being, absorb noise, improve air quality and promote on-site fruit and vegetable production. In the neighbourhood, residents can access private green areas and vegetable gardens.

Summary:

Use of passive and bioclimatic solution
Thermal break window Green-houses and wintergardens Angle-selective thermochromic materials Orientation

Improving infrastructure for soft mobility
Footpaths Garden squares Car sharing/pooling

Use of active devices to harness energy sources
Photovoltaics systems Biomass digesters Cogeneration

Use of blue infrastructures
Rain water collection and reuse Draining infrastructure systems Setting up phytodepuration spaces

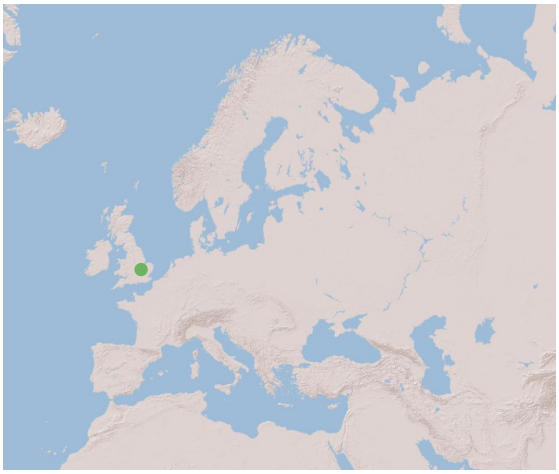
Ventilation control
Installation of openings inside buildings to promote pressure differences and thus ventilation Ventilating plate systems

Torrelago Ecodistrict

Informations:

Designer:	CityFIED
Stakeholders and owners:	About 8 mln euros from the European Commission, Veolia investment (about 2.5 mln euros), abidita to the refurbishment of the facades (5.5 mln euros)
Designing year:	2014
Building year:	2016
Finish year:	2019
Inhabitants:	5000 (31 dwellings)
Dimension:	14 ha
Cost:	16.7 M€

Collocation: Laguna de Duero, Spain



Neighborhood structure:



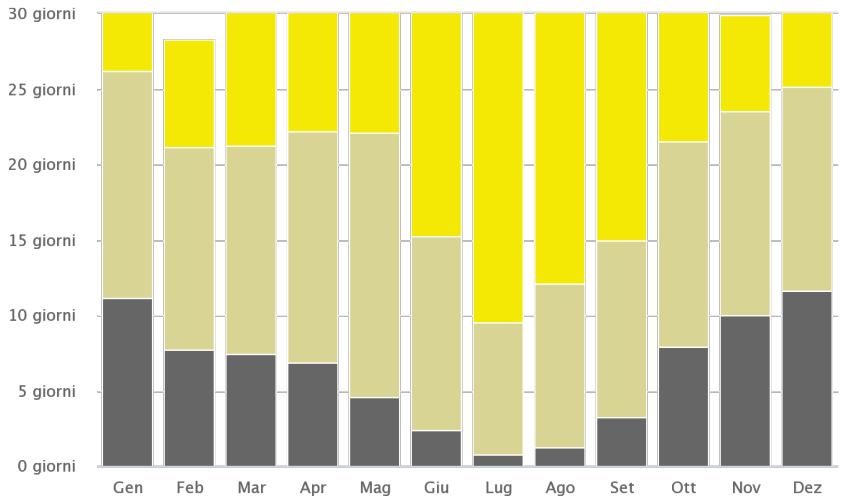
Pictures:



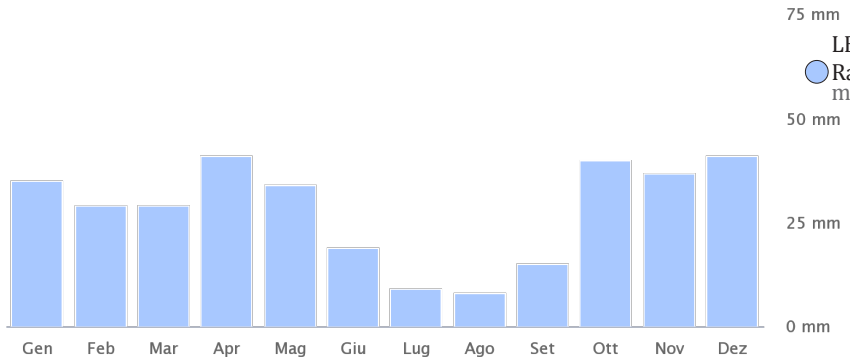


https://www.districtenergyaward.org/torrelago-district-heating-laguna-de-duero-spain/

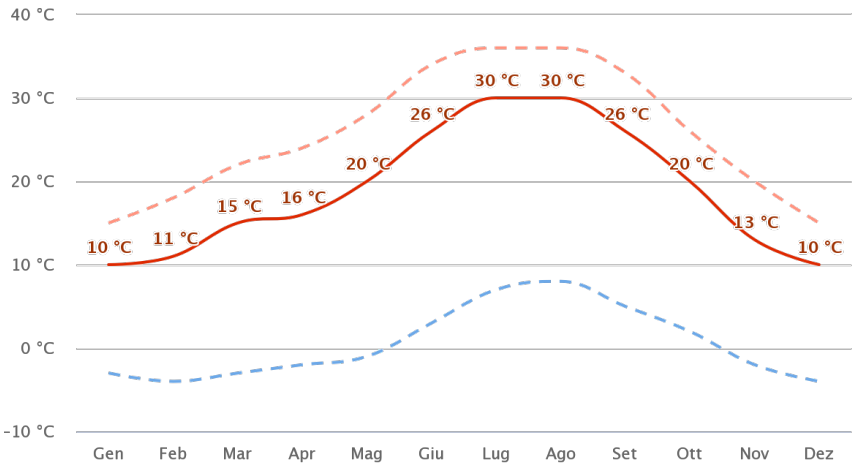
Climate conditions:



LEGEND:
Sunny days
Changeable weather
Cloudy
meteoblue.com



LEGEND:
Rainfall
meteoblue.com



LEGEND:
Warm days
Cold nights
Average maximum temperatures daily
meteoblue.com

GEN	FEB	MAR	APR	MAG	GIU	LUG	AGO	SET	OTT	NOV	DIC
O	ONO	NO	O	ONO	O	NO	O	O	O	OSO	OSO
5	9	9	11	9	11	9	9	8	7	7	7
3	4	5	5	4	5	4	4	4	3	3	4

Wind speed and direction per month; meteoblue.com

Issues:

- **The building envelopes were very leaky.**
- **Architecturally uneven neighbourhood**
- **Common urban and mobility problems defined by the planning directive for Valladolid and its surroundings**
- **Presence of a large natural lake drained in the 1970s**

History:

After draining the lake in the 1970s, Laguna de Duero went through a period of expansion that saw the construction of the Torrelago district. The district was built around 1980. The construction period was divided into two phases: the first comprised the construction of 12 storey buildings, with four flats per floor, for a total of 576 dwellings with an average surface area of 100 m^2 per dwelling. These buildings were built in 1977. The second phase saw the construction of 19 12-storey buildings, with four flats per floor, for a total of 912 dwellings with an average surface area of 100 m^2 per dwelling. Eleven buildings were built in 1979, and the remaining eight in 1981. Over time, many residents needed to modify the buildings, which led to the neighbourhood losing its uniformity. Nowadays, this metropolitan area is established by the Spatial Planning Directive for Valladolid and its surroundings, as all the municipalities in the region have similar urban characteristics and mobility problems. Four hundred sixteen thousand residents live in a total area of approximately 1,000 km^2. Retrofitting activities took place between May 2014 and March 2018, allowing 3,858 residents to benefit from the project.

Actions:

The project has a target of 80% energy reduction. Within the district, a biomass boiler replaced the old gas boiler. Substations have been set up for each tower block to facilitate the distribution of thermal energy. Monitoring devices control valves audit the amount of heat emitted in each house. In particular, BEMS (building energy management system) monitors energy flows in each of the buildings in the district, collecting all information on the exchange substations for the management of heating and DHW for each building. In addition, HEMS (Home Energy Management System) installs smart meters, thermostats, and shut-off valves to determine the behaviour and energy consumption of each dwelling. Residents can also manage the comfort temperature in their homes. Refurbishing the existing district heating network and installing a new centralised biomass generation plant (with a capacity of 3.5 MW) and an efficient distribution system allows efficient energy production and distribution. From a bioclimatic point of view, the renovation of the façades, combined with a choice of composite thermal insulation systems, allowed a 50% reduction in energy demand.

Summary:

Use of passive and bioclimatic solution
External coat

Use of active devices to harness energy sources
Biomass digesters

Improvement of the public transportation systems
Presence of proximity services

Setting up continuous monitoring systems
Home automation control and monitoring systems

Kortrijk

Informations:

Designer:	Reto M. Hummelshøj (Project Coordinator and Local Co-ordinator for Høje Taastrup Community, Denmark), Ilse Piers (Local Coordinator for Kortrijk Community, Belgium), Jolanta Žaltkauskiene (Local Coordinator for Birstonas Community, Lithuania)
Designing year:	2010
Building year:	2010
Finish year:	2016
Inhabitants:	1000
Dimension:	2.5 ha

Collocation: Kortrijk, Belgium



Neighborhood structure:



Pictures:

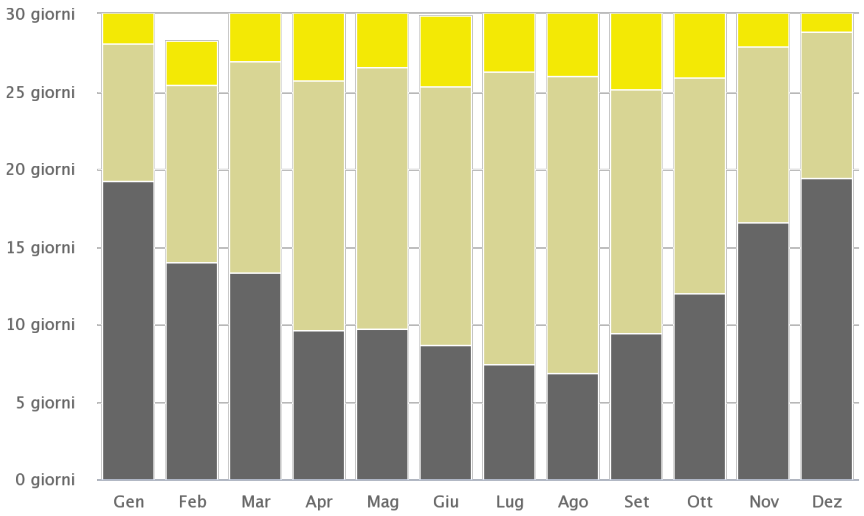




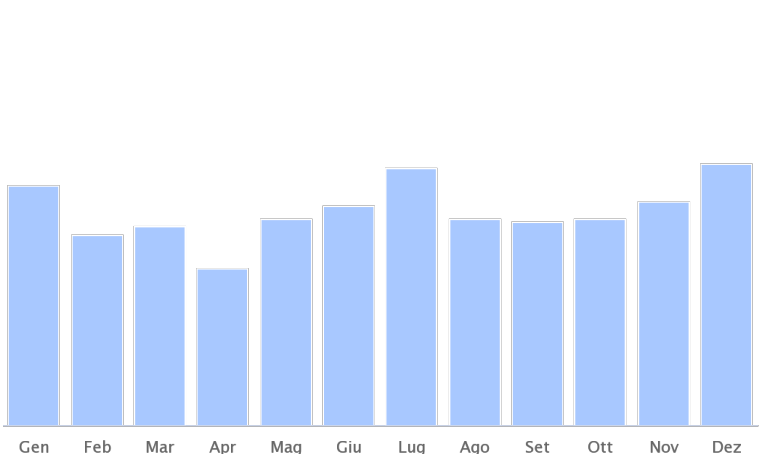


https://www.architravel.com/project/social-housing-estate-venning-kortrijk/

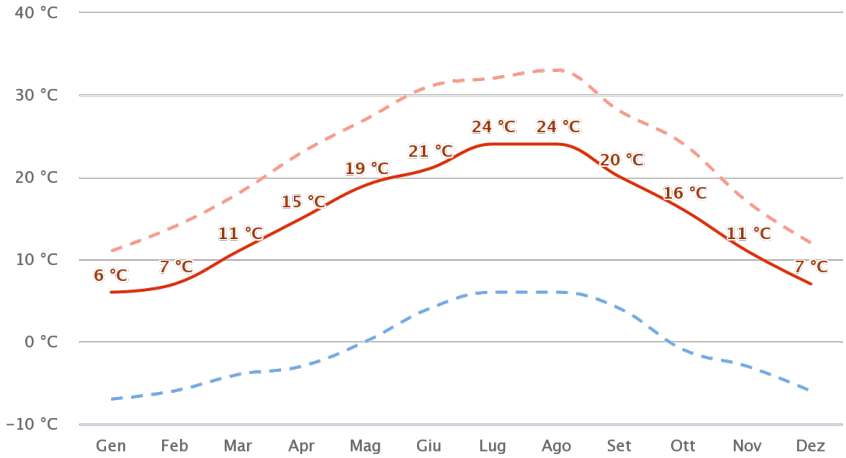
Climate conditions:



LEGEND:
Sunny days
Changeable weather
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meteoblue.com



LEGEND:
Rainfall
meteoblue.com



LEGEND:
Warm days
Cold nights
Average maximum temperatures daily
meteoblue.com

GEN	FEB	MAR	APR	MAG	GIU	LUG	AGO	SET	OTT	NOV	DIC
SO	SO	OSO	NNO	ONO	O	O	OSO	OSO	SSO	SSO	SO
7	9	8	7	7	7	7	6	7	7	7	8
4	5	5	4	4	4	4	4	4	4	4	4

Wind speed and direction per month; meteoblue.com

Issues:

- **“Ghetto” area**

History:

Kortrijk is located in West Flanders, on the river Lys, 42 km south-west of Ghent and 25 km north-east of Lille, France. Kortrijk is a town with an important historical architectural heritage, with its 200 protected monuments, two of which are world-renowned. Many of the town’s dwellings date back to before the 1960s, no longer meet the needs of modern life and have high energy standards. At the time of its construction, the district was considered a “social neighbourhood” and was built as a separate entity from the rest of the city. “Social neighbourhood” means affordable rents, even for low-income people. Over time, the term took on the connotations of a social ghetto. Inhabitants include many older people, people of different nationalities, and small households mainly live in multi-family buildings. The ECO-Life redevelopment project aims to establish a replicable planning and implementation approach and to demonstrate innovative and integrated supply- and demand-side energy concepts to achieve the goal of zero CO_2. The ECO-Life project in Belgium is a residential community of 274 dwellings grouped into six groups according to location, type, construction approach and timing. There are newly built or upgraded multi-family and single-family buildings. Among other buildings, the project includes subsidised housing for the disabled and several large houses for families of 5/8 members.

Actions:

The project includes installing various photovoltaic systems that generate from 13 kWp to 64 kWp. A biomass system allows the generation of 950 kW, while a biofuel mini-GHP system generates 14/9 kWth/kWel. Large heat pump systems are also installed in the district, generating 125 kWth and smaller ones (with a capacity of 21 kWth). Solar thermal is a technology in the area: approximately 77.8 m^2 of solar panels generate hot water. The annual primary energy balance averages 117 kWh/m^2/year, 39% less primary energy. In renovated buildings, the energy expenditure is 48 kWh/m^2/year (in line with national regulations). Street lighting is low consumption. There are wind turbines in the area. Residents can control their consumption through an energy monitoring and control system. The area has a district heating system whose energy comes mainly from a local power station based on renewable sources. The area also has micro-generators and mini CHP units powered by bio-fuel that provide 9 kW and 14 kW, respectively. These technologies save 476 tonnes of CO_2. In terms of bioclimatic and passive strategies, all existing buildings are renovated. In particular, they have undergone thermal insulation and installation of high-performance, airtight and thermally broken window frames. In addition, the increased insulation of plant pipes and the purchase of energy-efficient household appliances further reduce consumption.

Summary:

Use of passive and bioclimatic solution
External coat Thermal break window Pipe insulation

Use of active devices to harness energy sources
District heating Solar thermal systems for hot water Photovoltaics systems Heat pumps Biomass digesters Micro-wind turbines LED systems

Setting up continuous monitoring systems
Home automation control and monitoring systems

Ile de Saint Denis

Informations:

Designer:	**Housing:** Cobe Bérangère Giaux, Philippon - Kalt, Play-time AA; **Mixed used pro-grams:** Thibaud Babled ECDM, Hubert et Roy, Périphériques; **Public spaces:** Julien Beller, Inuit paysagistes; **Mobility Centre:** K architectu-re; **Archtect and urban plan-ner** Philippon - Kalt; **écologie urbaine:** AEU;
Designing year:	2006
Building year:	2013
Finish year:	On going
Inhabitants:	7000
Dimension:	22 ha

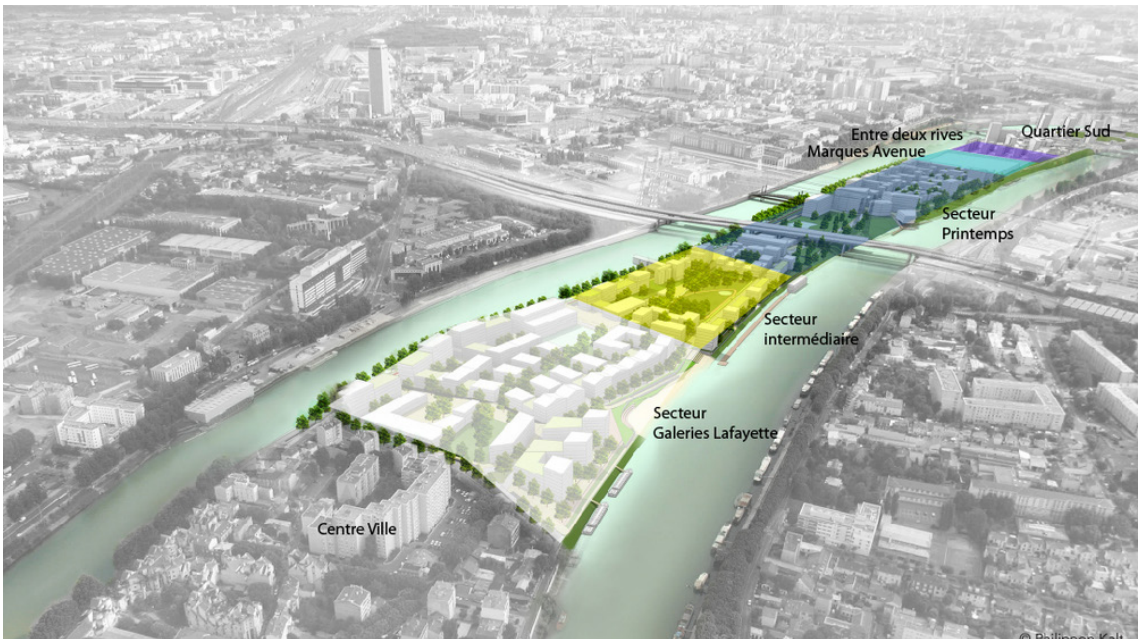
Collocation: Paris, France



Neighborhood structure:

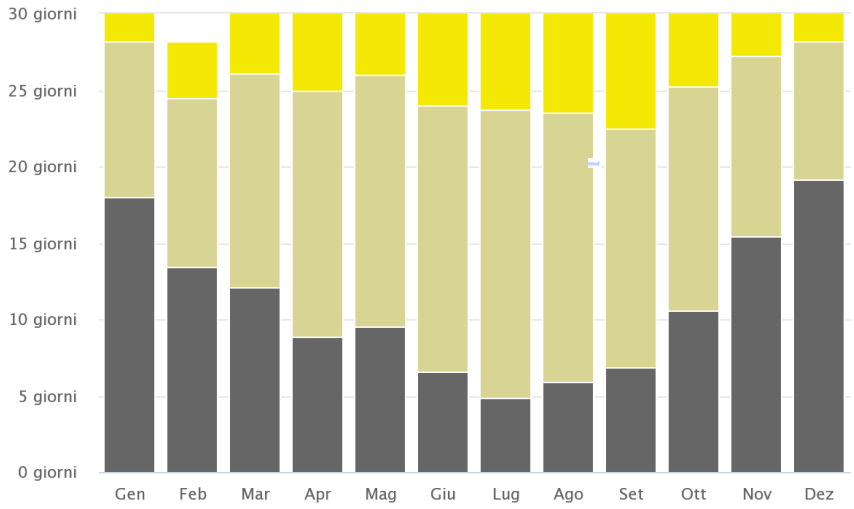


Pictures:

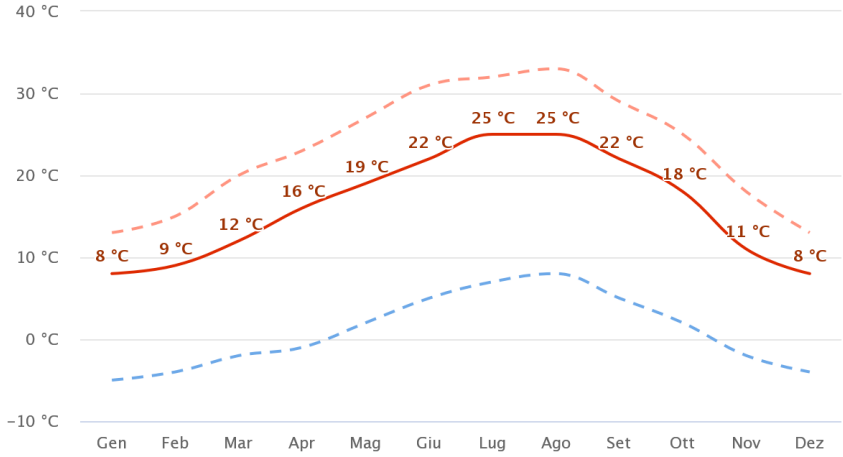


https://www.batiweb.com/actualites/collectivites-territoriales/un-ecoquartier-experimente-la-conception-partagee-de-l-habitat-23024

Climate conditions:



LEGEND:
Sunny days
Changeable weather
Cloudy
meteoblue.com



LEGEND:
Warm days
Cold nights
Average maximum temperatures daily
meteoblue.com

GEN	FEB	MAR	APR	MAG	GIU	LUG	AGO	SET	OTT	NOV	DIC
SO	SO	NO	NNE	NO	NO	ONO	OSO	O	SO	SSO	SO
7	10	10	9	9	9	8	7	8	7	9	8
3	4	3	3	3	3	3	3	3	3	3	3

Wind speed and direction per month; meteoblue.com

Issues:

- **Heavily degraded former industrial area.**
- **Flood risk zone: The island was heavily affected by the Seine flooding in 1910, which devastated the area. After 1910, the ground level was raised; today, only a few houses are still at the 'old level'.**
- **One-third of the developed area of L'Île-Saint-Denis is occupied by warehouses, many of which are no longer in use. This site covers 22 of the 100 hectares of the island.**
- **Presence of noise pollution**

History:

Île-Saint-Denis is one of the few French municipalities located exclusively on a river island. The half-moon-shaped area is located about ten kilometres north of the centre of Paris in one of the bends of the Seine. In the 17th century, the island was used as a city market. Two centuries later, residents built bridges to connect it with the mainland. In the 20th century, the area developed into a town and a storage centre. The 1970s saw the island's development through the installation of high-voltage power lines and the construction of the A86 viaduct. On the site were the Printemps and Galeries Lafayette department stores. The year 1991 saw the closure of the Printemps department store, followed by Galeries Lafayette (2007): a shock for the municipality and the entire Seine-Saint-Denis, which resulted in the loss of 500 jobs and left behind a desolate area. The warehouses remained uninhabited since 2004 until the Plaine Commune authorities transformed this problematic area into one rich in opportunity. This space enjoys a historical heritage unknown to many. After a century of industrial activity, the island's landscape inspired artists such as Alfred Sisley, Édouard Manet, Gustave Coubert and Berthe Morisot. Between 2008/2009, street artists moved into the area: they used an existing two-storey building with a vast expanse to create a gallery with a unique atmosphere, which later became a museum in 2013. Philippon-Kalt, architect and planner, designed a river eco-district on this land, with the first residential units built in 2012. The area is located 2 km from Saint-Denis station. The cornerstones of the project consist of an in-depth reflection on water, biodiversity, energy, mobility and pollution in collaboration with specialised companies to make the area a best practice from which to take an example. In 2009, the project, led by Michel Bouraìgain, mayor of Île-Saint-Denis, and the authorities of the wider Plaine commune area, was chosen as a 'prototype' commune, receiving the 'Prize of the Future', National List of Eco-Districts 2011. The eco-district revolves around three principal axes:

- Insularity: providing north-south connections between the two residential districts of Île-Saint-Denis.
- Inter-municipal links: improving communications with neighbouring municipalities and involving the new district in local development processes
- Identity: respecting the principle of good example in environmental matters and promoting water as a factor in citizens' identity

The ZAC, built in 2009, is divided into two parts: the first on the Printemps department store site and the second on the Galeries Lafayette department store site. Of the 301 planned housing units, 258 have already been delivered, and the first residents moved in 2018. The delivery of the last batch of housing units took Place in 2021. Phases 2 and 3 of the Printemps sector hosted the Paris 2024 Olympic Village and Paralympic Games before being reconfigured in their initial design. In total, the programme for the river eco-neighbourhood envisages the construction of 1,000 housing units, combining small social housing units, owner-occupied housing and social housing. Among these housing units, there are several participatory housing programmes. In addition, 50,000 m^2 of commercial premises are realised. These houses, shops, offices, and workshops are dedicated to the environment and culture. Lastly, 7.3 hectares of public spaces (parks, banks, squares, pedestrian paths, etc.) and 7,600 m^2 of public facilities (mobility centres, city of the arts, kindergartens, etc.) are realised. Organised around two public spaces, namely a two-hectare park and the Place de la Batellerie, the district provides ample access to the banks of the Seine and consists of different types of housing with up to four floors. Like a lighthouse, a slender seven-storey building marks the island's southwestern tip.

Actions:

A district heating network, extended to the older buildings in the city centre, allows the use of 60% renewable energy within the city through geothermal pumps. In addition, the roofs of the buildings house 2900 m^2 of photovoltaic panels. The district pays special attention to implementing noise protection on the A86 viaduct by installing photovoltaic panels that include vinyl fluoride acoustic films. There is also a bamboo pylon to reduce the low frequencies of sound waves. This insulation method allows noise reduction, limitation of the spread of polluting particles and renewable energy production.

Within the district, translucent LED tubes make up the illuminated signs and replace traditional ones. The buildings are extended in height to reduce the risk of flood damage. An isolated area is redeveloped through the construction of 165 dwellings that enjoy large balconies overlooking the Seine, naturally lit communal spaces with façades made of light, recyclable materials of organic origin. This attention to construction materials contributes to the reduction of the carbon footprint. The buildings generally meet SOLILEO's requirements regarding environmental excellence, accessibility, employment, and integration. The landscape within the district is shaped by water, contributing to residents' comfort and increased quality of life. The presence of phyto-purification systems, the provision of natural bathing areas, and increased purification and reuse of rainwater are strategies that work together to restore riparian zones. In particular, the entire ecosystem along the Seine is monitored through continuous cleaning of the banks to encourage the development of the riparian forest. Scenic viewpoints such as river paths, floating docks and shorelines connect the various parts of the island. However, some spots are still in the process of being purified. The still-polluted areas bordered by high-voltage power lines are transformed into a wetland nature reserve by forming basins and ponds that are home to flora and fauna. This action ensures biotic continuity between the two banks. Even within the buildings, the presence of planted spaces contributes to the development of biodiversity. The entire river eco-district is organised around the public green space: Place de la Batellerie.

Summary:

Use of passive and bioclimatic solution

Green walls
Orientation

Use of active devices to harness energy sources

Photovoltaics systems
Geothermal power
LED systems

Ventilation control

Morphological set-up of the system at neighbourhood level

Use of blue infrastructures

Rain water collection and reuse
Setting up wetlands

Improvement of the public transport systems

Presence of exchange nodes
Presence of proximity services

Control and increase of soil evapotranspiration

Permeable surfaces

Recovery and enhancement of the relationship with the aquatic/river environment

Natural bank protection
Artificial bank protection

Le Albere

Informations:

Designer:	Renzo Piano, RPBW
Stakeholders and owners:	Iniziative Urbane S.p.A., municipality of Trento
Designing year:	2002
Building year:	2009
Finish year:	2014
Inhabitants:	350 homes
Dimension:	116000 mq

Collocation: Trento, Italy



Neighborhood structure:



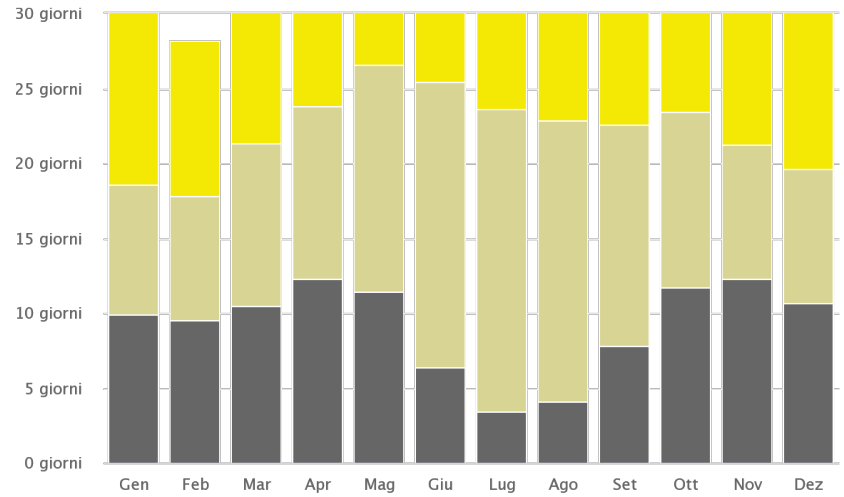
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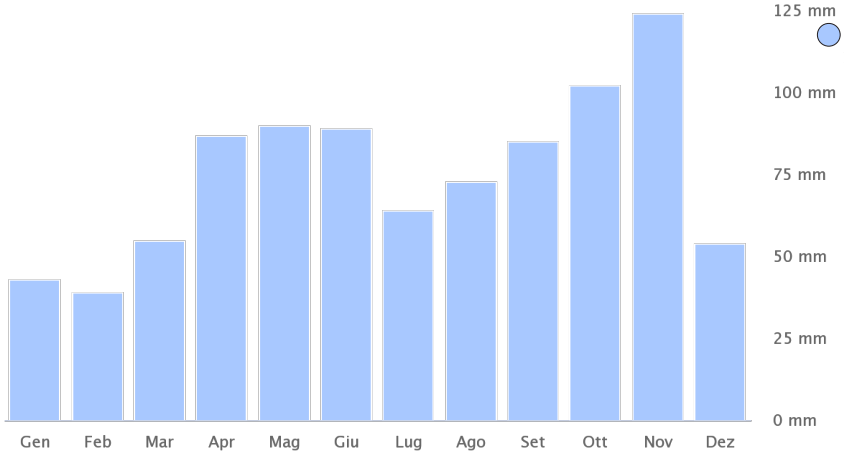
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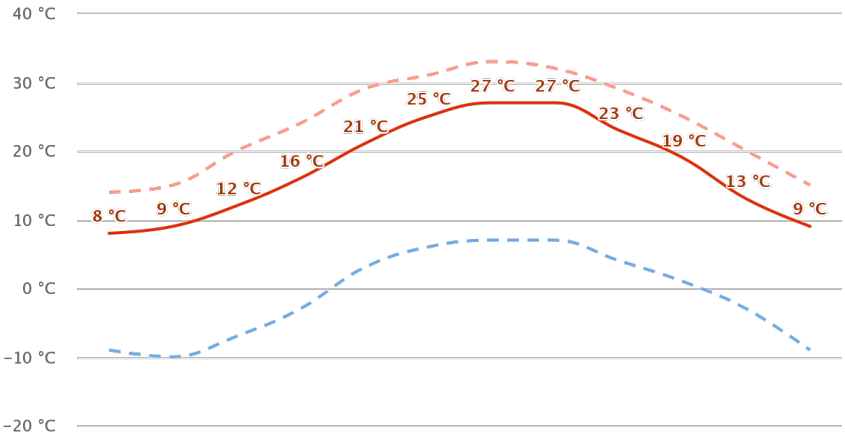
Climate conditions:



LEGEND:
Sunny days
Changeable weather
Cloudy
meteoblue.com



LEGEND:
Rainfall
meteoblue.com



LEGEND:
Warm days
Cold nights
Average maximum temperatures daily
meteoblue.com

GEN	FEB	MAR	APR	MAG	GIU	LUG	AGO	SET	OTT	NOV	DIC
NO	NO	O	O	O	OSO	O	O	O	ONO	NO	NNO
3	4	5	5	5	5	5	5	4	3	3	2
1	1	2	2		2	2	2	2	1	1	1

Wind speed and direction per month; meteoblue.com

Issues:

- **Abandoned former factory**
- **The presence of the railway that divides the neighbourhood from the rest of the city**
- **Brownfield: the transformation of the urban periphery, of places on the edge of the city**

History:

The district is about 800 m from the historic centre and near the Adige River. The area was formerly occupied by a Michelin factory, which opened in 1926. This factory was the city's main industrial engine. In 1998, the factory was closed. This event triggered new reflections on an area that held great symbolic value for so long. The historic centre of Trento does not have an attractive centre. With the recovery of this disused site, the intention is to address this lack. The aim is to transform the former industrial area into a part of the city with a mix of functions capable of making it alive 24 hours per day. Although the project started as a private initiative, the public sector maintains a strong guiding and coordinating role during the planning process. In March 2002, the municipality adopted the variant for the area, expressing the intent to 'hand over the area to future generations, as a sign of the best contemporary urban planning and architectural culture, for a balanced use, on functions that are homogeneous and synergic with those present in the historic city centre'. Renzo Piano designed the project, whose collaboration also includes the urban planning study, the design of the buildings, park design, and artistic direction. Between 2004 and 2005, the Guide and Subdivision Plan drawn up by the RPBW studio, in agreement with the municipal technical office, was approved. At the end of 2005, an agreement was signed between Iniziative Rubane S.p.A. (the client, a public-private company established in 1998 with private capital) and the Municipality of Trento, which, among other agreements, established the free transfer of the public park and the primary road system that would be built in the area. In 2009, work began and, as far as the first phase is concerned, finished in 2014. The urban layout designed for the area is based on a reticular grid broken by a strongly curved line that crosses the built-up area and connects the project's two 'magnet' buildings: a museum to the north and a multifunctional centre (now the university library) to the south. This new settlement, structured according to a functional mix of residences, commercial activities, offices, cultural spaces and public services, can accommodate about 1,000 inhabitants and 700 workers. The elements characterising the project are the centrality of a large public park extending towards the Adige River, opening up to the natural scenery of Monte Bondone; in this way, the wound represented by the railway between this urban segment and the remaining part of the city is sutured; another characteristic is the proportions of the volumes of the built and public spaces, which are also typical of the historic town and are in continuity with it; the role of water as an aesthetic and functional element that is preponderant; the aesthetic and technological quality of the public space and of the built environment that act as the project's principal axes.

Actions:

The buildings, consisting of a load-bearing structure in reinforced concrete with brick infill and a single-pitch wooden roof, composed in a 'courtyard' layout, which is more prevalent in the internal building fabric, are Casaclima Class B certified and have an energy requirement for heating of less than 50 kWh/m^2 per year. As far as public buildings are concerned, the 13,000 m^2 of the Muse are LEED Gold certified. This certification is also provided for the university library. Adherence to these protocols guarantees energy savings and optimisation. A central heating system serves the district to optimise resources and reduce costs. The system is connected to a trigeneration power plant, fuelled by natural

gas, capable of supplying thermal energy in the winter months and cooling energy in the summer months, in addition to electricity, the excess of which returns to the local grid. There are photovoltaic installations on the roof that generate about 0.6 MW. In addition, the area has eight geothermal probes, reaching a depth of 100 m, built to cover the MuSE's thermal needs.
As far as passive technologies are concerned, the twenty-eight wooden buildings with a maximum of three floors, built on private initiative, are energy-saving: in addition to Casaclima certification, Class B, they are made of renewable and recyclable materials, and an external insulation system consisting of polystyrene and graphite reduces heat loss to a minimum. The roof is thermally insulated with a wood fibre layer. In general, local materials have prevailed in the choice of materials: porphyry, stone and wood are from Trentino, with a view to the sustainability of the production cycle, the creation of a link with the context and identification with the project.
The buildings consume about one-third as much energy as other sites. This low consumption is due to various factors: the presence of high-performance low-emissivity glass, LED lighting, heat recovery from the outgoing air, optimisation in the use of daylight, and paying attention to positive solar radiation in winter and negative in summer. Attention is also paid to sound insulation: the built system is arranged parallel to the railway axis. The buildings closest to the railway are used for non-residential functions. Thanks to appropriate technological solutions on the eastern façades, they protect themselves and the rest of the settlement from the noise pollution the railway produces. The monitoring and planning of consumption on an individual flat and neighbourhood scale allows for optimisation and energy efficiency. From a morphological point of view, the heights and inclinations of the roofs are designed from a bioclimatic perspective to allow the passage of wind flows, light penetration, and greater visual unity.
From the point of view of green infrastructure, the district enjoys the presence of a five-hectare park, which extends as far as the Agide River, connecting it with the neighbourhood. In addition, every flat in the eighteen buildings has a small garden or loggia. The streets are lined with rows of trees. Throughout the neighbourhood, medium-height trees form groves with denser shade masses and monumental trees, some of which were already present in the area before the redevelopment. These trees are placed on a lawn extending from the front of the buildings to Via San Severino, beyond the river, and from Palazzo delle Albere to Monte Baldo. It is a large, equipped lawn with the only decoration element of seedlings mixed with tenacious turf mown at different heights. In general, the presence of the green infrastructure represents a unifying element between the existing city, the new district and the park on the river.

Summary:

Use of passive and bioclimatic solution

External coat
Thermal break window

Use of active devices to harness energy sources

District heating
Solar thermal systems for hot water
Photovoltaics systems
Cogeneration
Geothermal power

Use of green infrastructures

Parks
Tree lines
Pocket gardens
Green corridors

Improvement of the public transport systems

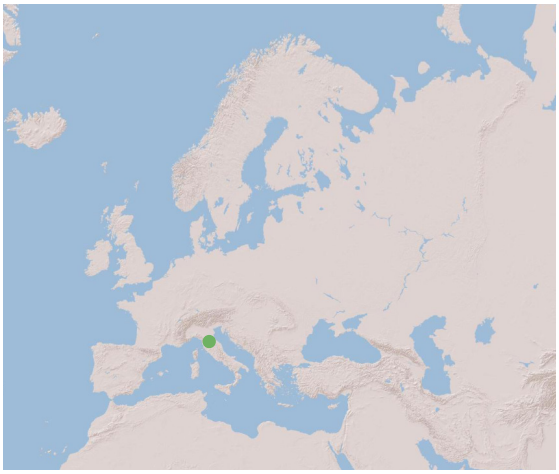
Presence of proximity services

Santa Giulia

Informations:

Designer:	Foster & Partners
Stakeholders and owners:	Lendlease, PSP Investments, municipality of Milan, Esselunga S.p.A.
Designing year:	2005
Building year:	2022
Finish year:	On going
Inhabitants:	2500 homes
Dimension:	110 ha
Cost:	Initial investment of about 250 mln €

Collocation: Milan, Italy



Neighborhood structure:



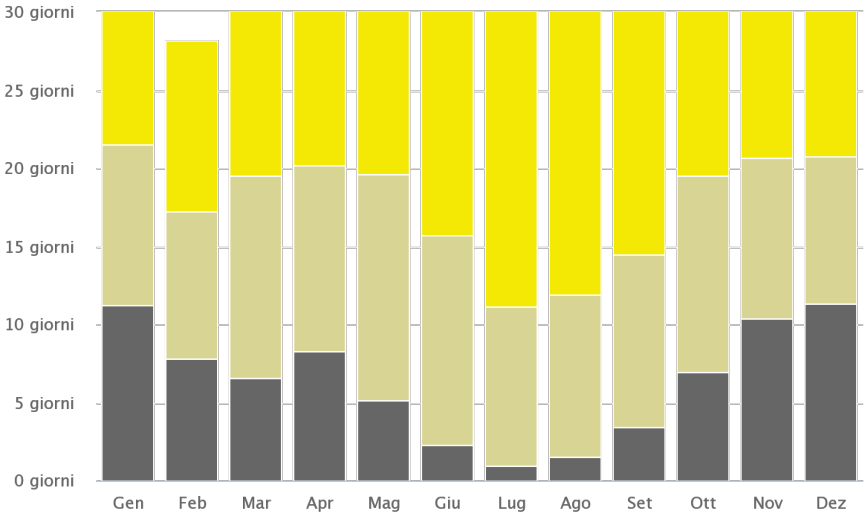
Pictures:



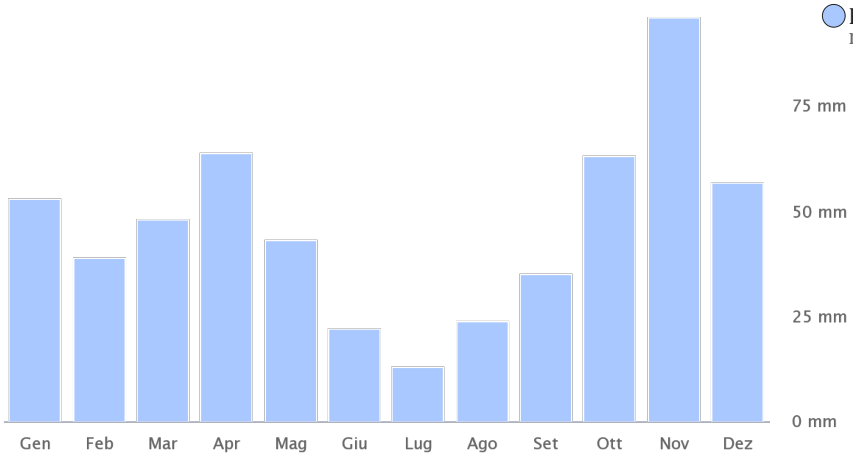


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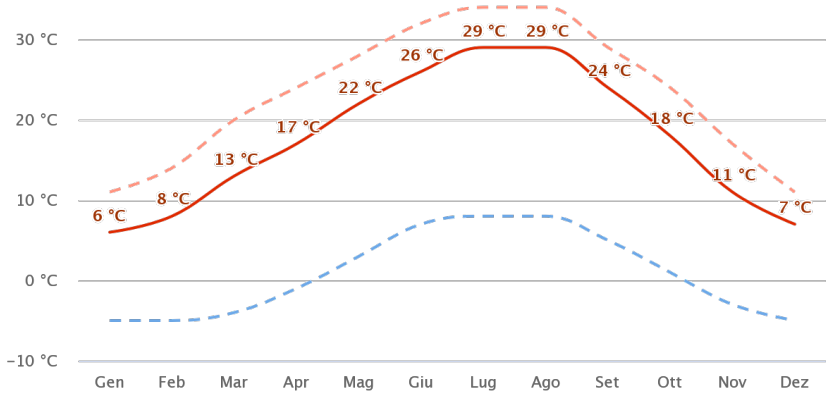
Climate conditions:



LEGEND:
Sunny days
Changeable weather
Cloudy
meteoblue.com



LEGEND:
Rainfall
meteoblue.com



LEGEND:
Warm days
Cold nights
Average maximum temperatures daily
meteoblue.com

GEN	FEB	MAR	APR	MAG	GIU	LUG	AGO	SET	OTT	NOV	DIC
SO	SSO	SSE	SE	SSE	S	SSE	SSE	SE	SE	SSE	SO
12	14	12	12	12	11	11	11	11	13	11	12
2	2	2	3	3	2	2	2	2	2	2	

Wind speed and direction per month; meteoblue.com

Issues:

- **The concept was redefined from an elite district to an open district, with a significant enhancement of recreational, social, and cultural services.**

History:

On 16 June 2022 in Milan, the urban planning agreement for the variant to the Milan Santa Giulia Integrated Intervention Plan was signed between the Municipality of Milan, the Risanamento group (Milano S.p.a.) and Esselunga. The document is preparatory to the start of work, which, as far as the Olympic Arena is concerned, will begin by the end of the year, and the other phases of the construction site will begin once the first phase of reclamation is completed, scheduled for the second half of 2023. This action will lead to the completion of Milan's Santa Giulia district, with the residual building of approximately 400,000 square metres of gross floor area, mainly for residential use, in addition to the 250,000 square metres already built in the area facing Rogoredo station. The signing represents the start of the implementation phase of the Variante project. It initiates the executive design, followed by the construction of the urban and infrastructural works envisaged by the area's development project, specifically those related to the Milan 2026 Olympics. Over the years, the lengthy administrative process has seen the active collaboration between the institutional parties and the Risanamento Group to give life to the completion of a development project in an international, as well as metropolitan, key. The project envisages handing over to the citizens of a historically closed area by creating an environment capable of attracting companies and families, and strengthening the concept of the local community. The project envisages the realisation of a new mixed-use urban district divided into two distinct areas to the north and south. The project aims to achieve zero carbon emissions and WELL certification. The district is strategically located, only 4 km from Milan and close to all national and international infrastructure. The new district consists of two parts: the southern area is located near Rogoredo station and has already been realised. This area includes a new residential neighbourhood, already inhabited and equipped with services, the European headquarters of Sky, an equipped park (Trapezium Park), a new kindergarten, a rental street (Promenade), and a new business centre soon to be built. The northern area still needs to be built. It will consist of a large urban park and a new project area with residences, offices, a retail and entertainment district and a network of pedestrian streets, squares and public spaces. This district is the first in Italy to adhere to the LEED Neighbourhood Development protocol.

Actions:

The project is characterised by high environmental quality in designing public spaces and building comfort through natural sources. All existing buildings have undergone extensive retrofitting. Some buildings have achieved LEED Gold certification by installing advanced fan coils and energy-saving air conditioning systems that reduce energy demand. The luminaires have dimmers to modulate light as required. The elevation systems have an energy recovery system. There is also a photovoltaic system on the buildings. On a neighbourhood scale, the orientation of the master plan concerning the built elements captures the winds, creating different temperature zones (sunny and shady) to activate natural air movement within the spaces. The arrangement of buildings with 'buffer functions' protects the residences from noise. In this way, the impact of noise can be reduced according to the function of the different buildings. In some buildings, a metal louvre sunshade system inside the envelope absorbs solar radiation and reduces

internal heating depending on the season. This system results from a careful preliminary analysis of the buildings' exposure to the sun. The shading system can retain 80% of the heat, reducing air conditioning consumption by up to 30%. Large windows with roller blinds modulate light penetration into the building. The presence of green roofs helps to insulate acoustically and thermally. Concerning thirty hectares of public parks within Santa Giulia, small buildings with public functions, wooded areas, and communal gardens have been built. This green area contributes to increasing the level of psycho-physical well-being, as well as increasing air quality and biodiversity.

Summary:

Use of passive and bioclimatic solution

Solar shading

Use of active devices to harness energy sources

Heat recovery and storage systems
LED systems

Use of green infrastructures

Parks
Urban gardens

Use of blue infrastructures

Rain water collection and reuse

Improvement of the public transport systems

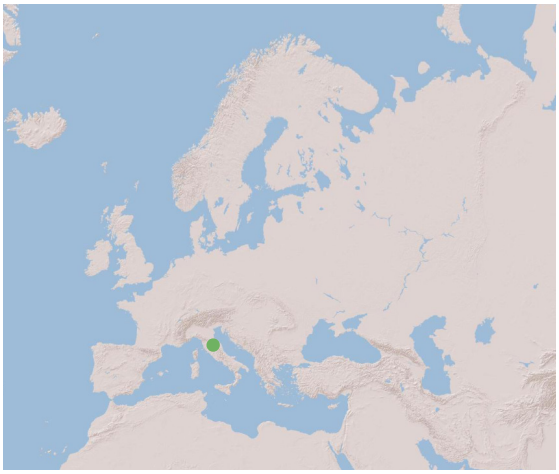
Presence of exchange nodes
Increasing the number of public transport stops
Increased frequency of public transport
Presence of proximity services

Cogneto

Informations:

Designer:	Arch. Irma Palmieri, Arch. Emilia Costa, Arch, Marco Stancaru, Ing. Mario Caccia, Ing. Mario Festa Caputo, Arch. Andrea Reggianini
Stakeholders and owners:	Modena municipality
Designing year:	2001
Building year:	2002
Finish year:	2013
Inhabitants:	770
Dimension:	1002 mq

Collocation: Modena, Italy



Neighborhood structure:



Pictures:

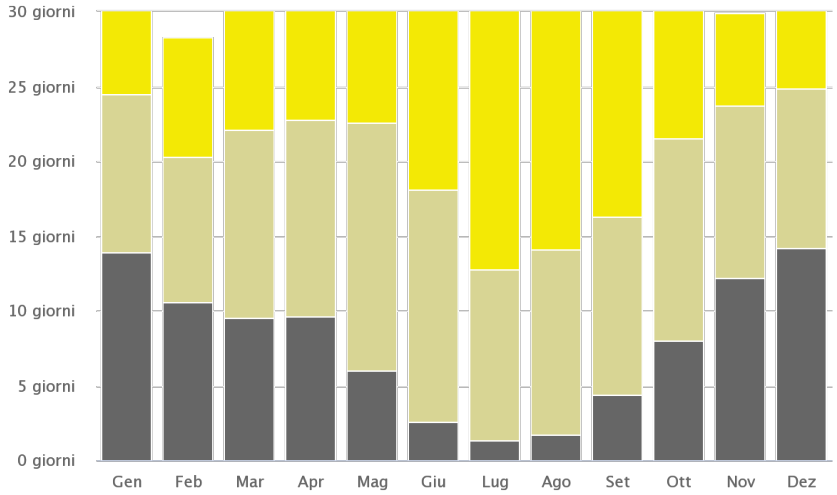


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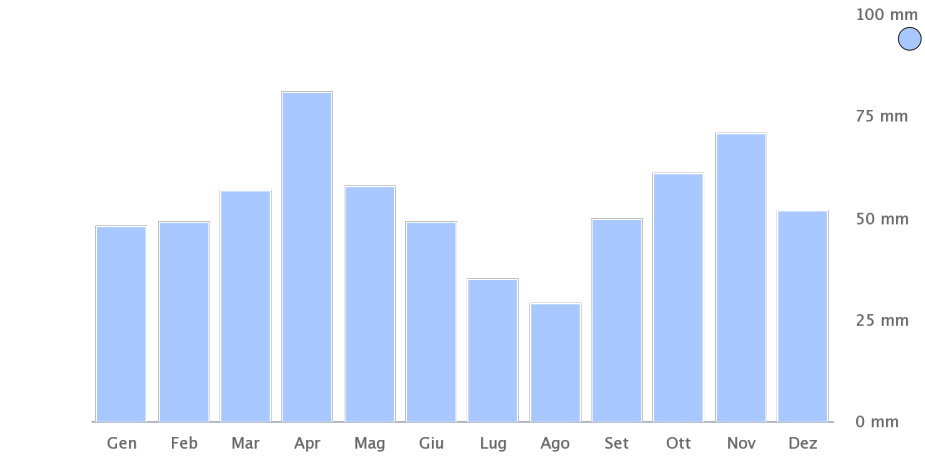
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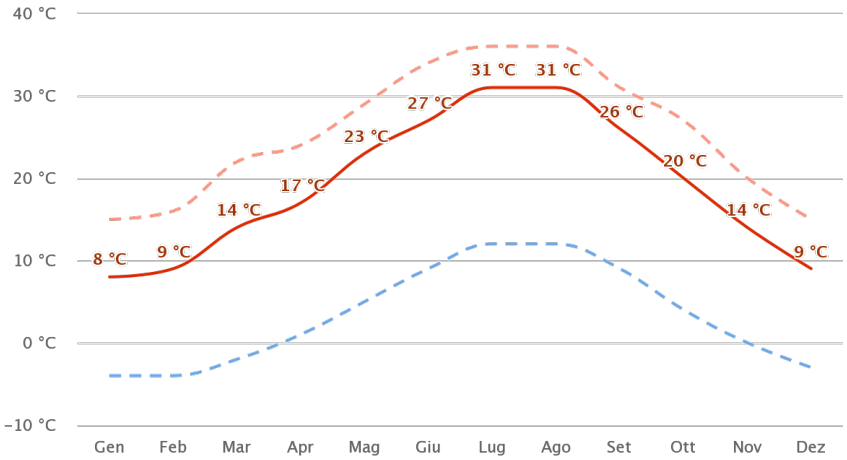
Climate conditions:



LEGEND:
Sunny days
Changeable weather
Cloudy
meteoblue.com



LEGEND:
Rainfall
meteoblue.com



LEGEND:
Warm days
Cold nights
Average maximum temperatures daily
meteoblue.com

GEN	FEB	MAR	APR	MAG	GIU	LUG	AGO	SET	OTT	NOV	DIC
NO	N	NE	NE	NNE	NNE	NNE	NE	NNE	NNE	NNO	NNO
3	4	6	6	6	6	6	6	5	4	3	2
2	2	3	3	3	3	3	3	3	2	1	1

Wind speed and direction per month; meteoblue.com

Issues:

- **Neighbourhood not connected to the existing urban fabric of the city**

History:

The Cognento PEEP Compartment project is the final product of a year of work by an 'interdisciplinary group' within the Municipal Administration of Modena, with the co-participation of external technicians appointed by the owner of the area to be developed in the future, and other interlocutors. The future residential district of Cognento has been conceived as an intervention that in the 'urban plan' and the 'building realisations' has the characteristics marked by eco-sustainability: the choice of materials and systems will be aimed at guaranteeing a low environmental impact, energy saving and resource conservation. The Peep Area, located along Via Jacopo da Porto Sud, will have a total surface area of 117,164 square metres, in order to build 220 dwellings for about 700 inhabitants (110 dwellings are planned in the area subject to public intervention, and the remaining 110 dwellings in the area subject to private intervention); the surface area allocated to public green spaces equipped as a park is 49,970 square metres. The Modena City Council adopted the project on 23/12/1999 and approved it on 27/7/2000. The attempt is an overall approach, as close as possible to a territorial and environmental balance methodology: 'the approach for networks (mobility, energy, water) and the sustainable city'. The Autostrada del Sole highway, the state railway, and the city bypass cross the district. The assessment of the factors contributing to the degree of sensitivity, environmental perception and the promotion of pro-environmental behaviour and participation: 'the perception of environmental issues by individuals, the links of these issues with the socio-economic aspects of sustainability, the exchange of information between institutional operators with the latter as their objective'.

Actions:

Special attention is paid to the public lighting system that illuminates 'by areas' the garden square, the heart of the neighbourhood: the arcades of the four buildings surrounding it, the lawn area using lighting from above (by inserting the light fittings into the buildings on the square), the path of the brook (with a ground-level/water blade installation, taking, for example, small seats articulated along its path as a pretext, installing the light fittings under the seats), and the wider space of the brook that widens near the main driveway (again with a type of 'ground-level' lighting like the previous one). This lighting efficiency decreases the environmental impact and energy consumption. The buildings that make up the district are equipped with high-efficiency condensing boilers - individual or centralised - that have replaced traditional ones. These boilers recover heat from flue gases and reduce nitrogen oxide and carbon monoxide emissions. This results in annual energy savings of at least 30% of the Normalised Energy Requirement (FEN - obtainable by calculating consumption according to Presidential Decree 412). The district also has a solar thermal system connected to the condominium heating plants to produce domestic hot water. Low-temperature hot water at a maximum of 50°C, and the heating techniques are as similar as possible to the hypocaust solution (vertical wall systems - with 'radiant panels' or skirting board or underfloor radiant systems). Inside the area is a domotic system for monitoring data and consumption provided by META S.p.a.
The volumes of the buildings are compact to reduce energy requirements further. The buildings are composed so that the shadow produced by the first building, the one furthest south, does not overlap the second building (using 21 December - the winter solstice - as a reference, in addition to the other angles of the sun's path). This urban planning attention allows for maximum winter sunshine on the southern façade. The smallest and lowest buildings (2/4 dwellings) are located on the southern strip of the subdivision, while the other buildings with 3 - 4 storeys above ground are close together. The morphology of the four building fronts is different to ensure maximum compliance with energy containment regulations. The direct energy gain of the south façade in winter can be achieved by placing solar windows, specially protected to avoid heat loss during the night and designed with elements to avoid overheating in summer, or by equipping the buildings with large unheated and fully openable glass greenhouses with the function of solar collection and winter garden. Each dwelling has a double exposure for cross-ventilation. The well-insulated roofs are pitched, terraces, roof gardens (walkable) or green roofs (not

walkable). At the bioclimatic level, an attempt is made throughout the plot to ensure maximum soil permeability. The distribution of tree essences is carried out taking into account the size of the plant at the time of maximum development and considering, in general, the importance of placing 'native deciduous plants' near the south-east and south-west fronts and 'evergreens' to the north. A study of the shadows cast by the trees is foreseen on residential frontages, near driveways and cycle-pedestrian paths, and relative parking areas or resting places. Tree and shrub species producing flowers and fruit are chosen. The design of the greenery within the 'garden square' aims to create a large lawn area within which there are two types of 'tree planting': The first consists of the insertion of large trees reminiscent of the 'essences once widespread in the Modenese countryside': oak, farnia, taxodium and salix Babilonia (in the presence of water);

• The second includes 'fruit trees': white mulberry, plum, persimmon, apricot, Sorbus printer media, and jujube.

•The presence of a 'small stream with a cobblestone reservoir', which runs diagonally across the entire square and ends in a larger area adjoining the main road, will not only make walking in the meadow pleasant but will also help optimise the micro-climate of the square surrounded by buildings.

•The 'parking area/public green area planned on the south side' will also be planted with 'fruit trees' to enhance the changing of the seasons, according to the spring flowering and fruit in the summer. The green areas are designed to give continuity with the existing public green areas within the district and are divided into two areas.

In the area located to the east, adjacent to the existing PEEP parcel, a large area of high-trunk woodland of the lowland type is planned. An integrated sewage treatment plant is also planned in this area. In this way, an attempt is made to reduce the risks of cheerfulness, electrosmog control, radioactivity, the absence of humidity, excellent brightness, quiet interior spaces, and large green spaces available. The second intervention area is located west, adjacent to the Casino Bonacini and the future new Elementary School building. This area sees the creation of a large grassy area used as a 'theme park' with botanical themes. Other parts of the park are not touched to respect the environmental protection constraint on maintaining old planted hedges (such as bramble, dog rose, and elm). Furthermore, organic and biodynamic farming techniques are used for cultivation, planting and maintenance to minimise groundwater pollution. A 1.5 m wide irrigation ditch and rows of trees mark the boundary between the residences and the farmland.

Summary:

Use of passive and bioclimatic solution

Thermal break window
Green roof
Orientation

Use of active devices to harness energy sources

Solar thermal systems for hot water
Heat pumps
Condensation boilers

Use of green infrastructures

Parks
Tree lines
Soft mobility
Green corridors
Arboreal Backdrops

Improvement of the public transport systems

Presence of proximity services

Improving infrastructures for soft mobility

Foothpaths
Cycle paths

Use of blue infrastructures

Setting up phytodepuration spaces
Rain water collection and reuse

CityZen - Amsterdam

Informations:

Designer:	/
Stakeholders and owners:	Amsterdam Metropolitan Area, Innovative SME's and start-ups, Operators and providers of electricity, district heating, fiber, telco, gas
Designing year:	2014
Building year:	2018
Finish year:	2020
Inhabitants:	850000
Dimension:	52000 mq
Cost:	€42,874,939

Collocation:

Amsterdam, Netherlands



Neighborhood structure:

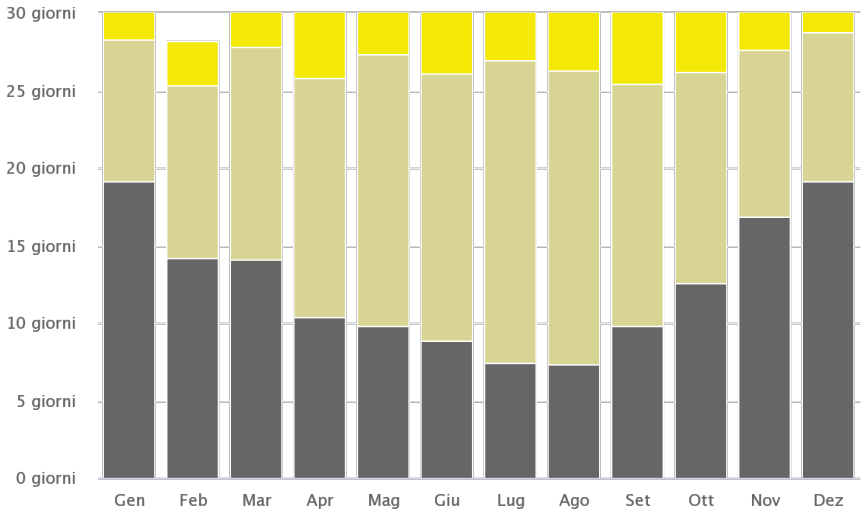


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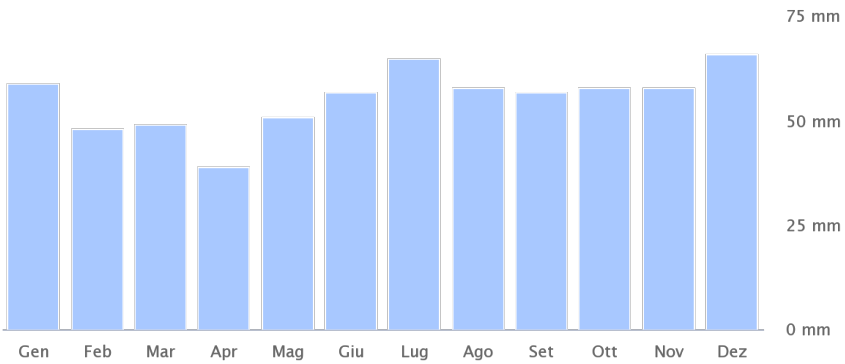


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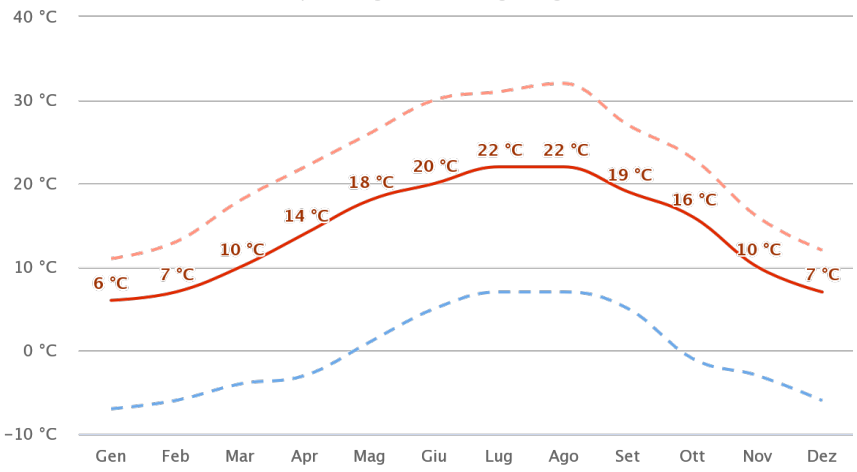
Climate conditions:



LEGEND:
Sunny days
Changeable weather
Cloudy
meteoblue.com



LEGEND:
Rainfall
meteoblue.com



LEGEND:
Warm days
Cold nights
Average maximum temperatures daily
meteoblue.com

GEN	FEB	MAR	APR	MAG	GIU	LUG	AGO	SET	OTT	NOV	DIC
SO	SO	OSO	NO	ONO	O	O	OSO	OSO	SSO	SSO	SSO
25	28	26	21	20	20	18	18	17	22	22	23
12	12	12	10	10	10	10	10	9	10	10	11

Wind speed and direction per month; meteoblue.com

Issues:

- **Some parts of the city were in a state of disrepair and heavily energy-intensive**

History:

The City-zen project, funded by EU FP7, addresses the urban energy transition task required to comply with the Paris Climate Agreement. Particular attention has been given to two neighbourhoods: the historical centre of Amsterdam, the area around the Brouwersgracht to the west, and the Slotermeer district, a post-war extension area to the west of the city centre.

- CITY CENTRE QUARTER: Comprises three main areas: a part of the 17th/18th-century workers' area of the Jordaan to the west, the Haarlemmerstraat and Haarlemmerdijk area to the north, and the area of the 17th-century merchant canal houses to the east. Two main canals run through this area: the Prinsengracht ('prince's canal', north to south) and the Brouwersgracht ('brewer's canal', east to west). These districts were built between 1600 and 1680. The Jordaan area took longer to build. A large part was built between 1890 and 1910. The Haarlemmerdijk area has all kinds of buildings built since the 17th century. The area contains many national or municipal monuments (about 50 per cent of the buildings) that are part of the UNESCO World Heritage of Amsterdam. The total area of the neighbourhoods is 55 ha (including 49 ha of land), with 228,000 m^2 of built-up area (residential and non-residential). 70% of the houses are rented, and 30% are owned. There are 10,600 inhabitants, 6900 housing units and 8800 registered businesses. The current total energy demand is 0.39 PJ; buildings have energy labels with mainly D-E-F-G levels.
- SLOTERMEER AREA: This area was mainly built between 1953 and 1960 (as part of the Amsterdam expansion master plan). It is 382 ha (of which 321 ha is inland), with 426,000 m^2 of built-up area (residential and non-residential). Twenty per cent of the houses are privately owned, and 80 per cent are rented. There are 27,000 inhabitants, 12,000 housing units (75 m^2 on average), and 1,400 business registrations.

Actions:

In the city centre area, there are three main strategies for energy redevelopment. The first consists of a radical renovation with the maximum application of invisible or integrated photovoltaic panels within the limits set by the historical constraints of the area. The second strategic axis connects the above-mentioned system to a district heating system. The third axis corresponds to utilising sustainable gas through the existing network used for natural gas. In Amsterdam, the availability of biogas is limited, which is why it is only used for heating the city centre. Hydrogen is a clean energy carrier with an efficiency of 80 per cent, and it's conversion to electricity has an efficiency of 50 per cent at most, resulting in a loss of at least 60 per cent. Synthetic methane also has inefficiencies in its conversion. Therefore, electricity over gas is preferred. In these areas, the potential for energy upgrading is quite limited, considering the historicity of the area. A district heating system within the canals would allow the water present to be used as a heat exchanger. As a side effect, this leads to a faster freezing of the water in winter. Solar cycle paths, cogeneration, and bio-fermentation systems are also planned in the central area. Considering the area's historical character, the buildings underwent minor retrofitting. In particular, double glazing is installed, external insulation is carried out, and the energy network is connected to a waste incineration plant that deep geothermal probes will replace shortly. The houseboats in the area are undergoing a renovation of the energy production system, achieving class A+ and A++. Heat

pumps are installed in these dwellings and exchange water from the canal. In the Slotermeer area, the strategies used consist of wind turbines from the lake in the neighbourhood. An energy upgrade of the deficit by installing heat pumps at around 40 °C (with a COP of 8), combined with ATES, ensures the system's efficiency. Electricity and hot water are generated through solar and photovoltaic systems on the sloping roofs of the buildings. Calculations show that the area required to cover the heat and electricity needs is 5500 m^2. The available space is only 10 per cent less. Therefore, some facades will be equipped with photovoltaic or solar systems to fill the gap. Energy storage systems are also planned within the district. The connection of the newly built blocks to the district heating network further avoids energy waste. From the bioclimatic point of view, the buildings have undergone retrofitting to renew the external insulation and replace the windows and doors. The new energy-saving and energy-efficient technological solutions do not affect these spaces' historical and architectural integrity, which contributes to the reduction of emissions, the absorption of heat and the creation of shaded areas. Finally, the interior of the aquifers serves as thermal energy storage.

Summary:

Use of passive and bioclimatic solution

Thermal break window
External coat

Use of active devices to harness energy sources

District heating
Solar thermal systems for hot water
Photovoltaics systems
Heat pumps
Biomass digesters
Cogeneration

Improving infrastructures for soft mobility

Cycle paths

Hikari - La Confluence

Informations:

Designer:	François Grether, Michel Desvignes, Herzog & De Meuron
Stakeholders and owners:	Communotè urbain du Grand Lyin
Designing year:	/
Building year:	2000
Finish year:	On going
Inhabitants:	1700
Dimension:	150 ha
Cost:	1,2 M€

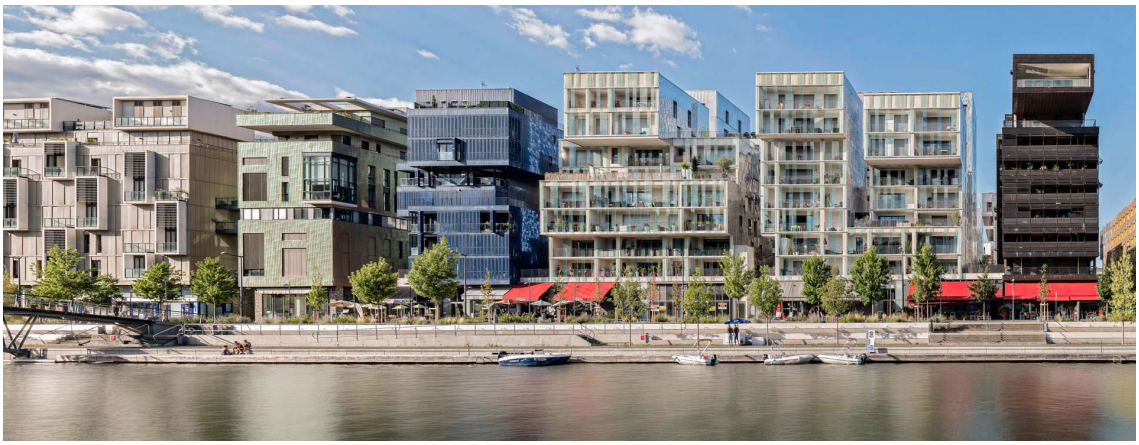
Collocation: Lyon, France



Neighborhood structure:

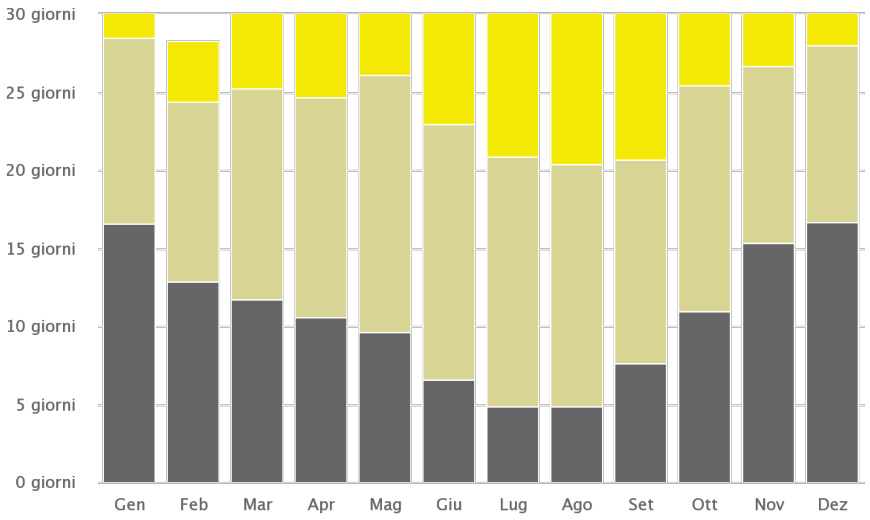


Pictures:

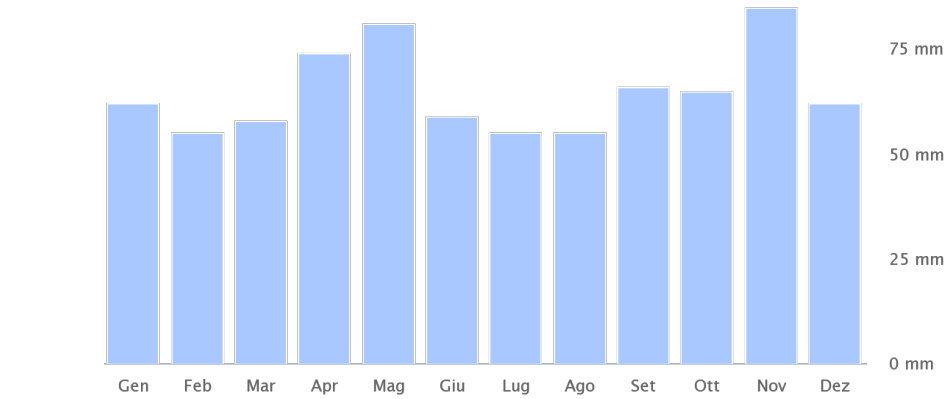




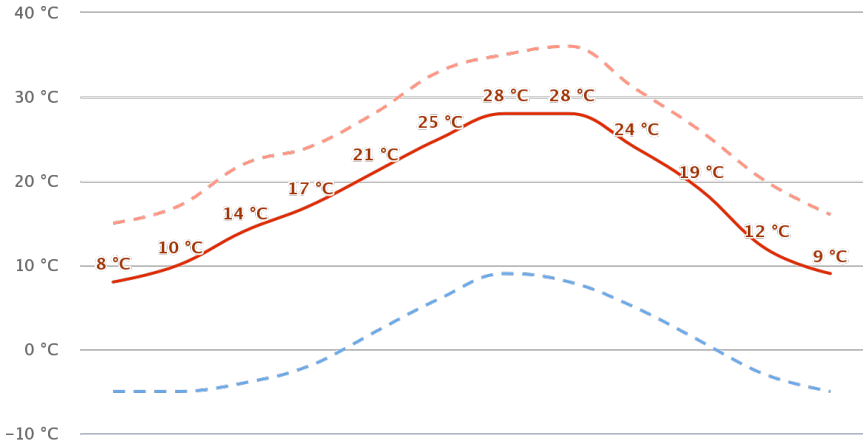
Climate conditions:



LEGEND:
Sunny days
Changeable weather
Cloudy
meteoblue.com



LEGEND:
Rainfall
meteoblue.com



LEGEND:
Warm days
Cold nights
Average maximum temperatures daily
meteoblue.com

GEN	FEB	MAR	APR	MAG	GIU	LUG	AGO	SET	OTT	NOV	DIC
ONO	NO	NNO	NO	NNO	NNO	N	N	NNO	SSO	S	SSO
10	11	10	11	9	9	9	9	8	10	10	10
4	4	4	4	4	4	4	4	4	3	4	3

Wind speed and direction per month; meteoblue.com

Issues:

- **Old industrial district, separated from the rest of the city by the Rhône and Saône rivers, the railway station and the motorway, which have given the district a marginal character despite its proximity to the historic city**
- **Abandonment of industrial areas**
- **Poor landscape quality along rivers**

History:

The 150-hectare area, previously occupied by industrial plants, became an intelligent and sustainable district. The district in question corresponds to the former industrial district of Perrache, separated from the rest of the urban fabric by two rivers (the Rhône and the Saône), a railway station and a motorway, which have given the area a marginal character due to its forced isolation, even though it is close to the historic city. The planning gives absolute priority to the existing urban fabric of Sainte Blandine. The project is divided into several phases: the first phase is designed to be realised over 10 to 15 years, during which time, in order to favour the initial reintegration of the Presqu'Île into the urban fabric, four intervention sectors are defined: the Perrache-Verdun pole of the railway station, the banks of the Saône, the Sainte-Blandine neighbourhood, the southern entrance to the Presqu'Île. Throughout the Perrache area, the urban planning rules concerning heights and contiguous fronts on the banks of the Rhône are replicated to obtain a homogeneous design in continuity with the city. Many designers have succeeded one another over the years at La Confluence, such as Fuksas, Gautrand, Kengo Kuma, and MVRDV, all actively committed to meeting the standards imposed by Grand Lyon, proposing original and energy-efficient architectural solutions.

Actions:

Various buildings are designed to be low-energy. For example, the Le Monolithé building runs on 8% renewable energy and has heat storage and photovoltaic systems to generate electricity. The Cube Orange by Jakob + MacFarlane Architects, which stands on the bank of the Saône River, represents a successful urban redevelopment of the industrial harbour. The building is a large cube with two perforations: a smaller hole at the bottom as an access point and another, larger hole at the top corner. The building has a large atrium for lighting, ventilation, and panoramic views. The building has a double skin made of perforated wire mesh with two circles of different sizes that allow light to filter through during the day, creating warm air channels that reduce energy costs. The Hikari building complex, part of the district, designed by Kengo Kuma, is one of the first positive energy buildings capable of producing more energy than it consumes. Photovoltaic panels cover the entire block's flat roofs (and glazed terraces). The block is powered for heating and electricity supply by two cogeneration power plants: one running on rapeseed oil, designed to cover 80 per cent of the estimated electricity needs and 90 per cent of the heating each year, and another photovoltaic power plant covering the remaining needs. Cooling is provided by a geothermal plant and an indirectly fed absorption machine from the cogeneration plant. From the bioclimatic point of view, 'Le Monolithé' complies with the High Environmental Quality (HQE) criteria through strong thermal insulation that increases thermal inertia, a careful choice of materials, the presence of solar filters, the presence of thermal break frames and double glazing, and the presence of a natural ventilation system. The Hikari complex, composed of three buildings, has a highly insulated technological envelope, and natural light penetrates the buildings thanks to the large openings of the southern fronts. There are lawns, gardens and a park in the neighbourhood. The greening in the area has a branched structure and features perennial elements such as tree rows and groups of trees, embankments and infrastructu-

re. The innovative technique of "garden plates" is employed within the area, consisting of a metal grid containing soil and plant seeds that, once grown, characterise the 'tiles' of the new puzzle gardens. When it is subsequently necessary to change the soil, the plates placed on the ground can be moved and reused. Points of contact between natural and built habitats are created. Following the course of the park, the naval and nautical environment of the current port (Quai Rambaud), which is being decommissioned, enters the urban fabric through transversal docks, leading to new and different water overlooks and reconstructing a relationship between the city and the river. Tree-lined boulevards, pedestrian and cycle paths are laid out, and green connections are increased.

Summary:

Use of passive and bioclimatic solution

External coat
Thermal break window
Angle-selective thermocromic materials

Use of active devices to harness energy sources

Solar thermal systems for hot water
Photovoltaic systems
Cogeneration
Geothermal power
Heat recovery and storage systems

Ventilation control

Morphological set-up of the system at neighbourhood level
Bioclimatic atria

Use of green infrastructure

Parks
Tree lines
Green corridors
Arboreal backbrops

Use of blue infrastructure

Rain water collection and reuse

Recovery and enhancement of the relationship with the aquatic/river environment

Natural bank protection
Use of the banks

Villa Fastiggi

Informations:

Designer:	Studio "Ricerca& Progetto, A. Galassi, A. Mingozzi e Associati"
Stakeholders and owners:	Pesaro Municipality
Designing year:	/
Building year:	2001
Finish year:	2007
Dimension:	15 ha

Collocation: Pesaro, Italy



Neighborhood structure:



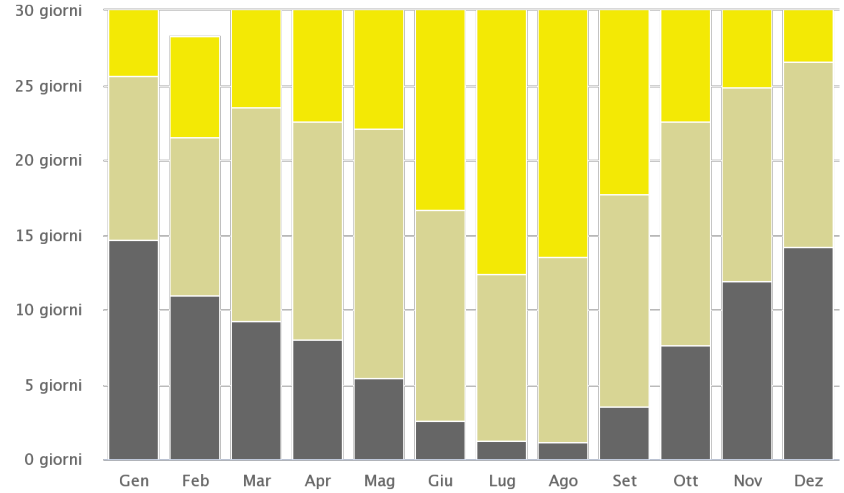
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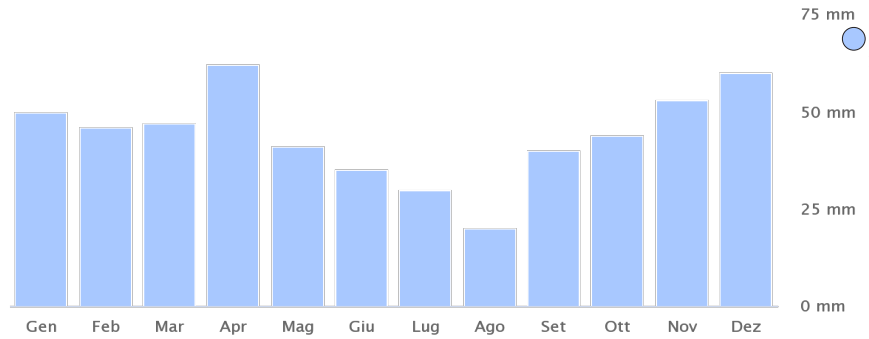


https://kosgroup.com/it/centri/villa-fastiggi

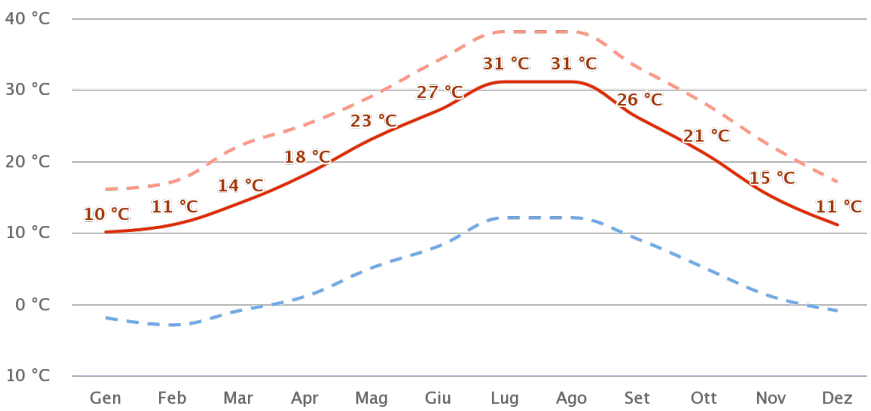
Climate conditions:



LEGEND:
Sunny days
Changeable weather
Cloudy
meteoblue.com



LEGEND:
Rainfall
meteoblue.com



LEGEND:
Warm days
Cold nights
Average maximum temperatures daily
meteoblue.com

GEN	FEB	MAR	APR	MAG	GIU	LUG	AGO	SET	OTT	NOV	DIC
NO	NNO	NE	ENE	NE	ENE	ENE	NE	NE	ENE	N	NO
5	6	6	7	6	6	6	5	5	5	5	5
3	3	4	4	4	3	3	3	3	3	3	3

Wind speed and direction per month; meteoblue.com

Issues:

- **The area represented a cut between the new settlement and the existing one. This cut represents the reason why the planners created a 'hinge' point between the two realities**

History:

Located southwest of Pesaro, the area where Villa Fastiggi stands is bordered on the north by a driveway, on the south by a residential expansion area, and to the southwest by industrial and artisan-use buildings. The area envisages conversion to tertiary and commercial activities to create a hinge between the new settlement and the existing district. To this end, a complex of buildings will be constructed to guarantee all the dwellings access to the sun and a correct exposure and internal distribution of the rooms. The working group in charge of the redevelopment is coordinated by Angelo Mingozzi, who, on this occasion, experiments with a new urban model, starting with a detailed and careful drafting of the Detailed Plan. On the occasion of the district's redevelopment, the municipality of Pesaro drafted the 'Implementation Regulations for Bio-architecture' for the first time. The work is included in the local 'Agenda 21' activities, involving citizens, especially in green and traffic issues, confirming the Administration's willingness to place sustainability at the centre of its policies and ready to revise its working tools. The PEEP is based on increasing public green space compared to the required standard. The dwellings are built two storeys above ground level, facing the inner garden, and consist of terraced houses for the larger flats and in line for the smaller ones. In particular, the dwellings are characterised by a wooden grid, with facades made of laminated larch wood beams. The wooden walkways, communal rooms, terrace floors, and private loggias are covered with elegant and robust outdoor wooden planks.

Actions:

All homes have a district heating system and a solar thermal system for heating hot water. These systems cover all energy needs. The buildings are also equipped with a photovoltaic system that contributes to most of the electricity needs in the homes. According to the Passivhaus Standard, the neighbourhood has a very low level of CO_2 emissions, having a primary energy consumption of less than 15 kWh/m^2 for heating, the same for cooling, and 120 kWh/m^2 for all utilities and domestic hot water production. From a bioclimatic point of view, the Villa Fastiggi district has 24 passive flats. The project follows the regional law on the Piano Casa (House Plan) and its incentives. Particular attention is paid to building the external façade, which represents a sort of 'barrier' that shields from the noise of passing cars. The buildings are constructed around an equipped condominium park, at the edges of which are the private gardens and the entrances to the individual dwellings. These are built with a wooden supporting structure and external insulation with high-density mineral wool fibre panels. All the apartments have a controlled ventilation system with heat recovery and are prepared for home automation control. The parapets are made of laminated glass to allow light to enter the environment. All these precautions allow for an internal consumption of less than 15 kWh/m^2. The layout of the buildings is designed to guarantee all the flats proper exposure to the sun, favouring the north-south axis: the stairwell, services and sleeping area are located to the north. The living area, balconies, loggias and porches are located to the south. Eleven buildings have an east-west exposure axis. The living area is positioned to the west, and the sleeping area is to the east to avoid summer overheating in the afternoon. All the flats are designed to have 'cross ventilation' through opposing windows. This way, it is possible to ensure air

exchange and improve thermo-hygrometric comfort levels. Green infrastructures act as an ordering system of the urban project. From the point of view of green infrastructure within the district, there is a 21,000 m^2 park. Public green areas are equipped with playgrounds and earth movements, unevenness, water features or left completely green. On the west and south sides and the north-south and east-west axes, bicycle and pedestrian paths are shaded by rows of trees. Deciduous trees shade all the streets so that there is shade in summer and sun in winter. A barrier of earth and trees screens the entire building from vehicular traffic noise on Via delle Regioni. The green infrastructure is designed to have low water consumption. The existing landscape and biotic-vegetation elements are generally enhanced and integrated with the new buildings and the urban park.

Summary:

Use of passive and bioclimatic solution

External coat
Orientation

Use of active devices to harness energy sources

District heating
Solar thermal systems for hot water
Photovoltaic systems
Heat recovery and storage systems

Ventilation control

Installation of openings inside buildings to promote pressure differences and thus ventilation

Use of green infrastructure

Parks
Tree lines
Soft mobility
Pocket gardens
Arboreal backbrops

Caserme De Bonne

Informations:

Designer:	Christian de Villére, Aktis Architecture
Stakeholders and owners:	Grenoble Municipality
Designing year:	/
Building year:	2001
Finish year:	2009
Dimension:	8.5 ha
Cost:	39 mln Euro

Collocation: Grenoble, France



Neighborhood structure:



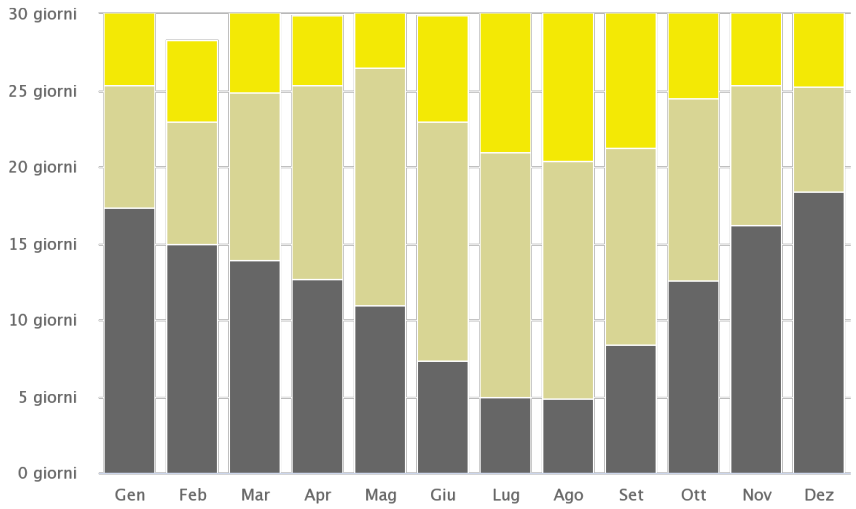
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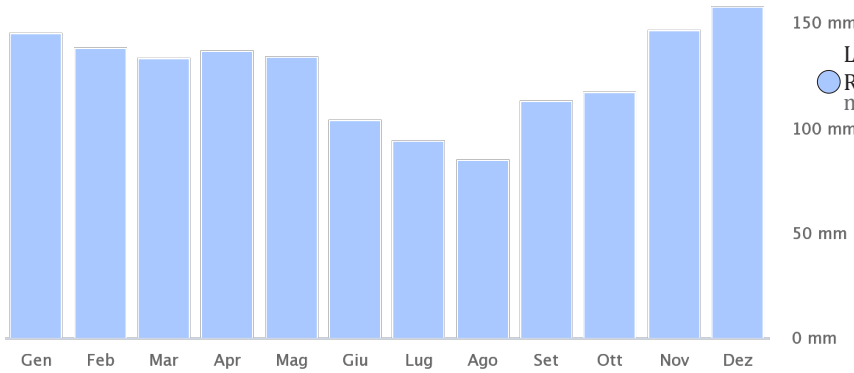


https://www.encyclopedie-energie.org/politique-energetique-et-collectivites-locales-temoignage-elu/

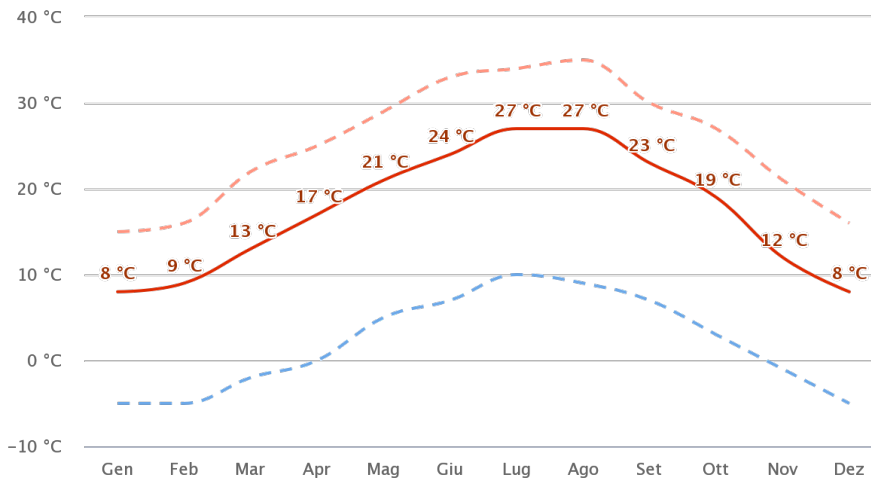
Climate conditions:



LEGEND:
Sunny days
Changeable weather
Cloudy
meteoblue.com



LEGEND:
Rainfall
meteoblue.com



LEGEND:
Warm days
Cold nights
Average maximum temperatures daily
meteoblue.com

GEN	FEB	MAR	APR	MAG	GIU	LUG	AGO	SET	OTT	NOV	DIC
NE	NNE	N	NNO	NNO	NNO	NNO	NNO	N	NNE	NE	ENE
8	9	9	9	8	8	8	8	7	9	9	9
3	4	4	4	3	3	3	3	3	3	3	3

Wind speed and direction per month; meteoblue.com

Issues:

- **Abandoned space located on a water table**

History:

Like the whole of Grenoble, the ZAC de Bonne site is located on a water table. A special focus on rainwater is needed. The project's main objective is to enlarge the city centre of Grenoble by rebuilding an entire neighbourhood to improve the liveability of the inhabitants to whom this space was previously precluded. The project preserves the elegant central courtyard and the three buildings above it by upgrading them regarding sustainability and energy saving.

History:

There are 850 dwellings within the district, of which 435 are new homes. The newly built and renovated houses in Rue A. Maginot and Allée H. Frenay are energy efficient. The housing organisation consists of seven-storey buildings arranged in a U-shape around the park. Each housing unit has 1.2 m^2 of solar thermal panels, and each building has nine small cogeneration modules to produce electricity and heat from natural gas. This action makes it possible to cover 50 per cent of hot water needs. The envisaged objectives for the district are to create a self-sufficient energy district, to halve energy consumption to a maximum of 75 kWh/m^2 per year, of which 50 kWh/m^2 per year for heating and cooling, 15 kWh/m^2 per year for domestic hot water and 10 kWh/m^2 per year for electricity consumption in common areas (ventilation, lighting, lifts). The district has 6000 m^2 of new and renovated office space, including a six-level Bonne Energy office building of 1685 m^2 with positive energy. In particular, 382 m^2 of photovoltaic panels are installed on the roof terrace, and a heating and cooling system is supplemented by a reversible geothermal heat pump and fan coils for distribution in the rooms. The shops in the shopping centre are heated or cooled with a system that exploits the underground water table using a groundwater pumping mechanism. During intense hot periods, an ammonia-based cooling unit provides air conditioning to the shops. A Building Management System (BMS) controls the cooling of the shops. It is only activated when three conditions are met: outside temperature above 28 °C, pumps running at maximum speed for more than a quarter of an hour, and when the temperature difference concerning the groundwater circuit is more than 1.8 °C. Regarding heating, the city's district heating system is used in addition to the heat provided by the shops and natural ventilation. In the centre of the district, the roofs of the buildings are equipped with 1,000 m^2 of photovoltaic solar panels (a dynamic public display on one of the centre's walls indicates real-time monitoring of energy production - a way to raise awareness among visitors). The new buildings constructed within the area feature a cogeneration plant that halves consumption, solar and photovoltaic panels and low-temperature, underfloor heating systems. These buildings (438 housing units, of which 40 per cent are socially rented) have the following standard consumption: between 44 and 73 kWh/sq m/year for heating (instead of 42.5 kWh/sq m/year in the project), for hot water between 19 and 40 kWh/m^2/year (instead of 17 estimated in the project), for common areas between 12 and 26 kWh/m^2/year (instead of 10 estimated in the project). The dwellings have 20 cm thick external insulation in glass wool and 24 cm thick polyurethane insulation on the roof. The window frames have a thermal break frame and energy-efficient triple glazing. The shutters are automatic and adjustable. The 382 square metres of photovoltaic panels form a bioclimatic pergola, providing shade for terrace use

and increasing thermal comfort. The centre was designed following the principles of bioclimatic architecture, favouring natural light, orientation for the wind and low-emissivity glazing. In particular, wood is one of the most commonly used materials to benefit from thermal inertia, including for the load-bearing structure. The primary school built in the district also follows bioclimatic principles and is made of wood, with large windows to capture the maximum amount of light. Each block between Rue A. Maginot and Allèe H. Frenay has a communal garden within the courtyard. Within the neighbourhood, there are five hectares of parks and open-air gardens. In particular, three gardens have different functions within the area: the Garden of the Valleys has terraces and spaces for relaxation and entertainment, the other garden contains green spaces and ornamental water basins, and the Hoche Park has amusement spaces and sports games. The buildings also have vegetated roofs treated in an 'ecological' manner, i.e., avoiding synthetic products and weeding by hand. These actions protect biodiversity and improve air quality.

Summary:

Use of active devices to harness energy sources

Low-temperature heating with radiant panels
District heating
Solar thermal systems for hot water
Photovoltaic systems
Heat pumps
Cogeneration
Geothermal power

Ventilation control

Morphological set-up of the system at neighbourhood level

Use of green infrastructure

Parks
Green corridors

Use of blue infrastructure

Setting up phytodepuration spaces
Rain water collection and reuse

Improvement of the public transport systems

Increasing the number of public transport stops
Increased frequency of public transport
Presence of proximity services

Setting up continuous monitoring systems

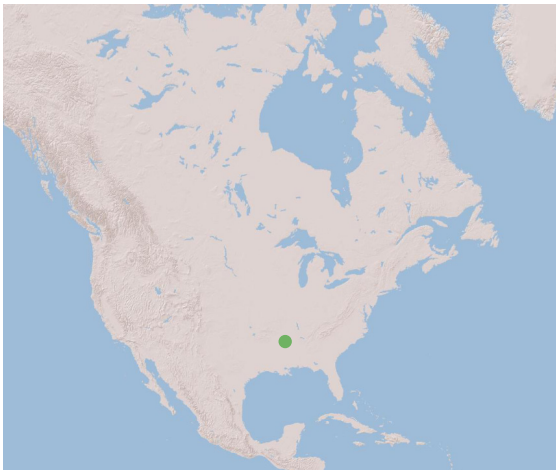
Home automation control and monitoring systems

Millvale Ecodistrict

Informations:

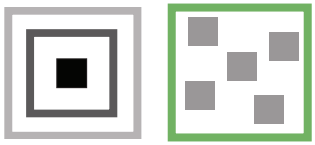
Designer:	Christian de Villére, Aktis Architecture
Stakeholders and owners:	Grenoble Municipality
Designing year:	/
Building year:	2011
Finish year:	2012
Inhabitants:	3744
Dimension:	181 ha

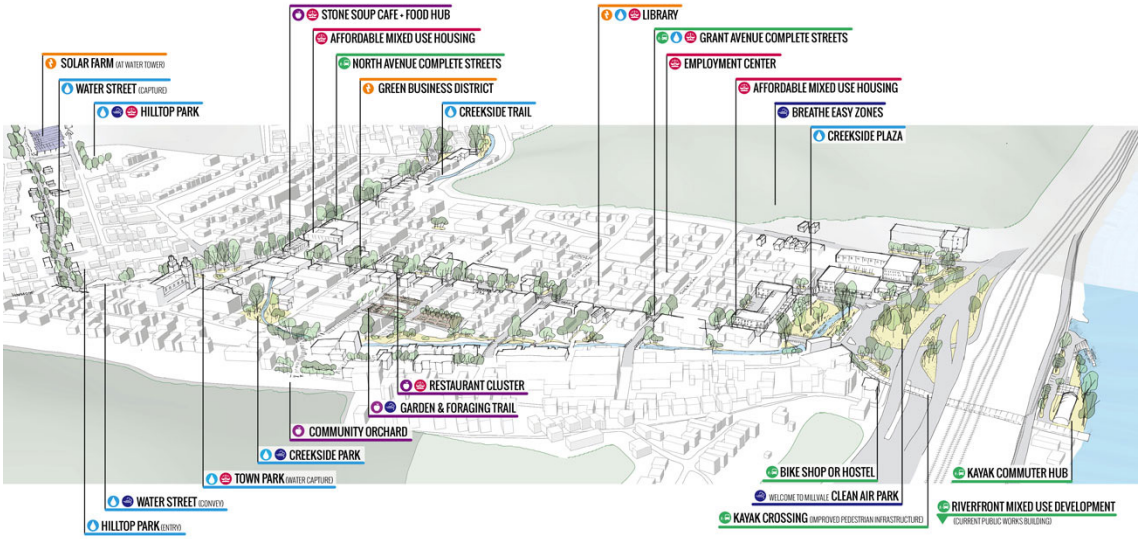
Collocation: Pittsburg, PA, USA



Pictures:

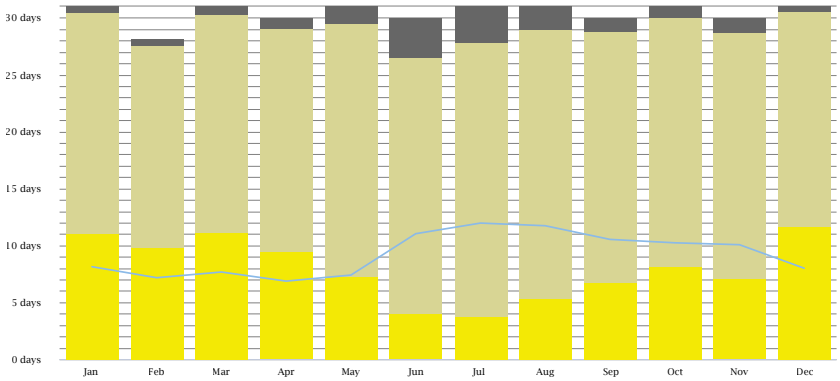
Neighborhood structure:





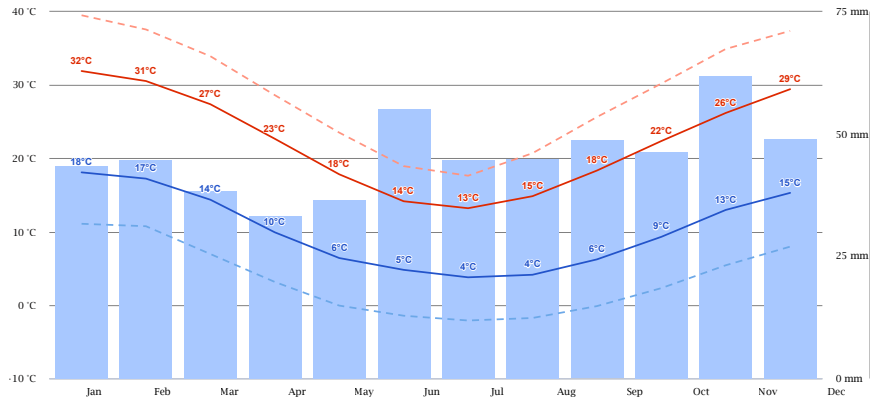
https://sustainableindianacounty.org/wp-content/uploads/2018/10/Millvale-Presentation.pdf

Climate conditions:



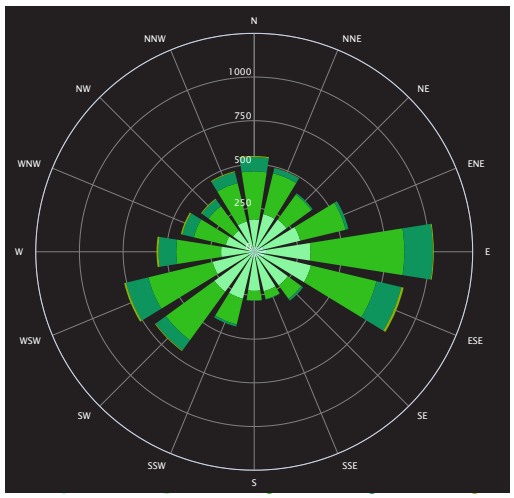
LEGEND:
Sunny days
Changeable weather
Cloudy
Precipitation days

meteoblue.com

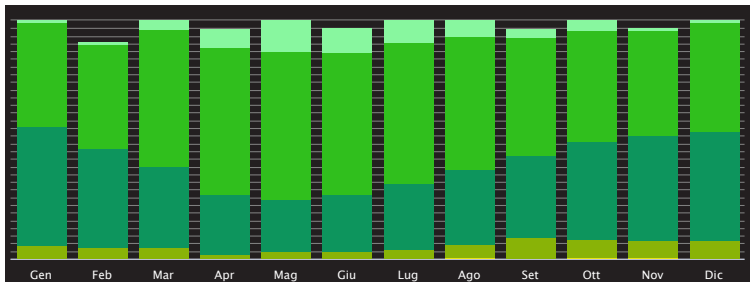


LEGEND:
Warm days
Cold nights
Average maximum temperatures daily
Rainfall

meteoblue.com



Wind speed and direction during the year; meteoblue.com



Issues:

- **This area was a poor, middle-class neighbourhood that found itself in a situation of severe decay after the hurricanes of 2004 and 2007**

History:

Millvale was a medium-poor neighbourhood of about 4,000 people along the Allegheny River near Pittsburgh. It has been in severe disrepair, especially after the hurricanes of 2004 and 2007. The goal is to make Millvalle Ecodistrict a fully solar district.

Actions:

There is a solar park in the area. The aim is to make the neighbourhood entirely 'solarised'. All buildings have photovoltaic systems on their roofs. To this end, 83 solar panels are installed on the roof of the Millvale Community Library, generating 25256 kWh/year of energy, more than the building needs. The surplus goes into the city's general energy grid. In the neighbourhood, at car parks, photovoltaic systems and wind turbines are installed along the highway. Renewable sources such as geothermal energy and hydroelectric power generation along the river are also present. Existing buildings are retrofitted, and various actions have been taken, such as increasing external insulation. By retrofitting existing buildings, a reduction in consumption of about 30 per cent is expected by 2030. A reduction of 6431 tonnes of carbon dioxide emissions per year is also likely. In the next ten years, the district hopes to reduce energy consumption by 50 per cent. There are bioswales, community gardens and composting facilities at the urban level. In general, the green infrastructure in the area has increased. The urban project used native species and local plants. Significant increases in outdoor comfort are expected through this intervention.

Summary:

Ventilation control
Bioclimatic atria

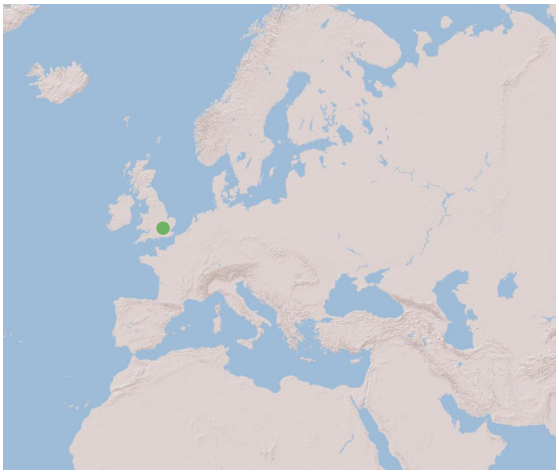
Use of active devices to harness energy sources
Solar thermal systems for hot water Photovoltaics systems

Greenwich Millennium village

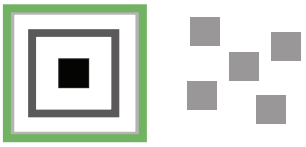
Informations:

Designer:	Homes and Communities Agency, Richard Rogers Partnership, Countryside Properties Pic and Taylor Woodrow, Edward Cullian Architects
Stakeholders and owners:	Homes and Communities Agency
Designing year:	1996
Building year:	1999
Finish year:	2015
Inhabitants:	7000
Dimension:	24 ha
Cost:	285 mln Euro

Collocation: London, UK

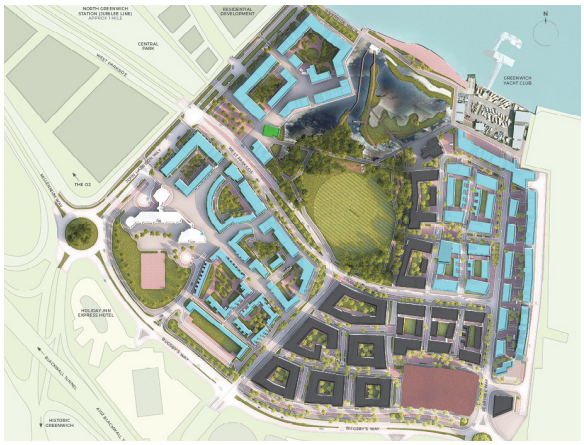


Neighborhood structure:



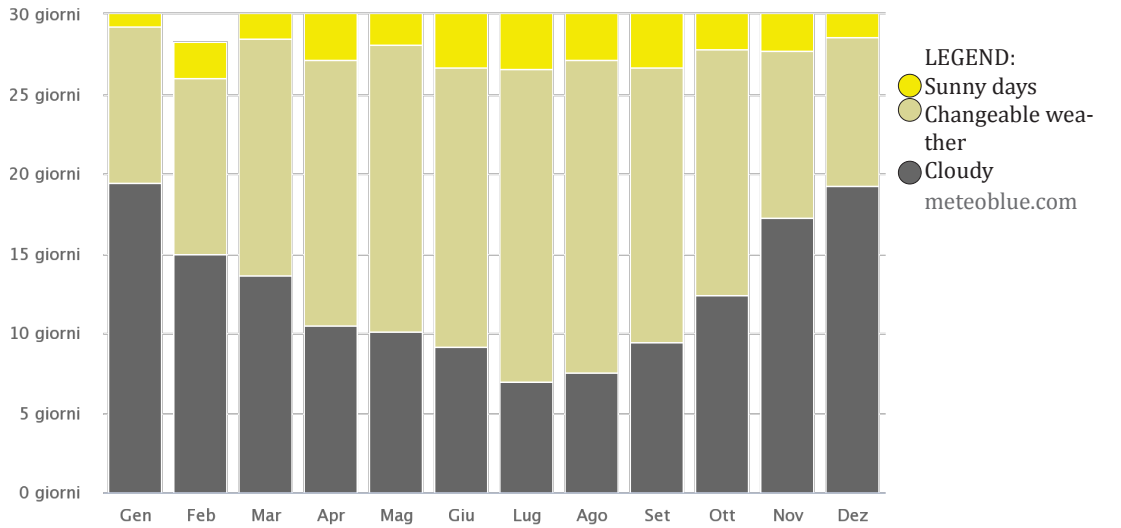
Pictures:

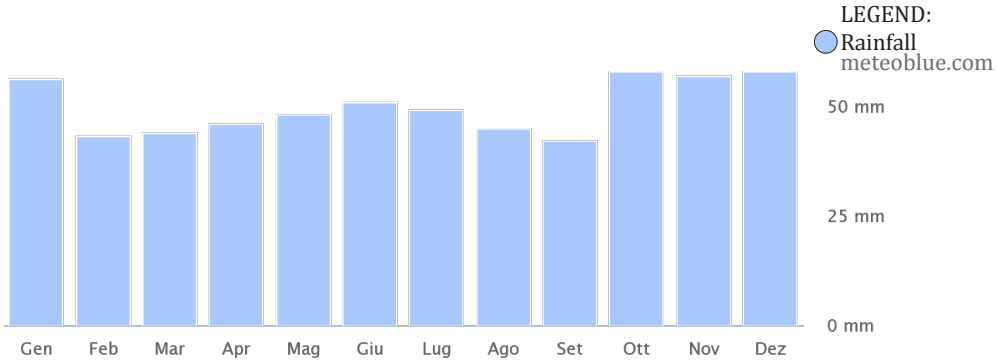


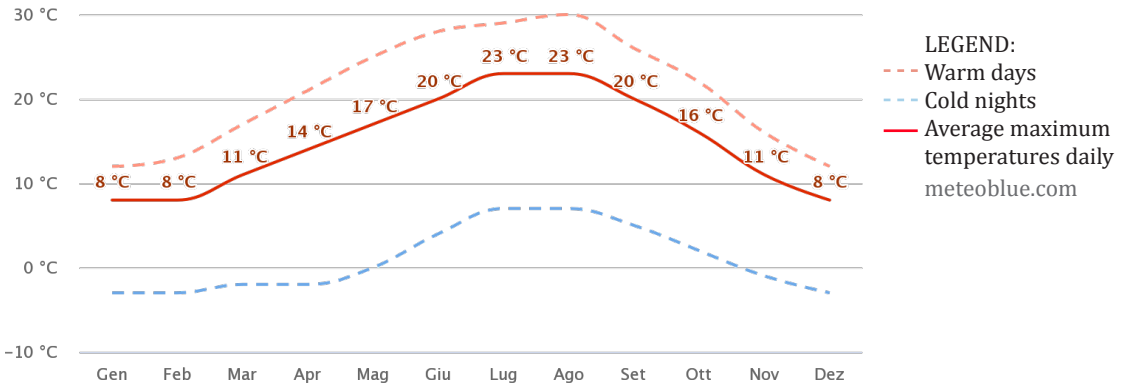


https://www.greenwichmillenniumvillage.co.uk/village-life/for-education

Climate conditions:







GEN	FEB	MAR	APR	MAG	GIU	LUG	AGO	SET	OTT	NOV	DIC
OSO	OSO	OSO	OSO	OSO	OSO	OSO	OSO	OSO	OSO	SO	SO
13	14	15	14	14	14	13	13	10	11	12	12
5	5	5	4	5	4	5	5	4	4	4	5

Wind speed and direction per month; meteoblue.com

Issues:

- **The abandonment of the British gas plant had transformed the Greenwich Peninsula from an active industrial area into a heavily polluted, disused marshland**

History:

In the early 1990s, the decommissioning of a large British Gas plant, which supplied gas to the city of London through the conversion of coal to fuel gas, made it necessary to plan the redevelopment of the peninsula, which had been left in a condition similar to that of a vast swamp with high levels of soil pollution. The English Partnership, now the Homes and Communities Agency, acquired the areas concerned and then took charge, at its own expense, of the regeneration of the land, the development of the general infrastructure to serve the area and the management of relations with property developers. The Jubilee Year 2000 and the focus on the Greenwich meridian were the occasion to start the redevelopment process of the peninsula that had experienced a dramatic industrial crisis in the twenty years between 1965 and 1985, with the loss of about 100,000 jobs. The project includes decontaminating the area by removing the top layer of soil and replacing it with topsoil. A geogrid system isolated the new layer on which the buildings rested from the underlying soil, which was probably still polluted. In 1996, the Richard Rogers Partnership won an urban planning competition for the eastern part of the peninsula with a masterplan design focused on environmental sustainability. The basic idea of the project was to create a new administrative and commercial district connected to a residential area. The relationship between its areas was a linear park crossed internally by a wide boulevard, the project's backbone. The new complex is connected to the rest of the project by a linear park along a wide driveway, cycle and pedestrian avenue of about 2 km to the south, forming the backbone onto which the residential blocks would face; the terminal extension of the park on the Thames, called Southern Park, formed the heart of the area on which the Greenwich Millennium Village would later be built. Thanks to a very dense system of buildings on both sides of the park, the masterplan envisaged a succession of sustainable neighbourhoods destined to host a mix of residential, social, commercial and administrative functions connected to the city's public transport system through an extension of the Jubilee Line and the London Transport Interchange, as far as transport on the river is concerned. The masterplan envisages the abandonment of the morphological patterns of the suburban periphery and a layout with city centre characteristics. The organisation of the spaces follows and emphasises the longitudinal development of the project. The Greenwich Millennium Village is the first example of the so-called 'Millennium Communities', a project of English Partnerships aimed at the birth, on disused and degraded land, of neighbourhoods based on the idea of a community founded on respect for the environment as an aggregating theme, aimed at increasing the quality of life and experimenting with innovative techniques and high environmental and social standards, even more binding than the regulations in force. Once the actual building phase begins, English Partnerships monitors the achievement of objectives by examining interim reports drawn up by the builders. The idea of community at the heart of the project is based on the tradition of the English village, conforming around communal and enclosed spaces with a clear hierarchy and with pathways from public to semi-public to private spaces.

Actions:

Among the solutions to save energy in buildings within the district are cogeneration plants that combine heat and power production. In this way, energy savings of 65% are possible. In each part of the district, a power station is built to supply the minimum heat load required by the flats, producing 0.8 kW of electricity per dwelling. In this way, primary energy consumption is reduced by 80%. The individual blocks must respond in their organisation to climatic factors, and the construction must follow ecological criteria. Taller buildings are placed to the north and east to shield them from cold winds. The buildings are planned with environmentally friendly materials and optimised on-site environmental management. In addition to the high-rise residential buildings, there are smaller interventions towards the centre of the lots in the southern part, which are staggered from north to south following studied inclines. This strategy allows a diffuse energy input of the radiation on the façades. The buildings surrounding the courtyards differ between those designed in the first and second phases. The former are built with massive structures, while the latter have dry-assembled technologies. In the former, high fronts with a screen effect against cold winds are emphasised, realised through buildings varying between 6 and 12 storeys. In both cases, however, the desire to create variable fronts in terms of type and size is readable, using different mate-

rials and solutions to treat façade elements to characterise individual dwellings or common fronts. Most of the flats have outdoor spaces on the south-facing fronts. The alignments towards the park are treated differently to emphasise the organic character of the intervention. This results in a:

- 65% reduction in primary energy consumption
- Reduction of energy used for building materials by 37%.
- 33% reduction in water consumption
- 18% reduction in construction time
- Development of quality control processes to eliminate construction defects
- Waste reduction by 65%
- All homes achieved the highest environmental certification standard per the 'Ecohomes' assessment procedure 4.
- 37% reduction in construction costs

In addition, sunshine and ventilation are optimised within the district. The proper orientation makes it possible to decrease dispersion and maximise thermal gains in winter. The vertical volumetric gradient, decreasing from north to south, deflects the cold that mainly blows to the northeast. This action allows an increase in daylighting with consequent electricity savings. The diversified volumetry of the buildings protects the inner courtyards and maximises the penetration of sunlight. Most of the flats have outdoor spaces on the south-facing fronts. The alignments towards the park are treated differently from each other to emphasise the organic character of the intervention. The proper orientation makes it possible to decrease dispersion and maximise thermal gains in winter. The vertical volumetric gradient, decreasing from north to south, deflects the cold that mainly blows to the northeast. Increased natural daylighting helps save energy. The north-facing façades are extensively insulated.

In terms of green infrastructure, local microclimatic environments are restored. The district has three parks: the central park, in the centre of the peninsula; the southern park, within the Greenwich Millennium Village; and a pedestrian and bicycle zone along the river. The three parks are differentiated naturally to promote the quality of the landscape and open space network. The green spaces are characterised by bicycle and pedestrian paths, sports facilities and areas dedicated to contemplating nature. Butterflies, moths, ducks, frogs, insects and aquatic plants are protected within the district. The mainly courtyard-like blocks are grouped around the green area designed by landscape architect Robert Rummey, with a large artificial lake and a system of ponds connected to the Thames to reform the wetland environment that once characterised the area. This area also serves as an ecological oasis for educational and recreational purposes. The inner courtyards are treated as public green spaces with controlled access and are equipped and designed for use by the corresponding courtyards' inhabitants. Inside the courtyards are, in addition to the central municipal space, the small private gardens of the dwellings according to a precise order that sees the public space, represented by the park and the pedestrian street, as the generator of a layout that gradually and neatly passes from public to private spaces. Deciduous tree species are present in the area to provide winter sunshine and shading in summer.

Summary:

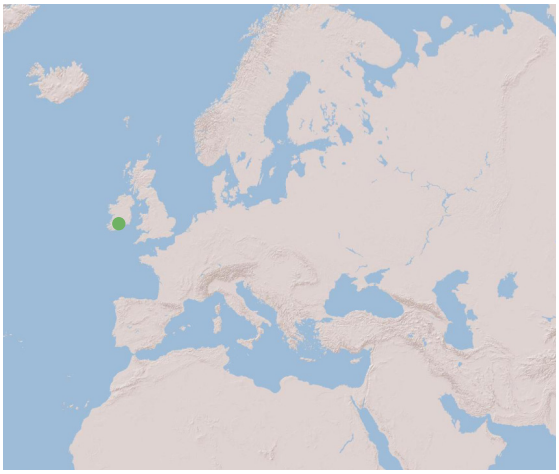
Use of passive and bioclimatic solution
Ventilated facades
Ventilation control
Morphological set-up of the system at neighbourhood level
Use of green infrastructure
Parks Tree lines Soft mobility

Limerick

Informations:

Designer:	+CITYXCHANGE
Stakeholders and owners:	Lighthouse Cities Trondheim Kommune, Limerick City, County Council
Designing year:	/
Building year:	2018
Finish year:	2023
Inhabitants:	194899
Dimension:	1.5 ha
Cost:	64 mln Euro

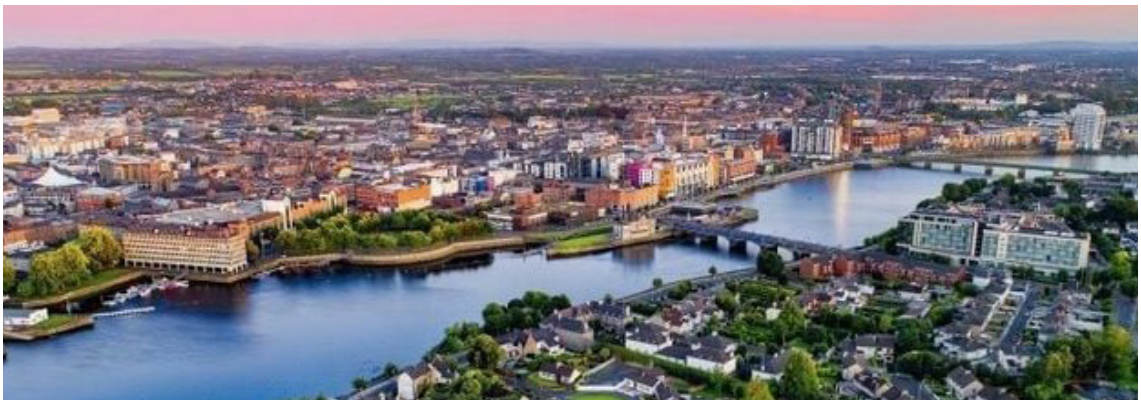
Collocation: Limerick, Ireland



Neighborhood structure:



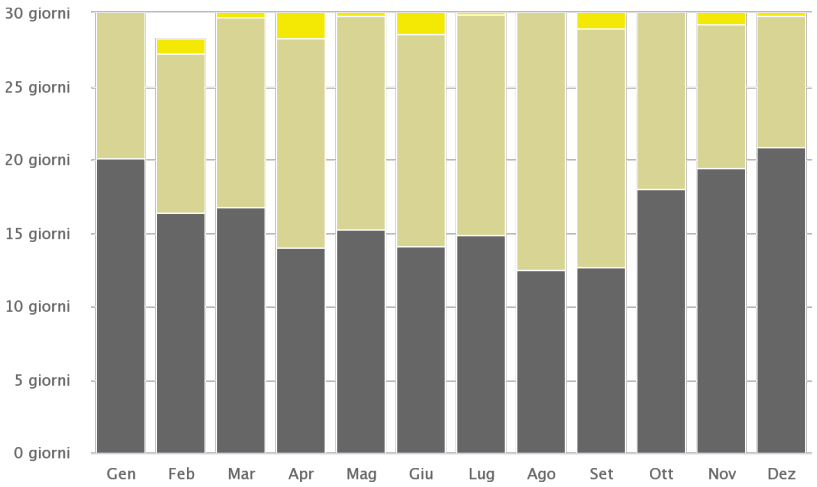
Pictures:



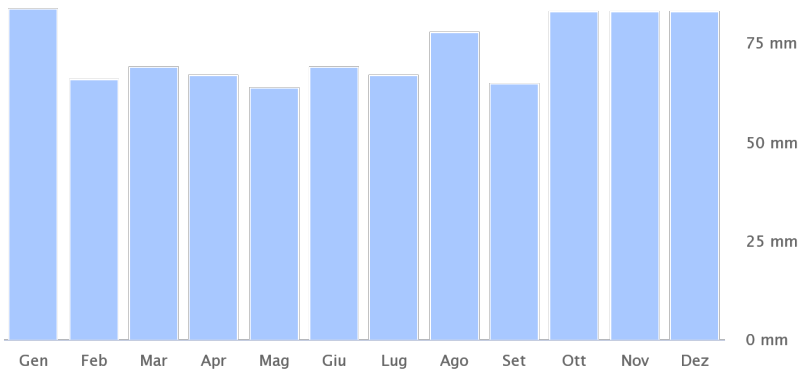


https://www.aerlingus.com/hub/inside-ireland-county-limerick/

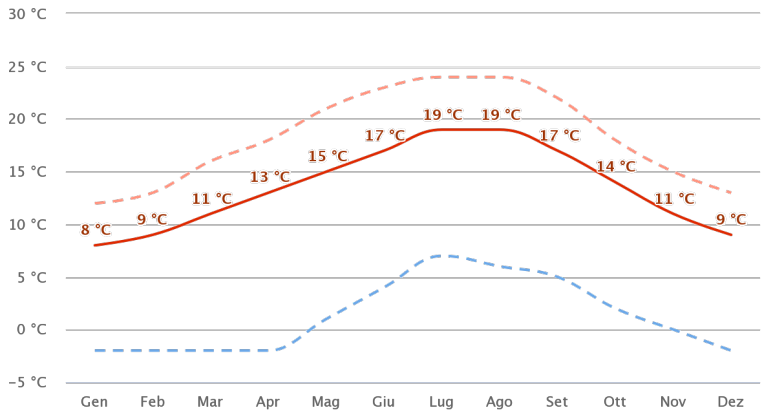
Climate conditions:



LEGEND:
Sunny days
Changeable weather
Cloudy
meteoblue.com



LEGEND:
Rainfall
meteoblue.com



LEGEND:
Warm days
Cold nights
Average maximum temperatures daily
meteoblue.com

GEN	FEB	MAR	APR	MAG	GIU	LUG	AGO	SET	OTT	NOV	DIC
SSO	SSO	SO	SSO	SO	OSO	OSO	OSO	SO	SSO	SO	SSO
18	19	19	17	18	16	16	17	17	17	18	19
5	6	6	5	6	5	5	5	5	5	5	5

Wind speed and direction per month; meteoblue.com

Issues:

- **High unemployment rate**
- **Inefficient housing stock**
- **Lack of functional and social mix**
- **Public space dominated by cars**
- **Risk of flooding**

History:

The area had an inefficient housing stock and a high unemployment rate.

Actions:

Within the buildings, there are heat pumps (600 in all, 400 installed in existing buildings) that produce 2.134 GWh of thermal energy. There are also solar thermal systems for hot water production. These systems allow for obtaining energy surpluses that other buildings use or charging electric vehicles. These installations provide 62 kWh/m^2 per year of surplus energy. There are also photovoltaic systems for electricity production. By these means, 70 per cent of electricity is produced from renewable sources. In addition, thanks to the restructuring of the energy infrastructure, losses are reduced by 20%. Around the city, wind power plants produce 205.75 MW, photovoltaic plants produce 113.49 MW, and two anaerobic biomass digesters produce 1 MW. In terms of passive solutions, the planners increase the insulation of the external envelope by increasing the air tightness, ensuring <3mc/sqm/hour at 50 Pa and increasing the transmittance of the walls to 0.18 W/m^2K. The windows and doors are also thermally insulated: the glazing reaches 0.85 W/m^2K. Outlet heat is mechanically recovered, and ventilation is controlled. Five hundred buildings will achieve a B2 equivalent BER (Building Energy Rating Certificate Assessors) by 2030. Inside the buildings, a Building Energy Management System (BEMS) or Home Management System (HMS) monitoring system interacts with the community network (energy exchange and control) systems.

Summary:

Use of passive and bioclimatic solution
External coat

Use of active devices to harness energy sources
District heating Photovoltaics systems Solar thermal systems for hot water Heat pumps Biomass digesters

Ventilation control
Morphological set-up of the system at neighbourhood level Installation of openings inside buildings to promote pressure differences and thus ventilation Ventilating plate systems

Setting up continuous monitoring systems
Home automation control and monitoring systems

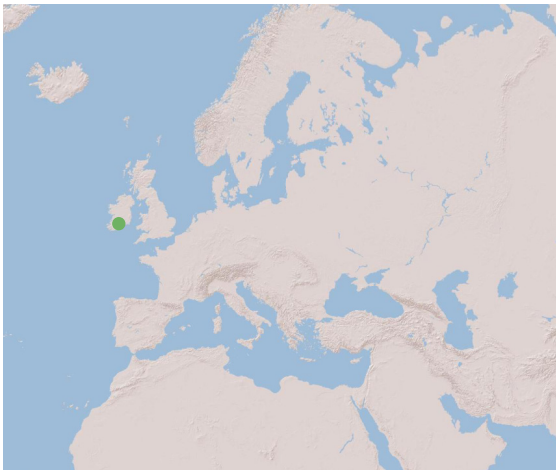
REPLICATE

Informations:

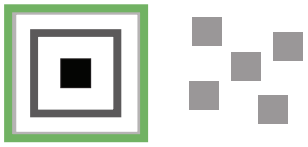
Designer:
Stakeholders and owners:

Designing year: /
Building year: 2017
Finish year: 2021
Inhabitants: 382258
Dimension: 2500 ha

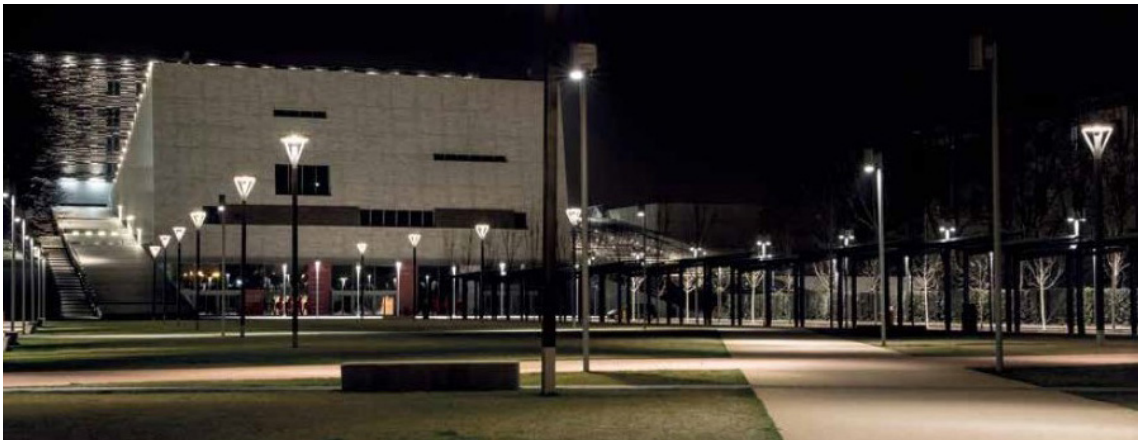
Collocation: Florence, Italy



Neighborhood structure:



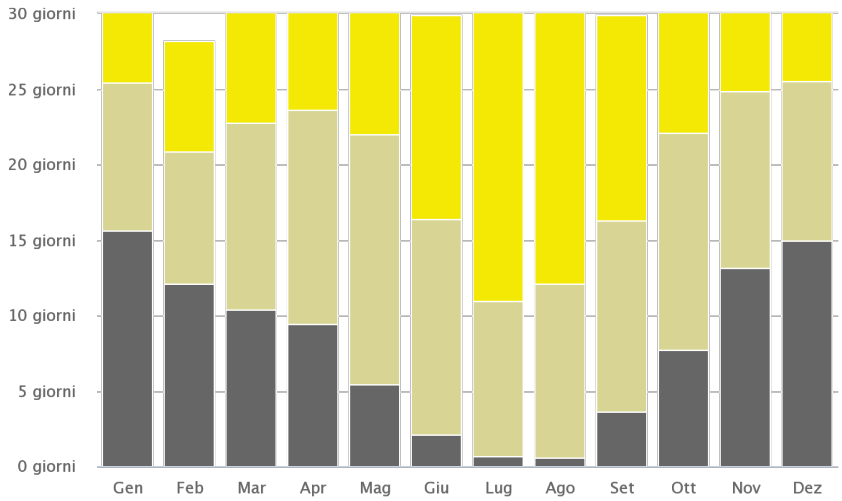
Pictures:



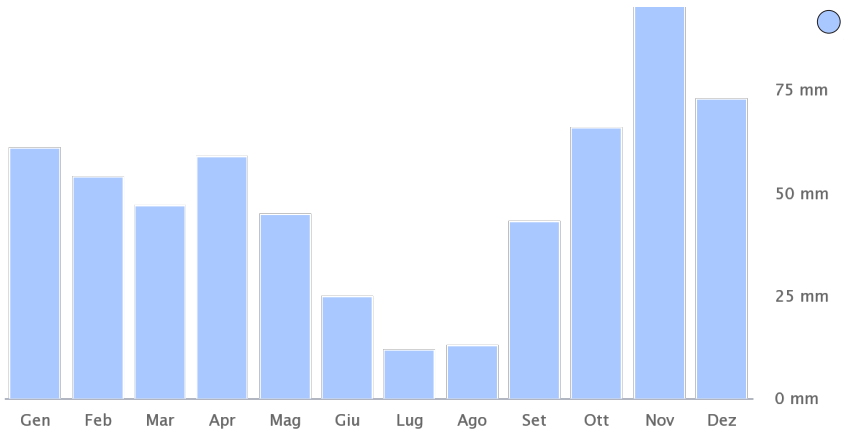


Comune di Firenze, 2021. Piano operativo città di Firenze, pon-metro, Firenze.

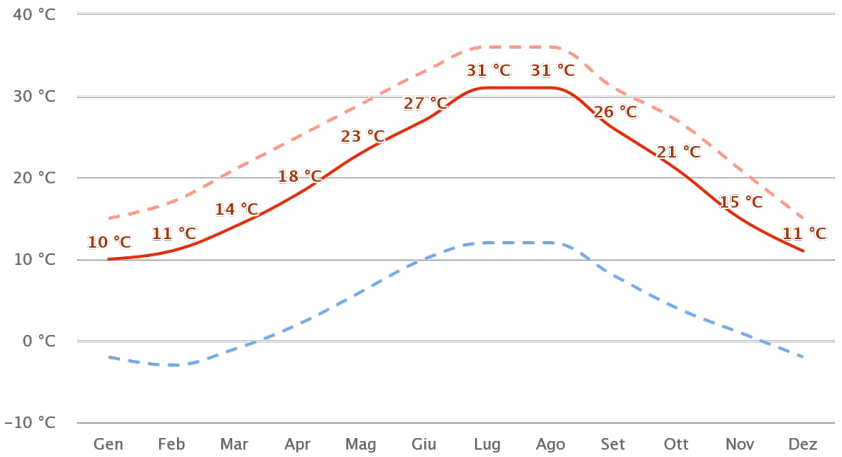
Climate conditions:



LEGEND:
Sunny days
Changeable weather
Cloudy
meteoblue.com



LEGEND:
Rainfall
meteoblue.com



LEGEND:
Warm days
Cold nights
Average maximum temperatures daily
meteoblue.com

GEN	FEB	MAR	APR	MAG	GIU	LUG	AGO	SET	OTT	NOV	DIC
NNE	NNE	NNE	NO	O	O	O	O	NO	NNE	ENE	ENE
23		24	23	23	22	22	21	23	22	24	23
4	5	6	6	6	5	6	6	5	4	4	3

Wind speed and direction per month; meteoblue.com

p. 262

Issues:

- **The area was subject to severe physical degradation.**

Actions:

The old heating systems have been replaced with high-efficiency micro DHS that produces energy with high RES utilisation through innovative seasonal solar thermal storage. Within the district, there is an intelligent LED street lighting system. A platform in the area monitors the mobility, environmental, residential, and social systems. Through the GoalGreen monitoring app, it is possible to control the energy expenditure of the neighbourhood. This way, the user can record energy consumption and compare it with the standard based on specific algorithms. Adaptation to the new standard Quadro allows savings of 346.3 MWh/y of CO^2/y. At the same time, the project includes the refurbishment of 1000 street lamps with LED lights (with 70 lighting points in the Cascine park), four smart ZTL gates (installed in the Cascine park, with LED, traffic control, WiFi and anemometer), adaptive lighting and 30 cameras, saving 10% of the district's total consumption by 2050. The designers have built a new school with criteria based on energy efficiency: in particular, this has a low-temperature heating system with radiant panels integrated into the attic and solar thermal systems for producing hot water and electricity with a photovoltaic system. The existing residential buildings are retrofitted; in particular, the envelope is insulated, allowing energy savings of 56%. There are also sensors and IoT systems for irrigating two parks: 'Ex Officine Galileo' and the Leopolda station.
Weather stations monitor the humidity of the ground to manage irrigation. There are also smart benches outside and inside the neighbourhood museum for charging smartphones and providing news about events in the surrounding area. The neighbourhood is home to the new Capuana and Italo Calvino school, built with a wooden load-bearing structure. The insulation is made of wood fibre, and the window and door frames are thermally breakable with low-emissivity glass. The façade is designed with eaves, overhangs and brise-soleil. The roof is ventilated, and the building has a primary air treatment and renewal system to ensure adequate air exchange. The designers generally referred to prefabrication to improve and speed up assembly operations. The per capita energy consumption in 2015 amounted to 346 kWh/a; in 2030, it is estimated to amount to 4000 kWh/a. In 2050, it is estimated to be 3000 kWh/a. The renovated buildings have very high energy performance.

Summary:

Use of passive and bioclimatic solution
Thermal break window External coat Ventilated facades

Use of active devices to harness energy sources
LED systems Solar thermal systems for hot water Photovoltaics systems

Setting up continuous monitoring systems
Home automation control and monitoring systems

		Use of passive and bioclimatic solution					
		External coat	Thermal break window	Pipe insulation	Solar shading	Green roof	Trombe-wall
1	Circular Buiksloterham	✓	✓			✓	
2	La Duchére	✓			✓		
3	Ecobarrio Trinitat Nova		✓				✓
4	Hikary project (La Confluence)	✓	✓				
5	Kortrijk	✓	✓	✓			
6	Laguna de duero	✓					
7	Le Albere	✓	✓				
8	Limerick	✓					
9	Greenwich Millennium Village						
10	Millvale						
11	Caserme de Bonne						
12	villa Fastiggi	✓					
13	Boucicaut				✓	✓	
14	Seaholm Ecodistrict		✓		✓	✓	
15	the Pearl						
16	BedZED		✓				
17	Ile de Saint Denis						
18	Santa Giulia Milano				✓		
19	Cogneto		✓			✓	
20	CItyZen - Paesi Bassi	✓	✓				
21	REPLICATE	✓	✓				

		Use active devices to harness energy sources				
		Low-temperature heating with radiant panels	District heating	Solar thermal systems for hot water	Photo-voltaics systems	Heat pumps
1	Circular Buiksloterham			✓	✓	
2	La Duchére			✓	✓	
3	Ecobarrio Trinitat Nova			✓	✓	✓
4	Hikary project (La Confluence)			✓	✓	
5	Kortrijk		✓	✓	✓	✓
6	Laguna de duero					
7	Le Albere		✓	✓	✓	
8	Limerick		✓	✓	✓	✓
9	Greenwich Millennium Village					
10	Millvale					
11	Caserme de Bonne	✓	✓	✓	✓	✓
12	Villa Fastiggi		✓	✓	✓	
13	Boucicaut			✓		
14	Seaholm Ecodistrict		✓	✓	✓	
15	the Pearl				✓	
16	BedZED				✓	
17	Ile de Saint Denis				✓	
18	Santa Giulia Milano					
19	Cogneto			✓		✓
20	CItyZen - Paesi Bassi		✓	✓	✓	✓
21	REPLICATE			✓	✓	

Use of passive and bioclimatic solution								
Face-change materials	Green-house and winter-gardens	Green walls	Cool roofs/ Cool pave-ments	Angle-selective thermo-chromic materials	Skylight	Ventilated facades	Orienta-tion	Permea-ble pavers
		✓		✓				
✓								
				✓				
						✓		
							✓	
							✓	
		✓	✓				✓	✓
	✓			✓			✓	
		✓					✓	
							✓	
						✓		

Use active devices to harness energy sources								
Biomass digesters	Cogenera-tion	Geothermal power	Heat reco-very and storage systems	Condensa-tion boilers	Micro-wind turbines	Hydrogen	LED systems	Energy efficient minisplit installation
✓			✓		✓	✓	✓	
✓								
	✓							
	✓	✓	✓					
✓					✓		✓	
✓								
	✓	✓						
✓								
	✓	✓						
			✓					
✓								
		✓					✓	
								✓
✓	✓							
		✓					✓	
			✓				✓	
				✓				
✓	✓							
							✓	

		Ventilation control				
		Morphological set-up of the system at neighbourhood level	Installation of openings inside buildings to promote pressure differences and thus ventilation	Ventilating plate systems	Bioclimatic atria	Urban canyon
1	Circular Buiksloterham		✓			
2	La Duchére	✓	✓			✓
3	Ecobarrio Trinitat Nova					
4	Hikary project (La Confluence)	✓			✓	
5	Kortrijk					
6	Laguna de duero					
7	Le Albere					
8	Limerick	✓	✓	✓		
9	Greenwich Millennium Village					
10	Millvale				✓	
11	Caserme de Bonne	✓				
12	Villa Fastiggi		✓			
13	Boucicaut					
14	Seaholm Ecodistrict					
15	the Pearl	✓				
16	BedZED		✓	✓		
17	Ile de Saint Denis	✓				
18	Santa Giulia Milano					
19	Cogneto					
20	CItyZen - Paesi Bassi					
21	REPLICATE					

		Use of blue infrastructure			
		Setting up phytodepuration spaces	Rain water collection and reuse	Draining infrastructure systems	Setting up wetlands
1	Circular Buiksloterham				
2	La Duchére		✓		
3	Ecobarrio Trinitat Nova		✓		✓
4	Hikary project (La Confluence)		✓		
5	Kortrijk				
6	Laguna de duero				
7	Le Albere				
8	Limerick				
9	Greenwich Millennium Village				
10	Millvale				
11	Caserme de Bonne	✓	✓		
12	Villa Fastiggi				
13	Boucicaut				
14	Seaholm Ecodistrict				✓
15	the Pearl		✓		✓
16	BedZED	✓	✓	✓	
17	Ile de Saint Denis		✓		✓
18	Santa Giulia Milano		✓		
19	Cogneto	✓	✓		
20	CItyZen - Paesi Bassi				
21	REPLICATE				

		Use of green infrastructure							
		Parks	Tree lines	Bioswales	Urban gardens	Soft mobility	Pocket gardens	Green corridors	Arboreal backdrops
1	Circular Buiksloterham								
2	La Duchére	✓	✓				✓	✓	✓
3	Ecobarrio Trinitat Nova				✓				
4	Hikary project (La Confluence)	✓	✓					✓	✓
5	Kortrijk								
6	Laguna de duero								
7	Le Albere	✓	✓				✓	✓	
8	Limerick								
9	Greenwich Millennium Village								
10	Millvale								
11	Caserme de Bonne	✓						✓	
12	Villa Fastiggi	✓	✓			✓	✓		✓
13	Boucicaut							✓	
14	Seaholm Ecodistrict		✓	✓					
15	the Pearl								
16	BedZED								
17	Ile de Saint Denis								
18	Santa Giulia Milano	✓			✓				
19	Cogneto	✓	✓			✓		✓	✓
20	CItyZen - Paesi Bassi								
21	REPLICATE								

		Improvement of the public transport system			
		Presence of exchange nodes	Increasing the number of public transport stops	Increased frequency of public transport	Presence of proximity services
1	Circular Buiksloterham		✓	✓	
2	La Duchére				✓
3	Ecobarrio Trinitat Nova				✓
4	Hikary project (La Confluence)				
5	Kortrijk				
6	Laguna de duero				✓
7	Le Albere				✓
8	Limerick				
9	Greenwich Millennium Village				
10	Millvale				
11	Caserme de Bonne		✓	✓	✓
12	Villa Fastiggi				
13	Boucicaut				
14	Seaholm Ecodistrict				
15	the Pearl				
16	BedZED				
17	Ile de Saint Denis	✓			✓
18	Santa Giulia Milano	✓	✓	✓	✓
19	Cogneto				✓
20	CItyZen - Paesi Bassi				
21	REPLICATE				

		Improving infrastructure for soft mobility					
		Fo-otpaths	Cycle paths	Garden squares	Shading systems for cycle and pedestrian paths	Car sharing/ pooling	Bicycle and/ or pede-strian par-king points
1	Circular Buiksloterham		√			√	
2	La Duchére	√	√		√		
3	Ecobarrio Trinitat Nova	√		√			
4	Hikary project (La Confluence)						
5	Kortrijk						
6	Laguna de duero						
7	Le Albere						
8	Limerick						
9	Greenwich Millennium Village						
10	Millvale						
11	Caserme de Bonne						
12	Villa Fastiggi						
13	Boucicaut						
14	Seaholm Ecodistrict	√	√				
15	the Pearl	√			√		√
16	BedZED	√	√			√	
17	Ile de Saint Denis						
18	Santa Giulia Milano						
19	Cogneto	√	√	√			√
20	CItyZen - Paesi Bassi		√				
21	REPLICATE						

Control and increase of soil evapotranspiration	Setting up continuous monitoring systems		Recovery and enhancement of the relationship with the aquatic/river environment		
permeable surfaces	Sensors to detect soil moisture	Home automation control and monitoring systems	Natural bank protection	Artificial bank protection	Use of the banks
		✓			
		✓			
			✓		✓
		✓			
		✓			
		✓			
		✓			
		✓			
		✓		✓	✓
✓	✓	✓		✓	✓
✓					
			✓	✓	
		✓			
		✓			

Results and discussion.

The case study analysis shows that solar thermal is the most widely used energy technology. Another widely used technology is photovoltaics, followed by biological biomass digesters, geothermal energy, district heating and LED lighting systems. In general, it emerges that technologies that have the sun as their primary source are the most widely used because, unlike other sources, it can consistently generate energy, even during cloudy days; it is versatile, can be used within the city and can also be easily applied to the built fabric. Wind micro-turbines are used less (found in only three case studies), and even less (in only one case out of 22) are condensing boilers, hydrogen systems, high-efficiency mini splits and low-temperature heating with radiant panels. Interestingly, no technologies emerged whose primary energy source is water: this type of energy source requires large spaces and the presence of moving or still water, in this case, used for energy storage, within the neighbourhoods. In addition, space for installations is also necessary.

From the bioclimatic point of view, external cladding solutions are widely used. They appear in nine cases out of the 22 analysed, such as the Limerick district, which increases the thermal inertia of its buildings by installing an external cladding system. Thermal break window frames and the study of orientation are also expedients adopted in many neighbourhoods, including Ile de Saint-Denis, which characterises building façades according to exposure, or Seaholm eco-district in the USA, which uses high-performance window frames. Vegetated roofs and sunscreens are used in several cases - in four and five cases out of the twenty-two, respectively. In contrast, green systems embedded in buildings and angle-selective thermochromic materials are not used, even though this type of action often appears in the literature as a solution to cope with rising temperatures and related phenomena. This absence is probably due to the type of material being poorly suited to the needs of redevelopment on an existing built fabric, which subtends specific rules dictated by construction methods, materials, and respect for the history and aesthetics of buildings, despite being a valid solution.

Many of the neighbourhoods analysed use natural ventilation to encourage indoor air exchange and create draughts outdoors. The Duchére morphology incentivises indoor and outdoor ventilation

flow. The Limerick district uses the wind to encourage cooling during the hot season due to the ventilation towers installed in the buildings and the careful morphological arrangement of the open spaces and fixtures.
Another action that impacts the occurrence of heat islands and the effects of heat waves is using green infrastructure. For example, establishing parks is one of the most frequently used solutions. The establishment of tree rows, tree wings, urban pocket gardens, and green corridors is also widely used in the case studies analysed.
Finally, most cases see the collection and reuse of rainwater as one of the leading blue technologies. Also of this type are phytopurification sites - as in the case of Deietenbach and Cogneto - the setting up of wetlands, as in the case of the Ecobarrio in Trinitat Nova, and drainage systems and infrastructures, as in the case of BedZED. The analysis shows that all the case studies facing the water have carried out works to protect the margins, the artificial protection of the banks and their use. These preventive measures are important to prevent extreme events such as flooding and to make usable green spaces otherwise left abandoned.
To be noted is the fact that various solutions indicated in the literature as performing well on heat islands and heat waves cannot be applied to the existing building, as this presents peculiarities and occasionally incompatibilities due to materials, structure, morphology, availability or local culture, as in the case of thermochromic or phase change materials, which conflict with potential expedients to leave the aesthetics of the neighbourhood intact.
The most complex part of the research is finding the data: sometimes, they are difficult to find, or the various documents omit specific technological solutions that others have. Very often, neighbourhoods are described using different parameters, and in general, there is no univocal way of describing the redevelopments carried out, even though many neighbourhoods belong to the same certifications—Cityfied, LEED, and EcoDistricts. Therefore, comparing several sources was important and characterised the whole research.
The analysis is the basis for the subsequent selection and analysis of the actions that significantly impact reducing extreme phenomena due to rising temperatures.

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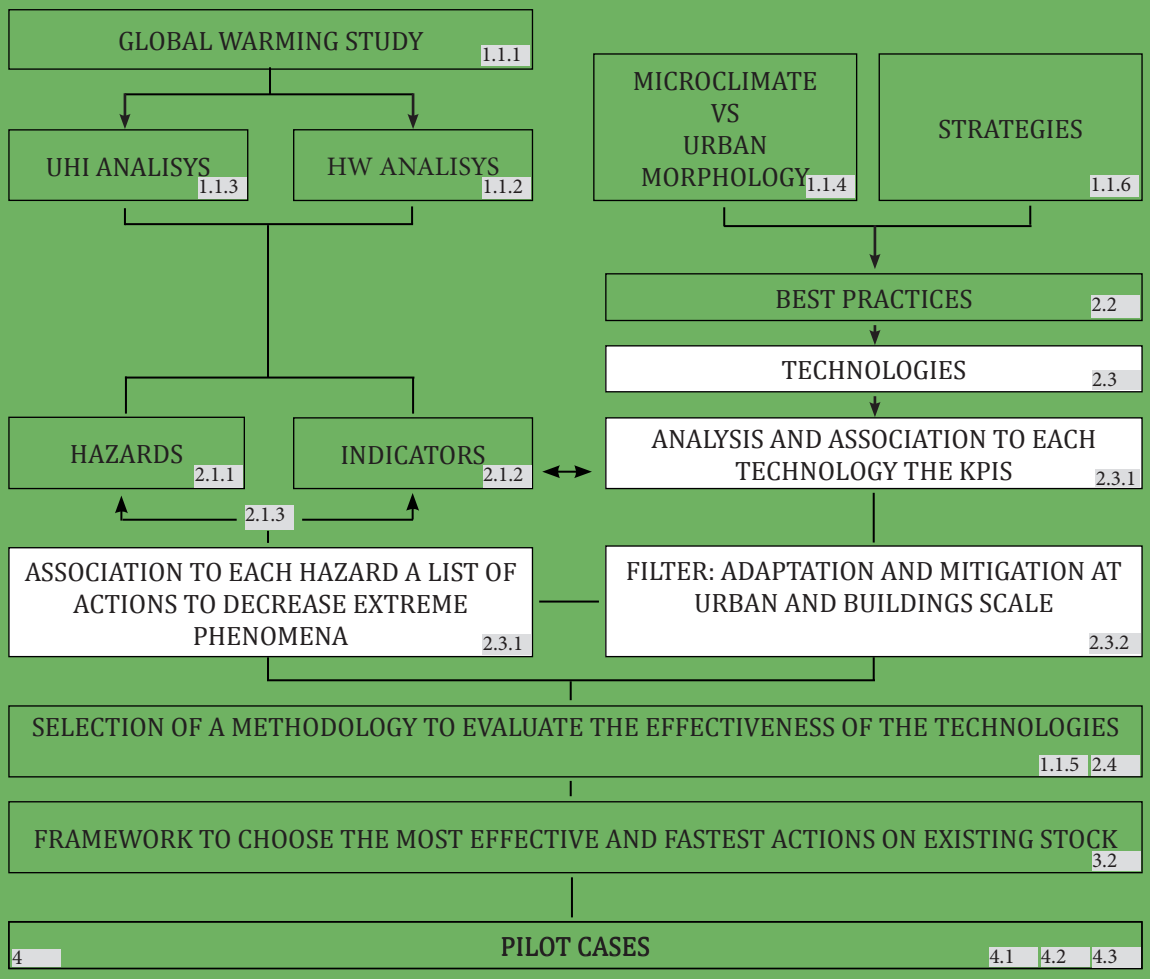
CHAPTER 2.3

2.3 | IDENTIFICATION OF ACTIONS FOR ADAPTATION TO URBAN HEAT ISLANDS AND HEAT WAVES

ABSTRACT

Various actions can be taken to mitigate and adapt the existing residential building landscape to heat islands and heat waves in warm temperate climates. The selected technologies have different functions and influences on the phenomena addressed. This part of the research aims to clarify the points mentioned above.
The chapter is divided into two paragraphs: the first consists of an in-depth review of the selected technological solutions following a cross-case study and literature analysis. This paragraph consists of fact sheets for each technology, highlighting various key factors concerning the versatility and response times of individual actions and areas of application. The second paragraph identifies the most effective technologies in mitigating and adapting to heat islands and heat waves. For this, a matrix determines the actions that affect the most indoor and outdoor hazards based on the analyses carried out in the previous section. In this way, it is possible to obtain a frame of reference to identify the main characteristics of the technologies that affect the extreme phenomena studied, the possible integrations with other actions, the way of operation and the physical indicators on which they influence. The effectiveness of solutions varies greatly depending on the context. Therefore, all solutions must always be contextualised to the type of territory through a case-by-case evaluation. Regardless of the most beneficial actions, this work can be used as a decision-making tool for professionals, public administrations, or researchers to understand the most appropriate solution in a given context. In conclusion, it appears from this study that solutions such as green infrastructure, cool materials, green roofs and green walls constitute a package of actions that act directly on the most significant number of hazards, have instantaneous response times, affect both indoor and outdoor areas and are very versatile and integrable actions.

KEYPLAN



Outcomes of this chapter:

- Identification and analysis of **strategies and actions** that help reduce impacts and occurrence of heat islands and heat waves
- Selection of the **most efficient actions**

2.3.1| Analysis of the actions undertaken by case studies to decrease urban heat islands and heat waves on existing built residencial stock

Summary.

The increase of extreme phenomena, such as heat islands and heat waves, poses many dangers to the existing environment and undermines the achievement of the UN 2030 and 2050 targets.
The previously elaborated case study analysis and the scientific literature concerning heat islands and heat waves have enabled the identification and analysis of strategies and actions to decrease the impacts and incidence of the dangers associated with the mentioned extreme phenomena.
This part of the thesis results in an analysis of the effectiveness and efficiency, based on the literature, of actions that contribute to mitigation and adaptation from heat islands and heat waves. The analysis has as its output the elaboration of technology fact sheets of the solutions found. These analyses form an initial decision-support tool. Subsequently, actions that influence all the KPIs of the hazard are associated with each one.
In this way, it is possible to lay the foundations of a decision-making tool, considering the phenomenon at different scales and multifunctional aspects.

Introduction.

Given the global increase in temperature, island and heat wave phenomena, and the consequent increase in risks to the existing environment, actions are needed to mitigate extreme phenomena in the short term and comply with the 2030 and 2050 Sustainable Development Agreements.
As seen in the previous paragraphs, many realities - Singapore, various neighbourhoods of Paris, Lyon, and Grenoble, part of Amsterdam's city centre - have already adopted plans, strategies, and actions with immediate results and, even more importantly, medium- and long-term results of reduced consumption and needs,

healthier environments, and increased levels of physical, psychological, and cognitive well-being.
Bioclimatic, energy, and indoor and outdoor actions applicable to buildings and existing contexts are considered. Other research has already investigated the effectiveness of specific actions concerning extreme phenomena related to rising temperatures in urban centres. In the research (Makido et al., 2019), through the ENVImet tool, the effectiveness of green-based solutions is evaluated in an outdoor environment in Portland. The research shows that increased vegetation and albedo contribute to temperature reduction in all areas where experiments were conducted. Another important project evaluating the effectiveness and efficiency of specific actions on the existing environment is the report (European Environment Agency., 2020b), where a chapter measures effectiveness and cost efficiency to adapt to too high temperatures. In particular, the chapter refers to the RESIN (climate resilient cities and infrastructures; 2015-2018) project, funded by the Horizon 2020 programme. This project, through the involvement of representatives from local government, research and business, aims to standardise strategies in the field of climate change adaptation (Jong, de Buck, & Bogen, 2018). The project developed both information and tools to support adaptation to climate change that have the potential to become formally and/or informally standardised.
Among the tools developed is a searchable database of information on the cost-efficiency and effectiveness of various adaptation measures (applicable at the facility, community and governance level) based on a literature review. High temperatures affect various aspects of the urban fabric. Therefore, the efficiency of adaptation measures on heat is measured through various indicators, such as comfort (see section 2.1.4), air and surface temperature or energy saved (see section 2.1.2). The adaptation planning process can be challenging for individuals and organisations that lead the climate change response, as they face multiple competing demands on their time and resources. The application of strategies and technological solutions to different contexts makes it difficult to assess effectiveness. The rationale is based on the risk that governs climate change adaptation and resilience processes, as defined by the (Intergovernmental Panel of Climate Change -IPCC-, 2023). The database, accessible at different levels by different types of users, allows advanced users to register adaptation options and, for others, serves as a reference tool and choice aid.

Figure 24. Based on scientific evidence from both within and outside Europe. For a description of the individual measures, see RESIN (2018). The colours reflect different heat-associated indicators; ETC/CCA analysis is based on RESIN (2018).

The aim is to develop a standardised method to increase resilience in European cities and urban areas to extreme weather events and climate change. The database is based on user feedback and the study of the state of the art, so it is limited to experiences up to 2017. In this study, effectiveness refers to the reduction of risk and vulnerability components through various adaptation options. Given the multisectoral nature of the latter, a single action can contribute to different dimensions of the adaptive management approach, such as reducing the magnitude of the impact, exposure (reducing the number of people exposed), sensitivity (number of buildings with improved insulation), and improving adaptive capacity (percentage of health centres). Therefore, the effectiveness of each dimension is measured using different metrics. In addition, the local conditions of the place where the measure is applied, the reference scenario, the time frame of the results and the place where they are achieved are also taken into account. Finally, criteria that do not directly affect the effectiveness of the actions are also considered, such as the range of impact, robustness, flexibility, time (understood as time horizon, implementation time and actual duration), possible side effects and uncertainty.

The research is divided into several reports that illustrate studies on rising temperatures and related extreme phenomena (such as heat islands during the hottest times of the year), how to assess a given area's vulnerability, the development of a decision support tool for increasing resilience, user guides, and the identification of the tool's strengths and weaknesses.

The evaluation criteria for climate adaptation are based on existing databases, platforms, and libraries of scientific reports and policy documents on climate adaptation. All these data are then arranged and formulated into Figure 24, which evaluates the efficiency of different actions concerning increasing temperatures. The size of the circles indicates the number of case studies where a specific technology is used.

Figure 24


Figure 3.1 Overview of effectiveness of adaptation measures: high temperatures
EFFECTIVENESS
Not effective
Low
Medium
High
Group
Option
Cool materials
Cool facade
Cool pavement
Cool roof
Energy system
Passive cooling
Green infrastructure
Grass
Combination of grass and green roof
Combination of grass and trees
Combination of grass, trees and green roof
Green facade
Green roof
Combination of green and white roof
Park
Trees
Combination of trees and green roofs
Shading
Exterior shading device
Photovoltaic panel
Urban configuration
Building density reduction
Building height increase
Building orientation
Street orientation
Street configuration
Transport system
Road traffic reduction or pedestrianisation
Water-based solutions
Outdoor water spraying
Pavement watering
Water body
Aspects of managing heat
Outdoor thermal comfort
Indoor thermal comfort
Air temperature reduction
Surface temperature reduction
Energy consumption reduction
Number of cases investigated
1-20
21-40
41-60
61-80
> 80
Number of scientific articles containing the cases
1-15
16-30
31-45

It is interesting to analyse some specific documents of this research: in particular, the report (Maddalen Mendizabal, 2015) indicates the structure of the database. It defines the most important terms on which the search is based, including effectiveness, as follows: "The effectiveness is the hazard and the vulnerability components reduction (i.e. magnitude reduction) due to the adaptation options. Due to the multi-sectoral nature of adaptation, one adaptation option can contribute to different dimensions of the adaptive management approach, such as reducing the magnitude of the impact (m^3 of rainfall caught by a green infrastructure), reducing the exposure (reduction of the number of people exposed to flooding), reducing the sensitivity (number of buildings with improved isolation), improving the adaptative capacity (rate of healthy centres). As a consequence, the effectiveness of each dimension is measured using different metrics. Apart from this, to contribute to the lack of metrics in the adaptation field, the following information will be included: local conditions (the effectiveness of adaptation options is highly dependent on the local conditions of the place where the measure is applied), the baseline scenario, the time expression of the results and the location where the results are achieved. There are more criteria linked with the concept of effectiveness (but they are not directly connected) that this dimension will cover: the impact radius, robustness, flexibility, time (time horizon, implementing time and effective lifetime), side-effects and uncertainty."

On the other hand, other reports focus on the general description of conducting vulnerability analyses of urban contexts, using a method called IVAVIA. Vulnerability analysis allows the selection of specific strategies and actions for the context in which the action is being taken, thus further increasing efficiency and durability (Tucci, 2018).

Although this research does not deal with existing buildings but evaluates technological actions in a standardised way, it is essential to compare the results obtained because the methodology used can be taken as an example.

Starting from this literature basis, the research extrapolates the salient features of mitigation and adaptation actions to heat islands and heat waves. The information hinged on fact sheets aids professionals and public administrations in evaluating the best actions individually and in combination, depending on the context. Then, a set of actions is associated with each hazard that affects all

the KPIs of the hazard itself, decreasing its occurrence.
Below is the method of constructing the fact sheets, the results and a graphitisation through a matrix that associates the different hazards in the city with sets of technologies that act on the KPIs of the hazard itself, decreasing its occurrence.

Way of conducting the research.

The research employs a systematic approach, structured in four parts. The first part builds on the research in the chapters preceding the thesis. The second part complements the first by conducting more detailed research on individual mitigation and adaptation actions. The third part is divided into the graphic elaboration of a collection and analysis of the individual actions. The fourth part associates the hazards identified in the city with the actions that, acting in an integrated manner on all the indicators influencing the hazard, can mitigate its occurrence.
The first phase is based on previous research on islands and heat waves. It aims to identify the hazards driven by extreme phenomena in cities and the most important indicators that can influence them.
The second step explores the most important strategies contributing to island and heat wave mitigation and adaptation. In this step, the strategies and actions indicated in the case studies in section 2.2 are identified and analysed in detail. Also, actions found in the literature for mitigating and adapting phenomena due to rising temperatures that are not present in the best practices are considered. For each action, research consists of consulting books on architectural technology, consulting manufacturers' data sheets, consulting the Scopus research platform and selecting review articles for individual technological solutions in order to understand their operation, types, maintenance, return and lifetimes, possible integration with other technologies, and the KPIs on which they influence.
Finally, the third phase consists of drawing up analysis sheets for the individual technologies (see Figure 25). These are analysed according to the following points of view:

- Extreme phenomena that can mitigate or adapt the context: Some actions can act on one of the phenomena addressed, and others influence both

- Reference environment: The selected actions may be installed inside buildings, including in infrastructure systems, or become an integral part of open spaces, such as squares or plazas.
- Type of solution: This refers to the scale on which a given action acts: it can act on an urban, morphological, technological or material level
- Working method: A distinction is made between active actions—i.e., those involving energy flows—and passive actions—i.e., those operating without the aid of energy sources (Lolasso, et al., 2020).
- Main components: These refer to the main parts that a given technology must have, irrespective of its different types
- Characteristic parameters: These are the KPIS that the considered action involves to cope with islands and heat waves. They are divided into main parameters and characteristic indicators, which significantly influence the phenomena being addressed - air temperature, mean radiant temperature, relative humidity, wind speed—and secondary parameters, other parameters.
- Hazards they affect: this refers to the hazards identified in the previous chapters of the thesis, concerning the impact of islands and heat waves on the existing fabric. If the technological solution influences the whole package of indicators explicated in section 2.1.3 of the considered hazard then this is highlighted through a black outline; if the hazard is not highlighted and is presented without transparency then it symbolises an influence of the analysed technology only on some of the indicators influencing the hazard; if it finally does not influence any indicator of a given hazard then the image representing it is in transparency.
- Presence in case studies
- Possible integration with other technologies and innovative solutions
- Life period: refers to the installation time, the time between maintenance and the expected life of the technology/action addressed
- Return period refers to the return period of the action or technology and the disposal method.

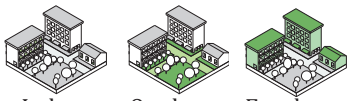
The last part consists of associating with each hazard a set of technologies that, acting on all the KPIs that influence the incidence of the hazard, can contribute to decreasing the probability of

its occurrence. In this way, it is possible to complete the matrix developed in the previous paragraphs - 2.1.1, 2.1.2, 2.1.3 - by associating each hazard with a technological set of actions capable of decreasing its incidence.

Figure 25. Example of a technology's summary

Figure 25

Technology:	**Critical issues related to climate change**
	Urban Heat Island  Heat waves 

Context:		
Spatial context: type of settlement	Application:	Main immediate environment:
 City centre; Suburban areas; Country-side	 Indoor; Outdoor; Envelope	 Buildings; Streets; Open spaces
Work metod:		
SMART	PASSIVE	ACTIVE
Type of solution:		
Typology		
Urban space device	Morphological	Technological	Materic	Plant engineering
Green / Blue / Gray		
		
Responsiveness:		
Period of installation:		Life span:
Maintenance:		Return environmental period:

Indicators:

Characteristic indicators:


Mean radiant temperature


Relative humidity


Air speed


Air temperature

Other parameters:


Geometry


Material thickness


Roughness


Soil moistre / permeability

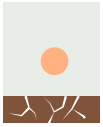

Conducibility

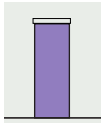

Emissivity

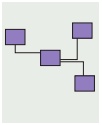

Albedo

Decreased Hazards:


Wildfires

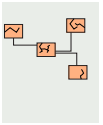

Drought


Stress of structures

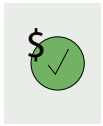

Stress of infrastructures


Rainfall

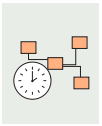

Decreasing of comfort conditions

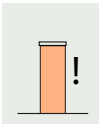

Energy transmission losses and facilities

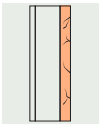

Negative impact for renewerable energies

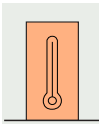

Increasing recovery costs


Increasing deterioration rate of systems and materials


Increasing deterioration rate of infrastructures

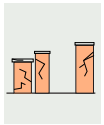

Buildings may became unsuitable for use

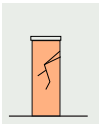

Problems with finishing materials


Increasing indoor temperature

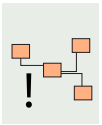

Increasing mortality


Increasing costs for preventing measures


Neighborhoods abandonement


Buildings abandonement


Increasing maintenace costs


Infrastructures may became unsutaible for use


Decrease of air quality

Technology:	Critical issues related to climate change
Evaporative cooling	Urban Heat Island  Heat waves 

https://www.shutterstock.com/it/video/search/evaporative-cooling-system



Context:

Spatial context: type of settlement	Application:	Main immediate environment:
City centre / Suburban areas / Countryside	 Indoor / Outdoor / Envelope	 Buildings / Streets / Open spaces

Work metod:

SMART PASSIVE ACTIVE

Type of solution:

Typology

Urban space device | Morphological | Technological | Materic | Plant engineering

Green / Blue / Gray

Responsiveness:

Period of installation:

Maintenance: !!!

Life span:

Return environmental period:

Indicators:

Characteristic indicators:



Mean radiant temperature



Relative humidity

Air speed



Air temperature

Other parameters:

Geometry

Material thickness

Roughness



Soil moistre / permeability

Conducibility

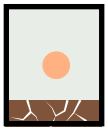
Emissivity

Albedo

Decreased Hazards:

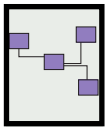


Wildfires



Drought

Stress of structures

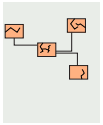


Stress of infrastructures

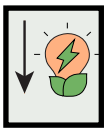
Rainfall



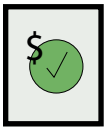
Decreasing of comfort conditions



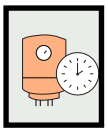
Energy transmission losses and facilities



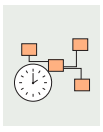
Negative impact for renewerable energies



Increasing recovery costs



Increasing deterioration rate of systems and materials



Increasing deterioration rate of infrastructures

Buildings may became unsuitable for use

Problems with finishing materials

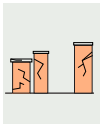
Increasing indoor temperature



Increasing mortality

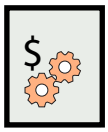


Increasing costs for preventing measures

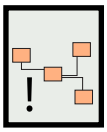


Neighborhoods abandonement

Buildings abandonement



Increasing maintenace costs



Infrastructures may became unsutaible for use

Decrease of air quality

Description.

Evaporative cooling systems are devices that cool the air through the evaporation of water by increasing humidity levels at the microclimate level by atomising and/or spraying water. Evaporative cooling increases thermal comfort by removing heat or reducing the body's skin surface temperature. In hot environments, evaporative cooling can create a calming effect. This measure is often used in hot environments, but is less effective in humid areas, as water in the air is already high and cooling effects are reduced. However, Farnham et al. (2015) show that tropical areas subjected to severe heat island effects can benefit from this mitigation measure to provide instantaneous outdoor cooling. Specifically, they find that the cooling effect of the combination of water mist and fan is highly efficient in reducing skin temperature almost instantaneously. This outdoor technology can reduce heat stress and discomfort, particularly at significant outdoor events such as festivals. As this measure benefits the outdoor environment, planning for new developments or urban retrofits could consider including it locally to create cooling points that allow people to enjoy the outdoors in public and private areas (Ruefenacht & Acero, 2017).

Integration possibilities with other technologies.

Water collection and reuse, possibility of automation.

Presence in the case studies.

/



https://bigfogg.com/



https://bigfogg.com/



https://www.icool.co/2019/07/07/mist-cooling-systems/

Innovative and integrated energetic and bioclimatic strategies for adapting existing contexts to climate change and extreme events, aiming to mitigate the environmental impact
p. 290

Technology:	Critical issues related to climate change
Water surfaces	Urban Heat Island  Heat waves 





https://www.archdaily.com/

Context:

Spatial context: type of settlement	Application:	Main immediate environment:
City centre; Suburban areas; Countryside	Indoor; Outdoor; Envelope	Buildings; Streets; Open spaces

Work metod:

SMART PASSIVE ACTIVE

Type of solution:

Typology

Urban space device; Morphological; Technological; Materic; Plant engineering

Green / Blue / Gray

Responsiveness:

Period of installation:

Maintenance: !!!

Life span:

Return environmental period:

Indicators:

Characteristic indicators:


Mean radiant temperature


Relative humidity

Air speed


Air temperature

Other parameters:

Geometry

Material thickness

Roughness


Soil moistre / permeability

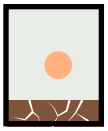
Conducibility


Emissivity

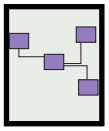

Albedo

Decreased Hazards:


Wildfires

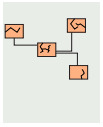

Drought

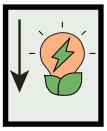
Stress of structures

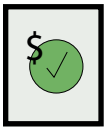

Stress of infrastructures

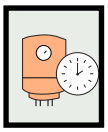

Rainfall

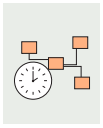

Decreasing of comfort conditions


Energy transmission losses and facilities


Negative impact for renewerable energies


Increasing recovery costs


Increasing deterioration rate of systems and materials


Increasing deterioration rate of infrastructures

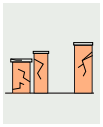
Buildings may became unsuitable for use

Problems with finishing materials

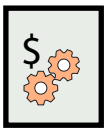
Increasing indoor temperature

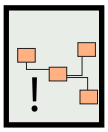

Increasing mortality


Increasing costs for preventing measures


Neighborhoods abandonement

Buildings abandonement


Increasing maintenace costs


Infrastructures may became unsutaible for use


Decrease of air quality

Description.

Planners and architects have used water mirrors as design tools to regulate urban temperature. The rationality behind using water mirrors manifests in increased evaporation during the day. Assuming net radiation as constant, water evaporation uses sensible heat energy, keeping the air temperature at a more comfortable level than without water bodies. In addition to the effect of evaporation, water also has a relatively high heat capacity. As a result, the diurnal temperature range of water is lower than in a rural landscape, i.e. maximum temperature decreases and nighttime cooling is limited (Heusinkveld et al., 2010).

Types.

This type of strategy can come in different forms: through the installation of more or less extensive fountains, through the setting up of water squares or ponds.

Integration possibilities with other technologies.

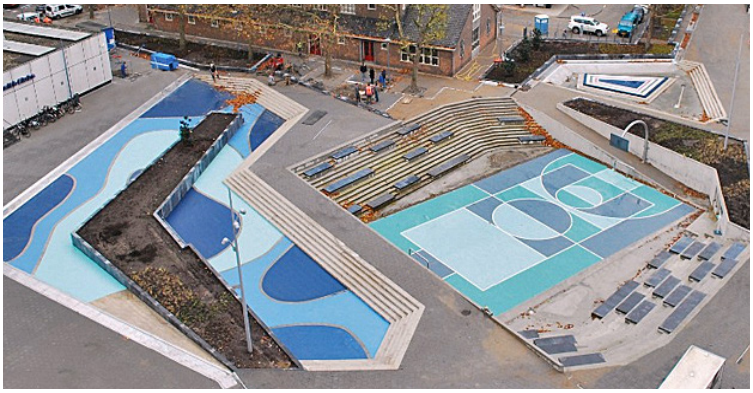
This solution can be integrated with other Blue Technology solutions. For example, with surface drainage systems, or with floodable spaces, ponds or fountains, by better managing runoff. In this sense, the design of open, buried or covered channels that can carry excess water to a cistern or drain it to the water table can be valuable additions. Natural drainage trenches using various plant species can also be a valid alternative. The choice of the type of material in the design of the ponds is decisive in the increase. For example, draining materials or permeable surfaces allow a faster water flow, averting the danger of flooding.

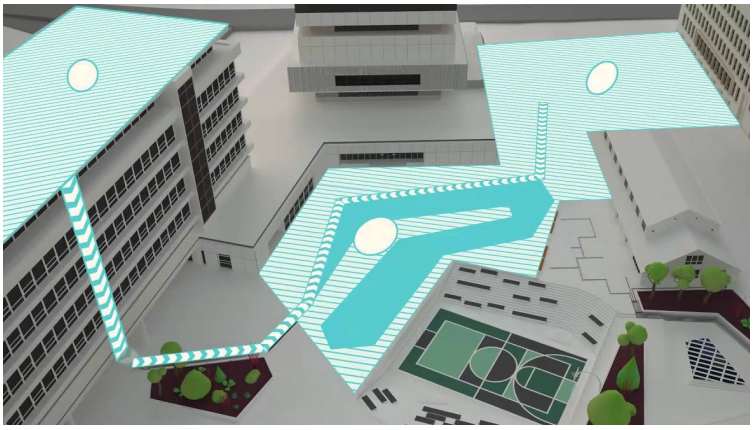
Maintenance.

The maintenance difficulty depends on the type of technological solution used. In general, there is a need to monitor and control electrical and mechanical equipment and hydraulic parts, check valves and flow regulation, control and clean probes and level floats, control, clean, and regulate nozzles, and control water treatment equipment.

Presence in the case studies.

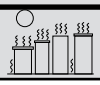
Ecobarrio Trinitat Nova, The Pearl, Ile de Saint Denis



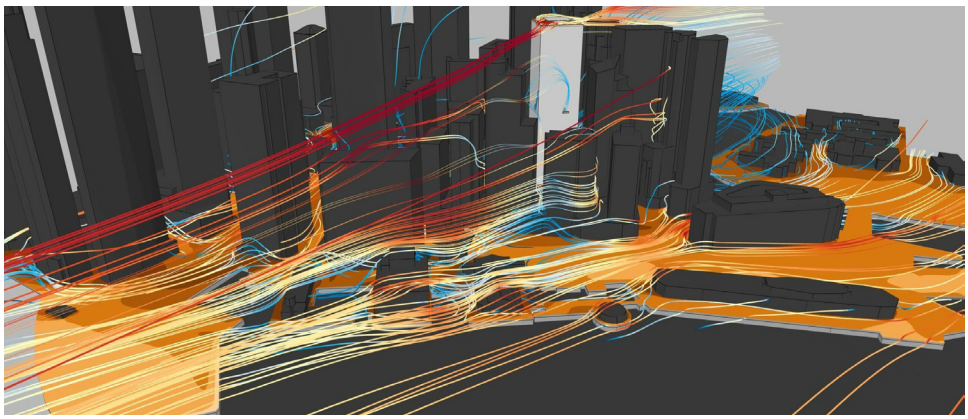


https://cittaclima.it/portfolio-items/rotterdam-piazza-benthemplein/#

https://cittaclima.it/portfolio-items/rotterdam-piazza-benthemplein/#

Technology:	Critical issues related to climate change
Artificial and natural urban devices for guide wind flows	Urban Heat Island  Heat waves 

https://orbital-stack.com/wind-effects-in-urban-design/



Context:

Spatial context: type of settlement	Application:	Main immediate environment:
City centre; Suburban areas; Countryside	Indoor; Outdoor; Envelope	Buildings; Streets; Open spaces

Work metod:

SMART | PASSIVE | ACTIVE

Type of solution:

Typology

Urban space device | Morphological | Technological | Materic | Plant engineering

Green / Blue / Gray

Responsiveness:

Period of installation:

Maintenance: !!!

Life span:

Return environmental period:

Indicators:

Characteristic indicators:


Mean radiant temperature

Relative humidity


Air speed


Air temperature

Other parameters:

Geometry

Material thickness

Roughness

Soil moistre / permeability

Conducibility

Emissivity

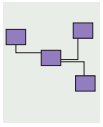
Albedo

Decreased Hazards:


Wildfires

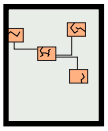

Drought

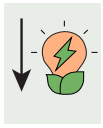
Stress of structures

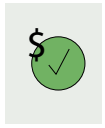

Stress of infrastructures

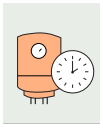

Rainfall

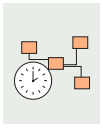

Decreasing of comfort conditions


Energy transmission losses and facilities


Negative impact for renewerable energies

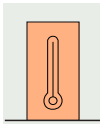

Increasing recovery costs

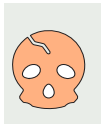

Increasing deterioration rate of systems and materials


Increasing deterioration rate of infrastructures

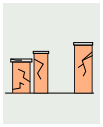
Buildings may became unsuitable for use

Problems with finishing materials


Increasing indoor temperature

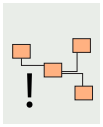

Increasing mortality


Increasing costs for preventing measures


Neighborhoods abandonement

Buildings abandonement


Increasing maintenace costs

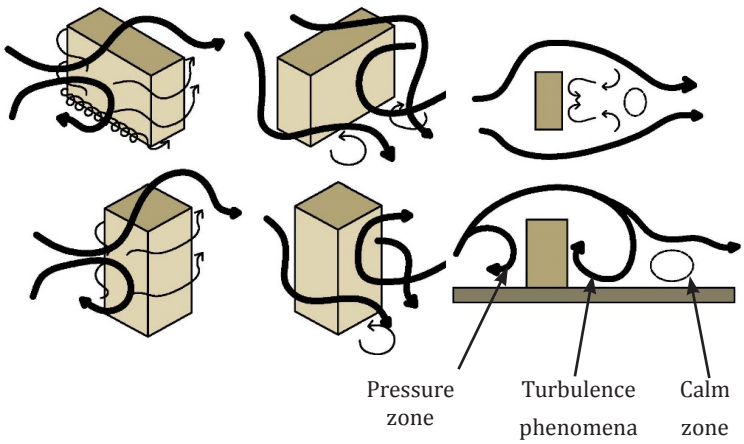

Infrastructures may became unsutaible for use


Decrease of air quality

Description.

The pressure development on a building envelope is represented by a dimensionless coefficient (pressure coefficient), which is defined as the ratio between the building envelope surface dynamic pressure and the dynamic pressure in free flow, calculated at a reference height.

Cp's behaviour:



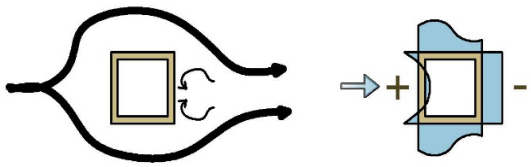
Author's elaboration on the basis of: "Tucci, 2020; Atlas of technological systems for bioclimatic architecture, Altralineaedizioni, Firenze".

When the wind bump into a barrier the air flux react in different ways depending from the shape of the barrier and the environment

- Vortex effect
- Tunnel effect
- Barrier effect
- Venturi effect
- Wake effect
- Canal effect
- Angle effect
- Pressure effect

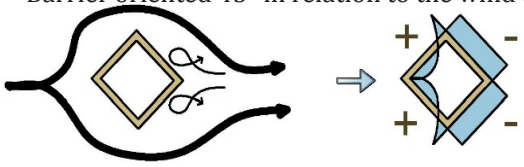
Ventilation around a barrier

- Barrier oriented 90° in relation to the wind direction

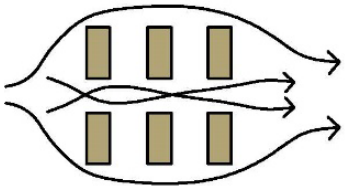


Author's elaboration on the basis of: "Tucci, 2020; Atlas of technological systems for bioclimatic architecture, Altralineaedizioni, Firenze".

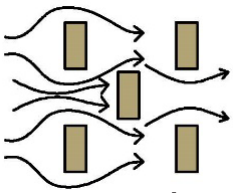
- Barrier oriented 45° in relation to the wind direction



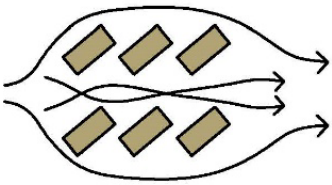
- Barrier arranged in terraced, parallel groups



- Barrier arranged in terraced, alternated groups



- Barrier arranged in terraced, oriented groups



Graphs prepared by the author on the basis of: "Tucci, 2020; Atlas of technological systems for bioclimatic architecture, Altralineaedizioni, Firenze".

Types.

Artificial barriers, green walls, height differences.

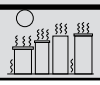
Integration possibilities with other technologies.

Strategies for directing ventilation are very versatile. They can be integrated with natural and artificial shading systems; the buildings that make up the built environment and trees contribute to wind direction. From a material point of view, these systems can complement their performance in combination with cold and reflective materials or in the presence of massive blocks, which increase inertia.

Presence in the case studies.

La Duchére, Hikary project (La Confluence), Limerick, Caserme de Bonne, the Pearl, Ile de Saint Denis

Innovative and integrated energetic and bioclimatic strategies for adapting existing contexts to climate change and extreme events, aiming to mitigate the environmental impact
p. 298

Technology:	Critical issues related to climate change
Artificial shade systems	Urban Heat Island  Heat waves


https://2030palette.org/shading-devices/


https://www.creativeshadesolutions.com/shade-structures/sails/

Context:

Spatial context: type of settlement	Application:	Main immediate environment:
 City centre; Suburban areas; Countryside	 Indoor; Outdoor; Envelope	 Buildings; Streets; Open spaces

Work metod:

SMART PASSIVE ACTIVE

Type of solution:

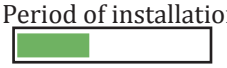
Typology

Urban space device | Morphological | Technological | Materic | Plant engineering

Green / Blue / Gray

Responsiveness:

Period of installation:



Maintenance:

! !

Life span:



Return environmental period:



Indicators:

Characteristic indicators:



Mean radiant temperature

Relative humidity

Air speed



Air temperature

Other parameters:

Geometry

Material thickness

Roughness

Soil moistre / permeability

Conducibility

Emissivity

Albedo

Decreased Hazards:

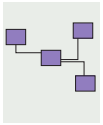


Wildfires



Drought

Stress of structures



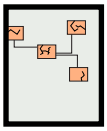
Stress of infrastructures



Rainfall



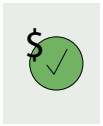
Decreasing of comfort conditions



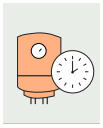
Energy transmission losses and facilities



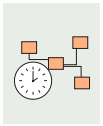
Negative impact for renewerable energies



Increasing recovery costs



Increasing deterioration rate of systems and materials

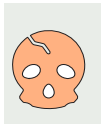


Increasing deterioration rate of infrastructures

Buildings may became unsuitable for use

Problems with finishing materials

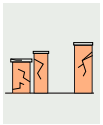
Increasing indoor temperature



Increasing mortality



Increasing costs for preventing measures

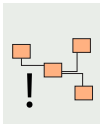


Neighborhoods abandonement

Buildings abandonement



Increasing maintenace costs



Infrastructures may became unsutaible for use



Decrease of air quality

Description.

This typology is divided into fixed exterior shading systems and mobile systems.

- Fixed systems: The objective is to minimize summer heat loads inside buildings. This shading allows for solar protection of transparent envelope surfaces, windows and glazing, avoiding the capture of solar radiation by glazed surfaces. The advantages include eliminating the problems inherent in the mechanization, handling, and motorization of solar shading components that characterize mobile shading systems. They are, therefore, more durable systems, requiring less maintenance. The disadvantages include less adaptability to changes in solar radiation and climatic conditions throughout the day and as the seasons change.
- Mobile shading systems are characterized by great adaptability. These systems can adapt their exposure to incoming solar radiation, changing orientation and location attaìraverso manual, electrical, electronic, or photosensitive activation mechanisms. These shading systems are suitable for situations during which it is important to benefit from the solar contribution.

Typologies.

- Fixed exterior screening systems are classified as:
    - horizontal overhangs
    - Horizontal overhangs are made with screens consisting of slats (horizontal louvres, blades).
- vertical projections
    - Vertical overhangs are made with screens consisting of elements (slats, vertical sunshades, vanes)
    - vertical screens consisting of horizontal and/or vertical elements
- Movable exterior screening systems can be classified into the following categories:
    - horizontal screens with movable elements (horizontal slats, blades)
    - vertical screens consisting of movable elements (vertical slats, blades, panels)
    - horizontal/vertical systems with a continuous surface that can be retracted/extended/wind-up

Integration wih other technologies.

SHADE SYSTEMS INTEGRATED WITH PHOTOVOLTAIC TECHNOLOGIES:
This is one of the most elegant and efficient ways of installing a solar generator, since the building skin doubles as the supporting structure for PV modules, and the building 's electrical installation doubles as the electrical interface between the solar generator and the public electricity grid (Rüther, 2004). PV building integration can thus provide savings in building materials and electricity costs, bring architectural interest to the context, besides reducing fossil fuel use and emission of greenhouse gases (Strong, 2016); pollution is reduced to the visual impact on built environments and landscapes.

Maintenance.

Except for exceptional cases, shading systems are not made of hazardous materials, so the system is disposed of at processing plants for non-harmful waste.

Presence in other case studies.

La Confuence, La Duchére, Seaholm Ecodistrict, Santa Giulia, Cogneto

Technology:	Critical issues related to climate change
Natural shade systems	Urban Heat Island  Heat waves 



https://www.visitgroningen.nl/nl/plekken/stad/parken/3926449168/noorderplantsoen



https://renew.org.au/sanctuary-magazine/ideas-advice/keep-your-cool-with-external-shading/

Context:

Spatial context: type of settlement	Application:	Main immediate environment:
City centre; Suburban areas; Countryside	Indoor; Outdoor; Envelope	Buildings; Streets; Open spaces

Work metod:

SMART | PASSIVE | ACTIVE

Type of solution:

Typology

Urban space device | Morphological | Technological | Materic | Plant engineering

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Maintenance: ! ! !

Life span:

Return environmental period:

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Emissivity

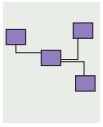

Albedo

Decreased Hazards:


Wildfires

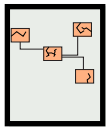

Drought

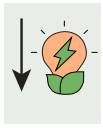
Stress of structures

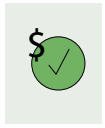

Stress of infrastructures

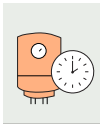

Rainfall

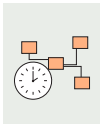

Decreasing of comfort conditions


Energy transmission losses and facilities


Negative impact for renewerable energies


Increasing recovery costs

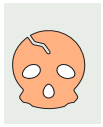

Increasing deterioration rate of systems and materials


Increasing deterioration rate of infrastructures

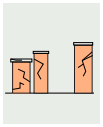
Buildings may became unsuitable for use

Problems with finishing materials

Increasing indoor temperature

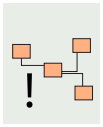

Increasing mortality


Increasing costs for preventing measures


Neighborhoods abandonement

Buildings abandonement


Increasing maintenace costs


Infrastructures may became unsutaible for use


Decrease of air quality

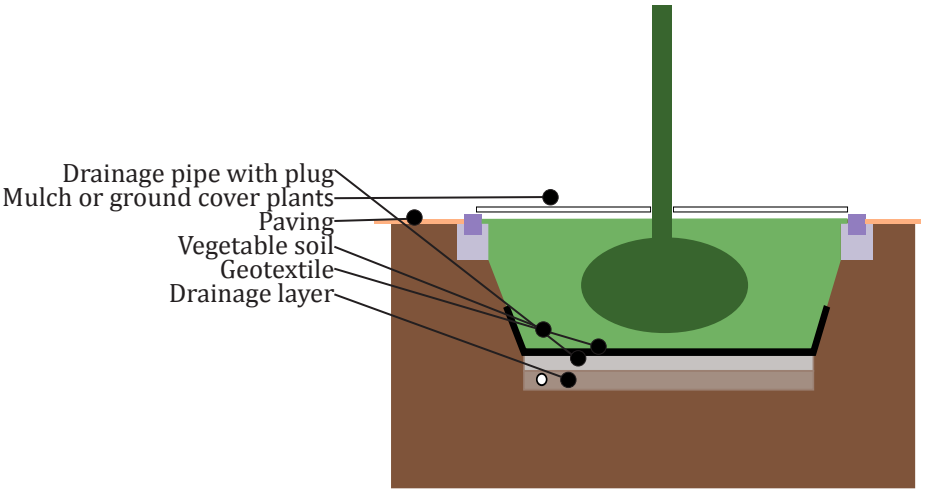
Description.

The design of vegetation screens is a function of the building and its context. This action mitigates the effects of rising temperatures but requires careful design. The parameters for the design are

- type of plant species: deciduous or evergreen
- morphology (size, height quantity and density of foliage)
- position concerning the building
- number of plantings and type of distribution.

Plant species must be selected not only for shading in the summer but also for allowing sunlight to penetrate in the winter. Deciduous types should be chosen to this end.
Plant species must be selected for solar radiation and ventilation: this can trigger ventilative effects such as vortex, barrier, Venturi, tunnel effects, wave, canal angle, and pressure effects; the turbulence must be considered during the design phase. In addition, the effects of vegetated screens cause a wind shadow in the area opposite to that exposed to the ventilative flow, within which the wind speed is reduced by more than 50%. The zone of calm is a function of the type of canopy, the barrier's length and the selected species' height.

Elaboration of the author.



Typologies.

Atificial barriers, green walls, height differences

Integration with other technologies.

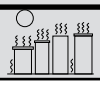
Strategies for directing ventilation are very versatile. They can be integrated with natural and artificial shading systems; the buildings that make up the built environment, as well as trees, contribute to wind direction. From a material point of view, these systems can complement their performance in combination with cold and reflective materials or in the presence of massive blocks, which increase inertia.

Maintenance.

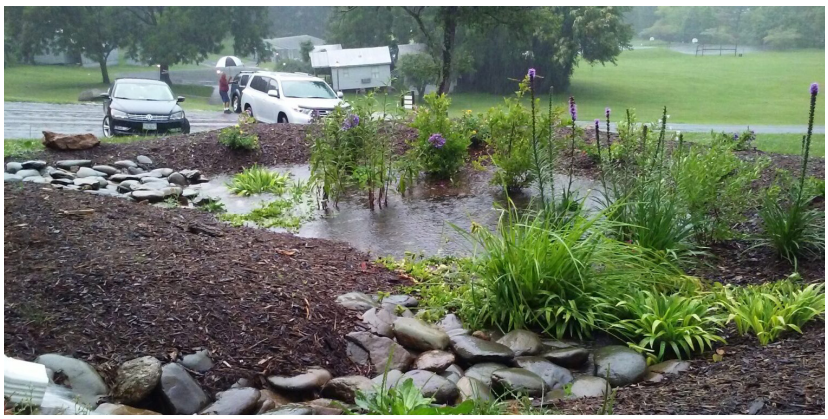
Maintenance varies according to the type of species selected. In general, vegetated walls still need constant watering and monitoring of the plant's health and growth mode so that they do not become dangerous—as in the case of dangerous branches. In the case of deciduous vegetation, the space below and adjacent to it must be cleared of foliage.

Presence in other case studies.

La Duchére, Hikary project (La Confluence), Limerick, Caserme de Bonne, the Pearl, Ile de Saint Denis

Technology:	Critical issues related to climate change
Rain garden and phytodepuration	Urban Heat Island  Heat waves 

https://ideagiardinosnc.it/rain-garden-larmonia-tra-natura-e-sostenibilita-nel-tuo-giardino/



Context:

Spatial context: type of settlement	Application:	Main immediate environment:
City centre; Suburban areas; Countryside	Indoor; Outdoor; Envelope	Buildings; Streets; Open spaces

Work metod:

SMART | PASSIVE | ACTIVE

Type of solution:

Typology

Urban space device | Morphological | Technological | Materic | Plant engineering

Green / Blue / Gray

Responsiveness:

Period of installation:

Maintenance: ! ! !

Life span:

Return environmental period:

Indicators:

Characteristic indicators:


Mean radiant temperature


Relative humidity

Air speed


Air temperature

Other parameters:

Geometry

Material thickness

Roughness


Soil moistre / permeability

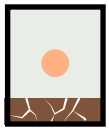
Conducibility

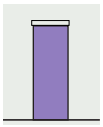

Emissivity

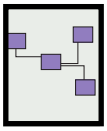

Albedo

Decreased Hazards:


Wildfires

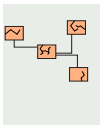

Drought

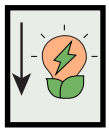

Stress of structures

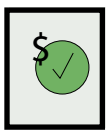

Stress of infrastructures

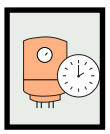

Rainfall

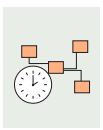

Decreasing of comfort conditions


Energy transmission losses and facilities


Negative impact for renewerable energies

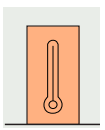

Increasing recovery costs

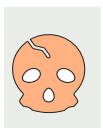

Increasing deterioration rate of systems and materials


Increasing deterioration rate of infrastructures

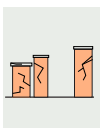
Buildings may became unsuitable for use

Problems with finishing materials

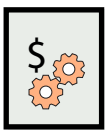

Increasing indoor temperature

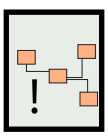

Increasing mortality


Increasing costs for preventing measures


Neighborhoods abandonement

Buildings abandonement


Increasing maintenace costs


Infrastructures may became unsutaible for use


Decrease of air quality

Description.

Rain gardens are shallow depressions perfectly integrated into the landscape. They serve to collect rainwater from roofs or the ground, which undergoes filtration and purification processes facilitated by the soil and plants. Various studies show that suspended solids, heavy metal ions, bacteria or other harmful substances can be removed in this way before entering the soil. (Siwiec, Erlandsen, & Vennemo, 2018) (Kumar, 2019) (Robinson, Schulte-Herbrüggen, Mácsik, & Andersson, 2019) (Shi et al., 2024). Due to their significant landscape and ecological benefits, rain gardens have gained popularity in various contexts, such as residential areas, streets and commercial districts. Rain gardens have been shown to mimic natural ecological processes, playing a key role in restoring the natural water cycle, ensuring the vitality of urban ecosystems and managing stormwater, mitigating water flow rates and volumes, and recharging groundwater aquifers (Caparrós-Martínez, Milán-García, Rueda-López, & de Pablo-Valenciano, 2020; Shi et al., 2024). Rain gardens are structured with multiple layers, including gravel, sand, topsoil, mulch and an aquifer layer, arranged from innermost to outermost (Yuan, 2016; Syafriana & Arifin, 2020; Shi et al., 2024). These systems use a perforated rainwater collection pipe and an overflow pipe to regulate water levels when they exceed the designated storage capacity (Steiner & Domm, 2012; Shi et al., 2024). Steiner and Domm verified that combining rain gardens with surface drainage or gully systems ensures complete drainage within 24-96 hours, thus reducing the likelihood of localised flooding (Steiner & Domm, 2012). Consequently, they act as efficient filters for urban run-off. Herbaceous species are crucial components of rain gardens as they have ecological functions and contribute to the aesthetics of the urban landscape. Herbaceous plants are crucial for retaining rainwater, supplying the soil with water, managing run-off, and contributing to soil stability and erosion resistance. Other studies show that the fibrous bark systems of herbaceous plants are efficient in soil stabilisation, reducing the risk of flooding and decreasing pollutants in water (Shi et al., 2024).

Typologies.

- Submerged flow systems
  - horizontal flow – HF
  - vertical flow – VF
- free water system – FWS

Integration with other technologies.

This type of technology lends itself to becoming part of the green infrastructure system by collaborating with green and blue technologies in water management, increasing soil permeability, and collaborating on urban landscape aesthetics.

Maintenance.

Phytodepuration and rain garden plants present a simple management that does not require continuous commitment or specialised labour. However, they do require some attention as dynamic ecosystems to which many variables contribute. Generally, malfunctioning conditions in a well-designed plant correspond with hydraulic and/or pollutant overload, malfunctioning of primary treatment systems, and clogging of pipes or filling medium. All the checks and actions to be taken to ensure proper operation and maintenance of the plant are contained in the maintenance plan. Each plant should have a 'Maintenance Booklet' recording all interventions carried out on the plant, the reasons why they were carried out and the results obtained. Such a file makes it possible to achieve a high degree of knowledge about the functioning of the system and the system's response to changes in operating modes, as well as establish operating costs. In general, maintenance work is divided into four groups:

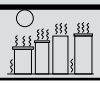
- Primary treatment: To guarantee the proper functioning of the phytodepuration systems, it is necessary to ensure the correct functioning of the primary system and control the deposit of solid material. This can cause clogging of the distribution systems and/or clogging of the filling medium, resulting in a lower efficiency of the purification process and, in the case of horizontal submerged flow systems, surface runoff phenomena. The interventions are monthly.
- For horizontal submerged flow (HF) systems: Horizontal flow (HF) systems are fed continuously, generally by gravity. For this type of system, it is essential to ensure that the free surface of the sewage remains constant at the level envisaged at the design stage. Keeping the inlet velocity at low values is advisable to avoid raising the free water surface near the distribution system outlets and depositing solids on the inlet surface. Interventions are carried out quarterly.
- For vertical submerged flow (VF) systems: Vertical flow (VF) systems are fed discontinuously through devices such as siphons, hoppers, electromechanical valves, or pumps of various types. Good operating conditions for such devices are necessary to achieve as uniform a feed as possible over the system surface, thus maximising purification efficiencies. Following the manufacturer's instructions for electromechanical equipment is usually good practice, while hydraulic or mechanical systems must be cleaned periodically with a pressurised water jet. The interventions are carried out quarterly.
- For free-flow systems: Free-flow systems evolve naturally depending on local environmental characteristics and the relationships between the different plant species. For this reason, if measures have not been taken at the design stage against the propagation of particular species concerning others, it is difficult to rectify abnormal propagation behaviour once it has arisen. Interventions are carried out quarterly.

Presence in the case studies.

Caserme de Bonne, BedZED, Cogneto

Innovative and integrated energetic and bioclimatic strategies for adapting existing contexts to climate change and extreme events, aiming to mitigate the environmental impact

p. 310

Technology:	Critical issues related to climate change
Wetlands and bioswales	Urban Heat Island  Heat waves 



https://www.turenscape.com/en/project/detail/4676.html



https://www.turenscape.com/en/project/detail/4676.html

Context:

Spatial context: type of settlement	Application:	Main immediate environment:
City centre; Suburban areas; Countryside	Indoor; Outdoor; Envelope	Buildings; Streets; Open spaces

Work metod:

SMART | PASSIVE | ACTIVE

Type of solution:

Typology

Urban space device | Morphological | Technological | Materic | Plant engineering

Green / Blue / Gray

Responsiveness:

Period of installation:

Maintenance: ! ! !

Life span:

Return environmental period:

Indicators:

Characteristic indicators:


Mean radiant temperature


Relative humidity

Air speed


Air temperature

Other parameters:

Geometry

Material thickness

Roughness


Soil moistre / permeability

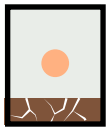
Conducibility

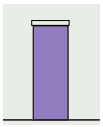

Emissivity

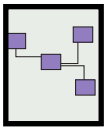

Albedo

Decreased Hazards:


Wildfires

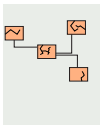

Drought

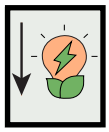

Stress of structures

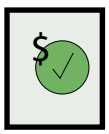

Stress of infrastructures

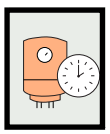

Rainfall

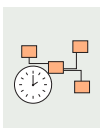

Decreasing of comfort conditions


Energy transmission losses and facilities


Negative impact for renewerable energies

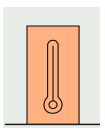

Increasing recovery costs

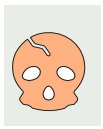

Increasing deterioration rate of systems and materials


Increasing deterioration rate of infrastructures

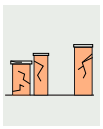
Buildings may became unsuitable for use

Problems with finishing materials

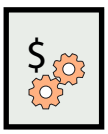

Increasing indoor temperature

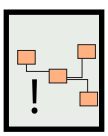

Increasing mortality


Increasing costs for preventing measures


Neighborhoods abandonement

Buildings abandonement


Increasing maintenace costs


Infrastructures may became unsutaible for use


Decrease of air quality

Description.

Wetlands reduce contaminant levels in surface waters, moderate negative impacts on water quality from soil erosion, runoff and wastewater contamination. These types of actions increase water quality by retaining pollutants through mechanical processes (e.g. sedimentation, filtration), uptake into the substrate, and other more complex, interconnected processes between plants and microorganisms, and disinfection due to UV radiation from sunlight (Hatvani IG, 2022; Préau C, 2022; Ferreira et al., 2023). The ability to remove various organic and inorganic substances (e.g. nutrients, heavy metals, pesticides, hydrocarbons, xenobiotics, antibiotics) from contaminated water has been demonstrated. These pollutants can originate from stormwater in agricultural areas (Vymazal J, 2020; Ferreira et al., 2023), from urban surfaces (e.g. roads; Wang J, 2021; Ferreira et al., 2023), and from municipal wastewater (especially from small urban agglomerations without access to municipal networks) (Tang X, 2021; Ferreira et al., 2023). Natural wetlands have a limit to the amount of water that can be added before natural chemical and plant processes are overloaded and interrupted, and thus have a relatively limited capacity to cope with continuous pollution (Saquib E, 2020). Artificial wetlands represent an alternative in wastewater treatment (both as secondary and tertiary treatment) in different climatic regions (temperate, cold, tropical) and particularly in developing countries due to their low cost (Tang X, Urban waterlogging susceptibility assessment based on a PSO-SVM method using a novel repeatedly random sampling idea to select negative samples., 2021; Ferreira et al., 2023). Purified water in wetlands can be used to recycle and reuse water and wastewater for various purposes (e.g., irrigation (Gonzalez-Flo E, 2023; Ferreira et al., 2023). In the last decade, existing wetlands have been integrated with microbial fuel cells as a new wastewater treatment technology that produces bioenergy (Saeed T, 2023; Ferreira et al., 2023). Wetlands can remove up to 90 per cent of sediment in runoff or watercourses (Tanveer S, 2021; Ferreira et al., 2023). These types of solutions increase the efficiency of the hydrological cycle and improve water quality. The effectiveness of wetlands in regulating flow during extreme weather events (floods and droughts) and in water purification depends on their size, location and local conditions. However, optimal water management requires a change of scale from a focus on individual wetlands to a focus on wetland landscapes (Ferreira et al., 2023)

Typologies.

It groups wetlands into marine/coastal, inland, and human-made wetlands, based on their location, vegetation format, hydrological conditions, and natural/man-made setting. These three main Ramsar classes are further subdivided into 42 wetland types according to several characteristics such as type of water and substrate.

Maintenance.

Frequency	Activity
One time—after first year	• Replant vegetation as needed.
Monthly to Quarterly	• Mow embankments—minimum Spring and Fall. • Remove Debris. • Repair eroded or bare soil areas
Several times per hot/warm season	• Check mosquitoes by controlling plant population and water flow into wetland
Semi-annually to annually	• Set-up a trash and debris clean-up day. • Remove invasive plants. • Remove selected wetland plant material or replant vegetation (as needed) • Repair broken mechanical components if needed.
Every 1 to 3 years	• Complete forebay maintenance and sediment removal when needed.

Integration with other technologies.

Tencologies for monitoring, water management and ecosystem preservation

Presence in the case studies.

Ecobarrio Trinitat Nova, Seaholm ecodistrict, the Pearl, Ile de Saint Denis

Technology:	Critical issues related to climate change
Parks, gardens squares, pocket gardens and urban farmings	Urban Heat Island  Heat waves 

https://www.passaggilenti.com/villa-pamphili-parco-roma/



Context:

Spatial context: type of settlement	Application:	Main immediate environment:
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Typology

Urban space device | Morphological | Technological | Materic | Plant engineering

Green / Blue / Gray

Responsiveness:

Period of installation:

Maintenance: ! ! !

Life span:

Return environmental period:

Indicators:

Characteristic indicators:



Mean radiant temperature



Relative humidity



Air speed



Air temperature

Other parameters:

Geometry

Material thickness



Roughness



Soil moistre / permeability

Conducibility



Emissivity



Albedo

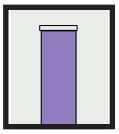
Decreased Hazards:



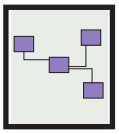
Wildfires



Drought



Stress of structures



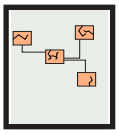
Stress of infrastructures



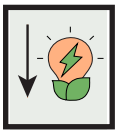
Rainfall



Decreasing of comfort conditions



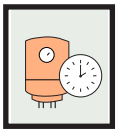
Energy transmission losses and facilities



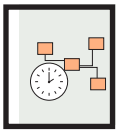
Negative impact for renewerable energies



Increasing recovery costs



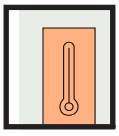
Increasing deterioration rate of systems and materials



Increasing deterioration rate of infrastructures

Buildings may became unsuitable for use

Problems with finishing materials



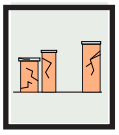
Increasing indoor temperature



Increasing mortality



Increasing costs for preventing measures

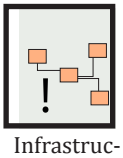


Neighborhoods abandonement

Buildings abandonement



Increasing maintenace costs



Infrastructures may became unsutaible for use



Decrease of air quality

Description.

Parks and greenery in urban areas increase contact with nature, providing crucial relief, considering projections about the increasing stress and number of work hours, and rising pollution in populated areas (Lederbogen et al., 2011). Additionally, urban areas are facing growing pressure due to urban land consumption and soil sealing, contributing to microclimate alteration phenomena, such as Urban Heat Island (UHI) and exacerbated heat waves (Kafy et al., 2021; Moriarty & Honnery, 2015). Previous studies have highlighted the importance of urban parks, demonstrating their role in citizens' psychological well-being (Kim and Jin, 2018), lowering the stress and anxiety of urban life (Schnell et al., 2019); providing restorative experiences, such as recovery from attention fatigue (Kaplan, 1995) as well as acting as recreational destination for nearby residents (Liu & Wang, 2021); and allowing high values of self-reported physical state and life satisfaction (AyalaAzcárraga et al., 2019; Rosso et al., 2022).

Typologies.

- **Parks:** The effects associated with the cooling of parks can be classified into three groups: the composition of the landscape, its spatial pattern and the characteristics of the surrounding areas. According to various research studies, large parks have shown the most significant advantages over other green areas regarding cooling and air purification (Dong, 2024; Peng, 2021; Li et al., 2025; Krekel & MacKerron, 2020). However, there is often not always ample space available in cities for parks.
- **Garden squares and pocket gardens:** While introducing large urban parks is complex in established urban areas, incorporating smaller parks in residual spaces is more easily implemented (Delgado-Capel, 2020). In particular, densely populated areas have paved or asphalted surfaces and a small amount of green space (Fischer, 2018). Smaller urban parks (or pocket gardens) can contribute to a smaller extent to the distribution of the benefits of large parks, allowing more citizens to benefit from green environments more frequently (Zhou, 2021). The key elements of pocket gardens are: their small/ pocket-sized, usually parcelled, built-in residual spaces; their visibility and spread throughout each neighbourhood; the inclusion of green and water features; accessibility and the presence of pedestrian furniture (Rosso et al., 2022).
- **Urban farms** Urban farms make it possible to grow or produce food within built-up areas. They can be installed at various locations in the city, inside or outside buildings, and in underused urban spaces such as rooftops, abandoned buildings, and vacant lots. Urban agriculture presents different opportunities and climatic constraints than rural agriculture. Urban farms can act as green islands within the urban landscape, providing shade and protecting impervious

surfaces from the effects of solar radiation. Like other types of traditional urban greenery, this type of action produces benefits similar to parkland, in terms of thermal comfort, and if extended to a large part of the urban area, can reduce the UHI effect and thus the energy consumption of buildings for cooling. Climate zones with frequent rainfall have an advantage in integrating urban agriculture within the city, as access to water and integration with the environment is easier. The benefits of urban agriculture are to increase the quality of locally grown and produced food, to provide access to quality food for weaker segments of the population, to develop self-sufficiency for city residents, to revitalise society by creating food-based employment, to grow the local community, to reduce CO2 emissions from transporting food from distant producers, to increase food control and safety, and to increase green space. Regarding thermal comfort, urban agriculture positively impacts and contributes to decreasing heat islands within the urban fabric (Ruefenacht & Maple, 2017; Wahdah & Maryono, 2018).

Maintenance.

- All types of green areas require periodic maintenance. However, a judicious choice of plant species, giving precedence to native species, decreases maintenance, as the habitat contributes largely to the needs of the native species.
- Pocket gardens: Compared to parks, these small gardens require less maintenance precisely because of their small size.

Integration with other technologies.

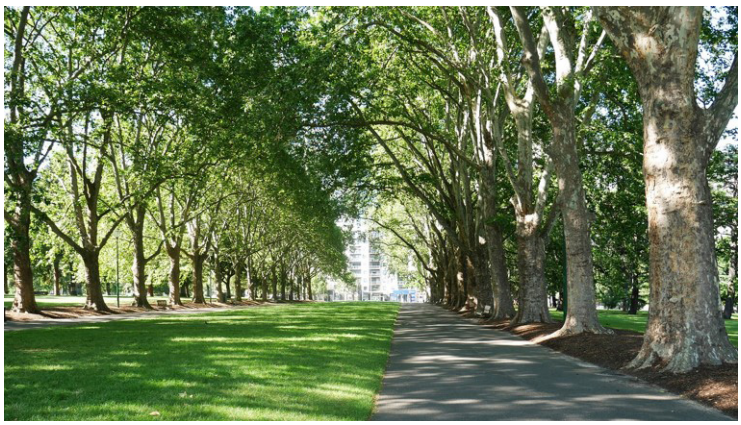
Parks, garden squares, and pocket gardens can easily be integrated with water-related technologies: rain gardens, canals, water retention basins, bioswales, and phyto-purification points can be installed in them. In addition, smart street furniture elements powered by renewable energy sources, permeable or draining surfaces, or cool pavements can be set up. The presence of tree rows increases the benefits of these actions.

Presence in the case studies.

La Duchére, Hikary project (La Confluence), Le Albere, Caserme de Bonne, Villa Fastiggi, Santa Giulia Milano, Cogneto, Ecobarrio Trinitat Nova

Technology:	Critical issues related to climate change
Trees and green corridors	Urban Heat Island  Heat waves 

https://unalab.eu/en/documents/planning-considerations-green-corridors-improvement-biodiversity-resilience-suburban



Context:

Spatial context: type of settlement	Application:	Main immediate environment:
City centre; Suburban areas; Countryside	Indoor; Outdoor; Envelope	Buildings; Streets; Open spaces

Work metod:

SMART | PASSIVE | ACTIVE

Type of solution:

Typology

Urban space device | Morphological | Technological | Materic | Plant engineering

Green / Blue / Gray

Responsiveness:

Period of installation:

Maintenance: ! ! !

Life span:

Return environmental period:

Indicators:

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Air speed



Air temperature

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Roughness



Soil moistre / permeability

Conducibility



Emissivity



Albedo

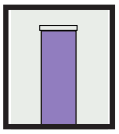
Decreased Hazards:



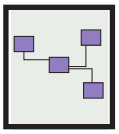
Wildfires



Drought



Stress of structures



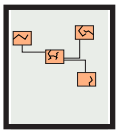
Stress of infrastructures



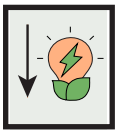
Rainfall



Decreasing of comfort conditions



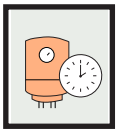
Energy transmission losses and facilities



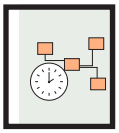
Negative impact for renewerable energies



Increasing recovery costs



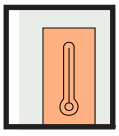
Increasing deterioration rate of systems and materials



Increasing deterioration rate of infrastructures

Buildings may became unsuitable for use

Problems with finishing materials



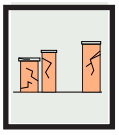
Increasing indoor temperature



Increasing mortality



Increasing costs for preventing measures

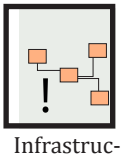


Neighborhoods abandonement

Buildings abandonement



Increasing maintenace costs



Infrastructures may became unsutaible for use



Decrease of air quality

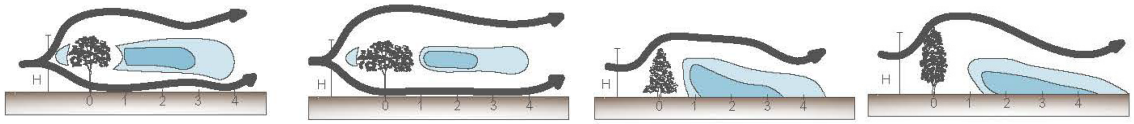
Description.

Vegetation arranged along the road network provides shade to surfaces and facilitates the formation of ventilation corridors. In particular, vegetation has several important effects on the microclimate: it shields solar radiation by absorbing it on the ground and building surfaces, it shields winter winds and channels winter breezes, it modifies the local temperature, it reduces soil evapotranspiration, it increases air humidity, it attenuates noise and reduces air pollution. The effect can vary depending on the density, height and species. These can absorb incoming solar radiation and thus reduce heat accumulation in urban elements. At the same time, the presence of tree rows provides shade to the surfaces below. Furthermore, establishing green rows can contribute to forming ventilation corridors by introducing fresh air into the urban fabric, removing heat build-up and increasing air quality. Therefore, these systems can contribute significantly to mitigating heat wave effects and the occurrence of heat islands. When planning the arrangement of vegetation along transport corridors, the exposure to direct solar radiation and dominant wind directions must be carefully considered. A combination of vegetation elements of different heights and their strategic location may allow for adequate airflow within the transport corridor, thus providing greater benefits to this mitigation measure. In the design phase, trees should be spaced far enough apart so that they do not form fringes, but on the contrary, allow the wind to be channelled. In addition, cool surfaces with low roughness, such as grass, can allow air to move smoothly along corridors, thus avoiding the turbulent vertical air movements produced by warm surfaces (Ruefenacht & Maple, 2017). In definition, establishing green corridors or vegetation barriers allows the implementation of natural ventilation control and management strategies to achieve year-round comfort (Tucci, 2020). In order to make the best use of the effects that the row induces on the vegetation, it is necessary to consider:

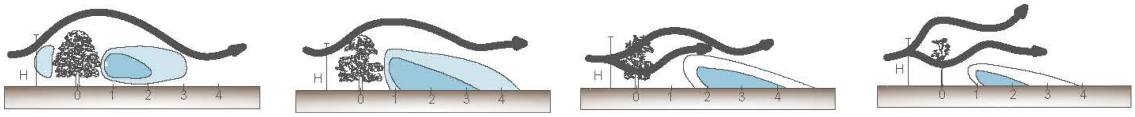
- The length of the row
- The arrangement concerning the direction of wind flow
- The density, i.e. the percentage of empty spaces and plant mass (dense, moderately dense or sparse row)
- The composition of the row (taking into account the individual plant elements next to each other)

Author's elaboration on the basis of: "Tucci, 2020; Atlas of technological systems for bioclimatic architecture, Altralineaedizioni, Firenze".

- Crown shape: calm zone relative calm zone

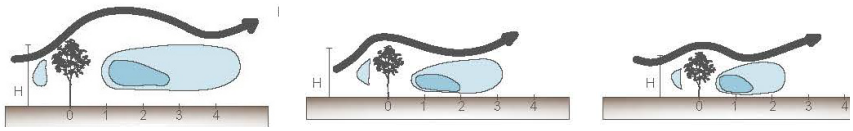


- Foliage density: calm zone relative calm zone

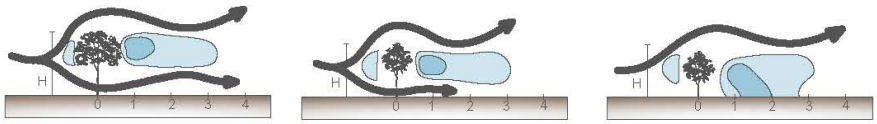


- Plant element height: calm zone relative calm zone

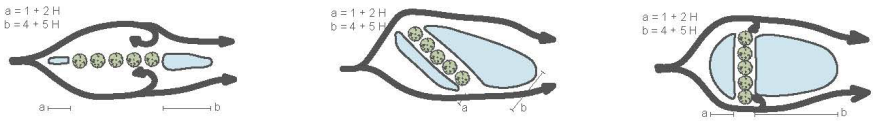
L= KH
with:
L= Shadow lenght
K= Coefficient of proportion
H= Tree's hignt



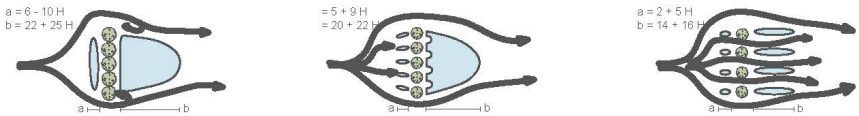
- Plant element height: calm zone relative calm zone



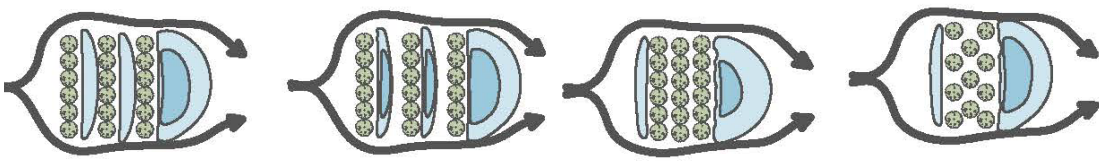
- Cover of soil:
  Vegetational barrier:
  Disposition: calm zone relative calm zone



- Cover of soil:
  Vegetational barrier:
  Density: calm zone relative calm zone

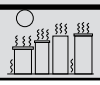


- Cover of soil:
  Vegetational barrier:
  Systems: calm zone relative calm zone



Presence in the case studies.

La Duchére, Hikary project (La Confluence), Laguna da Duero,
Villa Fastiggi, Seaholm Ecodistrict, Cogneto

Technology:	Critical issues related to climate change
Buffer zones	Urban Heat Island  Heat waves 





Context:

Spatial context: type of settlement	Application:	Main immediate environment:
City centre; Suburban areas; Countryside	Indoor; Outdoor; Envelope	Buildings; Streets; Open spaces

Work metod:

SMART PASSIVE ACTIVE

Type of solution:

Typology

Urban space device | Morphological | Technological | Materic | Plant engineering

Green / Blue / Gray

Responsiveness:

Period of installation:

Maintenance:

!

Life span:

Return environmental period:

Indicators:

Characteristic indicators:


Mean radiant temperature

Relative humidity

Air speed


Air temperature

Other parameters:


Geometry

Material thickness

Roughness

Soil moistre / permeability


Conducibility

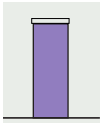

Emissivity

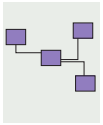

Albedo

Decreased Hazards:


Wildfires

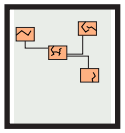

Drought

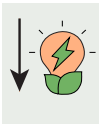

Stress of structures


Stress of infrastructures

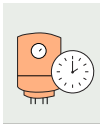
Rainfall


Decreasing of comfort conditions

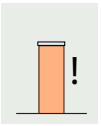

Energy transmission losses and facilities

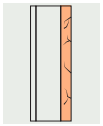

Negative impact for renewerable energies

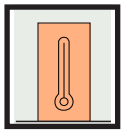

Increasing recovery costs


Increasing deterioration rate of systems and materials

Increasing deterioration rate of infrastructures


Buildings may became unsuitable for use

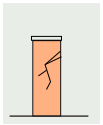

Problems with finishing materials


Increasing indoor temperature


Increasing mortality


Increasing costs for preventing measures

Neighborhoods abandonement


Buildings abandonement


Increasing maintenace costs

Infrastructures may became unsutaible for use


Decrease of air quality

Description.

Buffer zones act as intermediaries between the inside and the outside. They attenuate temperature differences and reduce the impact of winds and atmospheric agents on the building. In this way, they allow a decrease in winter heat loss and energy consumption. In winter, they preheat the outside air; in summer, they promote its exchange through the chimney effect or cross-ventilation. These spaces can be built in different positions:

- Predominantly outdoor space that develops in height. As the number of storeys increases, greater use can be obtained by the increased ventilation provided by the chimney effect in summer. However, if these spaces are not adequately screened in summer, they may lead to overheating of the rooms due to the formation of the greenhouse effect (Tucci, 2020).
- Predominantly internal space facing two sides of the building
- Predominantly external space on the upper side of the building
- Predominantly internal space on the upper side of the building
- Predominantly internal space on one side of the building
- Mainly exterior space on one side of the building
- Combined exterior-interior space on one side of the building

Typologies.

- Buffer spaces with predominantly opaque elements
- Buffer spaces with predominantly transparent elements
- Buffer spaces with combined transparent and opaque elements

Maintenance.

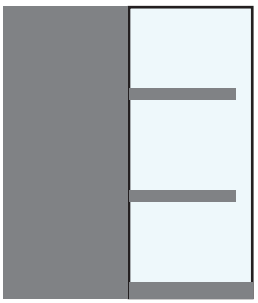
This technology usually requires low maintenance. However, there may be exceptional cases, such as automatically opening facades or maintenance due to water and plants on the walls.

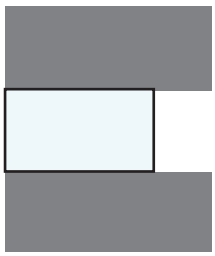
Integration with other technologies.

Buffer spaces can be integrated with green systems and water, enhancing their cooling properties. Water and plants remove the necessary heat from the environment for the change of state that occurs during transpiration and evapotranspiration. Vegetation screens out the sun's rays in summer and enriches the air with oxygen.

Presence in the case studies.

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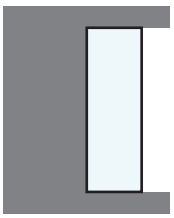


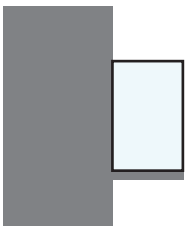


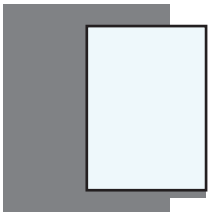
Types of buffer spaces in relation to their position within the building. The author's re-elaboration is based on
Tucci, F., 2021, Atlas of technological systems for bioclimatic architecture, Altralinea Edizioni, Florence.

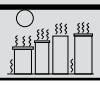










Technology:	Critical issues related to climate change
Bioclimatic atria	Urban Heat Island  Heat waves 





https://www.archdaily.com/772978/villa-blm-atria-arquitetos

Context:

Spatial context: type of settlement	Application:	Main immediate environment:
City centre; Suburban areas; Countryside	Indoor; Outdoor; Envelope	Buildings; Streets; Open spaces

Work metod:

SMART PASSIVE ACTIVE

Type of solution:

Typology

Urban space device | Morphological | Technological | Materic | Plant engineering

Green / Blue / Gray

Responsiveness:

Period of installation:

Maintenance:

!!

Life span:

Return environmental period:

Indicators:

Characteristic indicators:


Mean radiant temperature

Relative humidity


Air speed


Air temperature

Other parameters:


Geometry

Material thickness

Roughness

Soil moistre / permeability


Conducibility

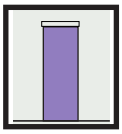

Emissivity


Albedo

Decreased Hazards:

Wildfires

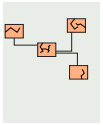
Drought

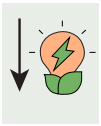

Stress of structures

Stress of infrastructures

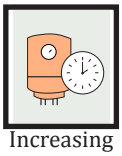
Rainfall


Decreasing of comfort conditions

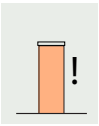

Energy transmission losses and facilities

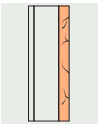

Negative impact for renewerable energies

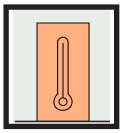

Increasing recovery costs


Increasing deterioration rate of systems and materials

Increasing deterioration rate of infrastructures


Buildings may became unsuitable for use

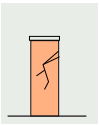

Problems with finishing materials


Increasing indoor temperature


Increasing mortality


Increasing costs for preventing measures

Neighborhoods abandonement


Buildings abandonement

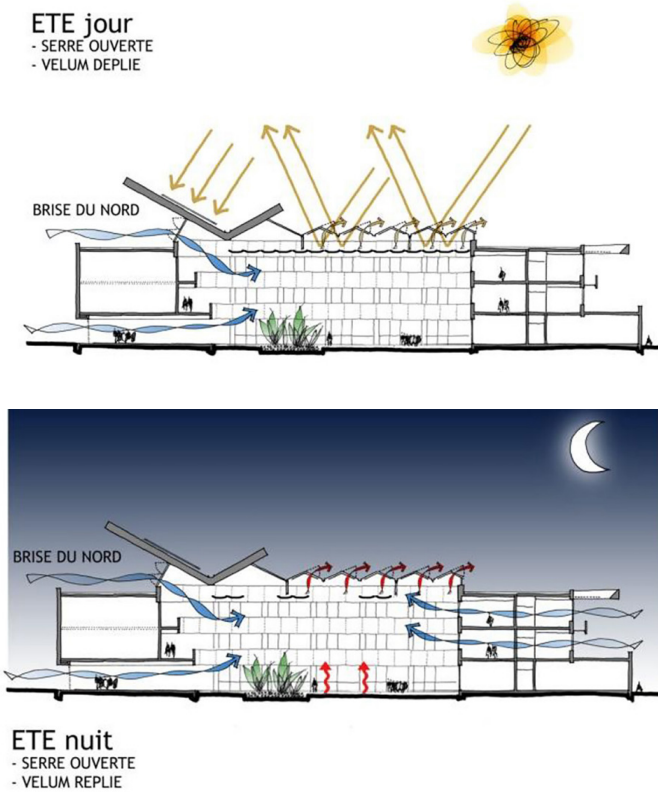

Increasing maintenace costs

Infrastructures may became unsutaible for use


Decrease of air quality

Description.

Bioclimatic atria are large spaces overlooked by the building's rooms on different floors. These solutions mediate between the internal and external environment, contributing to the mitigation of various problems that can occur in large buildings, such as natural lighting, ventilation, and a possible reduction in heating and cooling consumption. Bioclimatic atria always have openings that enable mechanisms based on natural ventilation, either through the chimney effect or cross ventilation. These rooms also act as a thermal flywheel as they delay and attenuate temperature changes from the outside by enclosing an important air mass in the building. During the winter, they act as a reservoir of pre-heated air; during the summer, they can extract exhausted air from the building by expelling it outside. (Tucci, 2020)

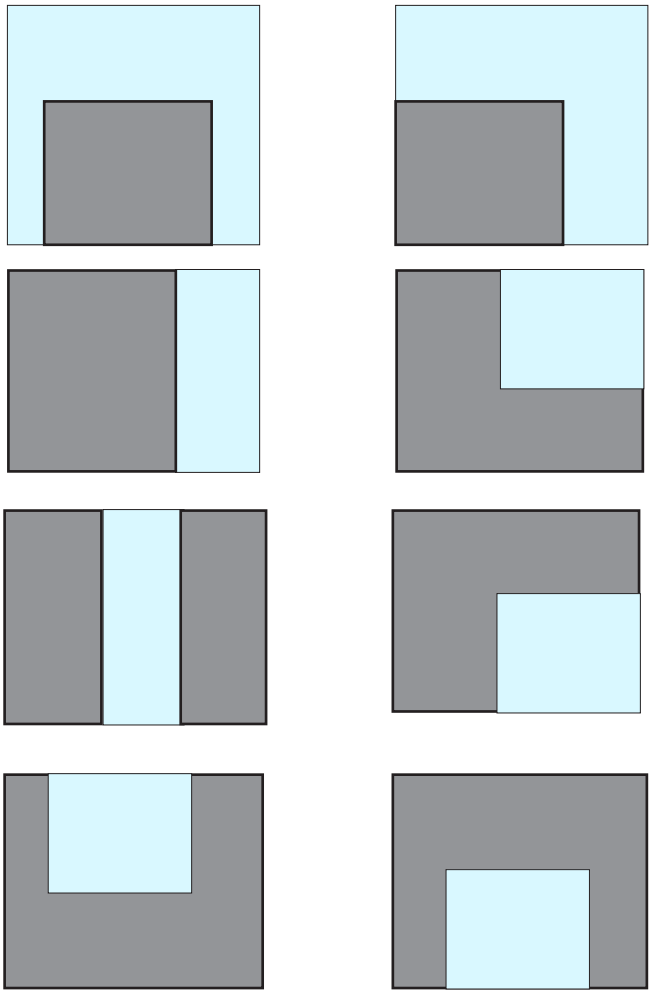


Atria working method. https://www.casaeclima.com/ar_21883_PROGETTI-Nuovi-edifici-edificio-bioclimatico-INES-Edificio-bioclimatico-per-la-sede-del-National-Solar-Energy-Institute-INES.

Typologies.

- Partially or fully enclosed atrium
- Lateral external atrium
- Interclosing or partially external atrium

The constituent elements of the atria may be fixed or openable. They may have openings at the ends of each element, a central opening at the ends of the walls, or diffuse openings.



Tipologie di bioclimatic atria in relazione alla pozizione all'interno dell'edificio. Rielaborazione dell'autrice sulla base di: Tucci, F.; 2021, Atlante dei sistemi tecnologici per l'architettura bioclimatica, Altralinea Edizioni, Firenze.

Maintenance.

Bioclimatic atriums must undergo regular maintenance, especially to maintain the envelope, the clean air circulation system and the proper functioning of the openings.

Integration with other technologies.

These spaces are easily integrated with planting plant species inside the atrium, which improves air quality and helps keep the environment fresh and healthy. Water mirrors can also be present to humidify the environment and improve comfort.

Presence in the case studies.

Hikary Project (La Confluence), Millvale

Technology:	Critical issues related to climate change
Cooling towers	Urban Heat Island  Heat waves 

https://www.architetturaecosostenibile.it/architettura/criteri-progettuali/torri-vento-sistemi-raffrescamento-833



Context:

Spatial context: type of settlement	Application:	Main immediate environment:
City centre, Suburban areas, Countryside	Indoor, Outdoor, Envelope	Buildings, Streets, Open spaces

Work metod:

SMART | PASSIVE | ACTIVE

Type of solution:

Typology

Urban space device | Morphological | Technological | Materic | Plant engineering

Green / Blue / Gray

Responsiveness:

Period of installation:

Maintenance:

!

Life span:

Return environmental period:

Indicators:

Characteristic indicators:


Mean radiant temperature


Relative humidity


Air speed


Air temperature

Other parameters:


Geometry

Material thickness

Roughness

Soil moistre / permeability

Conducibility

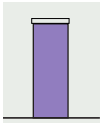
Emissivity

Albedo

Decreased Hazards:

Wildfires

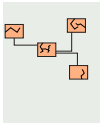
Drought

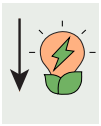

Stress of structures

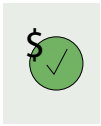
Stress of infrastructures

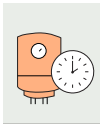
Rainfall


Decreasing of comfort conditions

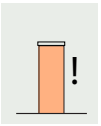

Energy transmission losses and facilities

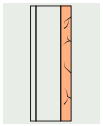

Negative impact for renewerable energies

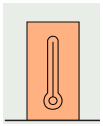

Increasing recovery costs


Increasing deterioration rate of systems and materials

Increasing deterioration rate of infrastructures


Buildings may became unsuitable for use

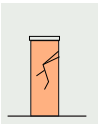

Problems with finishing materials


Increasing indoor temperature


Increasing mortality


Increasing costs for preventing measures

Neighborhoods abandonement


Buildings abandonement


Increasing maintenace costs

Infrastructures may became unsutaible for use


Decrease of air quality

Description.

These technological systems are rooted in history and have fields of application that are not only related to cooling. These solutions can contribute positively to satisfying ventilation needs at any time of year, either by expelling stale air to the outside or introducing replacement air into the building. The tower opening must be higher than the surrounding buildings for the system to function correctly. The chimney effect also benefits from the elevation of the towers. This effect can be increased by heating the upper portion of the tower. (Tucci, 2020)

Typologies.

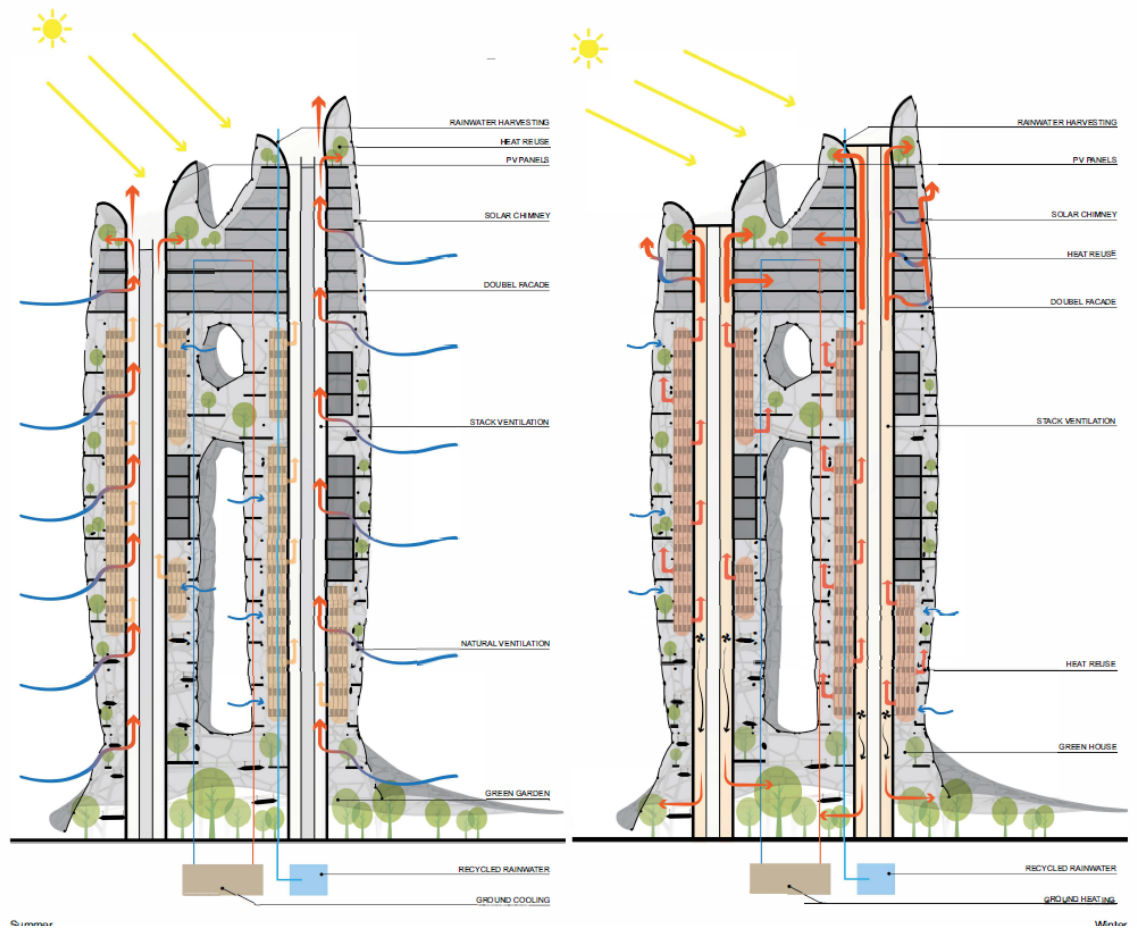
- Ventilation towers with downward air flow
- Extraction towers with upward air flow
- Integrated air intake and exhaust towers

Integration with other technologies.

- Ventilation towers with integrated cooling systems: the main integration possibilities concern soil, water and vegetation use. The thermal inertia of the soil is utilised by coupling the tower with underground ducts that can be located in an intermediate position between the room to be cooled and the ventilation tower, receiving external air from the latter and then feeding it into the building, or in a position at the beginning of the air duct, drawing it directly from the outside thanks to the draught from the tower. On the other hand, water and plants are used for cooling through evapotranspiration and transpiration processes that remove the heat necessary to pass the water state from the air. Cooling benefits are achieved by putting the air flow before it enters the indoor environment, in contact with vegetation, mirrors, sprays or mists of water. This system is recommended in hot, dry climates, but strongly discouraged in hot, humid climates, due to the excessive humidification that these systems would bring to the rooms.
- Ventilation channels
- Ventilation plate

Presence in the case studies.

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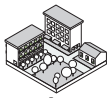
Example of the operation of an integrated ventilation tower with supply and return systems. https://ebd.design.upenn.edu/work/des-moines-bioclimatic-studio-2022.

Innovative and integrated energetic and bioclimatic strategies for adapting existing contexts to climate change and extreme events, aiming to mitigate the environmental impact
p. 334

Technology:	Critical issues related to climate change
Green systems embedded in buildings	Urban Heat Island  Heat waves



Context:

Spatial context: type of settlement	Application:	Main immediate environment:
City centre  Suburban areas  Countryside 	Indoor  Outdoor Envelope 	Buildings  Streets Open spaces

Work metod:

SMART PASSIVE ACTIVE

Type of solution:

Typology

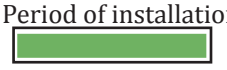
Urban space device | Morphological | Technological | Materic | Plant engineering

Green / Blue / Gray



Responsiveness:

Period of installation:



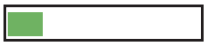
Maintenance:

! ! !

Life span:



Return environmental period:



Indicators:

Characteristic indicators:


Mean radiant temperature


Relative humidity

Air speed


Air temperature

Other parameters:

Geometry

Material thickness


Roughness

Soil moistre / permeability


Conducibility

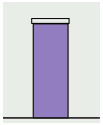

Emissivity


Albedo

Decreased Hazards:

Wildfires

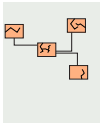
Drought

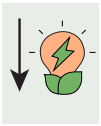

Stress of structures

Stress of infrastructures

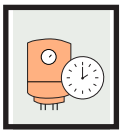
Rainfall


Decreasing of comfort conditions

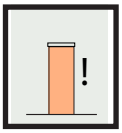

Energy transmission losses and facilities

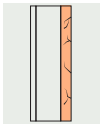

Negative impact for renewerable energies

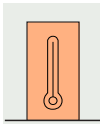

Increasing recovery costs


Increasing deterioration rate of systems and materials

Increasing deterioration rate of infrastructures


Buildings may became unsuitable for use

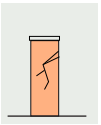

Problems with finishing materials


Increasing indoor temperature


Increasing mortality


Increasing costs for preventing measures

Neighborhoods abandonement


Buildings abandonement


Increasing maintenace costs

Infrastructures may became unsutaible for use


Decrease of air quality

Description.

The integration of greenery within the building has various advantages, both psychologically and physiologically. Various solutions are available and include different amounts of coverage. Particularly concerning the perception of well-being and stress reduction, a green density of 13%-24 % was found to be the most efficient in indoor environments (Rhee et al., 2023).

Typologies.

- Indoor vegetation
- Indoor green walls
- Combination of indoor vegetation, indoor green walls and windows with outdoor vegetation
- Presence of wood: The use of this material for construction or finishing is highly valued as it has low thermal conductivity values and has been proven to have significant psychological benefits. (Yan & Guo, 2023). In particular, the research finds less mental fatigue and decompression in the young and old (Rhee et al., 2023).

Integration with other technologies.

- Water reuse systems
- possibility of remote control

Presence in the case studies.

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www.archello.com



www.archello.com



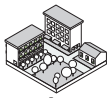
www.archello.com

Technology:	Critical issues related to climate change
Green houses and winter gardens	Urban Heat Island  Heat waves

https://eng.smania.it/blog/the-winter-garden/



Context:

Spatial context: type of settlement	Application:	Main immediate environment:
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Work metod:

SMART PASSIVE ACTIVE

Type of solution:

Typology

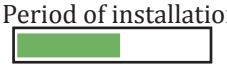
Urban space device | Morphological | Technological | Materic | Plant engineering

Green / Blue / Gray



Responsiveness:

Period of installation:



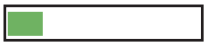
Maintenance:

!!

Life span:



Return environmental period:



Indicators:

Characteristic indicators:


Mean radiant temperature


Relative humidity


Air speed


Air temperature

Other parameters:


Geometry

Material thickness

Roughness

Soil moistre / permeability


Conducibility

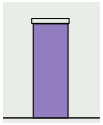
Emissivity

Albedo

Decreased Hazards:

Wildfires

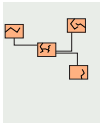
Drought

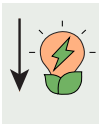

Stress of structures

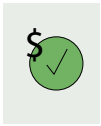
Stress of infrastructures

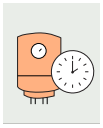
Rainfall


Decreasing of comfort conditions

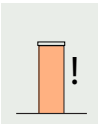

Energy transmission losses and facilities

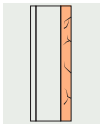

Negative impact for renewerable energies

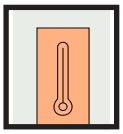

Increasing recovery costs


Increasing deterioration rate of systems and materials

Increasing deterioration rate of infrastructures


Buildings may became unsuitable for use

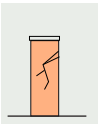

Problems with finishing materials


Increasing indoor temperature


Increasing mortality


Increasing costs for preventing measures

Neighborhoods abandonement


Buildings abandonement


Increasing maintenace costs

Infrastructures may became unsutaible for use


Decrease of air quality

Description.

These systems are among the bioclimatic technologies based on capturing solar energy by large glazed surfaces that delimit a greenhouse environment interposed between the exterior and the other building spaces. This environment can function as a solar collector, favouring the absorption and accumulation of heat energy by appropriate thermal masses. In energy retrofitting operations, these spaces can be realised by enclosing loggias or balconies with a glazed system and then increasing, if necessary, the thermal mass of the separating wall between the solar space and the inhabited space. These systems are suitable in winter as solar and thermal energy collectors. However, they also work well in summer by including external shading systems and the possibility of opening greenhouses that ensure ventilation and defence against excessive radiation and air stagnation. In this context of mitigating the effects of islands and heat waves, these technological solutions are also helpful for their summer behaviour, thus with openable shading systems. There are various shading methods for varying climatic zones to achieve different levels of cooling and ventilation.

Typologies.

1. The first type of solar greenhouses consists of three independent glass walls and a single vertical surface shared with the building to which they belong. In this case, the roof is also made of glass and is usually sloping.
2. The second type is the integrated solar greenhouse, which shares most of its surface area with the building. These systems share three of the four transparent walls with the building, and the roof is opaque.
3. Finally, the third type of storage greenhouse, which can be chosen according to the needs, is the semi-enclosed greenhouse, which encompasses the characteristics of the two previous solutions. This type of greenhouse has side walls and a roof partially attached to the building.

Regardless of the type chosen, the bioclimatic greenhouse is an excellent solution for improving the thermal performance of the building. Used since ancient times to optimise the climatic conditions necessary for the growth of plant species, it has developed over time, finding wide use in various sectors. Initially used to ensure comfort in winter, it was used in summer for its good bioclimatic behaviour. In some Northern European countries, solar greenhouses now constitute additional rooms for homes.https://www.archweb.com/en/the-bioclimatic-greenhouse/

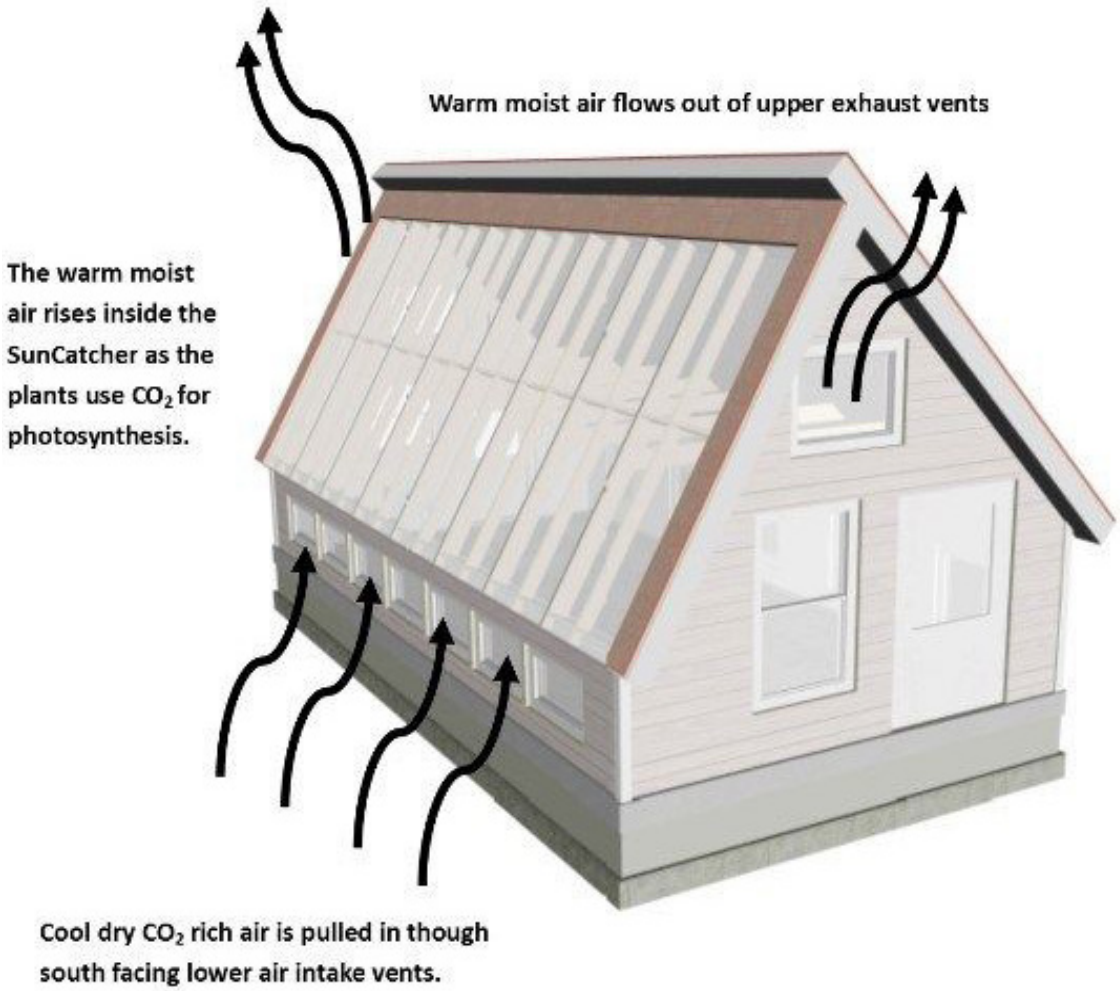
Integration with other technologies.

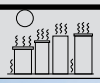
- Shading with an active cooling method
- Shading with increased humidity
- Integration with photovoltaic shading systems

Presence in the case studies.

BedZED

https://www.suncatchergreenhouse.com/science/



Technology:	Critical issues related to climate change
Shading building devices	Urban Heat Island  Heat waves



Picture taken by the author. Suzhou, Spring 2024.

Context:

Spatial context: type of settlement	Application:	Main immediate environment:
City centre, Suburban areas, Countryside	Indoor, Outdoor, Envelope	Buildings, Streets, Open spaces

Work metod:

SMART PASSIVE ACTIVE

Type of solution:

Typology

Urban space device | Morphological | Technological | Materic | Plant engineering

Green / Blue / Gray

Responsiveness:

Period of installation:

Maintenance:

!

Life span:

Return environmental period:

Indicators:

Characteristic indicators:


Mean radiant temperature

Relative humidity

Air speed

Air temperature

Other parameters:


Geometry

Material thickness

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Soil moistre / permeability

Conducibility

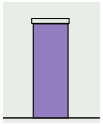

Emissivity


Albedo

Decreased Hazards:

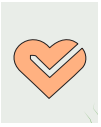
Wildfires

Drought

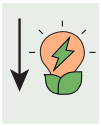

Stress of structures

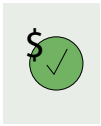
Stress of infrastructures

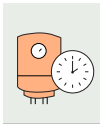
Rainfall


Decreasing of comfort conditions

Energy transmission losses and facilities

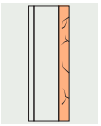

Negative impact for renewerable energies


Increasing recovery costs


Increasing deterioration rate of systems and materials

Increasing deterioration rate of infrastructures

Buildings may became unsuitable for use

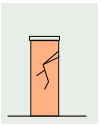

Problems with finishing materials

Increasing indoor temperature

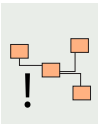

Increasing mortality


Increasing costs for preventing measures

Neighborhoods abandonement


Buildings abandonement


Increasing maintenace costs


Infrastructures may became unsutaible for use

Decrease of air quality

Description.

Outdoor shading systems in buildings allow solar protection of transparent envelope surfaces, windows, and glazing. These systems prevent the capture of solar radiation by surfaces that can generate greenhouse gases inside rooms and increase indoor temperature. Likewise, outdoor shading systems can protect pedestrians or cyclists from direct sunlight, rain, and high temperatures, increasing comfort.

Typologies.

- Fixed external shading systems: these systems eliminate the problems inherent in mechanisation, handling and possible motorisation of the solar shading components that characterise mobile systems. The advantages are in terms of durability and less need for maintenance. The disadvantages consist of less adaptability to the variability of sunshine. The dimensioning of these systems is done according to precise calculation methods, to provide adequate shading in the most unfavourable period and optimise shading behaviour at different times of day. These systems can be classified into:
  - Systems applicable to the external envelope of buildings, which are divided into
  - Horizontal projections: These can protect façades and openings exposed to the south, south-east, and south-west from sunlight. However, they are not functional for east and west orientations, as they have lower inclination angles of the sun's rays. This type of overhang intercepts the sun's rays depending on the angle of incidence. Horizontal overhangs can be realised through screens of elements, such as vertical louvres, blades, etc.
  - Vertical projections: this type of solar shading intercepts the sun's rays according to the direction of their origin, i.e. their azimuth angle. This type of overhang can be realised through screens of elements (vertical louvres, blades) and vertical screens of horizontal and/or vertical slats.
  - Outdoor systems
  - Outdoor Permanent shading devices
  - Shaded bicycle lanes
  - Shaded pedestrian lanes:
- Mobile external shading systems: these shading systems adapt their exposure to incoming solar radiation through the possibility of changing orientation and position through manual, electrical or electronic activation mechanisms, correlated to photosensitive solar radiation detection sensors. As the sunshine situation changes, the sun protection adapts, and the shading is constant, appropriate for any time of day or year. These solutions are suitable if solar gain is needed at certain times of the year. The macro-types into which external mobile shading solutions are divided are:
  - Systems applicable to the building envelope:

- Horizontal screens consisting of movable elements, such as horizontal slats or posts
- Vertical screens consisting of movable elements such as vertical slats, posts and panels
- Horizontal/vertical continuous-surface, retractable/ extensible/folding systems

Maintenace.

Fixed shading systems can be made of various materials: metal sheets, extruded aluminium, wood, glass, PVC, brick or ceramic material. Sometimes reinforced concrete is also used for fixed projections. By consulting and calculating sun diagrams, it is possible to dimension these shading systems. Mobile shading systems, on the other hand, can be moved by different types of operations and mechanics:

- Through a manual mechanical control
- Electric, with user control
- Automatic with electronic control unit
- Mixed

Presence in the case studies.

La Duchére, Boucicault, Seaholm Ecodistrict, Santa Giulia Milano

Innovative and integrated energetic and bioclimatic strategies for adapting existing contexts to climate change and extreme events, aiming to mitigate the environmental impact

p. 346

Technology:	Critical issues related to climate change
External coat and ETICS technology	Urban Heat Island  Heat waves





https%3A%2F%2Ffacade.agrob-buchtal.de

Context:

Spatial context: type of settlement	Application:	Main immediate environment:
City centre, Suburban areas, Countryside	Indoor, Outdoor, Envelope	Buildings, Streets, Open spaces

Work metod:

SMART | PASSIVE | ACTIVE

Type of solution:

Typology

Urban space device | Morphological | Technological | Materic | Plant engineering

Green / Blue / Gray

Responsiveness:

Period of installation:

Maintenance:

!

Life span:

Return environmental period:

Indicators:

Characteristic indicators:


Mean radiant temperature


Relative humidity

Air speed


Air temperature

Other parameters:


Geometry


Material thickness


Roughness

Soil moistre / permeability

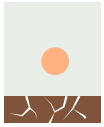

Conducibility

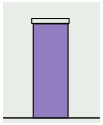

Emissivity

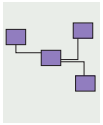

Albedo

Decreased Hazards:


Wildfires

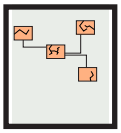

Drought

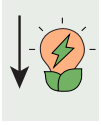

Stress of structures


Stress of infrastructures

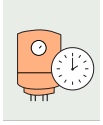
Rainfall

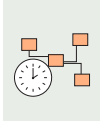

Decreasing of comfort conditions

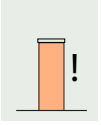

Energy transmission losses and facilities

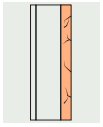

Negative impact for renewerable energies

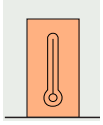

Increasing recovery costs


Increasing deterioration rate of systems and materials


Increasing deterioration rate of infrastructures


Buildings may became unsuitable for use

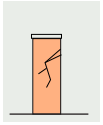

Problems with finishing materials


Increasing indoor temperature

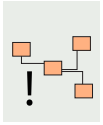

Increasing mortality


Increasing costs for preventing measures

Neighborhoods abandonement


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Increasing maintenace costs


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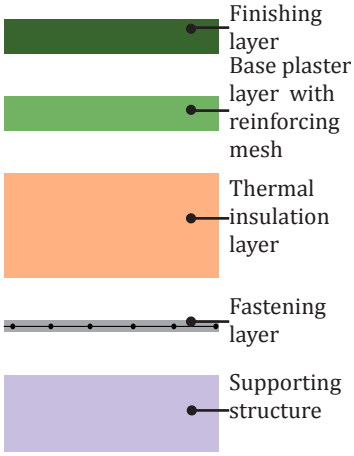

Decrease of air quality

Description.

There are two types of thermal insulation systems: the traditional type, in which the designer or project manager chooses the insulating materials and whose technical characteristics have not been verified as being compatible with each other, and the ETICS systems, i.e. 'External Thermal Insulation Composite System', characterised by certified technical solutions, realised with materials whose specific technical-performance properties have been previously verified, tested and certified as being compatible with each other.
Specialised labour is required to realise these systems. This type of technology allows high-energy performance to be achieved and maintained over time.
These types of systems differ from traditional systems in that they comply with three fundamental requirements

- ETAG 004 or EAD 040083-00-0404 certification
- design according to UNI/TR 11715:2018
- realisation and installation by specialised professionals according to UNI 11716:2018
  The advantages of using thermal insulation technology consist in the elimination of thermal bridges in the façade, as it completely covers the external surface of the building.
  The disadvantage is that this type of technology cannot be used for buildings of historical architectural value or where the aesthetic appearance of the external envelope must be preserved.

An ETICS insulation system consists of the following elements: a fixing layer, a thermal insulation layer, a base plaster layer with reinforcing mesh, and a finishing layer.
The fixing layer comprises an adhesive layer and a possible mechanical fixing made of dowels. The purpose of this layer is to allow the cladding to withstand the vertical loads due to its weight and the horizontal loads caused by the action of the wind.
The purpose of the thermal insulation layer is to insulate the building thermally. According to EN 17237 *Thermal Insulation products for buildings - External thermal Insulation - Specification,* the materials constituting this layer can be mineral wool, expanded polystyrene, extruded expanded polystyrene products, rigid expanded polyurethane, cellular glass, spanned phenolic resins, expanded cork, wood fibres. A reinforcing mesh characterises the plaster layer to absorb surface tension and mechanical stresses.
The finishing layer protects the building from atmospheric agents and enhances its aesthetic architectural character.



Author's elaboration on the basis of: "D'Olimpio, 2023; Il retrofitting tecnologico, energetico e bioclimatico nell'edilizia, Legislazione tecnica, Borgoricco".

Typologies.

- Phase change materials (PCM) are materials of natural or artificial origin characterised by the ability to change from a solid to a liquid state and vice versa, using latent thermal energy exchanged at constant temperature with the environment during phase transitions.
- Fibre-reinforced materials, alkaline activated fibres: This type of insulation is characterised by greater mechanical resistance and a longer life.
- Ultralight insulation foam consists of insulation materials derived from solid industrial, agricultural and forestry waste.
- Vacuum Insulation Panels (VIP) consist of a core material with a small pore size, approximately 10-100 nm, enclosed in a thin laminated film with low gas permeability. The core material is evacuated at pressures of 0.2-3 mbar, which, depending on the core material, gives a thermal conductivity of 2-4 mW/(m-K). The laminate is not perfectly gas-tight, which makes it possible for gas molecules to diffuse through the casing, leading to an irreversible pressure increase in the VIP. The speed of the increase in pressure depends on the core material, the type of laminate, and the surrounding climate (Simmler et al., 2005). This review is based on the available literature, where most of the studies are conducted on VIPs with a fumed silica core with a metallised multilayer laminate.

Maintenance.

Specific studies confirm the ETICS type of coat's durability; the components remain in good condition and retain their functionality even after 30 years.

Presence in the case studies.

Circular Buiksloterham, Seaholm Ecodistrict, BedZED, Cogneto, CitiZen Amsterdam

Technology:	Critical issues related to climate change
Green walls	Urban Heat Island  Heat waves 

https://www.jakob.com/dk/en/news/green-walls-as-natural-air-conditioning



Context:

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Type of solution:

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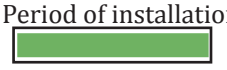
Urban space device | Morphological | Technological | Materic | Plant engineering

Green / Blue / Gray



Responsiveness:

Period of installation:



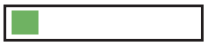
Maintenance:

! ! !

Life span:



Return environmental period:



Indicators:

Characteristic indicators:


Mean radiant temperature


Relative humidity

Air speed


Air temperature

Other parameters:


Geometry


Material thickness


Roughness


Soil moistre / permeability


Conducibility

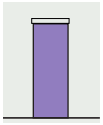

Emissivity

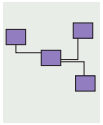

Albedo

Decreased Hazards:

Wildfires

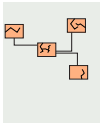

Drought


Stress of structures


Stress of infrastructures

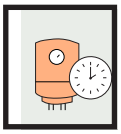
Rainfall

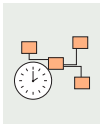

Decreasing of comfort conditions

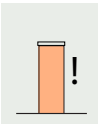

Energy transmission losses and facilities

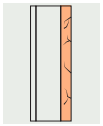

Negative impact for renewerable energies


Increasing recovery costs


Increasing deterioration rate of systems and materials


Increasing deterioration rate of infrastructures


Buildings may became unsuitable for use


Problems with finishing materials

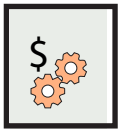
Increasing indoor temperature


Increasing mortality


Increasing costs for preventing measures

Neighborhoods abandonement

Buildings abandonement


Increasing maintenace costs

Infrastructures may became unsutaible for use

Decrease of air quality

Description.

'Green walls' refers to a built façade suitable for plant species' planting, development and permanence. The vegetation can be juxtaposed against the wall through screens and technological systems of vertically or horizontally growing plants - green façades. Alternatively, vegetation can become part of the opaque building envelope by defining green walls. In both cases, specific load-bearing and supporting substructures are required to allow the vegetation to be planted and to ensure proper irrigation and nutrition. The vegetation screens integrated in the façades make it possible to consider vegetation as an integral part and active component of the building envelope, capable of playing an important role in climatic moderation and active filtering against external climatic and atmospheric agents, which are also an important technological option in the context of interventions for the recovery of the existing building heritage and technological and energy retrofitting. Green envelopes affect structures' environmental and architectural qualities, influencing energy exchanges between the external environment and confined spaces. They also improve thermal acoustic behaviour and positively affect air quality.

Typologies.

- Green façades consist of vertical structures, generally metal or wood, anchored to the wall of the building envelope behind or self-supporting and placed adjacent to the building wall itself. These structures are two- or three-dimensional gratings that provide support for the vegetation itself and for the specific integrated planting, as well as directing the development of the vegetation. In this type of construction, the environmental effectiveness of the vegetation's mitigating action is conditioned by the distance between the green wall and the building and by factors such as the density of the foliage, after an adequate period of development, and the percentage of vegetation cover with the surface of the support. The technical realisation solutions fall into three categories:
- Grid or trellis systems on which climbing species grow. These structures have a low weight, are provided with wall spacers, or are autonomous structures.
- Plants with modular systems made with containers: These systems consist of horizontal resources supported by specific structures and intended to support vertical growth and development. This type of solution is also available prefabricated.
- Living walls: these solutions are more compact than the above-mentioned ones: the vegetation plants placed close to and in correspondence with the opaque surfaces of the building envelope are grafted onto areal supports in such a way as to allow uniform and rapid coverage of the vertical surfaces on which they are grafted. This solution is suitable for all building types as a retrofitting intervention and for new construction for low and high-rise structures. From a

technical constructional point of view, it can be conceived as a ventilated wall: a substructure allows it to be attached to the wall structure of the building to form an air space that can function similarly to conventional ventilated walls. Usually these solutions are characterised by the following construction elements: the internal wall - which represents the vertical wall of the envelope - the anchoring structure - mullions, transoms, brackets - air cavity, the load-bearing structure - made up of panels of different types anchored to the underlying structural mesh with the function of housing the vegetation, the growing substrate and the irrigation and fertirrigation system.

Maintenance.

The maintenance and life cycle planning of the green wall are important when designing these systems. This attention makes it possible to avoid deterioration and degradation of the planted vegetation systems. Vegetation development over time requires specific forecasting and planning, as it could result in degradation and could indicate the expected architectural and environmental quality. At the design level, the important factors to consider are the exposure of the walls, the climatic and microclimatic conditions of the site, the extent of the areas to be covered with greenery, and the objectives to be realised.

Presence in the case studies.

Circular Buiksloterham, Seaholm Ecodistrict, Ile de Saint Denis

Technology:	Critical issues related to climate change
Green roofs	Urban Heat Island  Heat waves 



https://unitedrw.com/understanding-green-roofs-commercial-building-benefits-installation-and-maintenance-guide/



https://www.sempergreen.com/se/senaste-nytt/can-i-have-a-green-roof-on-a-steeply-pitched-roof

Context:

Spatial context: type of settlement	Application:	Main immediate environment:
City centre, Suburban areas, Countryside	Indoor, Outdoor, Envelope	Buildings, Streets, Open spaces

Work metod:

SMART | PASSIVE | ACTIVE

Type of solution:

Typology

Urban space device | Morphological | Technological | Materic | Plant engineering

Green / Blue / Gray

Responsiveness:

Period of installation:

Maintenance:

! ! !

Life span:

Return environmental period:

Indicators:

Characteristic indicators:


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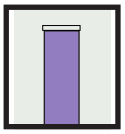

Emissivity

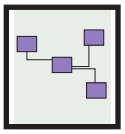

Albedo

Decreased Hazards:

Wildfires

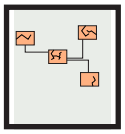

Drought

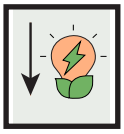

Stress of structures


Stress of infrastructures

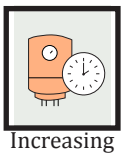

Rainfall

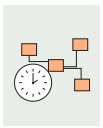

Decreasing of comfort conditions

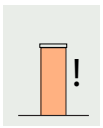

Energy transmission losses and facilities

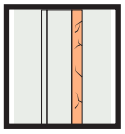

Negative impact for renewerable energies

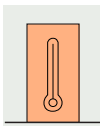

Increasing recovery costs


Increasing deterioration rate of systems and materials


Increasing deterioration rate of infrastructures

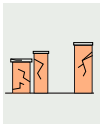

Buildings may became unsuitable for use

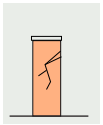

Problems with finishing materials


Increasing indoor temperature

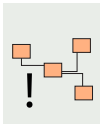

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Decrease of air quality

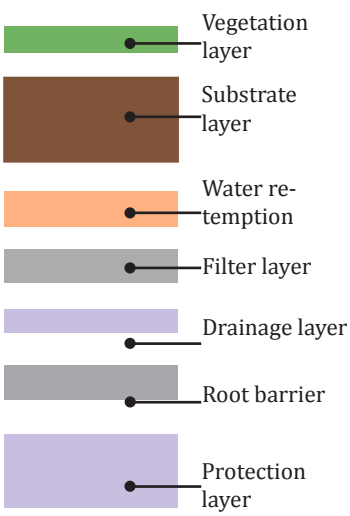
Description.

The disadvantage is that architectural and contextual features do not always allow for green roofs.
This design solution presents a vegetated roof with types ranging from sedum to shrubs to trees. This technology decreases the thermal transmittance of the roof structure, increasing the thermal mass of the structure, which has advantages in terms of heat absorption and stabilization of internal temperature.
Specific types of vegetated roofing are:

- **Usable lawn:** This lawn requires assiduous maintenance to maintain aesthetic quality and control degradation. Irrigation water consumption is high, and thermal energy performance is good.
- **Sedum carpet:** Extensive type is the most common solution. It requires minimal maintenance and irrigation.
- **The natural lawn** is an extensive type Used to construct extensive green roofs. It has low costs and maintenance burdens and better energy performance than sedum mats. However, it requires greater sub-layer thicknesses.
- **Herbaceous perennial carpet** has an extensive type performance comparable to a lawn. However, it needs more maintenance in the initial stage and higher costs.
- **Ground cover and suffruticose shrubs:** Extensive and intensive low maintenance and irrigation
- **Vegetable gardens** require very different technical planting methods than others. Care must be taken with the waterproofing layer, which could be damaged during tilling. Variable thickness of substrate
- **Trees and hedges:** intensive type relevant substrate thickness, high maintenance level. Of high landscaping and aesthetic value.

Planting vegetation on roofs is a custom that dates back to Babylonian times, around 500 BC. Modern green roofs were developed in Germany, followed by other countries such as the USA, Canada, Australia, Singapore and Japan.
The technical aspects governing the construction of green roofs today are regulated in DIN EN 1991-11, DIN 18195, DIN 18531, DIN 18532, DIN 18533 and in the ZVDH/HDB 'Fachregel für Abdichtungen - Flachdachrichtlinie'.
Different types of green roofs include intensive and simple or extensive green roofs.
From the point of view of intervention on existing buildings, extensive green roofs turn out to be the most easily usable type because their substrates are thinner and, therefore, lighter than other types of green roofs. They have minimal maintenance requirements and, therefore, excellent durability, excellent functionality, low cost, and versatility: they are usable for both flat and sloping roofs.
The average substrate thickness is about 10 to 15 cm, and the water storage capacity ranges from 40 to 60 l/m2. From an energy and thermodynamic point of view, performance is related to substrate thickness.

Author's elaboration on the basis of: "D'Olimpio, 2023; Il retrofitting tecnologico, energetico e bioclimatico nell'edilizia, Legislazione tecnica, Borgoricco".



Typologies.

The modular green roof system is a technically advanced design solution for roofing. It is an innovative technological solution with multifunctional advantages and the ability to integrate devices that convert solar and wind energy - solar panels and micro wind turbines. Modular trays are equipped with drip irrigation systems to create a microclimate zone directly above the roof of a green building. The research describes a modern green roof system that consists of green roof modular pots with a wide variety of configurations and integrated energy-effective devices

- Prefabbricated solutions: esistono tipologie di coperture vegetate formate da elementi prefabbricati prevegetati
- Integration with irrigation waste, phyto-purification, and purification of grey water from buildings
- Integration with photovoltaic technology

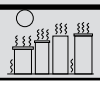
Maintenance.

- Develop a comprehensive maintenance plan: Develop a comprehensive maintenance plan that includes regular inspections, cleaning of drainage systems, and vegetation management.
- Monitor performance and consumption: Monitor water consumption, stormwater runoff, and overall system performance to identify opportunities for improvement and address any issues promptly.
- Periodic inspections and adjustments: Conduct periodic inspections to identify and address potential issues and make necessary adjustments to optimise water efficiency and sustainability.
- Stay updated on advances: Engage with research institutions and industry experts to stay informed about advances in green roof technologies, water management strategies, and best practices.
- Stakeholder feedback and engagement: Seek feedback from stakeholders, including building owners, occupants, and facility managers, to understand their needs, preferences, and concerns regarding water management.
- Involve stakeholders throughout the process to ensure their support and participation.

Apart from exceptional cases, green roofs are not made of dangerous materials, so the system is disposed of in non-harmful waste processing plants, like any construction material.

Presence in the case studies.

Circular Buiksloterham, Seaholm Ecodistrict, BedZED, Cogneto, CitiZen Amsterdam

Technology:	Critical issues related to climate change
Permeable surfaces	Urban Heat Island  Heat waves 



Example of permeable asphalt. https://www.archiexpo.it/prod/basf-usa/product-103548-1159597.html?srsltid=AfmBOoo3x4D_Cb_FTQ-Jn5pVUI6giD7qqJ-rAa_mVo_90r7-A0JcH6gY

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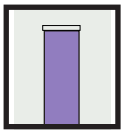
Decreased Hazards:



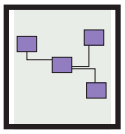
Wildfires



Drought



Stress of structures



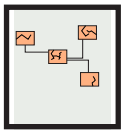
Stress of infrastructures



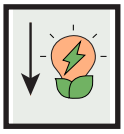
Rainfall



Decreasing of comfort conditions



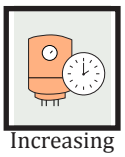
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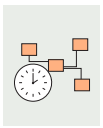
Negative impact for renewerable energies



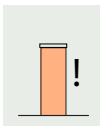
Increasing recovery costs



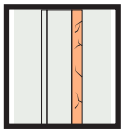
Increasing deterioration rate of systems and materials



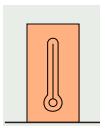
Increasing deterioration rate of infrastructures



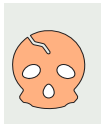
Buildings may became unsuitable for use



Problems with finishing materials



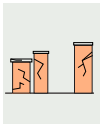
Increasing indoor temperature



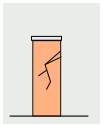
Increasing mortality



Increasing costs for preventing measures



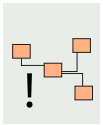
Neighborhoods abandonement



Buildings abandonement



Increasing maintenace costs



Infrastructures may became unsutaible for use



Decrease of air quality

Description.

Porous and water-retaining pavement systems include additional voids compared to conventional pavements, allowing water to drain into the ground or retention points. This action helps to store runoff, preventing it from accumulating or stagnating on the pavement surface. This type of pavement typically consists of porous hot mix asphalt or conglomerate, permeable Portland cement concrete, or plastic grid systems. In particular, pavements of this type consist of a mixture of cementitious materials, except for a fraction of fine aggregate, which is reduced, thus increasing the percentage of voids. In this way, a permeable surface allows water to infiltrate into the subgrade, stored in an aggregate reservoir that is either conveyed into a stormwater drainage system or seeps into the ground below. This type of solution is suitable for light and low-speed traffic. Compared to impermeable pavements, this type of pavement allows effective rainwater management and a reduction of urban impact on the hydrogeological cycle by reducing surface runoff. This type of pavement also improves the urban microclimate through evaporative cooling. By increasing the water retention capacity due to the higher volume of interconnected voids, the evapotranspiration rate is higher, increasing pedestrian comfort and decreasing energy requirements. It can also contribute to pollution control due to surface runoff from roads and parking areas and noise reduction. Adverse effects include the production of water vapour, which acts as a greenhouse gas.

Typologies and Integrations with other technologies.

When choosing the specific solution, the criteria to be taken into account are the ability to reduce surface temperature in good weather, the ability to suppress temperature rise after rainfall, maximum durability, and a minimum drop in performance over time (Katsunori, 2009). The most common applications can be public and private, such as vehicular access, parking, pedestrian access, and bicycle lanes (Scholz & Grabowiecki, 2007). Implementation varies greatly, depending on the specific project and can be integrated with vegetation-related factors. (Ruefenacht & Maple, 2017)

Presence in the case studies.

The Pearl

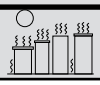


Examples of permeable pavements. Çelik, Filiz; 2013, Sustainability with landscape design: the example of Sille, in International Journal of Academic Research, vol. 5, pp. 134-142, doi: 10.7813/2075-4124.2013/5-4/A.19



Example of the behaviour of a draining concrete. https://www.archiexpo.it/prod/basf-usa/product-103548-1159597.html?srsltid=AfmBOoo3x4D_Cb_FTQ-Jn5pVUI6giD7qqJ-rAa_mVo_90r7-A0JcH6gY

Innovative and integrated energetic and bioclimatic strategies for adapting existing contexts to climate change and extreme events, aiming to mitigate the environmental impact
p. 362

Technology:	Critical issues related to climate change
Draining infrastructure systems	Urban Heat Island  Heat waves 

https://www.civilengineermag.com/road-drainage/



Context:

Spatial context: type of settlement	Application:	Main immediate environment:
City centre / Suburban areas / Countryside	Indoor / Outdoor / Envelope	Buildings / Streets / Open spaces

Work metod:

SMART | PASSIVE | ACTIVE

Type of solution:

Typology

Urban space device | Morphological | Technological | Materic | Plant engineering

Green / Blue / Gray

Responsiveness:

Period of installation:

Maintenance:

!!

Life span:

Return environmental period:

Indicators:

Characteristic indicators:

Mean radiant temperature


Relative humidity

Air speed

Air temperature

Other parameters:

Geometry

Material thickness


Roughness


Soil moistre / permeability

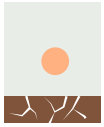

Conducibility

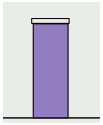
Emissivity

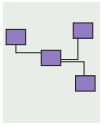
Albedo

Decreased Hazards:


Wildfires


Drought

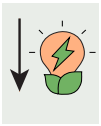

Stress of structures

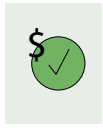

Stress of infrastructures

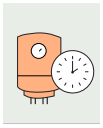

Rainfall

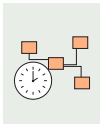

Decreasing of comfort conditions

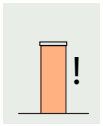
Energy transmission losses and facilities

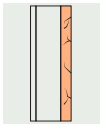

Negative impact for renewerable energies


Increasing recovery costs


Increasing deterioration rate of systems and materials


Increasing deterioration rate of infrastructures

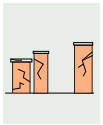

Buildings may became unsuitable for use

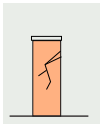

Problems with finishing materials

Increasing indoor temperature

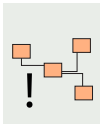

Increasing mortality


Increasing costs for preventing measures


Neighborhoods abandonement


Buildings abandonement


Increasing maintenace costs


Infrastructures may became unsutaible for use

Decrease of air quality

Description.

Some guidelines for the design of drainage infrastructure are listed below. Stormwater management is influenced by many components of neighbourhood form and design characteristics, such as lot and house size and the amount of sealing. In particular, large lot sizes result in: greater distances between the development and transport infrastructure, higher lot maintenance costs, higher costs of minor systems, higher water use for irrigation and a larger 'footprint' of the development; whereas small lot sizes generally result in a reduction of the above factors. However, small lot sizes generally have a higher density of development and lead to a broadening of the effects of urbanisation - increased runoff or peak traffic (Engel-Yan, Kennedy, Saiz, & Pressnail, 2005; Duque et al., 2024). In general, various approaches exist in drainage infrastructure design. A first step is to consider the effects of climate change by using historical design flow rates and accepting a gradual decrease in the level of service provided by the drainage infrastructure. This approach may be appropriate in situations where periodic flooding and minor damage associated with flooding are acceptable. However, when severe damage is expected as a result of flooding or when the lives and safety of people are threatened, this approach is unacceptable. A second approach that considers the effects of climate change is to design and build structures with sufficient flow capacity to handle future, rather than current, flow conditions. A third approach is to design and build infrastructure for a shorter useful life, and then retrofit or replace it in the future when conditions require it. The implications of climate change for drainage infrastructure can be managed through long-term planning that considers future flow rate increases (Denault, Millar, & Lence, 2002). Using shorter design lives makes it possible to consider the uncertainty associated with determining design flow rates over extended periods. The disadvantage of this approach is that the costs associated with upgrading the capacity of drainage infrastructure well before the end of its structural life are likely to be considerable. Finally, A fourth approach to planning and designing urban drainage infrastructure consists of combining the previous approaches for different components of the overall drainage or stormwater management system. This combined approach consists of using historical design flows and accepting a gradually decreasing level of service for the minor system, considering the expected future effects of climate change during the planning and design of the significant system. When using this approach, care must be taken that the overloading of existing sections of the minor system above the levels predicted during the original design does not cause unacceptable damage. When designing new drainage infrastructure, the interaction between the minor and major systems must be carefully evaluated, and the hydraulic performance of the combined minor/major system must be designed in an integrated way. That said, in addition to drainage systems, there are various methods for managing water flows, many of which also provide

for its reuse. The most significant of these are listed below.

Typologies and Integrations with other technologies.

- Surface drainage: often preferred to manage run-off as the water flow remains visible and reduced connections are prevented. It also avoids connection to the sewage system, thus preventing sewage from mixing with surface water. Finally, these systems can enrich the aesthetics of the outdoor environment. When designing these systems, it is necessary to avoid the formation of water accumulation or puddles. Technical solutions include: open channels, buried channels, and covered channels.
- Buffer and infiltration areas are designed to cope with increased rainfall in short periods caused by rising temperatures. Sewer systems struggle to handle the flows. Buffer and infiltration areas are designed to be flooded during rainy periods and to reuse the water collected in situ. The shape of buffer or infiltration areas depends on soil permeability, water table level, run-off quality, and available space.

Integration with other technologies.

These systems lend themselves well to integrating green systems, creating bioswales, rain gardens, green roofs, and grassy depressions. Water squares and the construction of artificial wetlands provide another possibility for integration.

Presence in the case studies.

BedZED



https://www.yeahlifestyle.com/5-important-tips-to-design-a-drainage-system/

Technology:	Critical issues related to climate change
Collection and reuse of rain water	Urban Heat Island  Heat waves

https://4perfectwater.com/blog/rainwater-collection-tanks



Context:

Spatial context: type of settlement	Application:	Main immediate environment:
 City centre; Suburban areas; Country-side	 Indoor; Outdoor; Envelope	 Buildings; Streets; Open spaces

Work metod:

SMART PASSIVE ACTIVE

Type of solution:

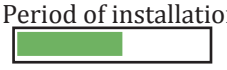
Typology

Urban space device | Morphological | Technological | Materic | Plant engineering

Green / Blue / Gray

Responsiveness:

Period of installation:



Maintenance:

!!

Life span:



Return environmental period:



Indicators:

Characteristic indicators:

Mean radiant temperature



Relative humidity

Air speed



Air temperature

Other parameters:

Geometry

Material thickness

Roughness



Soil moistre / permeability

Conducibility

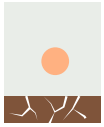
Emissivity

Albedo

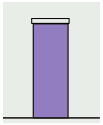
Decreased Hazards:



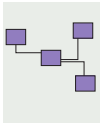
Wildfires



Drought



Stress of structures



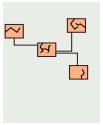
Stress of infrastructures



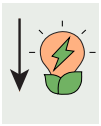
Rainfall



Decreasing of comfort conditions



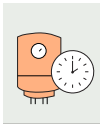
Energy transmission losses and facilities



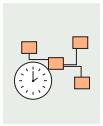
Negative impact for renewerable energies



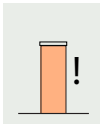
Increasing recovery costs



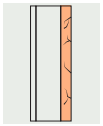
Increasing deterioration rate of systems and materials



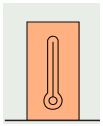
Increasing deterioration rate of infrastructures



Buildings may became unsuitable for use



Problems with finishing materials



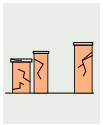
Increasing indoor temperature



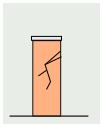
Increasing mortality



Increasing costs for preventing measures



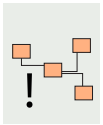
Neighborhoods abandonement



Buildings abandonement



Increasing maintenace costs



Infrastructures may became unsutaible for use



Decrease of air quality

Description:

Only a few communities recognise rainwater as the primary source of water supply. Rainwater harvesting and reuse systems, especially with local public control, are also particularly beneficial for promoting community development. Rainwater harvesting is an essential action against the danger of flooding. As a positive side-effect, it allows for less burdening of the stormwater drainage network, less soil erosion by streams from residential and industrial areas, more infiltration of water in a controlled manner within the urban fabric with a consequent possibility of more vegetation development, recharging the water table, providing drinking water and for irrigated agriculture.

Typologies.

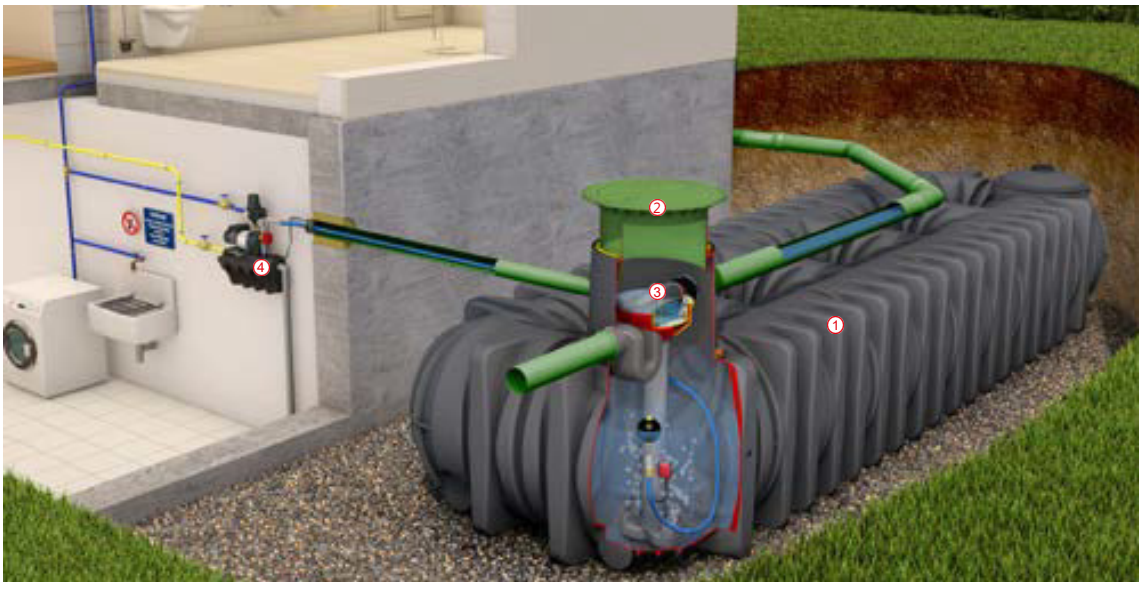
- Cisterns
- Ponds
- Tanks

Innovation and integration with other solutions.

These systems require continuous monitoring and regular maintenance to ensure proper water collection and cleaning. The water can then be reused for irrigation, cleaning or toilet flushes.

Presence in the case studies.

La Duchére, Ecobarrio Trinitat Nova, Hikary project (La Confluence), Caserme de Bonne, the Pearl, BedZED, Ile de Saint Denis, Santa Giulia Milano, Cogneto,



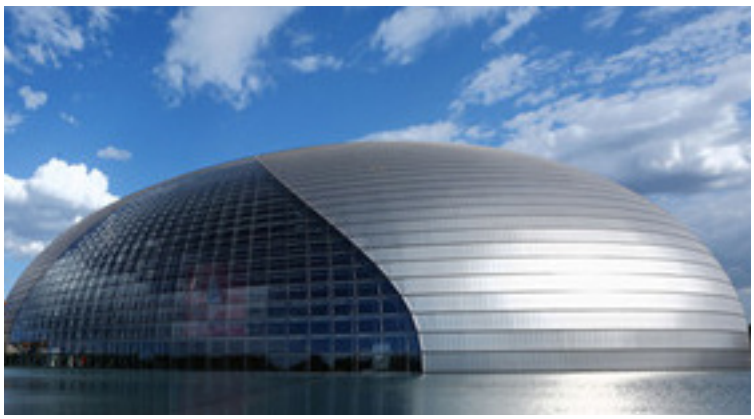


Top image: Example of a water tank for domestic use. https://www.graf.info/fileadmin/media/950743_Katalog_R43_Carat_IT.pdf

Left image: Example of a water tank. https://www.reidmiddleton.com/reidourblog/using-building-technology-to-seismically-upgrade-elevated-water-tanks/

Technology:	Critical issues related to climate change
Ponds on roof/ground floor	Urban Heat Island  Heat waves 

Beujing opera theatre.
https://cinaviaggio.com/cina-guida/cina-cultura/architettura/la-architettura-moderna-a-pechino-grande-teatro-nazionale.html



Context:

Spatial context: type of settlement	Application:	Main immediate environment:
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Work metod:

SMART | PASSIVE | ACTIVE

Type of solution:

Typology

Urban space device | Morphological | Technological | Materic | Plant engineering

Green / Blue / Gray

Responsiveness:

Period of installation:

Maintenance: !!

Life span:

Return environmental period:

Indicators:

Characteristic indicators:


Mean radiant temperature


Relative humidity

Air speed


Air temperature

Other parameters:


Geometry


Material thickness


Roughness


Soil moistre / permeability

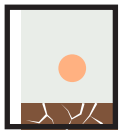

Conducibility

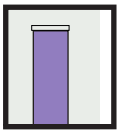

Emissivity

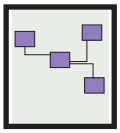

Albedo

Decreased Hazards:


Wildfires

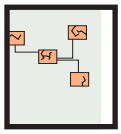

Drought

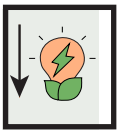

Stress of structures


Stress of infrastructures

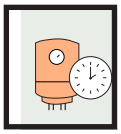

Rainfall

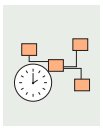

Decreasing of comfort conditions

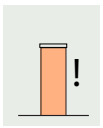

Energy transmission losses and facilities

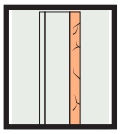

Negative impact for renewerable energies

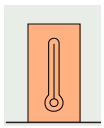

Increasing recovery costs


Increasing deterioration rate of systems and materials


Increasing deterioration rate of infrastructures

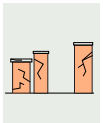

Buildings may became unsuitable for use

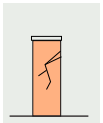

Problems with finishing materials


Increasing indoor temperature

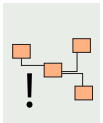

Increasing mortality


Increasing costs for preventing measures


Neighborhoods abandonement


Buildings abandonement


Increasing maintenace costs


Infrastructures may became unsutaible for use


Decrease of air quality

Description:

Roof basins benefit from indirect evaporative and/or radiant cooling. In both processes, the roof acts as a heat exchange element cooled by evaporation on its surface, longwave radiation to the sky, or both. It thus functions as a heat sink that absorbs internal heat and penetrates the building. Since the ceiling is thermally coupled to the roof pond, the interior space is also cooled by radiation and convection. The driving forces of evaporation and radiation are the 'difference between the vapour pressure at the water surface temperature and the surrounding air' and the 'difference between the water surface temperature and the actual temperature of the sky'. Since the roof acts as a heat exchange element, cooling the water on the roof does not increase the moisture content of the indoor air.
Rooftop ponds can also be used for passive heating during the winter. During the day, the pond is exposed to solar radiation and the water's thermal storage capacity stores solar energy in the pond as sensible heat. This stored energy is then transferred to the ceiling below by conduction and finally transmitted to the interior space by radiation and partly by convection. The thermal functions of roof ponds can vary depending on their configuration.

Typologies.

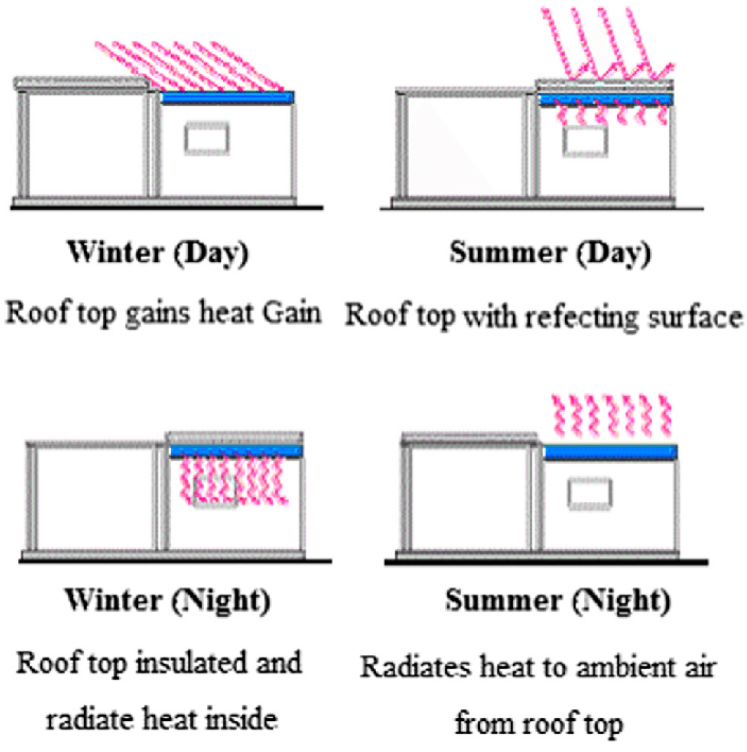
- Roof ponds with movable insulation
- Roof ponds with floating insulation
- Walkable roof ponds
- Roof ponds with gunny bags
- Shaded roof ponds
- Ventilated roof ponds

Innovation and integration with other solutions.

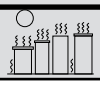
- Skytherm
- Roof-inte\grated water solar collector
- Walkable pond with water spraying during daytime hours
- Open pond without water spray

Presence in the case studies.

/



Operation of a roof ponds
Chel, Arvind; Kaushik, Geetanjali; 2017, Renewable energy technologies for sustainable development of energy efficient building, in Alexandria Engineering Journal, 57, doi: 10.1016/j.aej.2017.02.027

Technology:	Critical issues related to climate change
Photocatalytic materials	Urban Heat Island  Heat waves 

https://www.sustainablebusiness.com/2014/07/green-technology-spotlight-biodynamic-cement-purifies-the-air-52421/



Context:

Spatial context: type of settlement	Application:	Main immediate environment:
 City centre; Suburban areas; Countryside	 Indoor; Outdoor; Envelope	 Buildings; Streets; Open spaces

Work metod:

SMART | PASSIVE | ACTIVE

Type of solution:

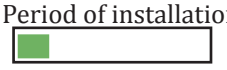
Typology

Urban space device | Morphological | Technological | Materic | Plant engineering

Green / Blue / Gray

Responsiveness:

Period of installation:



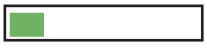
Maintenance:

!

Life span:



Return environmental period:



Indicators:

Characteristic indicators:



Mean radiant temperature



Relative humidity

Air speed

Air temperature

Other parameters:

Geometry

Material thickness



Roughness



Soil moistre / permeability

Conducibility



Emissivity

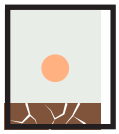


Albedo

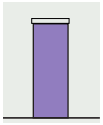
Decreased Hazards:



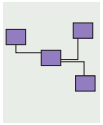
Wildfires



Drought



Stress of structures



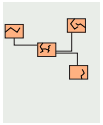
Stress of infrastructures



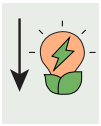
Rainfall



Decreasing of comfort conditions



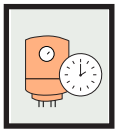
Energy transmission losses and facilities



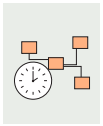
Negative impact for renewerable energies



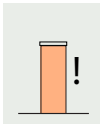
Increasing recovery costs



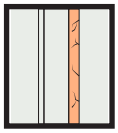
Increasing deterioration rate of systems and materials



Increasing deterioration rate of infrastructures



Buildings may became unsuitable for use



Problems with finishing materials

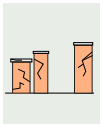
Increasing indoor temperature



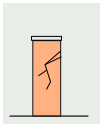
Increasing mortality



Increasing costs for preventing measures



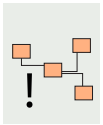
Neighborhoods abandonement



Buildings abandonement



Increasing maintenace costs



Infrastructures may became unsutaible for use

Decrease of air quality

Description.

Conditions of excessive air humidity, accompanied by situations of thermo-hygrothermal discomfort, can interact with the building structures, causing phenomena of deterioration of the surface finishing layers, with particular weight on the plasterwork, with the formation of stains, mould, exfoliation, detachment, etc.. These effects may increase under conditions of constant high humidity. To deal with these problems, surface treatment products that prevent the formation of mould, bacteria and prevent the deterioration of building structures and their surfaces can be helpful. For some years now, nanostructured elements and paints have been on the market that can counteract degradation phenomena through various mechanisms, among which the most efficient and significant is the principle of photocatalysis, activated in the presence of natural or artificial light, as a result of the reaction triggered by particular materials contained in the paint products. These are the so-called photocatalytic paints, available for both indoor and outdoor use and capable of preventing growth and disinfecting against bacteria, viruses, fungi and moulds (Sánchez, et al., 2012; Guillard, et al., 2008). Furthermore, photocatalysis of pathogens potentially involves one or more of the following: inhibition of their proliferation, disinfection, degradation of the toxins they produce, and/or degradation of the by-products of these organic decompositions (Rincón & Pulgarin, 2003; Yu, Leung, Guo, Lau, & Yang, 2011; Ren et al., 2017). Photocatalytic paints and varnishes use titanium dioxide (TiO_2) to activate a photocatalytic reaction on the treated surface. In this way, oxidation processes allow organic and inorganic pollutants to be transformed and decomposed into harmless compounds, purifying the air and preventing the proliferation of fungi and moulds. Improving the self-cleaning capacity of floors and maintaining a high level of solar reflectance with photocatalytic treatments makes it possible to maintain the original thermal and visual performance of floors.

Presence in the case studies.

/







Examples of structures with photo-catalytic materials. In particular:
1. Church “Dives in Misericordia” Rome, Italy
2. Great Lakes Science Center, USA
3. Air France heasquarters

Remediation of noxious pollutants using nano-titania-based photo-catalytic construction materials: a review - Scientific Figure on ResearchGate. Available from: https://www.researchgate.net/figure/Various-structures-made-of-photo-catalytic-materials_fig3_351430210 [accessed 14 May 2025]

Technology:	Critical issues related to climate change
Cool materials	Urban Heat Island  Heat waves 



https://www.heidelbergmaterials.it/it/citta-fresche-cool-materials



https://www.heidelbergmaterials.it/it/citta-fresche-cool-materials

Context:

Spatial context: type of settlement	Application:	Main immediate environment:
City centre; Suburban areas; Countryside	Indoor; Outdoor; Envelope	Buildings; Streets; Open spaces

Work metod:

SMART | PASSIVE | ACTIVE

Type of solution:

Typology

Urban space device | Morphological | Technological | Materic | Plant engineering

Green / Blue / Gray

Responsiveness:

Period of installation:

Maintenance: !!

Life span:

Return environmental period:

Indicators:

Characteristic indicators:


Mean radiant temperature


Relative humidity

Air speed


Air temperature

Other parameters:

Geometry

Material thickness


Roughness

Soil moistre / permeability

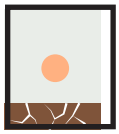
Conducibility

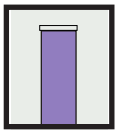

Emissivity

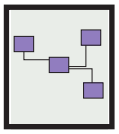

Albedo

Decreased Hazards:


Wildfires

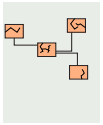

Drought

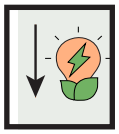

Stress of structures


Stress of infrastructures

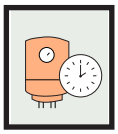

Rainfall

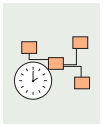

Decreasing of comfort conditions

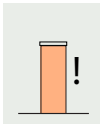

Energy transmission losses and facilities

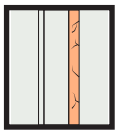

Negative impact for renewerable energies

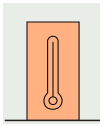

Increasing recovery costs


Increasing deterioration rate of systems and materials


Increasing deterioration rate of infrastructures

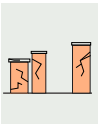

Buildings may became unsuitable for use

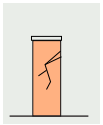

Problems with finishing materials


Increasing indoor temperature

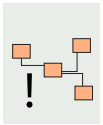

Increasing mortality


Increasing costs for preventing measures


Neighborhoods abandonement


Buildings abandonement


Increasing maintenace costs


Infrastructures may became unsutaible for use


Decrease of air quality

Description.

The cladding of external and internal surfaces with reflective elements - the so-called 'cold' surfaces - makes it possible to decrease the amount of solar radiation absorbed and subsequently transferred to the inhabited space. The physical dynamics are governed by the principle of conservation of energy, which, assuming that radiation incident on a surface is partly reflected (G_{refl}), partly absorbed (G_{abs}) and partly transmitted (G_{trans}), posits that the energy of the incident radiation is equal to the sum of the energy of the reflected, absorbed and transmitted radiation:

$G_{tot} = G_{refl} + G_{abs} + G_{trans}$

by posing :
- reflection coeff.: r G_{refl}/G_{tot}
- absorption coeff.: a Gass/G_{tot}
- transmission coeff.: t Gtrasm/G_{tot}

We have:
r+a+t=1
Since the materials constituting the opaque building envelope are not transparent to radiation but opaque, then t=0
Then we have:
r+a=1
As the amount of reflected radiation increases, the amount of absorbed radiation will decrease, and consequently, the amount entering the interior spaces will decrease.
That said, increasing the reflectance of building surfaces is a valuable intervention strategy for decreasing the envelope's thermal energy absorption.

Typologies.

There are different types of reflective materials. Very effective results in the reflection of incident radiation are obtained through sandwich panels made of aluminium foil cladding. They comprise a thermoplastic material core sandwiched between 4 or 5 mm aluminium alloy sheets, heat-fixed to a thicker central layer - 'Reynobond' panel. Another type is the 'Alucobond' panel, which

consists of two aluminium alloy sheets enclosing a high-density thermoplastic or mineral core. The special coating of the surfaces, made of polyvinylidene fluoride (PVDF), makes them insensitive and unaffected by weathering. Treating and coating façades with reflective paints is an effective technique compared to coatings. The colour characteristics of exterior surfaces determine the amount of solar energy reflected and absorbed. Dark colours have a higher absorption coefficient and a lower solar reflection coefficient, while light colours have a higher and lower absorption coefficient. In addition to the choice of finishing colour for the surfaces of buildings or outdoor spaces, materials developed in nanotechnology can also be used, depending on the microclimate and sunlight characteristics. These materials include nanostructured paints and varnishes with a high SRI index and efficiency. Another option may be paints with IR-reflecting pigments, i.e., based on complex metal oxides capable of reflecting the solar radiation's infrared (IR) component.

Maintenance.

Maintaining clean surfaces on chilled pavements is an important part of the overall measure. Therefore, they can be implemented for private and public pavements or renovated or new pavement scenarios. Photocatalytic pavements have attracted great interest over the past decade. Their ecological abilities to provide reactive (self-cleaning and anti-smog) and reflexive (cooling) effects have been extensively studied (Sikkema et al., 2014). Some varieties of titanium dioxide (TiO_2) are known for their ability to act as photocatalytic agents in the oxidation reaction (Venturini & Bacchi, 2009) and to increase the solar reflectance and cooling properties of the materials in which they are included. For these reasons, TiO_2 is widely used as a component of photocatalytic cold floors.

Presence in the case studies.

/

Technology:	Critical issues related to climate change
Phasechange materials, thermochromic materials and selective materials	Urban Heat Island  Heat waves

https://www.building.co.uk/news/phase-change-materials/3111760.article



Context:

Spatial context: type of settlement	Application:	Main immediate environment:
City centre; Suburban areas; Countryside	 Indoor; Outdoor; Envelope	 Buildings; Streets; Open spaces

Work metod:

SMART | PASSIVE | ACTIVE

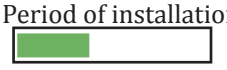
Type of solution:

Typology

Urban space device | Morphological | Technological | Materic | Plant engineering

Green / Blue / Gray

Responsiveness:

Period of installation: 

Maintenance: !

Life span: 

Return environmental period: 

Indicators:

Characteristic indicators:


Mean radiant temperature

Relative humidity

Air speed


Air temperature

Other parameters:

Geometry


Material thickness


Roughness

Soil moistre / permeability


Conducibility

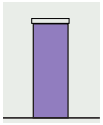

Emissivity

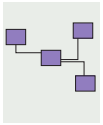
Albedo

Decreased Hazards:


Wildfires

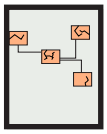

Drought

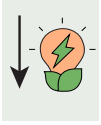

Stress of structures


Stress of infrastructures

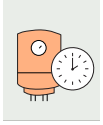
Rainfall

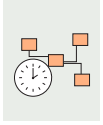

Decreasing of comfort conditions

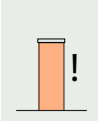

Energy transmission losses and facilities

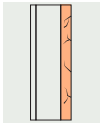

Negative impact for renewerable energies

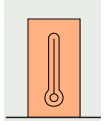

Increasing recovery costs


Increasing deterioration rate of systems and materials


Increasing deterioration rate of infrastructures

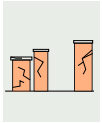

Buildings may became unsuitable for use

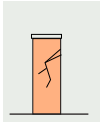

Problems with finishing materials


Increasing indoor temperature

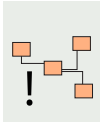

Increasing mortality


Increasing costs for preventing measures


Neighborhoods abandonement


Buildings abandonement


Increasing maintenace costs


Infrastructures may became unsutaible for use


Decrease of air quality

Description.

This type of material could have an artificial or natural origin that can change from a solid to a liquid state or vice versa, thanks to latent thermal energy exchanged at a constant temperature with the environment during phase transitions. The transition from solid to liquid state depends on ambient temperature levels, accumulating thermal energy, and maintaining a constant temperature. During the transition from a liquid to a solid state, the stored thermal energy is released to the environment at low temperatures, and the material changes state. The operating temperature of PCMS is around 20 °C. When choosing this type of material, the latent heat of fusion, density - which should be relatively high in order to contain the functional dimensions to obtain satisfactory thermal performance - chemical stability - which must be high to avoid premature degradation of the material - compatibility with building materials, availability and ease of retrieval, hygroscopicity - which must be absent - and toxicity, which must be zero - must all be evaluated. The correct type of phase change material and dimensioning must be based on the temperature fluctuations that characterise inhabited spaces throughout the day.

Typologies.

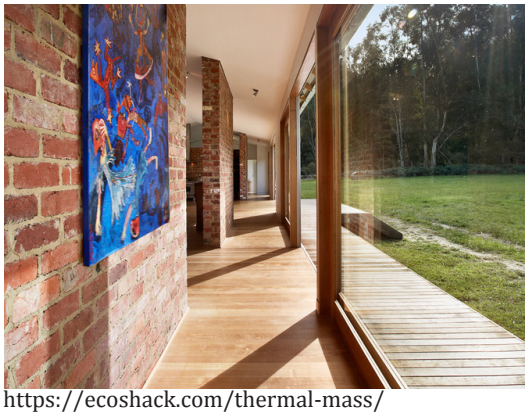
PCMS can be encapsulated in inert materials to be contained in a liquid state. The systems used are macro and micro encapsulation or immersion in porous matrices. These methods have enabled the realisation of rigid panels in plastic, aluminium, double-glazed glass, gypsum panels, cement or mixed with PCM capsules. Etc. In terms of realisation, PCM can be organic - this is the case with paraffins - or inorganic - this is the case with hydrated salts. These materials can be used for the realisation of:

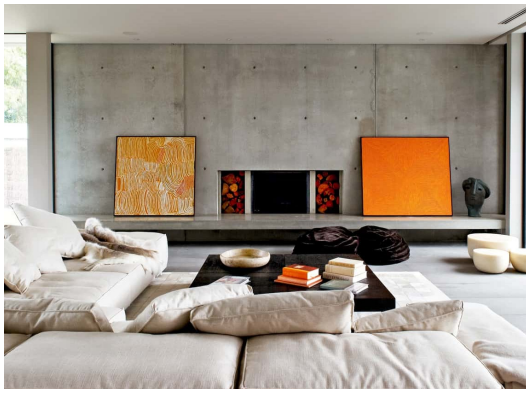
- Plasters are made by immersing and mixing PCM capsules in the porous matrices that make up the mortar mix.
- Panels of various types using micro and macro encapsulation, to be installed on walls or ceilings
- Transparent or Plexiglas façade components, where the transparent PCM is inserted into the cavities between two sheets of glass to create an envelope component with high thermal inertia capable of ensuring diffuse natural lighting
- Filling of wall cavities, vertical or horizontal, with containers

of various types
- Specific components of heating and cooling systems, with particular reference to heat exchangers and thermal storage tanks.

Presence in the case studies.
/

Technology:	Critical issues related to climate change
Thermal mass	Urban Heat Island  Heat waves





https://ecoshack.com/thermal-mass/

Context:

Spatial context: type of settlement	Application:	Main immediate environment:
City centre, Suburban areas, Countryside	Indoor, Outdoor, Envelope	Buildings, Streets, Open spaces

Work metod:

SMART PASSIVE ACTIVE

Type of solution:

Typology

Urban space device | Morphological | Technological | **Materic** | Plant engineering

Green / Blue / Gray

Responsiveness:

Period of installation:

Maintenance:

!

Life span:

Return environmental period:

Indicators:

Characteristic indicators:


Mean radiant temperature

Relative humidity

Air speed


Air temperature

Other parameters:

Geometry


Material thickness


Roughness

Soil moistre / permeability


Conducibility

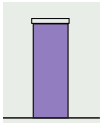
Emissivity

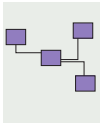
Albedo

Decreased Hazards:


Wildfires

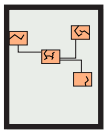

Drought

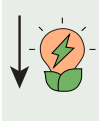

Stress of structures


Stress of infrastructures

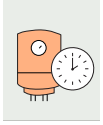
Rainfall

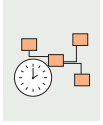

Decreasing of comfort conditions

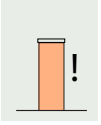

Energy transmission losses and facilities

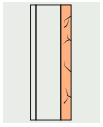

Negative impact for renewerable energies

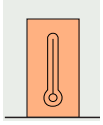

Increasing recovery costs


Increasing deterioration rate of systems and materials


Increasing deterioration rate of infrastructures

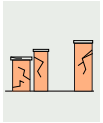

Buildings may became unsuitable for use

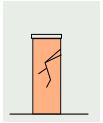

Problems with finishing materials


Increasing indoor temperature

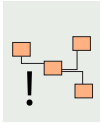

Increasing mortality


Increasing costs for preventing measures


Neighborhoods abandonement


Buildings abandonement


Increasing maintenace costs


Infrastructures may became unsutaible for use


Decrease of air quality

Description.

The utilisation of thermal masses is based on the creation of special structures, of external vertical borders that delimit the environment with materials with a high thermal capacity, capable of absorbing energy, increasing internal thermal loads, and returning it to the environment at a later time, characterised by a lower direct solar thermal load. These solutions require specific dimensioning according to the desired return times and the thermal energy to be stored. The most commonly used materials are concrete, solid or semi-full bricks, and natural stone, all characterised by high density: the greater the density, the greater the thermal storage capacity. Conversely, the higher the air content and voids within the material, the lower the thermal storage capacity. Through appropriate dimensioning, it is possible to regulate the thermal radiation by the installed thermal mass and favour it at times when the ambient thermal load is lower. The materials most commonly used in retrofit thermal masses are solid or half-filled bricks, or concrete bricks and blocks.

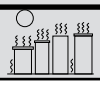
Typologies.

- Types: thermal masses can be realised in different ways:
  - By implementing building envelope structures from the outside;
  - By working within the confined spaces on the inner layer of walls
  - By implementing ceiling thicknesses
  - By realising internal partition walls with high thermal inertia materials

Maintenance.

These technological solutions usually have very low maintenance levels. When designing a retrofit, it is important to pay attention to compatibility with the existing layer to avoid thermal bridges or moisture stagnation between the existing and new layers.

Presence in the case studies.
/

Technology:	Critical issues related to climate change
Renewable energy systems	Urban Heat Island  Heat waves



https://www.ul.com/services/building-integrated-photovoltaic-bipv-system-testing-and-certification



Nonomura, Yoshitami and Hirahara, Hiroyuki and Zair, Md and Kawahashi, Masaaki and Kobayashi, Nobuyuki. 2006, Huge 3-D lattice structure with small wind turbine for amenity space, in Proceeding of European Wind Energy Conference 2006, Athens, v. 1

Context:

Spatial context: type of settlement	Application:	Main immediate environment:
City centre  Suburban areas  Countryside 	Indoor Outdoor  Envelope 	Buildings  Streets  Open spaces 

Work metod:

SMART PASSIVE ACTIVE

Type of solution:

Typology

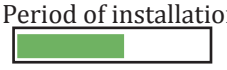
Urban space device | Morphological | Technological | Materic | Plant engineering

Green / Blue / Gray



Responsiveness:

Period of installation:



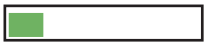
Maintenance:

!!

Life span:



Return environmental period:



Indicators:

Characteristic indicators:

Mean radiant temperature


Relative humidity

Air speed


Air temperature

Other parameters:

Geometry

Material thickness

Roughness

Soil moistre / permeability

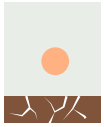
Conducibility

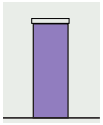
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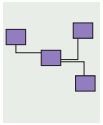
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Decreased Hazards:


Wildfires

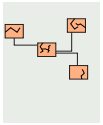

Drought

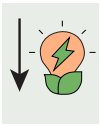

Stress of structures


Stress of infrastructures

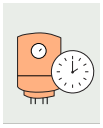

Rainfall

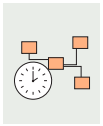

Decreasing of comfort conditions

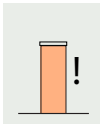

Energy transmission losses and facilities

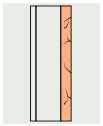

Negative impact for renewerable energies

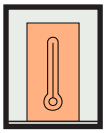

Increasing recovery costs


Increasing deterioration rate of systems and materials


Increasing deterioration rate of infrastructures

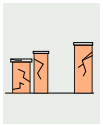

Buildings may became unsuitable for use

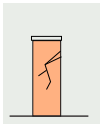

Problems with finishing materials


Increasing indoor temperature

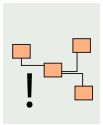

Increasing mortality


Increasing costs for preventing measures


Neighborhoods abandonement


Buildings abandonement


Increasing maintenace costs


Infrastructures may became unsutaible for use


Decrease of air quality

Description.

According to Article 1, paragraph 3 of Law 10 of 09/01/1991: 'the following are considered renewable or assimilated sources of energy: the sun, wind, hydraulic energy, geothermal resources, tides, wave motion and the transformation of organic and inorganic waste or plant products. In addition, the following are considered as energy sources that can be assimilated to renewable sources: cogeneration, - that is, the combined production of electrical or mechanical energy and heat, recoverable heat in exhaust fumes and from thermal plants, from electrical plants from industrial processes, as well as other forms of recoverable energy in processes, in plants and in products, including energy savings that can be achieved in the air-conditioning and lighting of buildings with interventions on the building envelope and plants'. Subsequently, Legislative Decree No. 387 of 19/12/2003 specified the term 'biomass', meaning 'the biodegradable part of products, waste, residues from agriculture (including plant and animal substances) and forestry and related industries, as well as the biodegradable part of industrial and municipal waste'. The feasible technological options in this sense are vast and diverse and can be implemented in different environmental and architectural contextual conditions. Therefore, today it is possible for designers to identify optimal technological solutions for each design requirement, relating to the level of architectural 'interference' desired or required by the design objectives. It is essential to achieve adequate integration between the building and RES systems right from the design stages at the architectural level.
In general, the various renewable source technologies available on the market interfere very little with the morphological characteristics of buildings and their adjacent surroundings. The installation needs of technological apparatuses connected with the instances of safety, protection from fire, storage of fuels in a safe manner, require specific environments and filter zones for safety and manoeuvre, specific and hoped-for technical paths, accommodation cavities even of significant dimensions for both vertical and horizontal ducts.

Typologies.

The most common types of building-integrated systems and technologies for energy production from renewable sources are the following

- Photovoltaic systems for the production of electrical energy from renewable sources
- Solar collector systems for the production of thermal energy from renewable sources
- Thermodynamic solar energy
- Thermo-photovoltaic
- Biomass boilers
- Biomass cogeneration

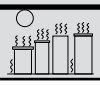
- Endogenous heat geothermal systems
- Low-enthalpy geothermal systems
- Micro-wind
    - Horizontal-axis wind microturbines
    - Vertical-axis wind microturbines
- Gas heat pumps
- Electric heat pumps

Integration with other technologies.

- Photovoltaic technologies
    - Photovoltaic technologies integrated into vertical envelope structures
    - Photovoltaic shingles for PV systems integrated into roof structures
- Possibility of integration with traditional energy supply systems
- Possibility of integration with rainwater and wastewater collection and reuse
- Possibility of integration with green and grey infrastructure
- Possibility of integration with existing energy networks

Presence in the case studies.

Circular Buiksloterham, La Duchére, Ecobarrio Trinitat Nova, Hikary project (La Confluence), Kortrijk, Le Albere, Limerick, Seaholm Ecodistrict, the Pearl, BedZED, Ile de Saint Denis, CityZen – Amsterdam, Replicate

Technology:	Critical issues related to climate change
Active outdoor and indoor cooling systems	Urban Heat Island  Heat waves

https://www.independent.co.uk/extras/indybest/house-garden/household-appliances/best-fan-b2123032.html



Context:

Spatial context: type of settlement	Application:	Main immediate environment:
City centre; Suburban areas; Countryside	Indoor; Outdoor; Envelope	Buildings; Streets; Open spaces

Work metod:

SMART PASSIVE ACTIVE

Type of solution:

Typology

Urban space device; Morphological; Technological; Materic; Plant engineering

Green / Blue / Gray

Responsiveness:

Period of installation:

Maintenance: !!!

Life span:

Return environmental period:

Indicators:

Characteristic indicators:

Mean radiant temperature



Relative humidity

Air speed



Air temperature

Other parameters:

Geometry

Material thickness

Roughness

Soil moistre / permeability

Conducibility

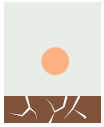
Emissivity

Albedo

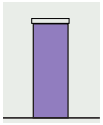
Decreased Hazards:



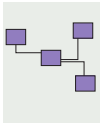
Wildfires



Drought



Stress of structures



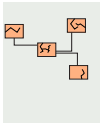
Stress of infrastructures



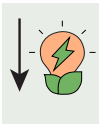
Rainfall



Decreasing of comfort conditions



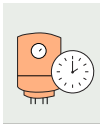
Energy transmission losses and facilities



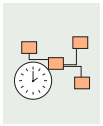
Negative impact for renewerable energies



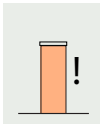
Increasing recovery costs



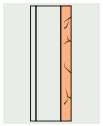
Increasing deterioration rate of systems and materials



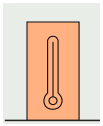
Increasing deterioration rate of infrastructures



Buildings may became unsuitable for use



Problems with finishing materials



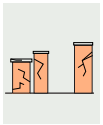
Increasing indoor temperature



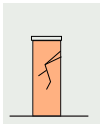
Increasing mortality



Increasing costs for preventing measures



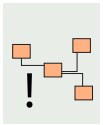
Neighborhoods abandonement



Buildings abandonement



Increasing maintenace costs



Infrastructures may became unsutaible for use



Decrease of air quality

Description.

The closer the internal building conditions are to the external microclimate conditions, the more efficiently the systems work. If the microclimate deviates significantly from the building's internal temperature, large amounts of cooling energy may be required to create a comfortable indoor environment. Similarly, a decrease in air and surface temperature, even at the point level, and the right humidity level would mitigate the occurrence of heat islands within the urban fabric, which would also benefit comfort. Active energy cooling systems work very well for temperature reduction, increased ventilation, relative humidity control and comfort at the indoor level. However, at the outdoor level, they are more punctual in their effectiveness. Active methods mainly use electricity and heat as the primary energy sources. The most widely used in the residential sector are three: fans, evaporative coolers and heat pumps (compression and absorption refrigeration machines; Oropeza-Perez & Østergaard, 2018)

Typologies.

Indoor:

- Fans
- Evaporative coolers
- Heat pumps
- Active recovery systems operate on the principle of the heat pump and refrigeration cycle or thermoelectric heat pump. This system can recover latent heat from the exhaust air and actively control the temperature and humidity of the fresh air. Compared to conventional air-conditioning systems, these have higher energy efficiency (Liu et al., 2019)

Outdoor:

An outdoor cooling system lowers the ambient temperature in outdoor spaces, making them more comfortable for occupants, especially during hot weather conditions and mitigating the effects of urban heat islands. These systems are commonly used in various circumstances, such as restaurants, bars, courtyards, stadiums, parks or outdoor events. The most used technologies are:

- Evaporative coolers
- Misting fans
- Portable air conditioning units
- High-pressure fans
- Active recovery systems

(https://www.equipmentshare.com/articles/the-best-event-cooling-solutions-for-outdoor-spaces)

Integration with other technologies.

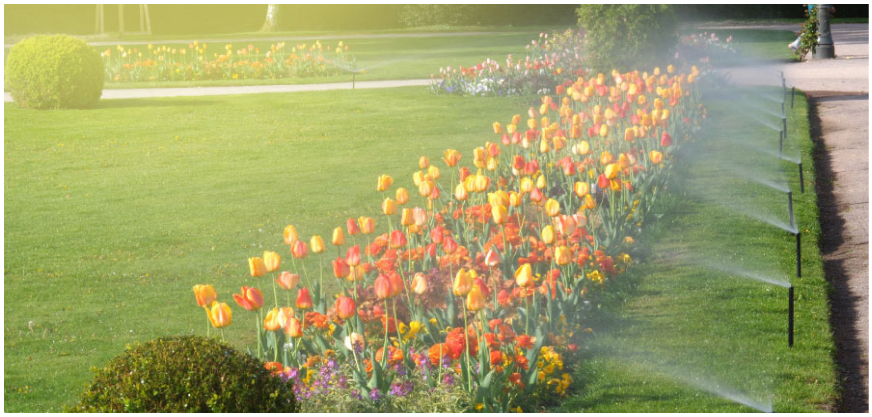
Active systems must be integrated with passive and bioclimatic systems to reduce energy requirements indoors and outdoors. Furthermore, these technologies should work with renewable energy sources (photovoltaic, geothermal, solar wind) and can also use energy storage systems to function continuously.

Presence in the case studies.

Circular Buiksloterham, La Duchére,Ecobarrio Trinitat Nova, Hikary project (La Confluence), Kortrijk, Laguna de duero, Le Albere, Limerick, Greenwich Millennium Village, Millvale, Caserme de Bonne, villa Fastiggi, Boucicaut, Seaholm Ecodistrict, the Pearl, BedZED, Ile de Saint Denis, Santa Giulia Milano, Cogneto, CityZen - Amsterdam, REPLICATE

Technology:	Critical issues related to climate change
Irrigation systems	Urban Heat Island  Heat waves 

https://www.facilitie-snet.com/groundsmanagement/article/Water-saving-Benefits-of-Smart-Irrigation-Systems-19904



Context:

Spatial context: type of settlement	Application:	Main immediate environment:
City centre; Suburban areas; Countryside	Indoor; Outdoor; Envelope	Buildings; Streets; Open spaces

Work metod:

SMART | PASSIVE | ACTIVE

Type of solution:

Typology

Urban space device | Morphological | Technological | Materic | Plant engineering

Green / Blue / Gray

Responsiveness:

Period of installation:

Maintenance: !!

Life span:

Return environmental period:

Indicators:

Characteristic indicators:

Mean radiant temperature


Relative humidity

Air speed


Air temperature

Other parameters:

Geometry

Material thickness

Roughness


Soil moistre / permeability

Conducibility

Emissivity

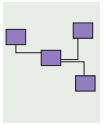
Albedo

Decreased Hazards:


Wildfires

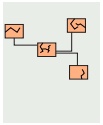

Drought

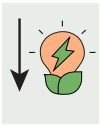
Stress of structures


Stress of infrastructures

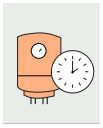

Rainfall

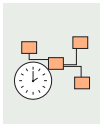

Decreasing of comfort conditions


Energy transmission losses and facilities

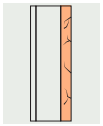

Negative impact for renewerable energies


Increasing recovery costs


Increasing deterioration rate of systems and materials


Increasing deterioration rate of infrastructures

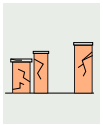
Buildings may became unsuitable for use


Problems with finishing materials

Increasing indoor temperature

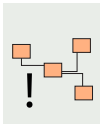

Increasing mortality


Increasing costs for preventing measures


Neighborhoods abandonement

Buildings abandonement


Increasing maintenace costs


Infrastructures may became unsutaible for use


Decrease of air quality

Description.

Artificial irrigation systems consist of the application of water to land or soil. They are used to promote the cultivation of crops, landscape maintenance and the reforestation of land in arid areas and during periods of insufficient rainfall. In addition, irrigation also has other benefits in landscape management, such as protecting plants from frost, suppressing weed growth in wheat fields and preventing soil erosion. Irrigation is often studied together with drainage, which is the natural or artificial removal of surface and sub-surface water from an area. Irrigation has been a central element of agriculture for over 5000 years. One of the oldest methods of irrigating fields is surface irrigation (sprinkler irrigation or furrow irrigation), in which farmers run water into small trenches through crops (Reddy, 2017). Using irrigation methods utilising city wastewater can be a valuable tool to mitigate the effects of heat waves and islands within the ubiquitous fabric. The possible consequences of global warming lead to the consideration of water adaptation measures to ensure water availability for food production and consumption. For this reason, studies on saving water in the irrigation process have increased over the years. Various irrigation methods exist in any agricultural activity of any type and size. The different possible options provide different efficiencies, and in some cases, particular plant species have specific irrigation methods. Concerning irrigation sensors, there are various types and they are divided into irrigation without control instruments, when the amount of water is not calculated or estimated, scheduled irrigation, when water is supplied automatically according to the different time of year, and ad hoc irrigation when the amount of water supplied to the plants is calculated using sensors (García et al., 2020). The choice of irrigation type must be made considering the natural conditions, per soil-climate, water quality, availability, and surroundings.

Typologies.

various types of irrigation on the market vary according to the plant species or area to be irrigated. Historically, the most commonly used irrigation techniques are:

- Surface irrigation
  - Furrow irrigation: small channels which carry water down the land slope between the crop rows
  - Basin irrigation involves flat land areas surrounded by low bunds that prevent water from flowing to the adjacent fields.
  - Border irrigation: sloping strips of land separated by the ground bring the water to the cultivation
- Localised irrigation:
- Subsurface textile irrigation:
- Drip irrigation
- Sprinkler irrigation
- Centre pivot irrigation

- Lateral move (side roll, Wheel line) irrigation
- Sub-irrigation
- Auomatic, non-elettric using buckets and ropes
- Using water condensed from humid air
- In-ground irrigation

Integration with other technologies.

- PV minigrids
- Use of sensors
- Integrated systems with water collection and reuse

Presence in the case studies.

La Duchére, Hikary project (La Confluence), Le Albere, Caserme de Bonne, Villa Fastiggi, Santa Giulia Milano, Cogneto

Technology:	Critical issues related to climate change
Ventilated roofs and walls	Urban Heat Island  Heat waves



https://wfmmedia.com/ventilated-facade-systems/

https://www.archiproducts.com/en/products/aertet-to/ventilated-roof-system-aertegola_69889



Context:

Spatial context: type of settlement	Application:	Main immediate environment:
 City centre; Suburban areas; Countryside	 Indoor; Outdoor; Envelope	 Buildings; Streets; Open spaces

Work metod:

SMART | PASSIVE | ACTIVE

Type of solution:

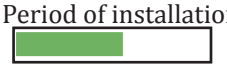
Typology

Urban space device | Morphological | Technological | Materic | Plant engineering

Green / Blue / Gray

Responsiveness:

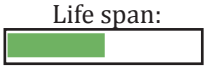
Period of installation:



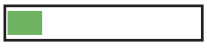
Maintenance:

!!

Life span:



Return environmental period:



Indicators:

Characteristic indicators:


Mean radiant temperature


Relative humidity

Air speed


Air temperature

Other parameters:

Geometry


Material thickness


Roughness

Soil moistre / permeability


Conducibility

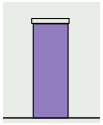

Emissivity


Albedo

Decreased Hazards:

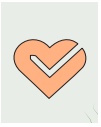
Wildfires

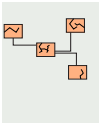
Drought

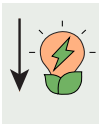

Stress of structures

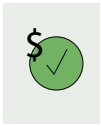
Stress of infrastructures

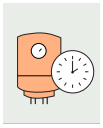
Rainfall


Decreasing of comfort conditions

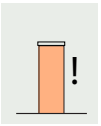

Energy transmission losses and facilities

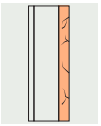

Negative impact for renewerable energies

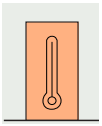

Increasing recovery costs


Increasing deterioration rate of systems and materials

Increasing deterioration rate of infrastructures


Buildings may became unsuitable for use

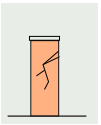

Problems with finishing materials


Increasing indoor temperature


Increasing mortality


Increasing costs for preventing measures

Neighborhoods abandonement


Buildings abandonement


Increasing maintenace costs

Infrastructures may became unsutaible for use

Decrease of air quality

Description.

These technology solutions consist of two layers separated by an air gap with openings outside or inside, allowing air to flow in and out of the gap. The openings can be placed at the base and top of the joints or take advantage of those left open between the outer cladding slabs. The dimensions of the cavity vary from 4 to 20-30 cm. Ventilation usually follows an external-external path, exploiting the chimney effect. In this way, in summer, by convection, part of the heat caused by solar radiation to the outer layer is subtracted from the structure. Heat loads are also subtracted from the inner layer. In winter, the ventilation contributes to reducing the thermal resistance that the structure would have with still air; at the same time, it contributes to the disposal of vapour, preventing the risk of condensation. The openings may also be closed to transform the cavity into an air chamber. There is a height difference between roofs and ventilated façades, which is higher for roofs, and exposure, almost horizontal for roofs and vertical for façades. In addition, compared to vertical walls, roofs are more exposed to atmospheric conditions and experience stronger wind pressures.

Typologies.

Ventilated façades: the methodology to be followed for the design of ventilated façades can be summarised in the following points:

- Definition of the desired type of ventilation among the existing types:
    - Very weakly or micro-ventilated walls
    - Weakly ventilated walls
    - Medium or strongly ventilated walls
- Definition of the type of external cladding, in harmony with the general architectural choices
- Definition of the type of substructure fixing system, depending on the technical-dimensional characteristics of the type of cladding chosen

The choice of the type of ventilation is a function of the environmental and design objectives, which are defined upstream of the specific design phase of the intervention.

Ventilated roofs: This type of solution lends itself to mitigating the effects of heat islands and waves, as it has good thermal dispersion and hygrometric control of the roof itself and the rooms underneath it. The main feature of ventilated roofing is a specific ventilation layer created through an aerated cavity between the roof covering and the thermal insulation layer. By constructing ventilated roofs, it is possible to reduce the summer solar heat loads that the roof tends to transmit to the rooms below. Among other things, the high surface temperatures reached in the summer by the roof covering exposed to the sun, alternating with the

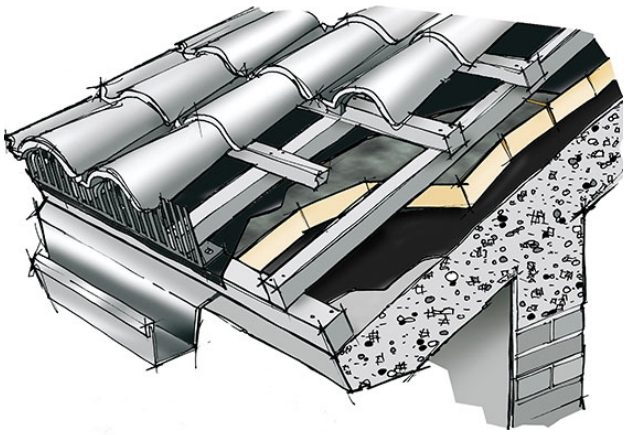
reduced temperatures that can occur at night, induce thermal stress on the structures and constituent materials. This type of solution avoids the stagnation of any humidity due to precipitation, preventing it from permeating the covering. It also eliminates any problems of interstitial condensation of water vapour produced in the rooms. It is possible to distinguish between three major technical solutions:

- Insulated-ventilated roof with underlay ventilation
- Insulated-ventilated roof with double ventilation space
- Ventilated, insulated, non-habitable attic roof with attic space ventilation

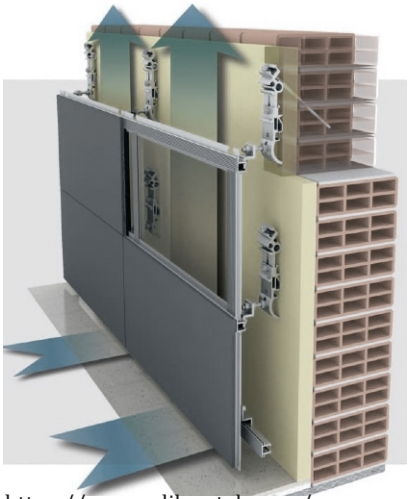
Regarding technical construction precautions, the height of the ventilation batten is of utmost importance. An adequate air inlet section on the roof must be ensured at the eaves line and an outlet section at the ridge. These sections are made up of both continuous and discontinuous slits, protected from the entry of insects or small animals, and punctual openings made up of protected vents. At the ridge, the technical solution for air outflow must ensure water and snow tightness. In addition, ventilation tiles should be provided to ensure adequate ventilation of the underlay, which can increase the flow.
Both ventilated façades and roofs are often integrated with photovoltaic or green systems.

Presence in the case studies.

Greenwich Millennium village, Replicate



https://italy.ediltec.com/it/applicazione/isolamento-sotto-guaina-bituminosa/coperture-a-falde-ventilate-sottoguaina



https://www.edilportale.com/news/2016/01/focus/facciate-ventilate-

Results and discussion.

The intervention strategies and technical solutions analysed for heat island control address and mitigate the occurrence of urban microclimate problems by acting on the same factors that generate the phenomenon. On the contrary, in the case of heat waves, since the phenomenon is mainly exogenous to urban systems, intervention strategies and technical solutions serve primarily as mitigation and compensation measures. For example, cool materials, particularly on the average radiant temperature of surfaces, reduce the heat island's occurrence and the heat wave's impacts on the city by acting on the radiation incident on surfaces.
The analysis of individual technologies shows that wildfires can be discouraged by installing green infrastructure, which moistens the soil. Various actions can be implemented to decrease the occurrence of drought events. First, blue infrastructures can collaborate in collecting, storing, and reusing rainwater. In addition, using permeable and photocatalytic materials increases moisture levels in the air and soil, helping to ward off the phenomenon. Finally, all typologies involving greenery increase water retention in the soil. Stress problems in structures and infrastructure due to heat islands and heat waves can be mitigated by the use of cool materials, which decrease the absorption of thermal energy by surfaces, by solutions that increase humidity, such as evaporative cooling, as an active strategy, by the use of urban greenery, of bioclimatic atriums - which pre-treat the air before it enters the interior spaces, which often act as exhaust air extractors and inject clean air into the interior spaces, and where good ventilation is guaranteed thanks to the possibility of opening windows. Finally, using permeable surfaces also contributes to reducing the occurrence of situations that can lead to stress on structures and infrastructure. Finishing materials are among the components of building packages that external agents stress most. The choice of material is essential to reduce the stress caused by rising temperatures. By favouring the use of cool materials, photocatalytic materials, or permeable materials, it is possible to achieve good levels of resistance to extreme phenomena related to climate change. Green infrastructure can cooperate in preserving finishing materials by providing shaded areas or green façades that protect structures. An increase in temperature inside buildings, the consequent decrease in comfort levels and the rise in mortality linked to heat islands and heat waves can

be mitigated through active solutions, from the presence of greenhouse spaces and bioclimatic atria, providing ventilation, wind chimneys, and the installation of indoor and outdoor greenery. Green and blue infrastructure is essential to diminish the effects of flooding phenomena, avoid it, and ensure proper water absorption in the water table or collection and reuse points. Artificial and natural devices for guiding wind flows, shading and shadowing systems, green infrastructure, ponds of water, buffer zones, cladding systems, thermal masses and special materials - cool, phase-change, permeable and thermochromic materials, can contribute to the mitigation of losses due to excessively high temperatures in energy transmission systems and to the decrease of efficiency in energy production from renewable sources. Infrastructure and the presence of green corridors, in particular, are solutions that enable the mitigation of issues concerning the increased cost of preventive measures, the abandonment of neighbourhoods and buildings and the increased deterioration of infrastructure. The presence of evaporative cooling, green and blue infrastructures, bioclimatic atria, green walls and roofs, indoor greenery, and photocatalytic or cool materials can decrease maintenance and recovery costs and the deterioration rate of materials and installations. Finally, the decrease in air quality can be mitigated by devices for guiding wind flows, shading systems, green infrastructures, greenhouses that allow the exchange of air indoors, and systems guided by renewable energy sources.
Urban greenery and green infrastructure, in general, are versatile and effective actions for mitigating island and heat wave hazards. However, using active technologies involving a limited number of KPIs and acting at an indoor level presents limitations in mitigating and adapting to these phenomena.
Trees and green corridors are the most effective as they affect air temperature, surface temperature, humidity, and wind speed. Urban greenery and green infrastructure, in general, are versatile and effective actions for mitigating island and heat wave hazards. It should be noted that the use of active technologies, even if driven by renewable sources, involving a small number of KPIs and acting purely at an indoor level, presents limitations in mitigating and adapting to these phenomena on a large scale.

Figure 26 shows the technologies that can help reduce the occurrence of each hazard. These technologies are identified according

to whether they act indoors or outdoors, on the building or infrastructure, purely on the individual or the context, and only if they involve all the indicators affected by the hazard under consideration.

Specific studies, cited in the paragraphs of the first part of this thesis, have shown a direct relationship between ambient humidity conditions and heat wave phenomena: for heat waves to occur, the previous winter and spring must be dry[24]. This phenomenon, combined with ventilative blockage, increases heat, heat islands within population centres and heat waves. Adopting technologies that increase the specific humidity in the environment can be an excellent solution. In particular, misting and blue infrastructure are particularly suitable for this purpose.

Moisture is also a significant parameter for heat island mitigation[25]: solutions that include vegetation and the general use of permeable solutions favour maintaining adequate moisture levels in the air and soil.

Emissions and unscrupulous soil use generally increase the effects of solar radiation, consequently increasing the effects of heat islands and heat waves in the longer term[26]. In this sense, using technologies such as cool materials contributes to mitigating and adapting both phenomena.

24. See paragraph 1.1.3 (Chen et al., 2024; Kong et al., 2023)

25. (M. Imran et al., 2021; O'Malley et al., 2015) see par 1.1.2

26. For urban heat islands (Patz et al., 2005; Rosenfeld et al., n.d.); for heat waves (Barriopedro et al., 2023).

2.3| Identification of actions for adaptation to islands and heat waves
p. 409

Figure 26 a

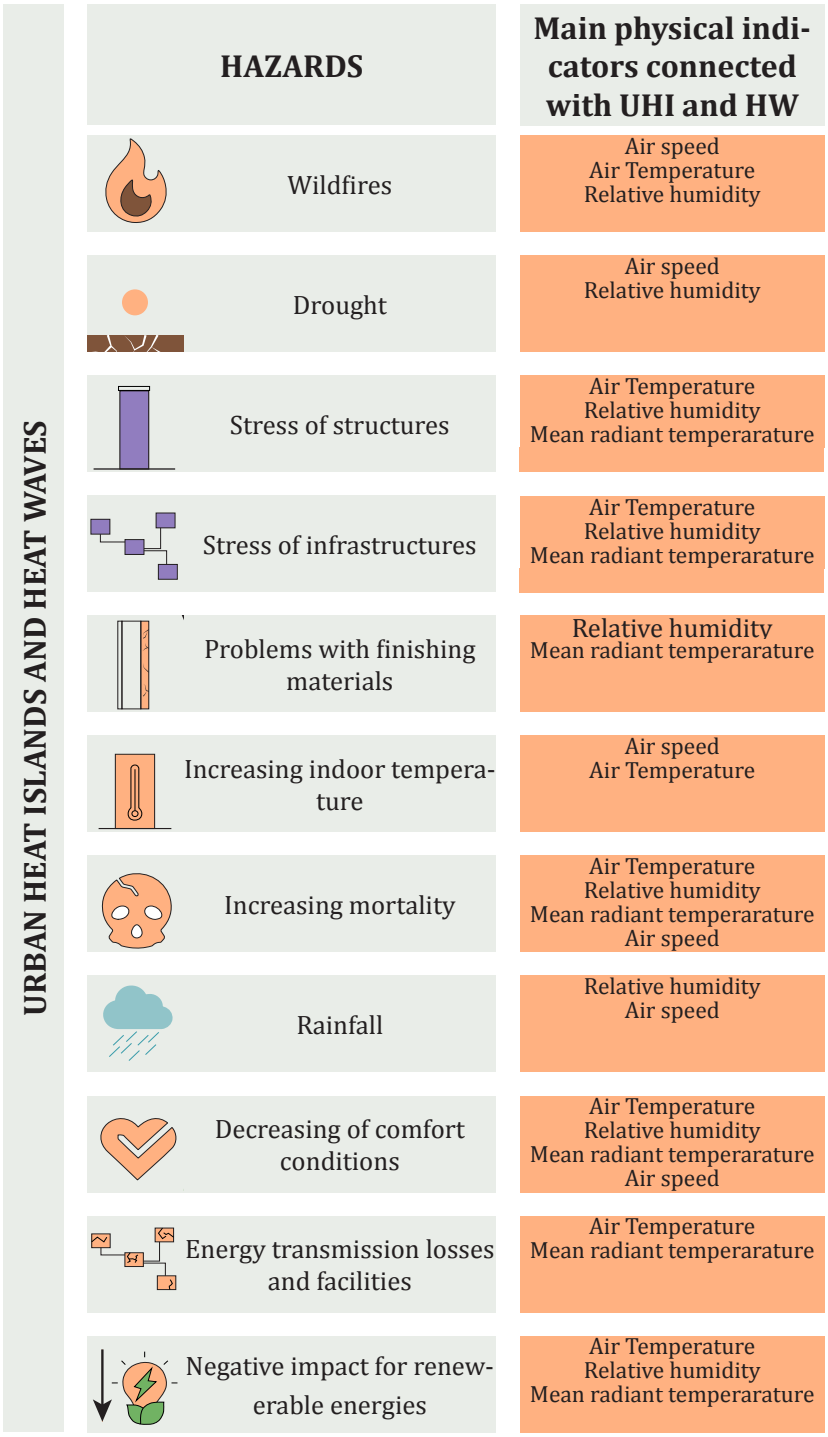


Figure 26 a, b. In the matrix, for each corresponding hazard, it can be seen that the indicators that collaborate in reducing the phenomenon and the technologies that can intervene in all indicators can be seen. Author's elaboration

Figure 26 a

TECHNOLOGIES THAT CAN INTERVENE ON ALL THE INDICATORS
Parks, garden squares, pocket gardens, and urban farmings, trees and green corridors
Parks, garden squares, pocket gardens, and urban farmings, trees and green corridors
Water surfaces, rain garden and phytodepuration, wetland ad bioswales, parks, garden squares, pocket gardens, and urban farmings, trees and green corridors, Cooling towers, green systems embedded in buildings, green houses and winter gardens, external coat, green roofs, green walls, ventilated roofs/floors, permeable surfaces, ponds on roof/ground floor, cool materials
Evaporative cooling, water surfaces, rain garden and phytodepuration, wetland ad bioswales, parks, garden squares, pocket gardens, and urban farmings, trees and green corridors, permeable surfaces, ponds on roof/ground floor, cool materials
External coat, Parks, garden squares, pocket gardens, and urban farmings, trees and green corridors, green roofs/walls, permeable surfaces, cool materials, cooling towers, green systems embedded in buildings, ventilated roofs/walls
Artificial and natural urban devicesfor guide wind flows, parks, garden squares, pocket gardens, and urban farmings, trees and green corridors, bioclimatic atria, cooling towers, green houses and winter gardens
Parks, garden squares, pocket gardens, and urban farmings, trees and green corridors, bioclimatic atria, wind chimney, reen houses and winter gardens
Parks, garden squares, pocket gardens, and urban farmings, trees and green corridors
Parks, garden squares, pocket gardens, and urban farmings, trees and green corridors, bioclimatic atria, wind chimney, reen houses and winter gardens
Artificial and natural urban devicesfor guide wind flows, artificial shade systems, natural shade systems, Parks, garden squares, pocket gardens, and urban farmings, trees and green corridors, buffer zones, external coat, green roofs, permeable surfaces, ponds on roof/ground floor, phasechange and thermocromic materials, thermal mass
Evaporative cooling, water surfaces, rain garden and phytodepuration, wetland ad bioswales, Parks, garden squares, pocket gardens, and urban farmings, trees and green corridors, green roofs/walls, permeable surfaces, ponds on roof/ground floor, cool materials, external coat, ventilated roofs/walls

Figure 26 b

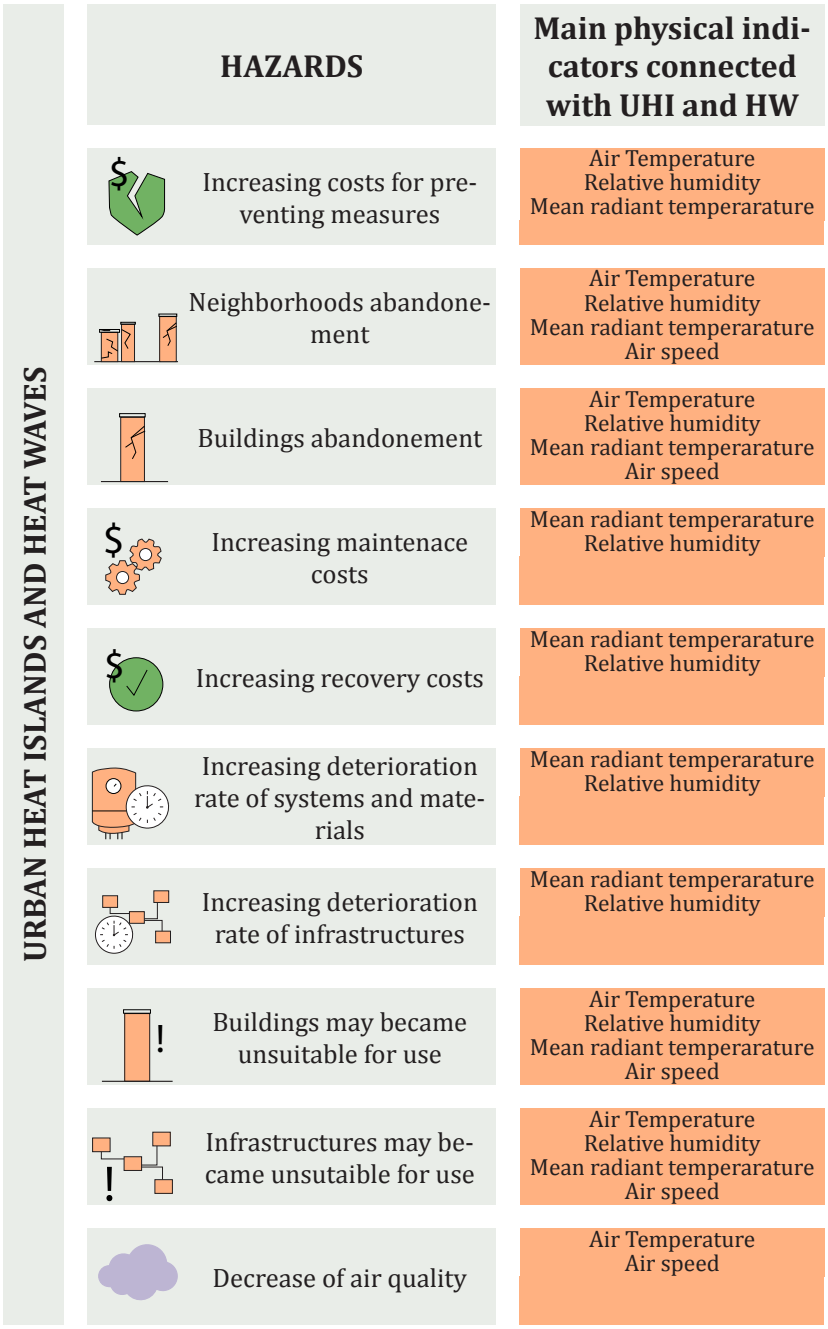

URBAN HEAT ISLANDS AND HEAT WAVES
HAZARDS
Main physical indicators connected with UHI and HW
Increasing costs for preventing measures
Air Temperature
Relative humidity
Mean radiant temperarature
Neighborhoods abandonement
Air Temperature
Relative humidity
Mean radiant temperarature
Air speed
Buildings abandonement
Air Temperature
Relative humidity
Mean radiant temperarature
Air speed
Increasing maintenace costs
Mean radiant temperarature
Relative humidity
Increasing recovery costs
Mean radiant temperarature
Relative humidity
Increasing deterioration rate of systems and materials
Mean radiant temperarature
Relative humidity
Increasing deterioration rate of infrastructures
Mean radiant temperarature
Relative humidity
Buildings may became unsuitable for use
Air Temperature
Relative humidity
Mean radiant temperarature
Air speed
Infrastructures may became unsutaible for use
Air Temperature
Relative humidity
Mean radiant temperarature
Air speed
Decrease of air quality
Air Temperature
Air speed

Figure 26 b

TECHNOLOGIES THAT CAN INTERVENE ON ALL THE INDICATORS

Water surfaces, raingardens and phytodepuration, wetlands and bioswales, parks, garden squares, pocket gardens, and urban farmings, trees and green corridors, cooling towers, green systems embedded in buildings, green houses and winter gardens, cool materials, green roofs/walls, permeable surfaces, ponds on roofs/ground floors, ventilated roofs/walls, green systems embedded in buildings

Parks, garden squares, pocket gardens, and urban farmings, trees and green corridors

Parks, garden squares, pocket gardens, and urban farmings, trees and green corridors, bioclimatic atria, cooling towers

Water surfaces, rain garden and phytodepuration, wetland ad bioswales, parks, garden squares, pocket gardens, and urban farmings, trees and green corridors, green systems embedded in buildings, green walls, green roofs, permeable surfaces, ponds on roof/ground floor, photocatalityc materials, cool materials, cooling towers, ventilated roofs/walls

Water surfaces, rain garden and phytodepuration, wetland ad bioswales, parks, garden squares, pocket gardens, and urban farmings, trees and green corridors, green systems embedded in buildings, green walls, green roofs, permeable surfaces, ponds on roof/ground floor, photocatalityc materials, cool materials, cooling towers, ventilated roofs/walls

Water surfaces, rain garden and phytodepuration, wetland ad bioswales, parks, garden squares, pocket gardens, and urban farmings, trees and green corridors, green systems embedded in buildings, green walls, green roofs, permeable surfaces, ponds on roof/ground floor, photocatalityc materials, cool materials, cooling towers, ventilated roofs/walls

Rain garden and phytodepuration, wetland ad bioswales, parks, garden squares, pocket gardens, and urban farmings, trees and green corridors, permeable surfaces, ponds on roof/ground floor, photocatalityc materials, cool materials, cooling towers, ventilated roofs/walls

Parks, garden squares, pocket gardens, and urban farmings, trees and green corridors, bioclimatic atria, cooling towers

Parks, garden squares, pocket gardens, and urban farmings, trees and green corridors

Artificial and natural urban devicesfor guide wind flows, parks, garden squares, pocket gardens, and urban farmings, trees and green corridors

2.3.2| Selection of technologies

Summary.

Mitigation and adaptation strategies should consider the phenomenon's multifactorial aspects, the scales of analysis, and the response to which the project must adapt.
Of the actions identified to deal with islands and heat waves, not all act efficiently and in the short term.
The research implements a decision-making framework for bioclimatic and energy retrofit. The technologies analysed above are compared to identify those that respond to the most significant number of city hazards previously identified—Section 2.1.1—that can provide both indoor and outdoor feedback and have short payback times.
This part of the research is articulated in three different steps: the first consists of a literature review concerning the identification of efficiency parameters of the technologies considered; the second consists of analysing, comparing, and evaluating the efficiency of the individual technologies; and the third corresponds to the identification of the technological solutions most in line with the required objectives.
Mitigation and adaptation strategies should consider the phenomenon's multifactorial aspects, the scales of analysis, and the response to which the project must adapt.

Introduction.

This part of the research aims to identify the most effective technological solutions addressed in the previous sections. These solutions should have short payback periods to meet the UN's 2030 and 2050 targets.
Actions aimed at mitigation and adaptation to heat islands and heat waves have different effectiveness and response times. According to Treccani[27], effectiveness means: 'the ability to fully produce

27. Treccani: https://www.treccani.it/vocabolario/efficacia/. Consulted on 14/02/2025.

the intended effect, and the achievement of the effect itself'. The Cambridge Dictionary defines effectiveness as 'the ability to be successful and produce the intended results' (Cambridge Dictionary, 2024). According to the Oxford Learner's Dictionaries[28], effectiveness means: 'the fact of producing the result that is wanted or intended; the fact of producing a successful result, the power to produce an effect'. With these definitions in mind, in this research, effectiveness means the level of influence that actions and strategies aimed at mitigating and adapting to heat islands and heat waves have on the KPIs identified above (Section 2.1.3), on their influence, both at the building and neighbourhood scale, indoor and outdoor.

We find the term efficiency used in the context of sustainability in 1992 (International Monetary Fund, 1992) and then in 2000 with Huber, who states that increasing efficiency means minimising resource consumption (Huber, 2000). According to the dictionary, efficiency means: 'effective operation as measured by a comparison of production with cost (as in energy, time and money)' or 'the ratio of the useful energy delivered by a dynamic system to the energy supplied to it'. In this research, efficiency means the combination of effectiveness and response time of actions on the existing system to use as few resources as possible in the shortest time.

The research carried out in the previous chapter is extended and supplemented by connecting this analysis to effectiveness and efficiency. Technological solutions are evaluated by identifying the KPIs and hazards on which they have an effect.

Thanks to this work, it is possible to identify the indicators that can contribute most to decreasing the risk of each hazard and the response time each technological solution possesses.

The proposed device's development, results, potential, and weaknesses are illustrated below.

28. https://www.oxfordlearnersdictionaries.com/definition/english/effectiveness. Consulted on 14/02/2025.

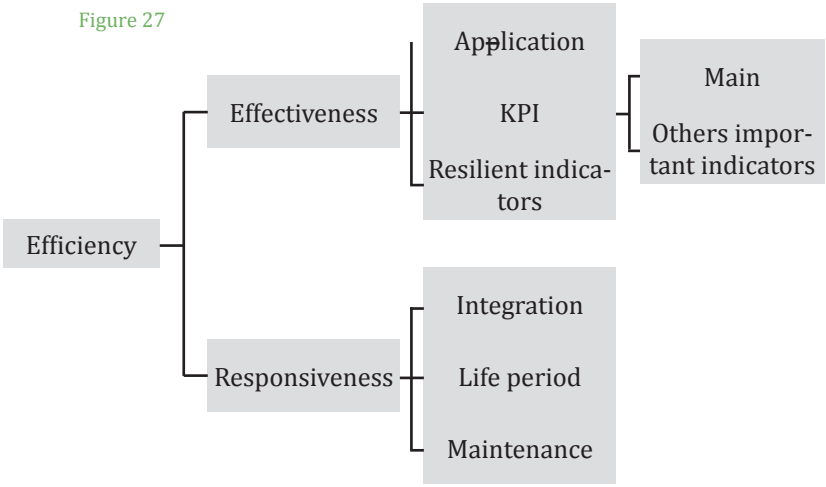
Way of conducting the research.

The research adopts a systematic approach consisting of three phases. The first phase consists of an in-depth literature review to identify the main parameters that define an 'efficient' technology concerning islands and heat waves during the hottest periods of the year. The second phase explores each action identified in the previous section, 2.3.1, according to the abovementioned pa-

Figure 27. Interrelation between the characteristics of technological solutions to mitigate and adapt to heat islands and waves

rameters. The third phase indicates which hazards the different actions may affect. This way, the author sets up a decision-support framework by analysing the technological, bioclimatic, and energy solutions identified in the previous paragraphs.
In particular, the first phase consists of identifying the parameters that characterise a technological action and contribute to evaluating its effectiveness and efficiency for island and heat wave mitigation. The graph in Figure 27 shows the interrelationships between the parameters that contribute to the analysis of the technologies. In this thesis, 'efficient' combines effectiveness and responsiveness. In this thesis, the effectiveness of a technology is given by the combination of the scope of application - the greater the versatility of the scope, the greater the effectiveness of a technology - the resilience indicators it affects - whether the technology influences adaptation or mitigation, or comfort referred to islands and heat waves - the number of KPIs it affects. The most important KPIs are mean radiant temperature, air temperature, speed, and relative humidity. Other indicators influence the occurrence and intensity of heat islands and heat waves, such as geometry, material thickness, roughness, emissivity, albedo, conductivity, and soil moisture. The components contributing to the increase in responsiveness are the level of integration with other actions, the lifespan and the level of maintenance required.

Figure 27



All these parameters are investigated and explained in a graphic representation, visible in Figure 28 for each action identified.

Figure 28

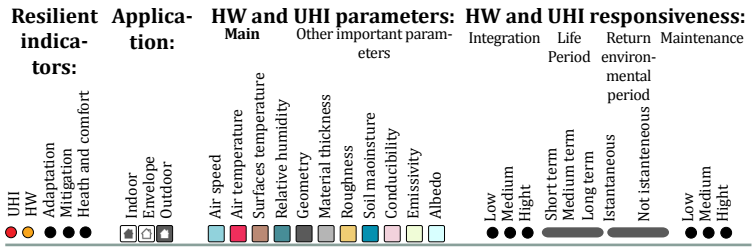


Figure 28. Figure 28 shows the parameters underpinning the assessment of the effectiveness and efficiency of the selected actions for adapting to and mitigating islands and heat waves.

29. The term comfort refers to thermo-hygrometric one: thermal comfort and humidity within an environment. Factors influencing thermo-hygrometric comfort are air temperature, relative humidity, airspeed, physical activity and clothing (Ergonomia degli ambienti termici - Determinazione analitica e interpretazione del benessere termico mediante il calcolo degli indici PMV e PPD e dei criteri di benessere termico locale, 2008)

The individual parameters identified for each action are explained in detail below:

- **Resilient indicators:** These are divided into two groups. The first group indicates the phenomenon towards which the technological solution under analysis acts: on the heat island, heat waves, or both. The second group indicates the mode of action: adapting the existing to extreme phenomena, mitigation, or increasing comfort conditions[29].
- **Application:** This parameter indicates where the considered action can be applied to mitigate heat wave and heat island impacts: outdoors, indoors or on the envelope of buildings.
- **Heat waves and urban heat island parameters:** This indicates the parameters towards which the action under analysis affects. In particular, the most important parameters affecting extreme phenomena, found in the previous paragraphs (see section 2.1.3), are made explicit: air temperature, wind speed, mean radiant temperature and relative humidity. In addition, other parameters such as geometry, material thickness, roughness, water in the soil, conductivity, emissivity and albedo are also present within the matrix, all of which influence the extreme events considered.
- **Responsiveness:** This parameter indicates the level of responsiveness the action analysed has on the existing stock. A further division allows for the explicit expression of the different nuances:

  - Possibility of **integration** with other technological solutions: The level is considered low if at least one reference demonstrates an increase in effects when combined with another technology or system. The level of integration is considered medium if, in addition to the studies mentioned above, there are studies on home automation control and contributions concerning innovative versions, in combination with other technologies. The level of integration is considered high if, in addition to the characteristics mentio-

ned above, a specific action can perform multiple functions, becoming a hub containing various actions that together respond passively and actively to changes in environmental stimuli. This assessment was conducted based on the available scientific literature (Tucci, Atlante dei sistemi tecnologici per l'architettura bioclimatica. Ventilazione naturale negli edifici, 2020; Tucci, Climate Responsive Envelopes. Frontiere del'innovazione tecnologica e prestazionale nel progetto della pelle degli edifici, 2020).

- **Life period:** providing three opportunities, schematised through different segment lengths: less than 10 years, between 10 and 30 years, and greater than 30 years.

- **Response time:** with two options: instantaneous and non-instantaneous

- **Maintenance:** indicating the periodicity and complexity of maintenance interventions, and evaluated based on the available scientific literature. It is divided into low if the technology envisages sporadic and occasional interventions during its life (an example of this are the 'cool' and external coat solutions); medium, in the case of the technology under analysis, envisages minimally invasive but regular interventions - such as bioclimatic atriums, which require cleaning interventions and the control of the proper functioning of the fixtures to guarantee the passage of the wind during the summer season. Finally, a high level of maintenance is assumed for all technological solutions that require regular interventions and monitoring; this is the case for most green solutions, which involve irrigation and the control of plant species' health.

The second phase consists of the analysis of the actions. This part of the research is supported by an analysis, illustrated in the previous paragraphs (Section 2.3.1). The resulting chart defines a decision support framework concerning the effectiveness of the actions previously identified for adapting existing contexts and mitigating impacts concerning heat islands and heat waves. The matrix represents and summarises the characteristics of each action applicable to the existing fabric that may influence the increase in frequency and intensity of islands and heat waves, thus functioning as a decision support.

The third step, corresponding to the second part of the matrix, illustrates the hazards each technology can contribute to reducing

their occurrence, intensity and frequency. In particular, it makes explicit whether or not the solution considered influences concerning the dangers to which towns and cities are exposed due to islands and heat waves. From a graphical point of view in the matrix, the influence of actions on hazards is made explicit through small squares: black squares indicate that a given technological solution affects all the KPIs of a given hazard. In contrast, white squares only affect some of them. This part of the matrix helps understand to what extent a solution can act on the indicators that characterise a given hazard. Thus, it is possible to evaluate a level of influence.

Figure 29 a, b, c. Technology summary matrix. Author's elaboration

Figure 29 a.

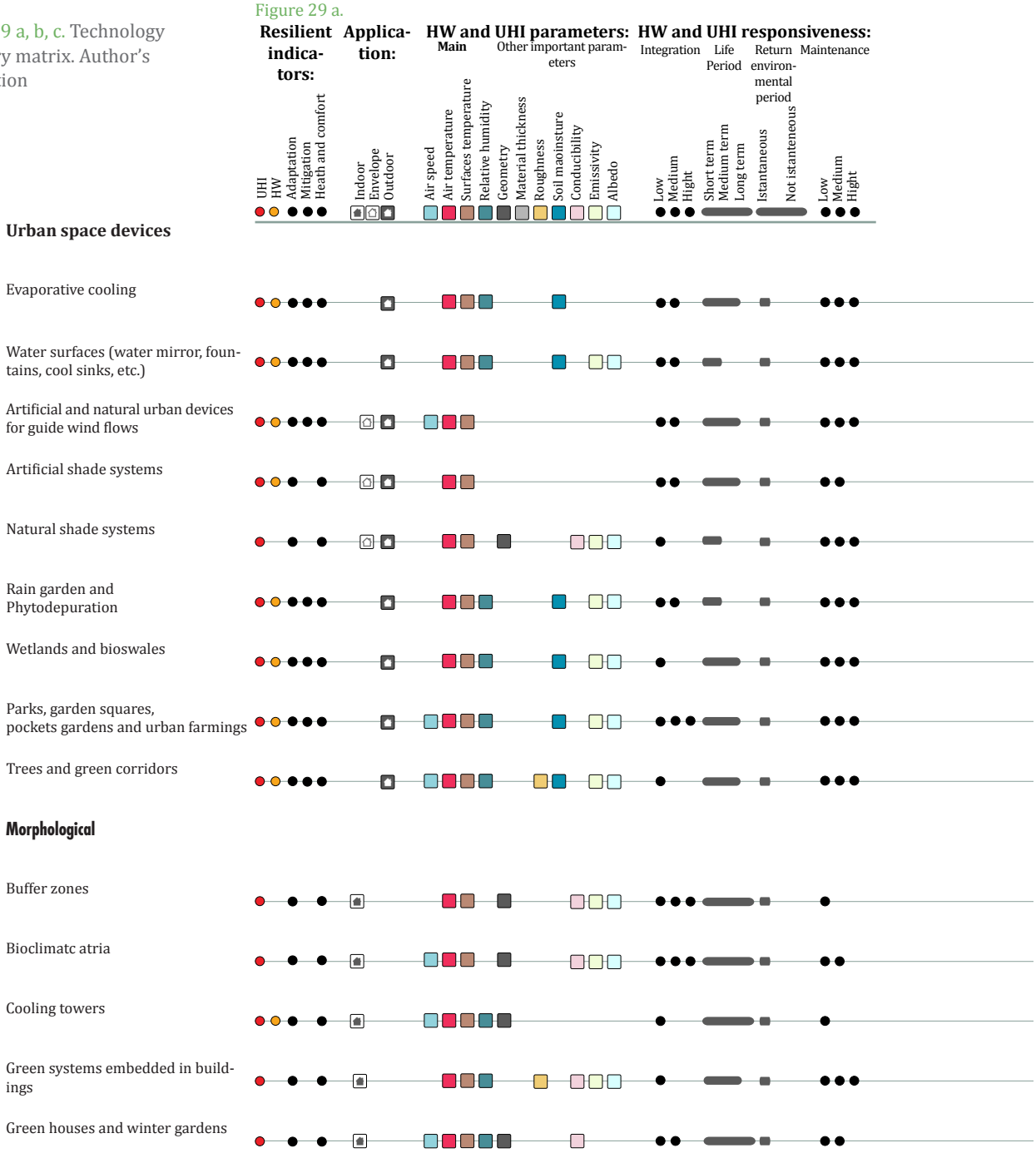


Figure 29 a.

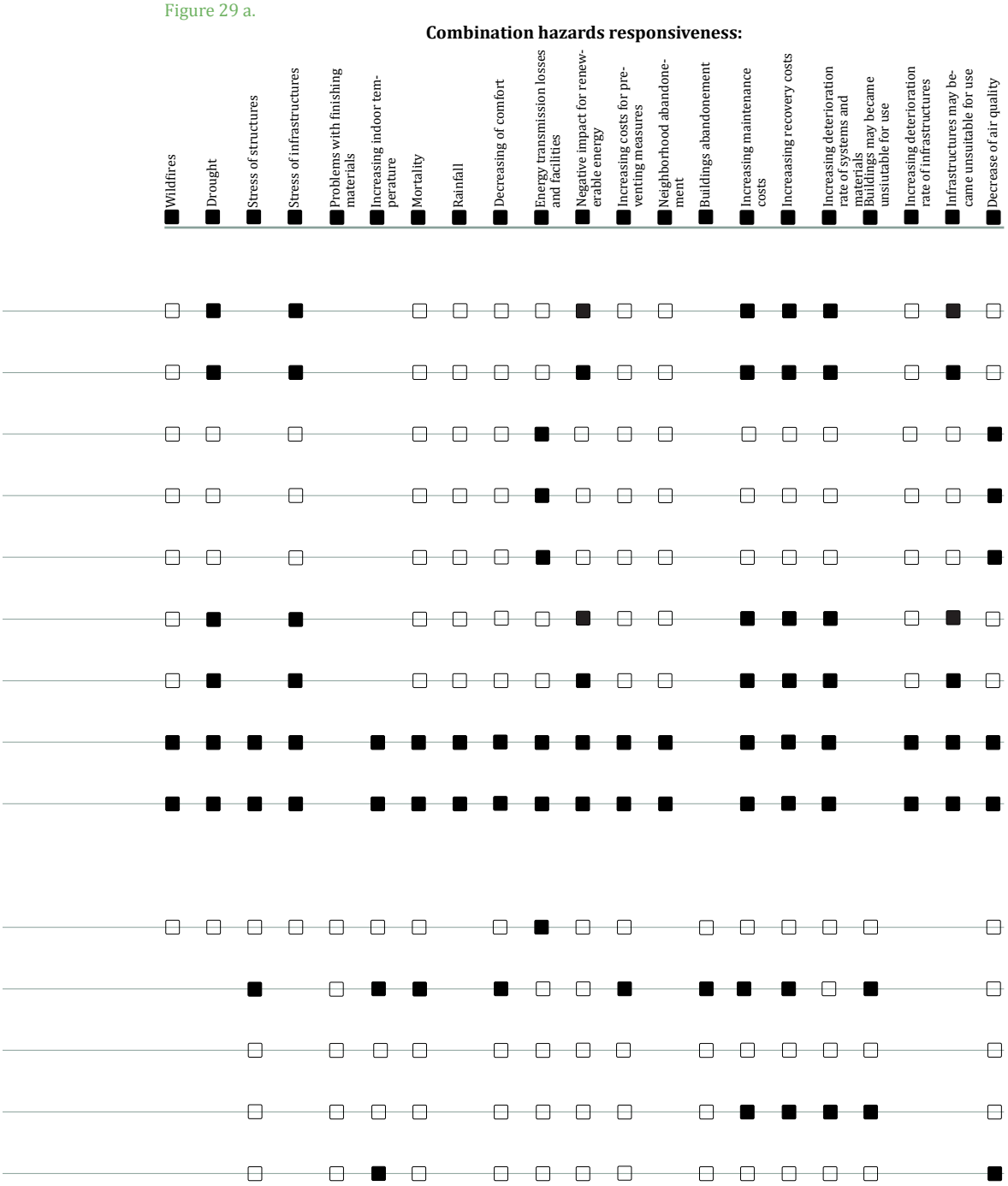

Combination hazards responsiveness:
Wildfires
Drought
Stress of structures
Stress of infrastructures
Problems with finishing materials
Increasing indoor temperature
Mortality
Rainfall
Decreasing of comfort
Energy transmission losses and facilities
Negative impact for renewerable energy
Increasing costs for preventing measures
Neighborhood abandonement
Buildings abandonement
Increasing maintenance costs
Increaasing recovery costs
Increasing deterioration rate of systems and materials
Buildings may became unsiutable for use
Increasing deterioration rate of infrastructures
Infrastructures may became unsuitable for use
Decrease of air quality

Figure 29 b.

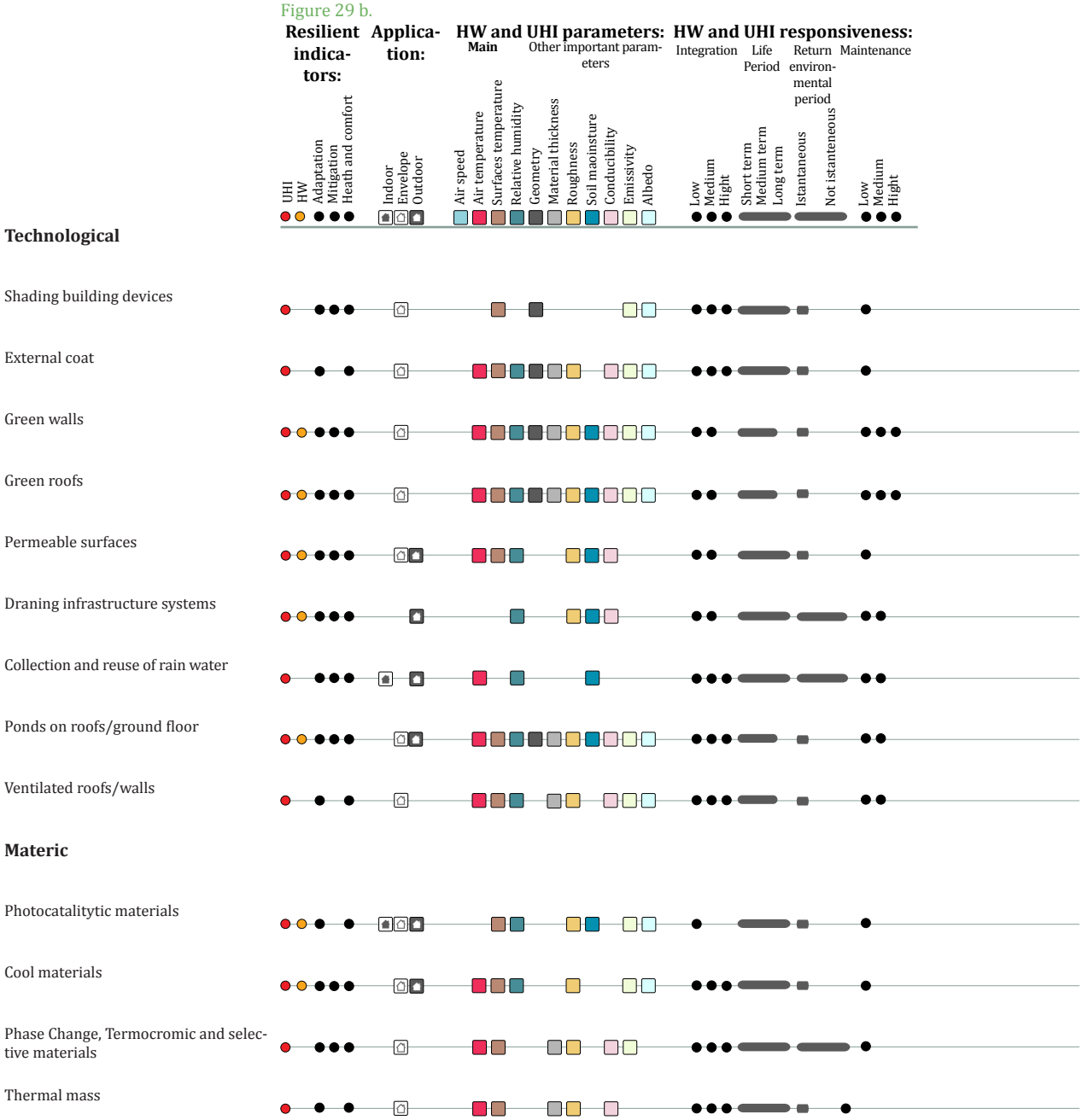

Resilient indica-tors:
Applica-tion:
HW and UHI parameters:
Main
Other important param-eters
HW and UHI responsiveness:
Integration
Life Period
Return environ-mental period
Maintenance
UHI
HW
Adaptation
Mitigation
Heath and comfort
Indoor
Envelope
Outdoor
Air speed
Air temperature
Surfaces temperature
Relative humidity
Geometry
Material thickness
Roughness
Soil maoinsture
Conducibility
Emissivity
Albedo
Low
Medium
Hight
Short term
Medium term
Long term
Istantaneous
Not istanteneous
Low
Medium
Hight
Technological
Shading building devices
External coat
Green walls
Green roofs
Permeable surfaces
Draning infrastructure systems
Collection and reuse of rain water
Ponds on roofs/ground floor
Ventilated roofs/walls
Materic
Photocatalitytic materials
Cool materials
Phase Change, Termocromic and selec-tive materials
Thermal mass

Figure 29 b.

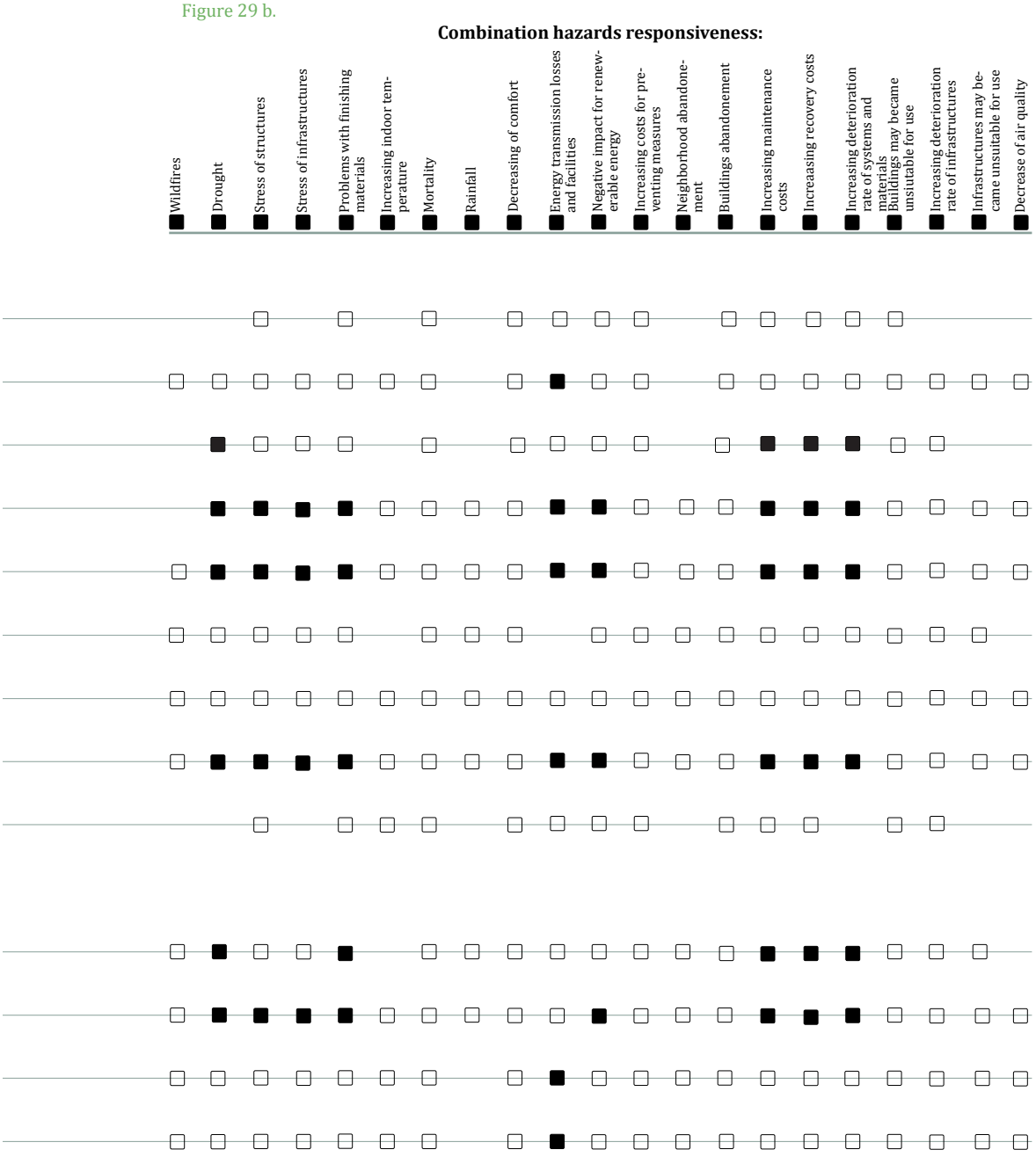
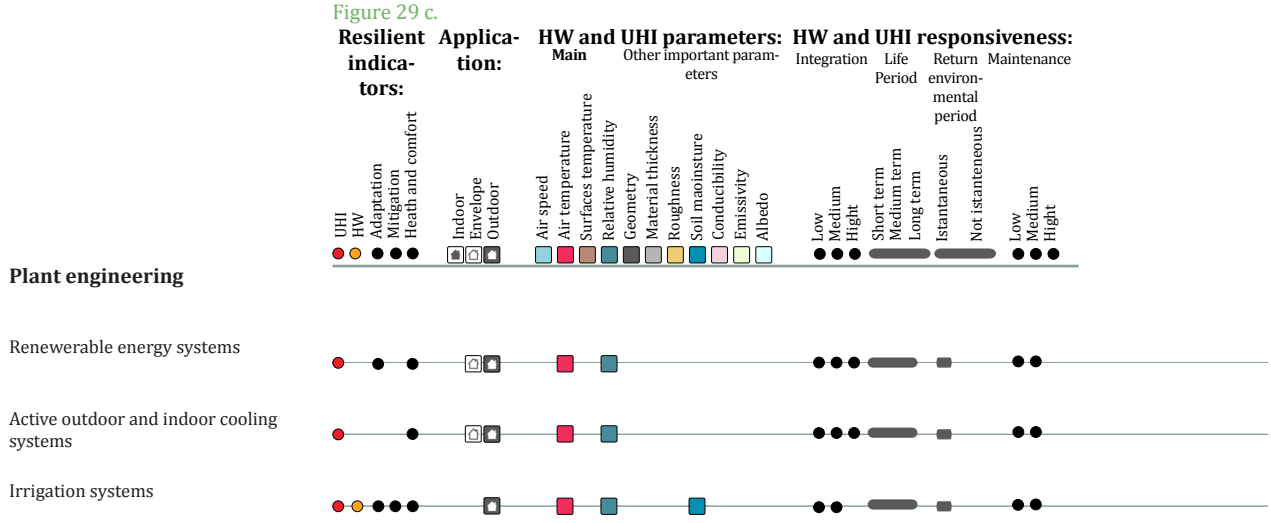
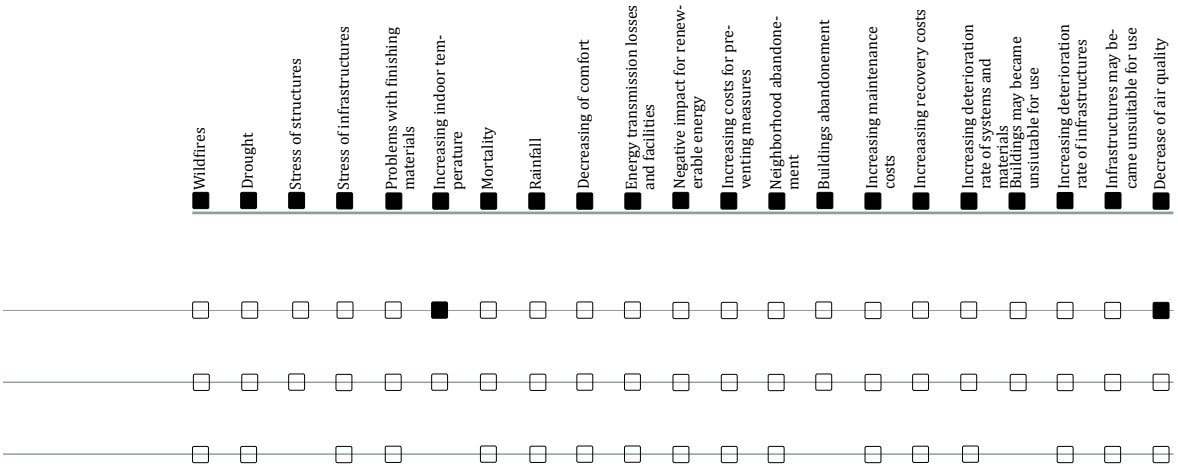

Combination hazards responsiveness:
Wildfires
Drought
Stress of structures
Stress of infrastructures
Problems with finishing materials
Increasing indoor temperature
Mortality
Rainfall
Decreasing of comfort
Energy transmission losses and facilities
Negative impact for renewerable energy
Increasing costs for preventing measures
Neighborhood abandonement
Buildings abandonement
Increasing maintenance costs
Increaasing recovery costs
Increasing deterioration rate of systems and materials
Buildings may became unsiutable for use
Increasing deterioration rate of infrastructures
Infrastructures may became unsuitable for use
Decrease of air quality

Figure 29 c.


Resilient indica-tors:
Applica-tion:
HW and UHI parameters:
Main
Other important param-eters
HW and UHI responsiveness:
Integration
Life Period
Return environ-mental period
Maintenance
UHI
HW
Adaptation
Mitigation
Heath and comfort
Indoor
Envelope
Outdoor
Air speed
Air temperature
Surfaces temperature
Relative humidity
Geometry
Material thickness
Roughness
Soil maoinsture
Conducibility
Emissivity
Albedo
Low
Medium
Hight
Short term
Medium term
Long term
Istantaneous
Not istanteneous
Low
Medium
Hight
Plant engineering
Renewerable energy systems
Active outdoor and indoor cooling systems
Irrigation systems

Combination hazards responsiveness:



Results and discussion.

The matrix elaborated in Fig. 29 a, b, c shows that green-based technologies directly influence the most significant number of hazards. Buffer zones, bioclimatic atria, greenhouses, and cooling towers also influence the decrease in hazards related to rising temperatures. However, their range of action is restricted to the indoor environment. Among the solutions affecting public space, green corridors and green spaces have the most significant influence on heat islands and heat waves in a direct way. Technological solutions include green walls, roofs, and drainage infrastructure systems. Cool materials have the most effect on solutions involving materials. Irrigation systems also directly impact some hazards, including mitigating fire risk and dry periods, soil dryness and comfort. The data shows that the most effective solutions for mitigation and adaptation to islands and heat waves are parks, gardens, pocket gardens, urban farming, trees, green corridors, green walls, green roofs and cool materials.

It is necessary to emphasise that the scale of mitigation interventions plays a preponderant role: large-scale solutions offer a higher level of mitigation and adaptation than point systems, which can only offer significant contributions if they are repeated and placed within a 'system' and not left at the level of individual episodes. An example of this kind is provided by the design of green infrastructure for the city of Milan, part of the 'Forestami' project, which plans to plant 3 million new trees by 2030 (to date, almost 20% of the entire project has been completed), within the entire urban fabric. Furthermore, smart technologies are important in planning, designing, managing, and optimising strategies and specific technical solutions. The interaction between these constitutes a significant prospect for future scientific research to increase the technological solutions proposed here, progressively increasing the scope of application. The development of these actions will shortly contribute to the definition of strategies against waves and heat islands that are more manageable and have a more significant impact on the health of the urban ecosystem and its inhabitants.

The subsequent development of this phase of the research is to try to quantify the level of effectiveness of the solutions that, at this first step, are found to have the shortest return periods, to have both outdoor and indoor effects and to act on the most significant number of indicators that influence heat islands and heat

30. 'Forestami' is a Project promoted by the metropolitan city of Milan, the Municipality of Milan, the Lombardy Region, North Milan Park, South Milan Agricultural Park, ERSAF, and the Milan Community Foundation; it is the result of research conducted by the Politecnico di Milano with the support of the Falck Foundation and FS Urban System.

waves and decrease the dangers associated with them. According to the analysis, these solutions include increasing urban greenery (through parks, green infrastructure, urban gardens, pocket gardens), using cool surfaces and installing vegetated walls and roofs.

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2.3| Identification of actions for adaptation to islands and heat waves
p. 433

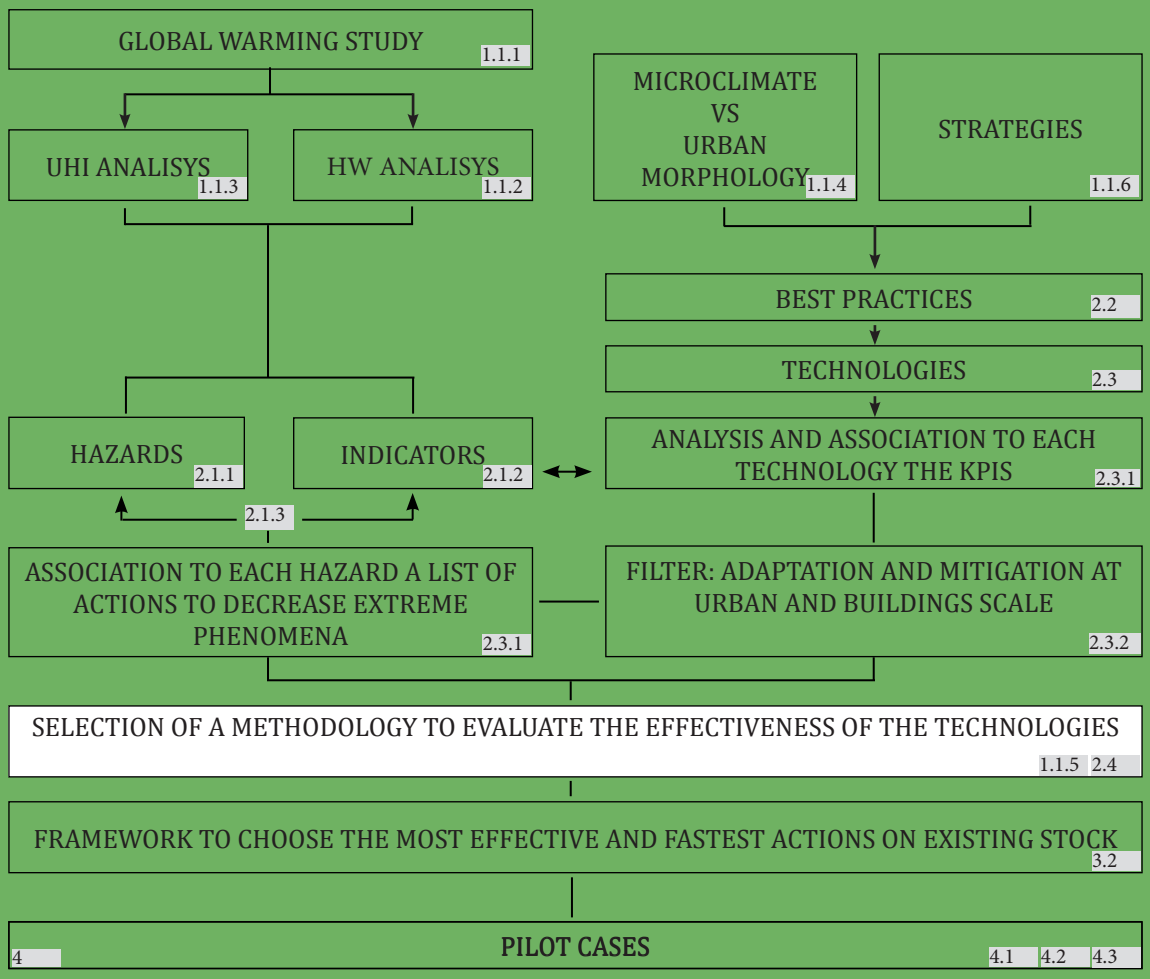
CHAPTER 2.4

2.4| Construction of a tool to define the effectiveness of the solutions examined

ABSTRACT

Evaluating the effectiveness of the actions considered in the previous paragraphs regarding extreme phenomena related to rising temperatures is not trivial. The author attempts to approach the problem through parametric modelling with Ladybug tools based on microclimate simulation.
The experimental approach evaluates the indicators that most affect heat islands and heat waves with and without the actions studied in the previous paragraphs and different morphological contexts.
This approach allows for the development of an algorithm for evaluating the effectiveness of actions in different built contexts under indoor and outdoor conditions. Developing a parametric algorithm makes the tool very versatile and easily manageable.
However, this analysis method is not the only way to evaluate the effectiveness of specific actions in established cities to cope with rising temperatures. According to Salvati et al. (2019), the software overestimates the daytime results when comparing these with in situ surveys. It is also necessary to consider that the algorithm does not calculate wind speed. Therefore, this tool can be a helpful aid, accompanied by an evaluation on a case-by-case basis and with studies focused on the site under analysis.

KEYPLAN



Outcomes of this chapter:

- **Identification of an algorithm** to build up an **effectiveness evaluation tool**

2.4.1| The UWG model: modules and parameters (identification of morphological parameters, buildings and elements)

Introduction.

This study aims to define a method for evaluating the effectiveness of technological solutions within a context. To do this, following a careful analysis of the simulation models available, the UWG model was used, which allows the development of microclimates, the evaluation of temperature, humidity, average radiant temperature and comfort in a given built-up area based on the EnergyPlus database - see par. 1.1.5.
Global warming and the need for technologies that respond effectively to mitigating extreme phenomena due to climate change coexist. The dangers arising from these phenomena range from increased hazard of fires, decreased welfare levels, increased mortality, and increased deterioration of structures and infrastructure. For the determination of effectiveness, in addition to analysing the state of the art, numerous tools allow for various ways of obtaining reliable models, which vary in complexity, engine and input and output data. However, as Xu et al. (2022) write, these models are based on the representation of individual processes specific to the thermal environment and require a high degree of familiarity with the software interface and specialist knowledge. To date, various tools are available that allow an integrated evaluation of various indicators and are user-friendly. As a result of the analysis carried out above, the UWG model satisfies the need for an assessment of the effectiveness of technologies against heat islands and heat waves on a neighbourhood scale through the modelling of microclimates, with fast simulation times, accurate characterisation of the model and the possibility of parameterisation. UWG is a tool developed by the Massachusetts Institute of Technology to analyse the local effects generated by urban geometries on urban comfort and energy consumption. It represents an atmosphere-building simulation tool capable of assessing the urban heat island effect and modifying a generic meteorological data file into an 'urban' meteorological data file (Ottone et al., 2019).

The UWG model was developed in 2012 by Bueno (Bueno et al., 2012) and calculates the energy exchanges between the environment and climate. Based on physical foundations, four coupled modules formed the basis of the UWG model: RSM - simulating the rural station, VDM - vertical diffusion model, the UBLM - modelling the urban boundary layer, and the UC-BEM - modelling the urban geometry and buildings. The UWG underwent later implementations (Bueno et al., 2014). Subsequently, Nakano et al. (2015) integrated the module into Rhinoceros software, creating an independent interface. Further developments of the model were achieved by Yang (J. H. Yang, 2017) - who refined the boundary conditions with (Mao et al., 2017) and (Awino, 2019), who incorporated the tool into practical design workflow in order to shape urban design practices that influence building performance (Xu et al., 2022).
The research ratio consists of evaluating the difference between the values of the indicators—indoor and outdoor air temperature, indoor and outdoor relative humidity, UTCI, and indoor mean radiant temperature—' ante opera' and 'post opera'—on the identified models through the development of 4 different morphological models. In this way, for each morphology, it is possible to assess the effectiveness of specific solutions concerning islands and heat waves.
Through the simulation of microclimates, it is possible to assess the effectiveness of specific actions on the existing indoor and outdoor environment. However, the UWG model does not consider air flows within it. Therefore, the results obtained through the algorithm represent a helpful tool that must be accompanied by research in the area. The data required for the algorithm's development is based on Rome's climate.
Below are the steps required to define the algorithm and how to set the individual components.

Figure 30. Representation of a city and the control volumes considered in the UWG. The model estimates the UHI effect in the city from meteorological information measured at a reference weather station upwind by applying energy conservation principles (Bueno et al., 2014).

Materials and methodology.

The methodology is based on an experimental approach to develop a calculation algorithm. In the simulation, parameters derived from human factors are considered, which allows an assessment of the comfort level and environmental parameters of the built environment and the site under investigation (see Fig. 30).
The simulation is based on the workflow in Fig. 31 and includes building and evaluating an outdoor and indoor model. The input data includes location information: weather data, data on the type and amount of vegetation, urban conditions, and the built environment: reflectance of surfaces, the type of materials used, the geometry of the built environment, and the intended use of buildings. Through these data, the UWG generator can create an outdoor microclimate and, through further steps, an indoor microclimate from which the KPI value can be derived.

Figure 30.

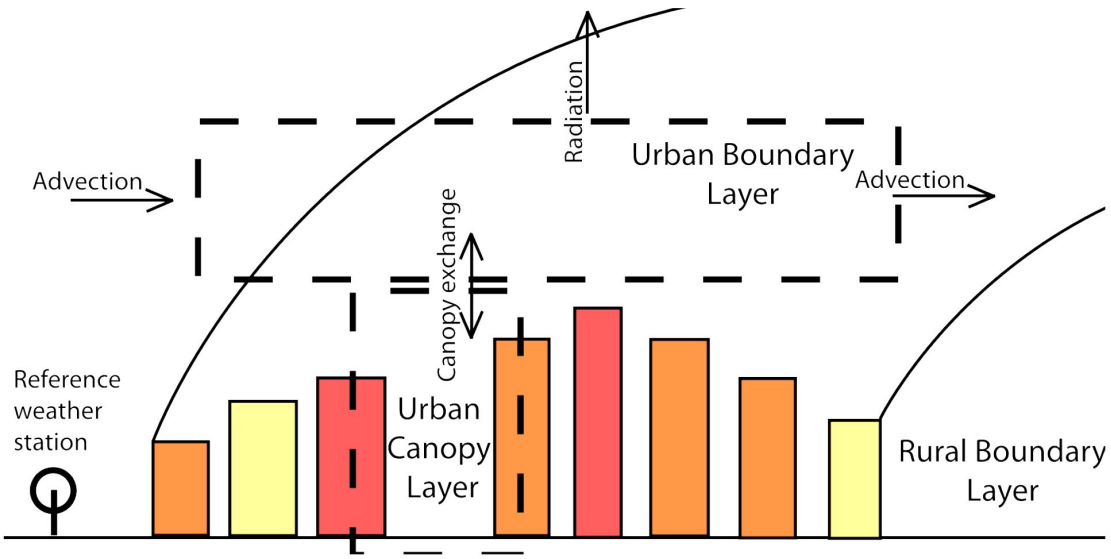

Radiation
Urban Boundary Layer
Advection
Advection
Canopy exchange
Reference weather station
Urban Canopy Layer
Rural Boundary Layer

Figure 31.

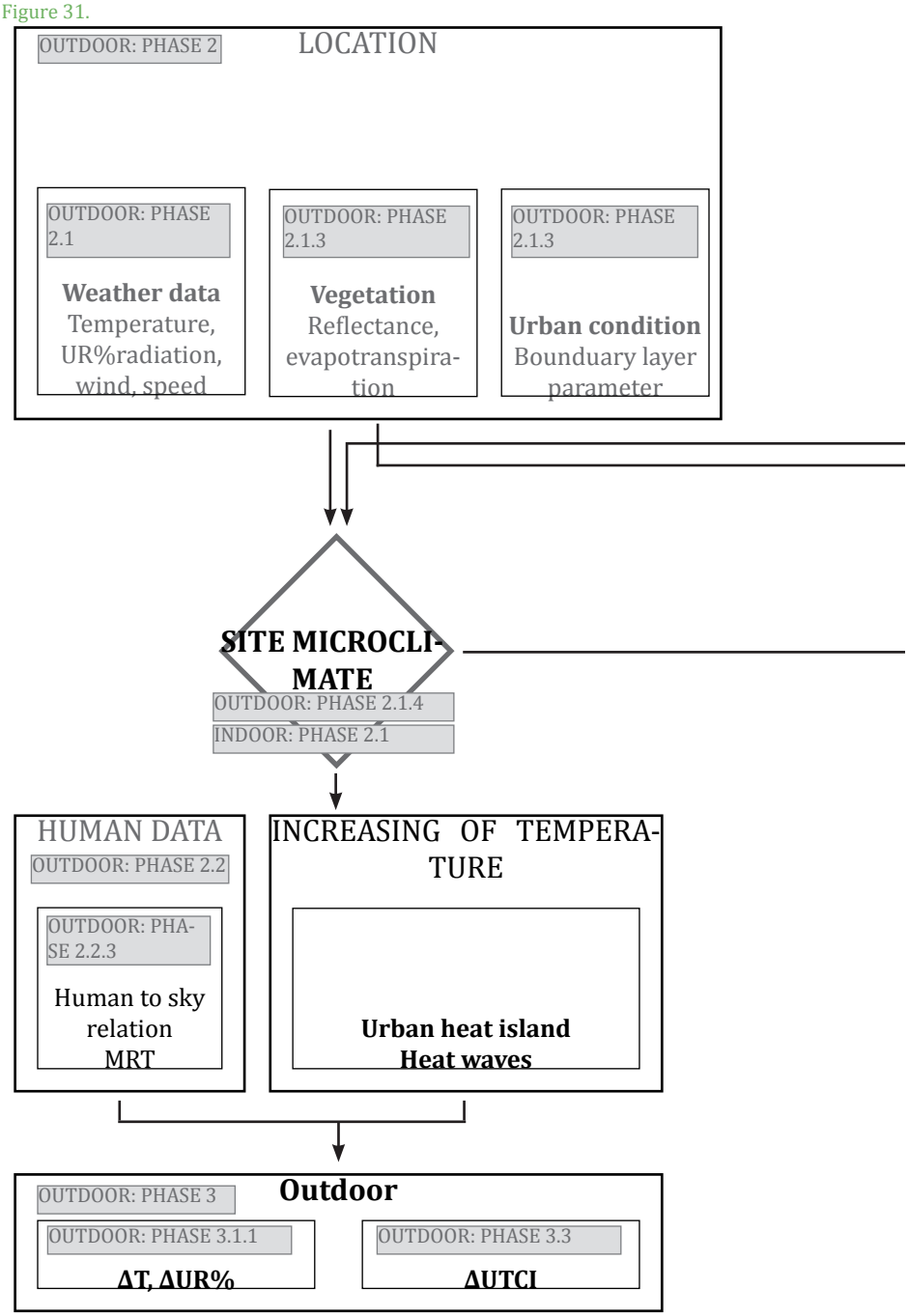
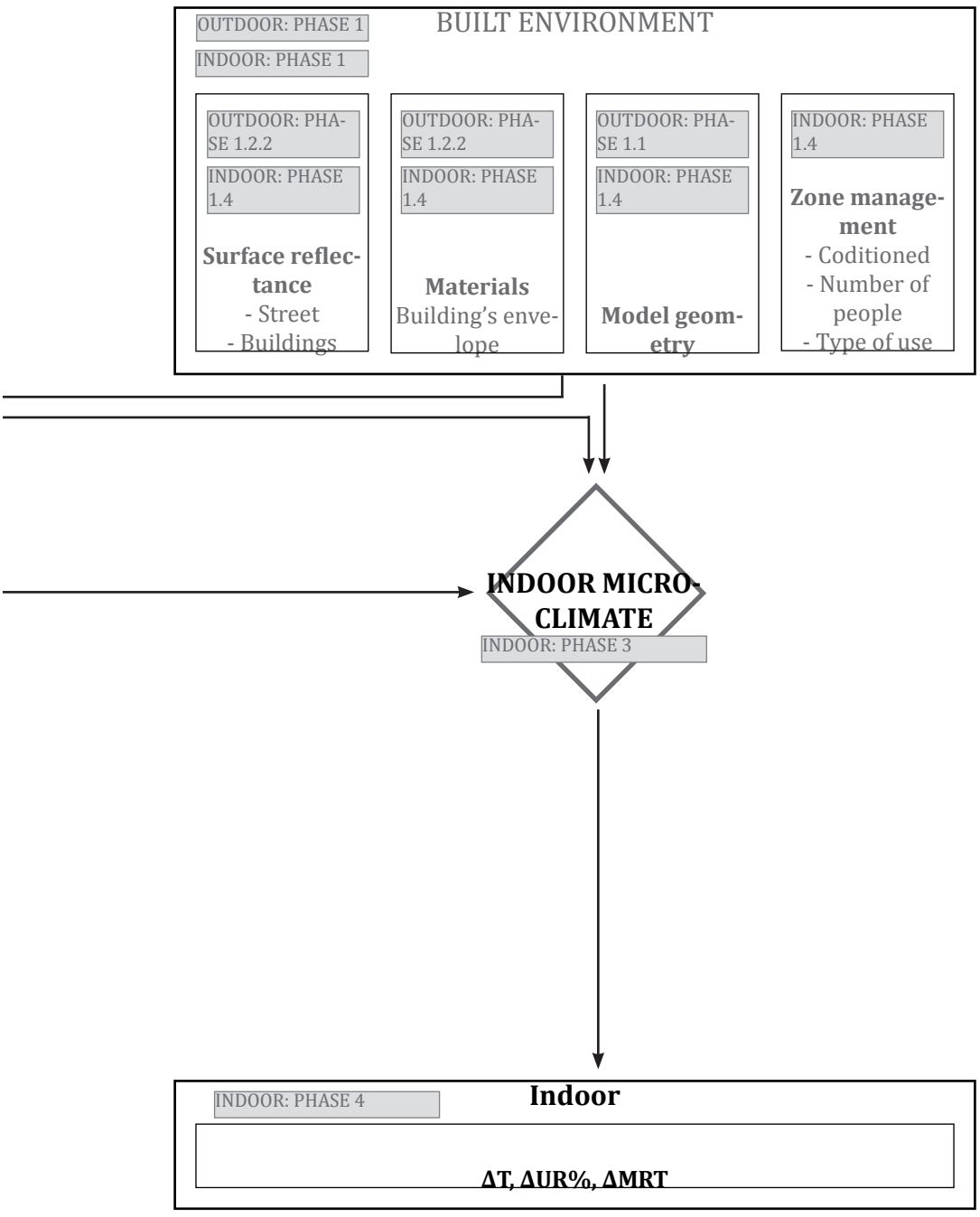


Figure 31. Simulation workflow: input parameters are indicated in grey, and outputs in black. The grey boxes indicate at which algorithm development stage the parameters come into play. Author's elaboration.


BUILT ENVIRONMENT
OUTDOOR: PHASE 1
INDOOR: PHASE 1
OUTDOOR: PHASE 1.2.2
INDOOR: PHASE 1.4
Surface reflectance
- Street
- Buildings
OUTDOOR: PHASE 1.2.2
INDOOR: PHASE 1.4
Materials
Building's envelope
OUTDOOR: PHASE 1.1
INDOOR: PHASE 1.4
Model geometry
INDOOR: PHASE 1.4
Zone management
- Coditioned
- Number of people
- Type of use
INDOOR MICRO-CLIMATE
INDOOR: PHASE 3
Indoor
INDOOR: PHASE 4
ΔT, ΔUR%, ΔMRT

The methodology is divided into five different phases (Fig. 31): the first phase consists in the elaboration of the model and its connection with Grasshopper, the second phase in the setting of the rooms and the context, the third phase in the development of the microclimate, the fourth phase in the simulation of the indoor environment and the calculation of the average outdoor radiant temperature, the fifth phase in the extrapolation of the results, via .csv output and the visualisation of the same on Rhinoceros. The various phases are explained in detail below.

1. The first phase comprises the elaboration of the model, see Fig. 31. This can be either modelled on the Rhinoceros interface or modelled parametrically directly from Grasshopper. In this case, the algorithm is linked to a model in Rhinoceros. The buildings, the street, and the interior of the building, the object of analysis, are modelled (see Figure 32). Subsequently, the necessary steps in Grasshopper are:
    a. Connection of the .epw file to the platform [31]
    b. Connection of the Rhinoceros model to the Grasshopper file.

31. For more information, see the webpage: ladybug.tools/epwmap/

Figure 32.

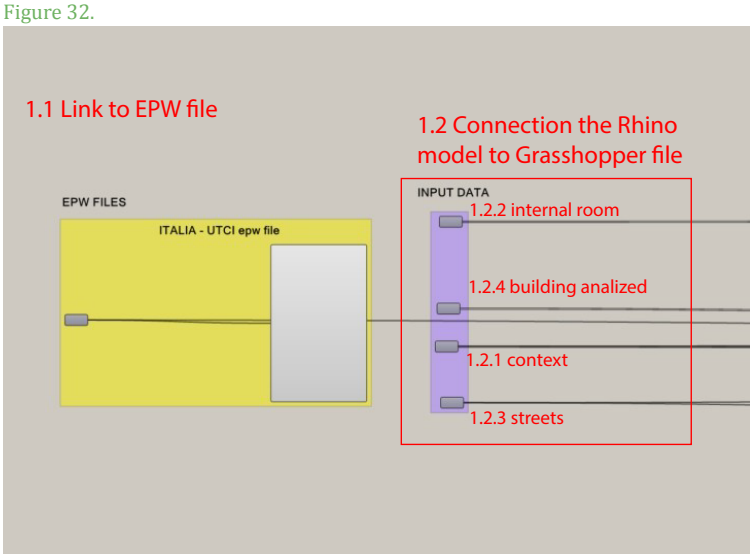


Figure 32. Graphicisation of phase 1 of the algorithm. Author's elaboration

2. The second phase, visible in Fig. 34, consists of setting up the wall packages of the indoor and outdoor built environment. In particular, it consists of:

a. Characterisation of the building materials, fig. 33: A typical reinforced concrete wall package is defined in this phase. The frames and the composition of the fixtures are also defined.

b. Next, we move on to the definition of the surroundings through the explication of the climatic band - Band 3, Warm -, the approximate age of the building - pre-1980 - the type of construction - massive, the air conditioning - set as absent[31]-, the type of user - midrise Apartment - the floor number and the height of the inter-storey. At this stage, a survey grid is generated and placed on the asphalt to sample the results.

31. To assess the indoor conditions, it is necessary to set up the building without air-conditioning systems. The aim of the work is to evaluate the effectiveness of each indoor and outdoor technological solution. Air conditioning systems contribute to increased levels of adaptation to extreme temperatures inside the building, so they cannot be considered.

Figure 33.

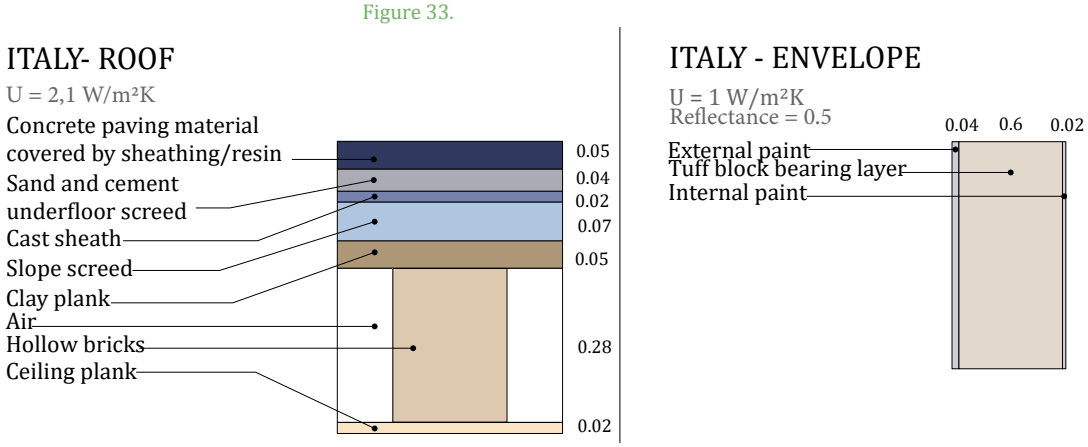
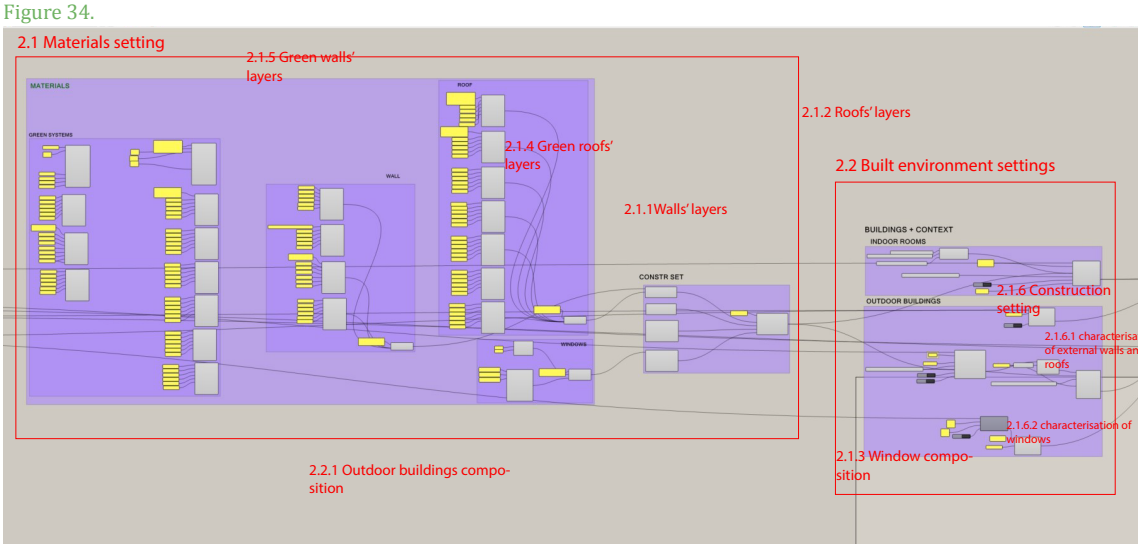


Figure 33. Standard wall and roof package. The buildings in Rome's suburb of Quarticciolo were taken as a model. Author's elaboration

Figure 34. Graphitization of phase 2 of the algorithm for analysing the effectiveness of technologies concerning islands and heat waves on the existing Author's elaboration

Figure 34.



3. The third phase, visible in Fig. 35, generates the microclimate (UWG). For this, it is necessary to input data concerning the context analysis and the setting of the simulation parameters. For the former, the input data consists of a Dragonfly model, which contains information about buildings and context and average traffic data – in this case, referring to the traffic in a mixed-use area of a European city, the ground covered with grass or trees. On the other hand, the required simulation parameters consist of information concerning vegetation: in particular, albedo, the months where plant species have foliage, thus where there is evapotranspiration, the latent heat of the lawn and trees. Other required information concerns the reference meteorological station: the height of the wind measurement, the presence of obstacles, and the vegetation cover. This way, an 'urban' .epw file is generated, i.e. set in the built environment. From this file, compared with the data from the meteorological station, it is possible to obtain information on the heat island and the effectiveness of the technological solutions applied to the existing context.

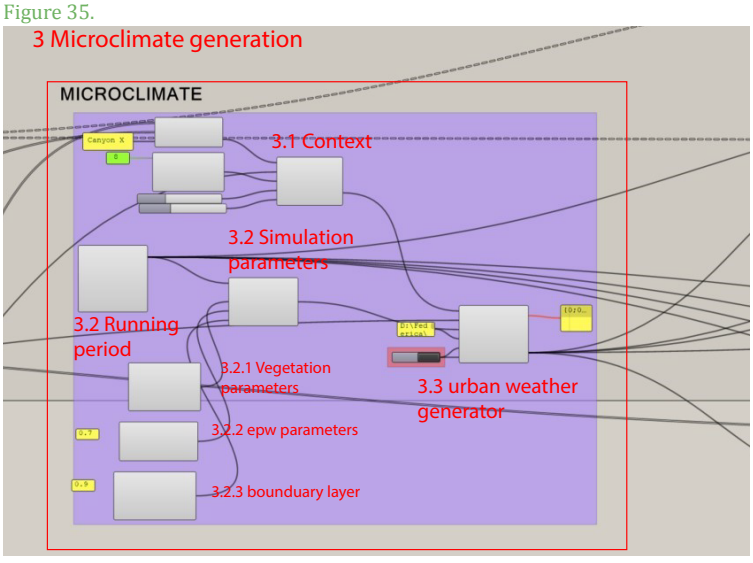
Figure 35.


Figure 36. Graphitisation of the third modelling phase: the construction of the microclimate. Author's elaboration

4. The fourth phase in Fig. 36 is divided into the outdoor and indoor parts:

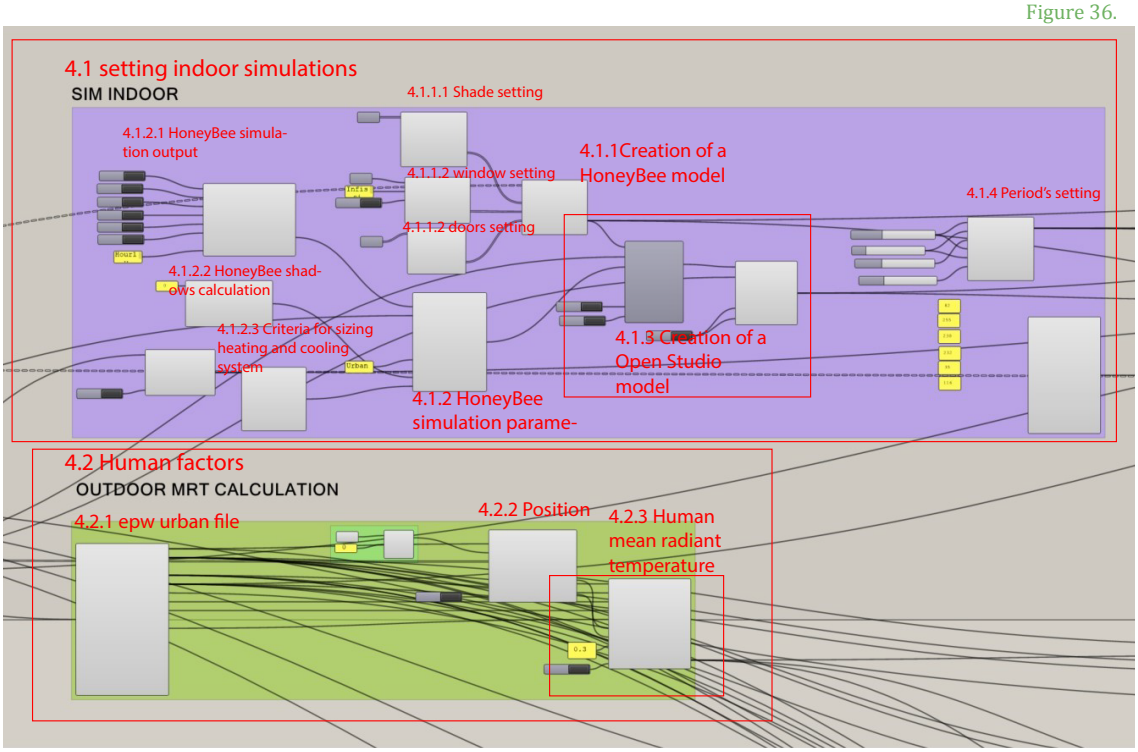
a. The programme uses OpenStudio modelling to assess indoor environmental conditions. The HoneyBee model can be converted into an OpenStudio model by transforming it into an IDF file compatible with EnergyPlus. The converted model includes information on the room, which is the object of analysis, and information on the presence of shading devices, fixtures, and doors.

b. For the UTCI comfort[33] calculation, outdoor environmental conditions and the average radiant body temperature are needed. Three points are chosen and explicit, representing where the calculation is performed. These points are placed near buildings, assessing an individual's comfort on the pavement, in the centre of the street, and at a crossway. This type of data changes depending on the individual's position in the context. In selecting the three points, I looked for the most significant ones, considering determining factors such as the thermal environment

33. The Universal Thermal Comfort Index (UTCI) is used to assess an individual's comfort. In this research, various comfort indices are compared (see section 2.1.4). The UTCI is also a function of external factors such as temperature and relative humidity.

Figure 36. Fourth stage of the algorithm: evaluation of environmental conditions in indoor and outdoor environments. Author's elaboration

Figure 36.



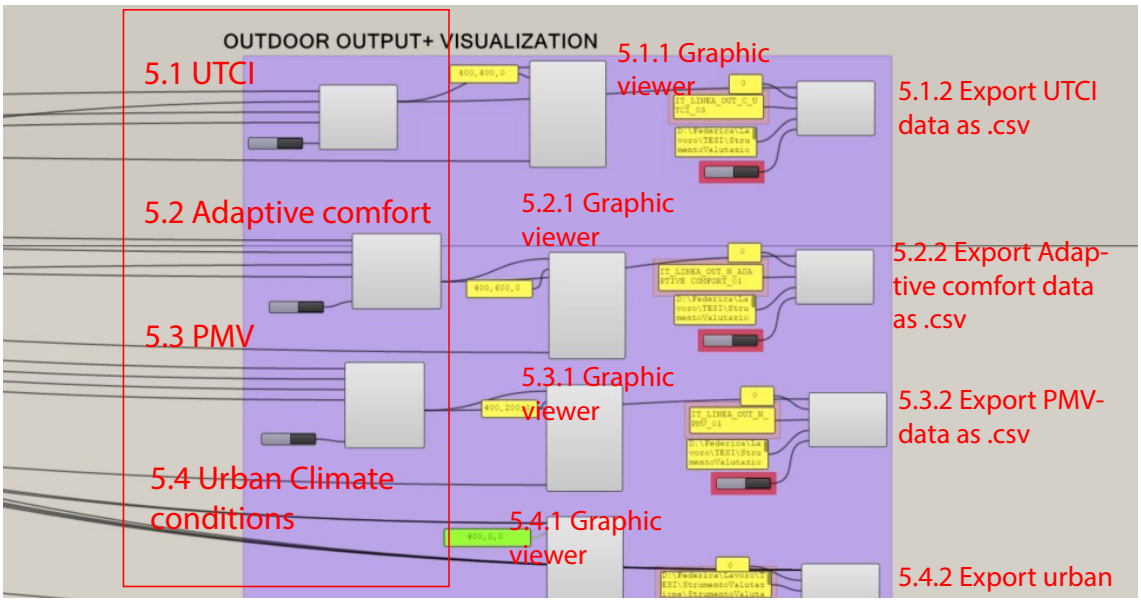
– proximity between buildings and positioning in the urban canyon – and typical pedestrian flows within the urban fabric, to show the most diverse situations that can arise, such as:

- Next to a building on the pavement, therefore, with greater shading and screening from morphological elements
- In the centre of the road, in the middle of the urban canyon, therefore with less impact from buildings and the surrounding area
- At the intersection between roads, therefore, in the condition least screened by buildings and the surrounding morphology, but still affected by their effects.

5. The fifth step in Fig. 37 involves extrapolating the results: the results are downloaded in .csv files for outdoor and indoor environments. In addition, visual representations can be obtained via the Grasshopper interface. Particularly in an indoor environment, the point that is usually most exposed is considered: the top floor, at the corner, near a window frame.

FIgure 37. Export and visualisation of results. Author's processing

Figure 37.



Results.

By processing this algorithm on Grasshopper, given a geometry, it is possible to generate the microclimate of the area considered, taking into account the physical and climatic characteristics of the location. This tool is handy, not only for the present research but also because the parameters that can be calculated are various, including air temperature - indoor and outdoor - several indices of indoor and outdoor comfort (such as the UTCI, used in the present research, the Adaptive thermal comfort, the PET, or the PMV), indoor and outdoor relative humidity, and the average radiant temperature, indoor and outdoor. Calculating the energy required to operate the element(s) considered and modifying room climate control systems, intended use, or number of people in the rooms is also possible. This algorithm makes it possible to quickly assess the effect of heat islands and heat waves on buildings (assessing both active and bioclimatic, passive energy behaviour), on infrastructures and people, as the morphology, materials, technologies, and type of vegetation indoors and outdoors vary.
The present algorithm is based on contributions provided first by (Bueno et al., 2013) and then by subsequent developments by (Bueno et al., 2014; Nakano et al., 2015; Salvati, Coch Roura, et al., 2017; Salvati et al., 2019). It does not present elements of innovativeness, except for its use: it is not used for the analysis of a specific area but for the evaluation of the variation of certain parameters (see Section 2.1.2) influenced by islands and heat waves, which can increase the intensity and frequency of hazards on population centres (see Section 2.1.3).
The presence of various parameters to be evaluated, which change at every point in the model, is complex to manage. It makes it impossible to obtain quantitative values to describe the effectiveness of individual technologies in an area.
Despite this, the model developed can provide significant qualitative results. In the following section, simulations based on the algorithm described in this section and applied to different morphologies allow a quali-quantitative assessment of the effectiveness of the actions selected in section 2.3.2, as those that affect the most significant number of hazards and act in an integrated manner on the most significant number of indicators influencing islands and waves and the hazards themselves.

2.4| References:

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PART 3

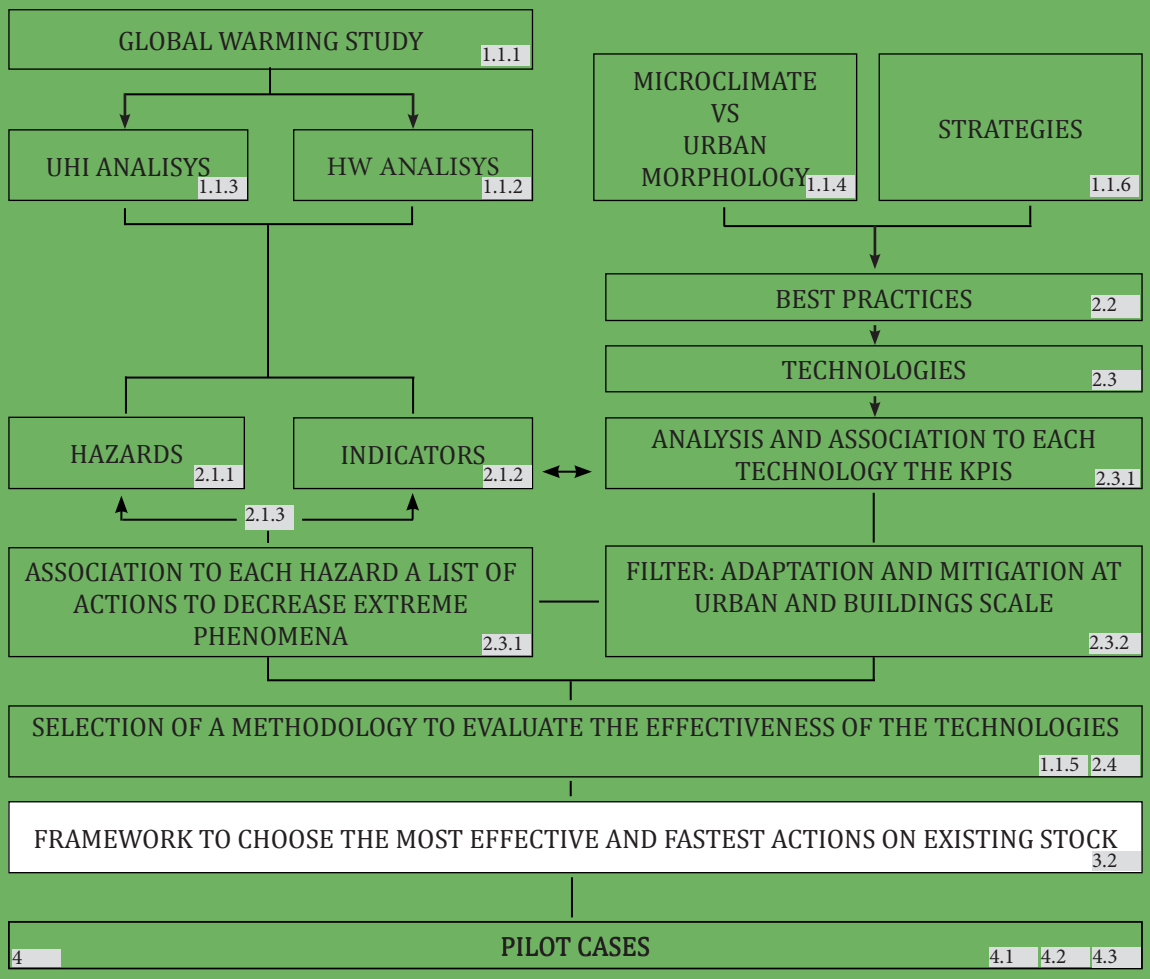
Development of a support tool

CHAPTER 3.1

3.1| DEVELOPMENT OF A SUPPORT TOOL

ABSTRACT
Not all technological solutions, strategies, and actions are equally effective in decreasing urban heat islands and heatwave-driven problems, especially given the time constraints brought about by the inexorable rise in temperatures.
Through a top-down approach to identifying morphological types, Ladybug simulations text single actions with the UWG algorithm, considering outdoor and indoor conditions. In this way, it is possible to obtain a support tool for professionals, public administrations and researchers that quantifies the effectiveness of individual actions according to the morphology of the built-up area. Thus, depending on the prevailing morphological types and the problems of individual realities, choosing the type of action that most effectively responds to them is possible.
Although the simulation software presents a certain approximation in modelling vegetated walls, and the suggested actions are to be evaluated on a case-by-case basis and according to each place's uniqueness, this tool represents a valid decision-support framework for understanding the response of mitigation and adaptation actions in different types of urban contexts.

KEYPLAN



Outcomes of this chapter:

- **Development of a tool** through which it is possible **to evaluate the effectiveness of the** different **actions** identified on different morphologies

Introduction.

In this part of the research, the development, using the UWG generator algorithm explained in the previous chapters, is explained as an aid tool for evaluating the behaviour of actions on the existing islands and heat waves. Does the effectiveness of individual technologies vary when applied to different contexts in the same climate zone? It is not certain that the effectiveness and efficiency of different actions on heat islands and heat waves do not change when the context under consideration varies.
Oke was one of the first to study the relationship between urban geometry and the heat island and found a logarithmic dependence between the increase in heat island intensity and the canyon aspect ratio. Further studies were developed on how morphology influences air temperature, relative humidity, wind speed and mean radiant temperature (Oke, 1973; Salvati et al., 2019). Having to act on the existing consolidated stock - see section 1.1.4 - a morphological analysis in a transcale and generative perspective can act as a detector of the transformative potential of the building and the urban compartment by identifying the transformative potential and the environmental characteristics generated by the climatic and morphological conditions (Guidetti & Massarente, 2021).
The tool proposed in this research was developed by modelling microclimates with similar climatic conditions and different morphological types. Once generated, key performance indicators—temperature, relative air humidity, UTCI, and radiant temperature—are evaluated in the absence and presence of individual mitigation and adaptation actions.
Using EnergyPlus as a simulation engine, it is possible to assess the effectiveness of individual solutions in different urban contexts, indoors and outdoors. The results have good reliability and have been validated over the years by several researchers, who have carried out studies based on the morphology and climatic data of different locations - Rome, Barcelona, Singapore - and validated the results through the use of sensors, in the field - see section 2.4.1. On the other hand, as already pointed out in section 1.1.5, the model considered does not perform fluid-dynamic calculations, so it cannot consider the ventilation behaviour inside the built-up area. Similarly, the programme does not provide a special command for modelling green façades, as it does for green roofs.

EnergyPlus includes many ways of calculating and analysing green roofs. However, it is not possible to use the same modelling methods for vegetated walls because all the solar exposures of the surfaces behind the green roof are not considered in the model, so it is impossible to simulate the solar radiation transmitted by the green façade.
Another reason vegetated walls cannot be modelled as green roofs is that the radiative heat exchange between the foliage and the soil is calculated for soil temperature and emissivity; by making the soil properties similar to those of the wall, only the emissivity changes. However, the temperature is still the soil temperature defined during the input phase and does not represent the surface temperature of the wall. Finally, the code automatically calculates the convective heat transfer coefficients between the foliage and the soil (the user cannot change them) from unique relationships valid for horizontal grass. These coefficients are not appropriate for vertical plants. Having said this, however, there are various methods of approximating plant walls, such as setting them as shading systems, changing the transmittance, reflectance alone and visible equal to green facades (Larsen, 2014).
The tool's processing method and results, rendered in analytical tables, are illustrated below.

34. This research refers to the climate characterisation carried out by Vladimir Koppen and analysed in chapter 1.1.1 Reference scenario: a global response to climate change. Rising temperatures in warm temperate climates

Tool construction.

The algorithm developed on Grasshopper and illustrated in section 2.4.1 evaluates the effectiveness of actions aimed at mitigation and adaptation to heat waves and heat islands on the existing. Various researchers have based their studies on the simulation of microclimates through the UWG generator model, an algorithm first developed by (Bueno et al., 2012), which was based on the calculation of heat exchanges between the environment and climate (Bueno, Norford, Hidalgo, & Pigeon, 2013; Bueno, Roth, Norford, & Li, 2014; Rotach, et al., 2005; Street, Reinhart, Norford, & Ochsendorf, 2013; Masson, et al., 2008).
The analysis of the form of the cities in warm temperate climates[34] allows the identification of four morphological types. The different geometries are used as a model for creating microclimates using the UWG generator algorithm, illustrated above - Chapter 2.4.1. Performing a simulation for each morphological typology in the

absence of actions and technologies that mitigate and adapt the existing to the extreme events caused by the increase in temperature, evaluates the effectiveness. Subsequently, simulations are carried out by adding the technologies that, from the state-of-the-art analysis, are considered the most effective in coping with the aforementioned phenomena - urban greening, cool materials, vegetated roofs, and walls.
The tool's construction is divided into three phases: the first phase involves applying the algorithm to the different morphologies identified, the second involves managing the raw data, and the third involves preparing the summary sheets.
The first phase involves applying the algorithm developed on the Grasshopper platform to four different morphological types: small isolated buildings, courtyards, blocks, and in-line buildings (Fig. 39).

In part 2.4.1, a detailed explanation of the algorithm used is provided. The period analysed corresponds to when temperatures are warmest; for the Italian case, it is from 1 June to 31 August. For the

Figure 39.

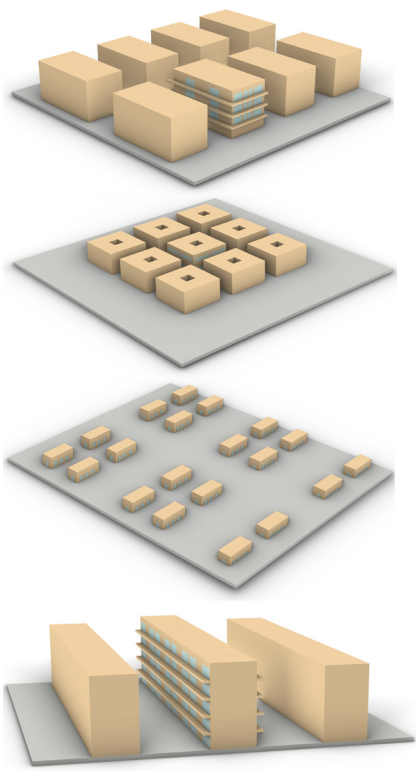


Figure 39. Modelled morphological types. Author's elaboration

calculation of the Universal Thermal Comfort, UTCI, it is necessary to obtain the radiant temperature of the human body at a precise point of the geometry. Therefore, three different points are chosen for all morphological types (see par. 2.4, p. 447) and the results correspond to the maximum of difference in outdoor temperature - one of the most decisive parameters that islands and heat waves influence and which in turn influences others - calculated between these. It should be noted that the points are shaded at different times of day for all morphological types. There are 20 simulations carried out:

- 4 simulations in the absence of adaptation and mitigation actions, one for each morphology.
- One simulation per morphological type was carried out with the inclusion of cool materials in the model,
- One simulation per morphology type with the inclusion of urban green,
- One simulation per morphology type with the inclusion of green roofs,
- One simulation by type with the inclusion of vegetated facades.

These simulations yield data on air temperature, relative humidity, outdoor UTCI, radiant temperature, and indoor UTCI, which are extrapolated as .csv documents. In addition, for the UTCI, a graphical output was processed to visualise the outdoor comfort condition for each model point.

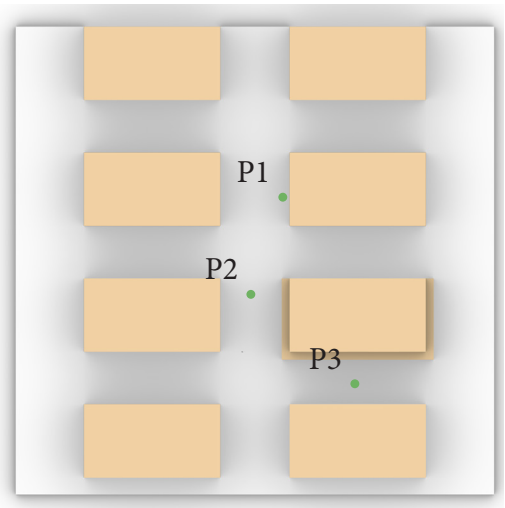
The second step is inherent to the data processing: the .csv files obtained from the simulations contain a list of data for each hour of the day. It is necessary to compare the data of microclimates with adaptation and mitigation actions with those without solutions for a time range coinciding with the hottest season, 1 June to 31 August, in Italy. The difference between the temperature, UTCI, mrt and UR% in the absence of actions and with them is taken for each hour of each day. The maximum difference was taken into account and divided by 3: in this way, it was possible to report the overall effectiveness of each solution qualitatively: if the result is less than 1, then the solution is marked with one marker, two if the result is between 1 and 2, three if the result is greater than 2.

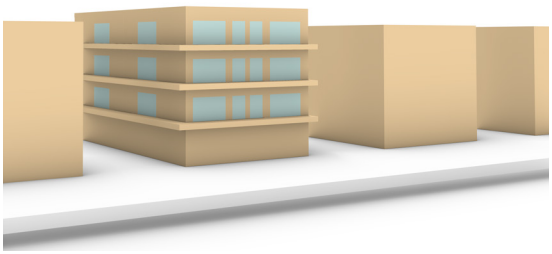
The third phase includes elaborating 16 analytical tables illustrating the effectiveness and efficiency of each technology according to its morphological type and characteristics. At the side of each sheet, the input data, indoor and outdoor effectiveness and efficiency, are explained in terms of air temperature and outdoor UTCI and terms of air temperature and indoor mean radiant temperature. Each simulation produces graphical information regarding indoor and outdoor UTCI. This information makes it possible to associate outdoor comfort with indoor comfort, completing the analysis.

Below are the 16 analytical tables and the outline.

OUTPUT BLOCK

Cool materials:





Input data setting:

- DF Building from solid:
  - Floor to floor: 4 floors with 3m height
  - program: Midrise Appartment
  - Conditioned: false
- DF Apply facade parameter:
  - ratio wind parameter: 0.34
- DF Assign Building UWG Properties:
  - program: Midrise Appartment
  - vintage: Pre 1980 (CBECS)
  - wall albedo: 0.98
  - roof albedo: 0.98
  - wall vegetation: 0
- terrain:
  - albedo: 0.98
  - thickness: 0.5 m
- DF assign Model UWG properties:
  - traffic: typical mixed use part of Toulouse, France
  - tree cover: 0
  - grass cover: 0
- DF vegetation parameters:
  - albedo: 0.25
  - tree latent: 0.7
  - grass latent: 0.5

EFFECTIVENESS OUTDOOR

Air temperature ● UTCI ● UR% ● MRT ● ●

EFFECTIVENESS INDOOR

Air temperature ● ● UTCI ● ● ● UR% ● ● ● MRT ● ●

25th of August h 14:00 dry bulb temperature outdoor

T0= 36.1 °C Tc= 35.60 °C Δ °C=0.50

25th of August h 14:00 Universal Thermal Comfort outdoor

T0= 36.79 Tc= 36.25 Δ °C=0.54

25th of August h 14:00 dry bulb temperature indoor

T0= 35.63°C Tc= 32.87 °C Δ°C=2.76

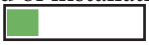
25th of August h 14:00 mean radiant temperature indoor

T0= 34.88 °C Tc= 31.23 °C Δ °C=3.65

Responsiveness:

Life period:

Period of installation:



Maintenance:

!

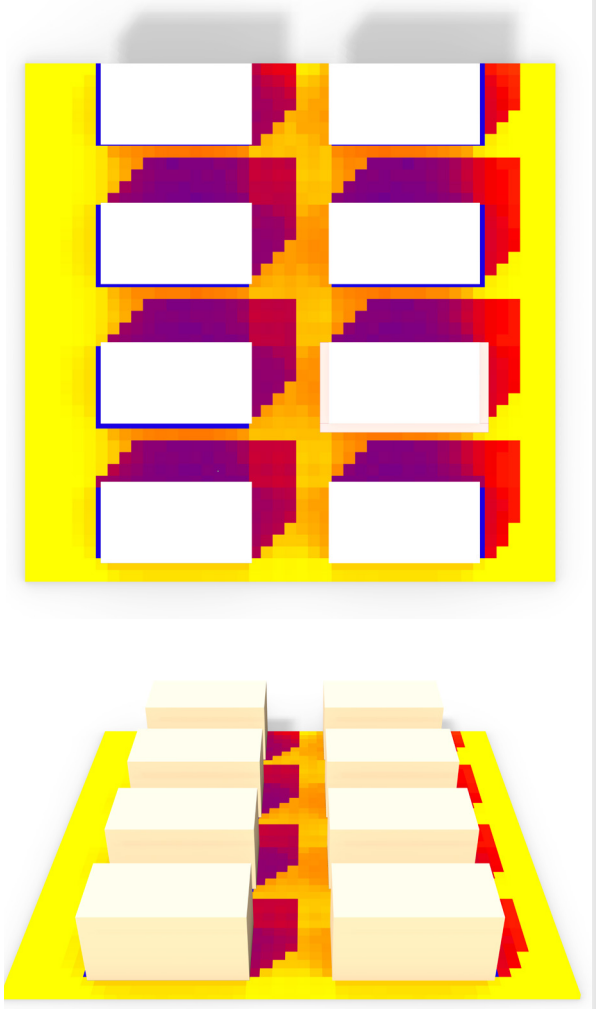
Life span:



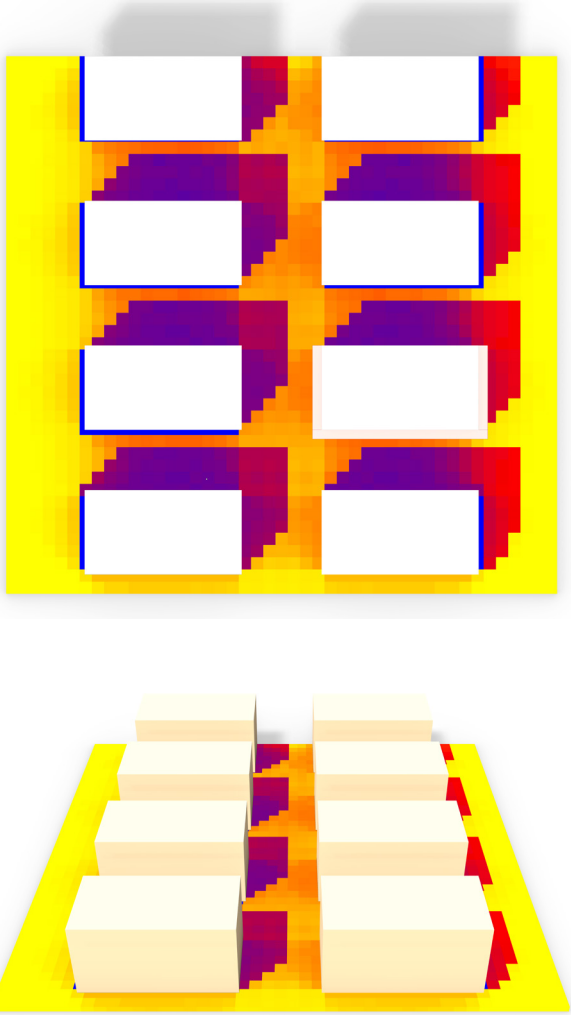
Return environmental period:



25th of August 14:00 Universal thermal comfort outdoor with no actions

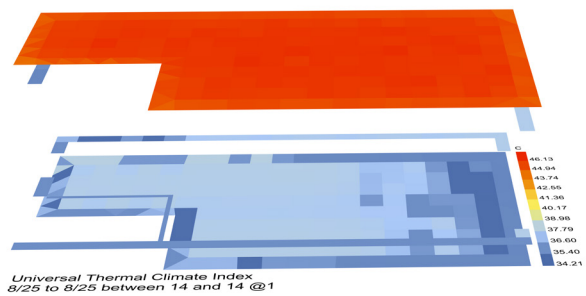


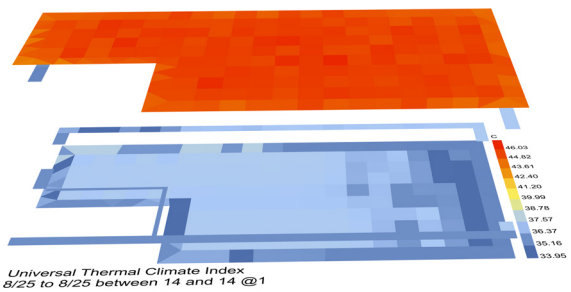
25th of August 14:00 Universal thermal comfort outdoor with cool materials



25th of August 14:00 Universal thermal comfort indoor with no actions

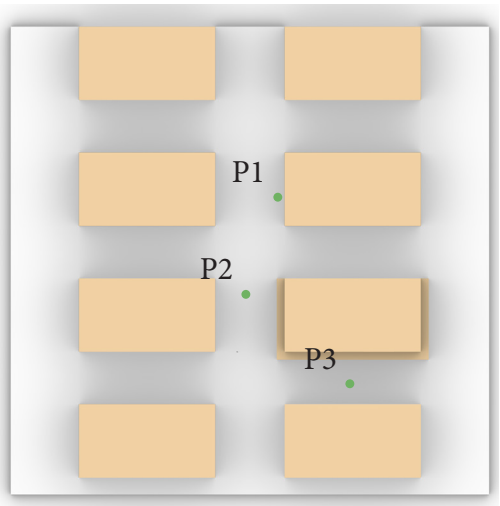
25th of August 14:00 Universal thermal comfort with cool materials

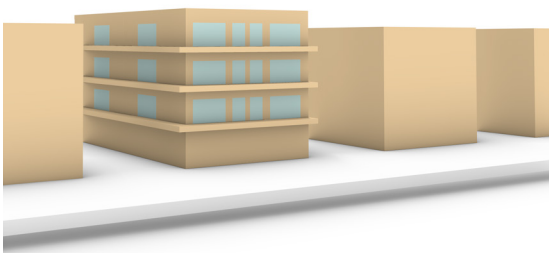




OUTPUT BLOCK

Greening:





Input data setting:

- DF Building from solid:
  - Floor to floor: 4 floors with 3m height
  - program: Midrise Appartment
  - Conditioned: false
- DF Apply facade parameter:
  - ratio wind parameter: 0.34
- DF Assign Building UWG Properties:
  - program: Midrise Appartment
  - vintage: Pre 1980 (CBECS)
  - wall albedo: /
  - roof albedo: /
  - roof vegetation: 0
- terrain:
  - albedo: 0.1
  - thickness: 0.5 m
- DF assign Model UWG properties:
  - traffic: typical mixed use part of Toulouse, France
  - tree cover: 0.5
  - grass cover: 0.6
- DF vegetation parameters:
  - albedo: 0.25
  - tree latent: 0.7
  - grass latent: 0.5

EFFECTIVENESS OUTDOOR

Air temperature ● UTCI ● UR% ●● mrt ●

EFFECTIVENESS INDOOR

Air temperature ●● UTCI ●● UR% ●●● mrt ●●●

25th of August h 14:00 dry bulb temperature outdoor

T0= 36.1 °C Tg= 34.70 °C Δ °C=0.50

25th of August h 14:00 Universal Thermal Comfort outdoor

T0= 36.79 Tg= 35.30 Δ °C=0.54

25th of August h 14:00 dry bulb temperature indoor

T0= 35.63 °C Tg= 32.78 °C Δ°C=2.85

25th of August h 14:00 mean radiant temperature indoor

T0= 34.88 °C Tg= 31.39 °C Δ °C= 3.50

Responsiveness:

Life period:

Period of installation:



Maintenance:

! ! !

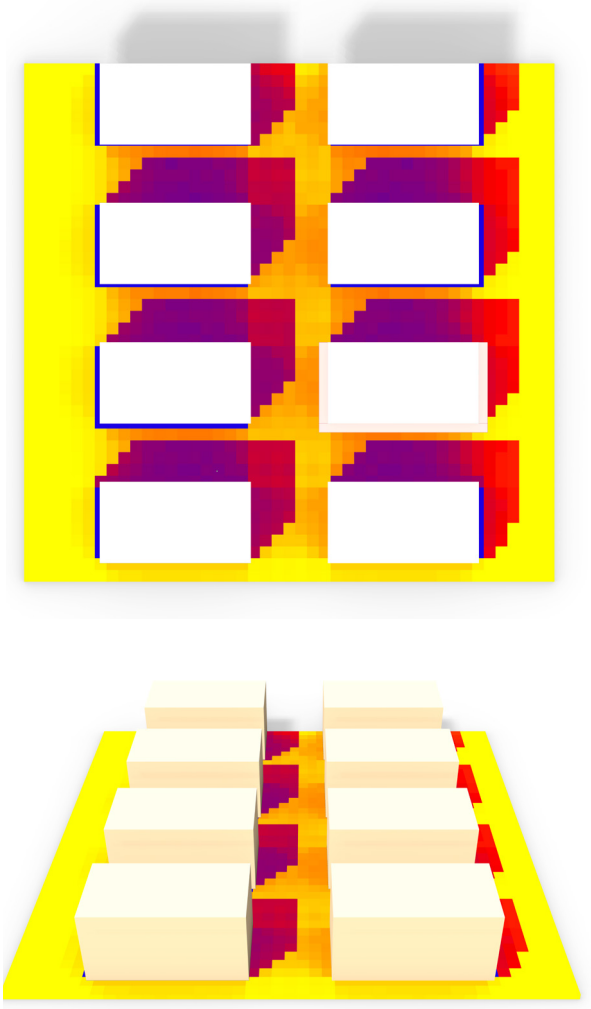
Life span:



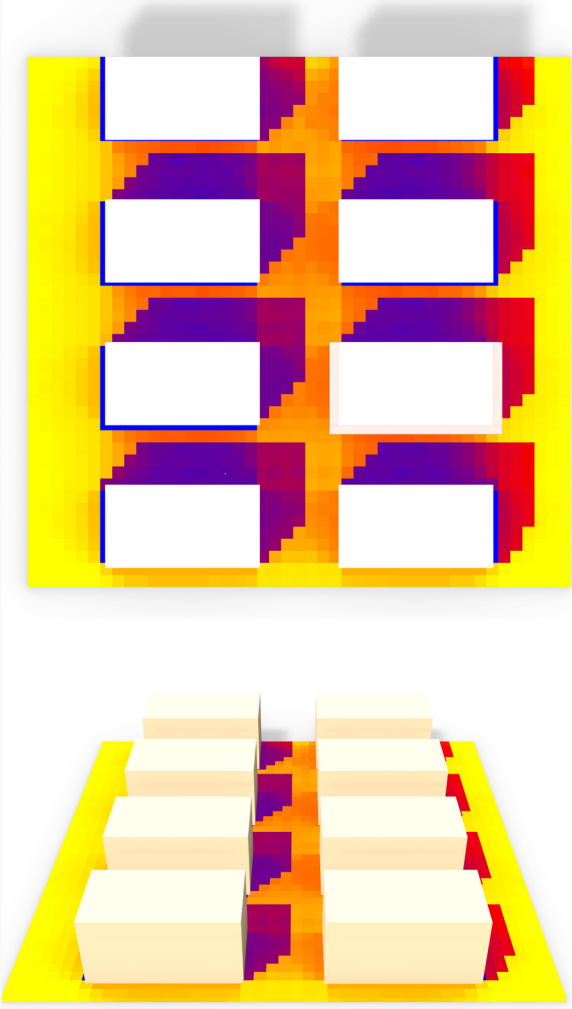
Return environmental period:



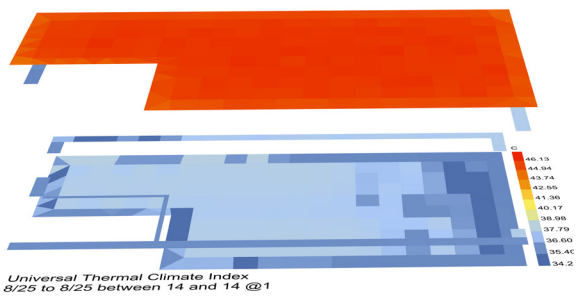
25th of August 14:00 Universal thermal comfort outdoor with no actions



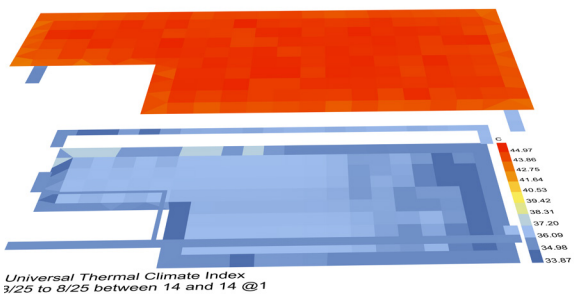
25th of August 14:00 Universal thermal comfort outdoor with greening



25th of August 14:00 Universal thermal comfort indoor with no actions

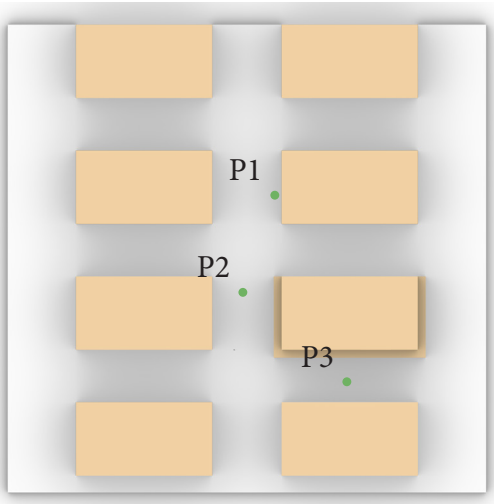


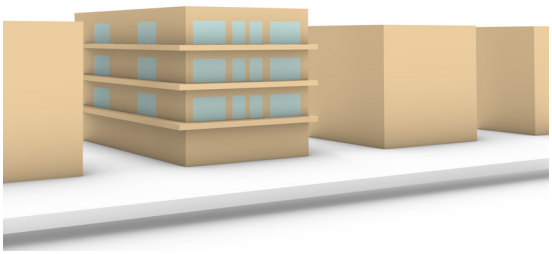
25th of August 14:00 Universal thermal comfort with greening



OUTPUT BLOCK

Green roofs:





Input data setting:

- DF Building from solid:
  - Floor to floor: 4 floors with 3m height
  - program: Midrise Appartment
  - Conditioned: false
- DF Apply facade parameter:
  - ratio wind parameter: 0.34
- DF Assign Building UWG Properties:
  - program: Midrise Appartment
  - vintage: Pre 1980 (CBECS)
  - wall albedo: /
  - roof albedo: /
  - roof vegetation: 1
- terrain:
  - albedo: 0.1
  - thickness: 0.5 m
- DF assign Model UWG properties:
  - traffic: typical mixed use part of Toulouse, France
  - tree cover: 0
  - grass cover: 0
- DF vegetation parameters:
  - albedo: 0.25
  - tree latent: 0.7
  - grass latent: 0.5

EFFECTIVENESS OUTDOOR

Air temperature · UTCI · UR% · mrt

EFFECTIVENESS INDOOR

Air temperature · UTCI · UR% · mrt

25th of August h 14:00 dry bulb temperature outdoor

T0= 36.10 °C Tgr= 34.90 °C Δ °C=1.20

25th of August h 14:00 Universal Thermal Comfort outdoor

T0= 36.79 Tgr= 35.47 Δ °C=1.32

25th of August h 14:00 dry bulb temperature indoor

T0= 35.78 °C Tgr= 34.73 °C Δ°C=0.95

25th of August h 14:00 mean radiant temperature indoor

T0= 36.96 °C Tgr= 35.61 °C Δ °C=1.34

Responsiveness:

Life period:

Period of installation:

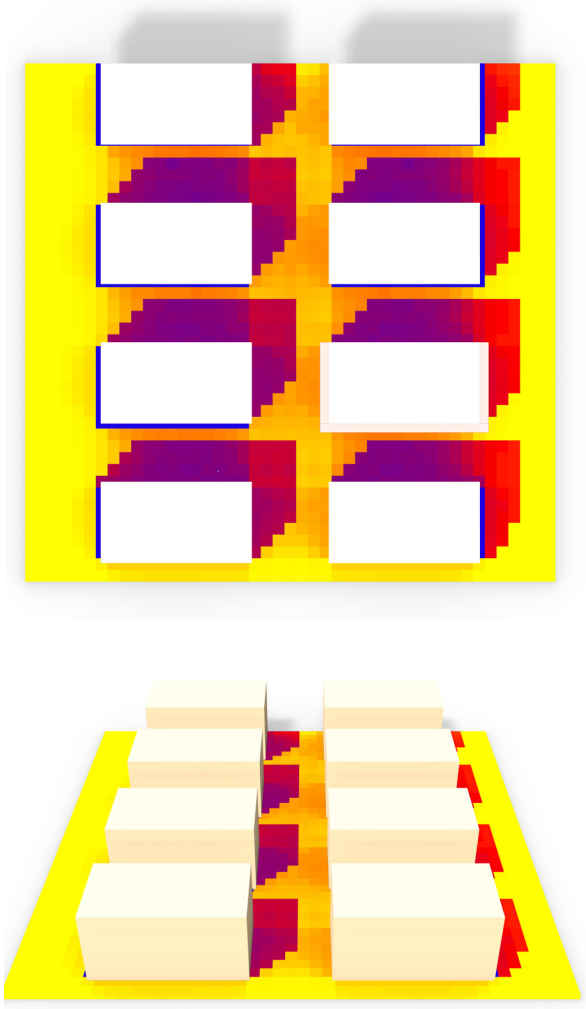
Maintenance:

! ! !

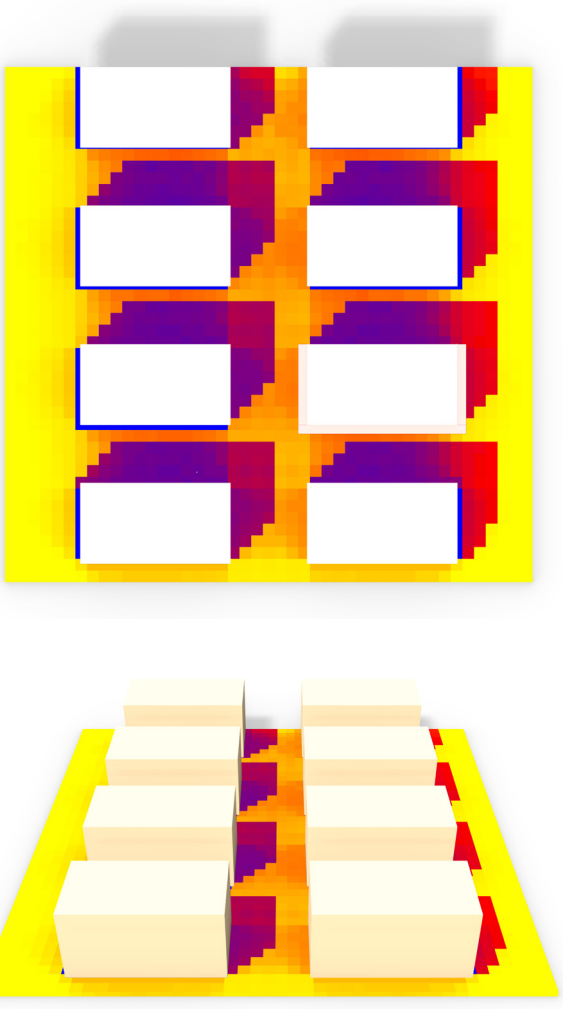
Life span:

Return environmental period:

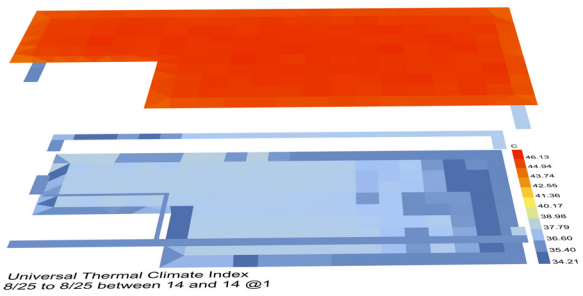
25th of August 14:00 Universal thermal comfort outdoor with no actions



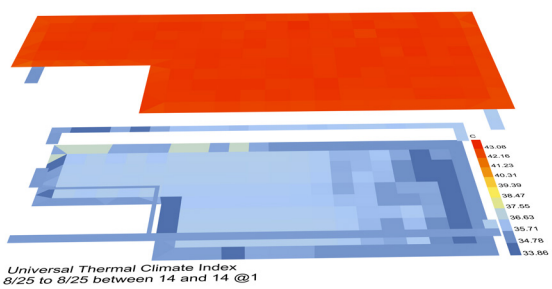
25th of August 14:00 Universal thermal comfort outdoor with green roofs



25th of August 14:00 Universal thermal comfort indoor with no actions

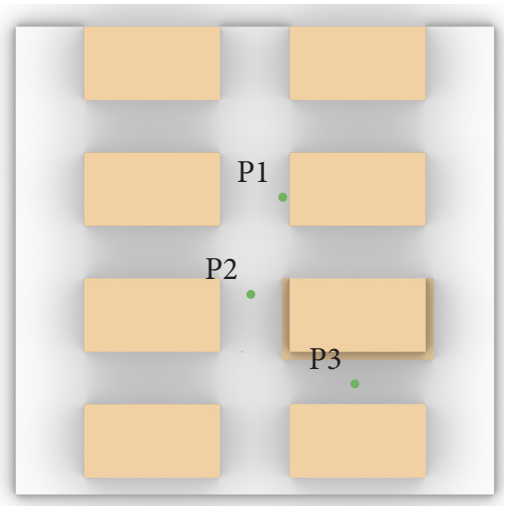


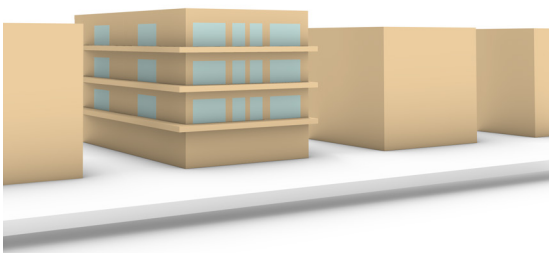
25th of August 14:00 Universal thermal comfort with green roofs



OUTPUT BLOCK

Green walls:





Input data setting:

- DF Building from solid:
  - Floor to floor: 4 floors with 3m height
  - program: Midrise Appartment
  - Conditioned: false
- DF Apply facade parameter:
  - ratio wind parameter: 0.34
- DF Assign Building UWG Properties:
  - program: Midrise Appartment
  - vintage: Pre 1980 (CBECS)
  - wall albedo: 0.2
  - roof albedo: 0.2
  - roof vegetation: 0
- terrain:
  - albedo: 0.1
  - thickness: 0.5 m
- DF assign Model UWG properties:
  - traffic: typical mixed use part of Toulouse, France
  - tree cover: 0
  - grass cover: 0
- DF vegetation parameters:
  - albedo: 0.25
  - tree latent: 0.7
  - grass latent: 0.5

EFFECTIVENESS OUTDOOR

Air temperature · UTCI · UR% · mrt

EFFECTIVENESS INDOOR

Air temperature · UTCI · UR% · mrt

25th of August h 14:00 dry bulb temperature outdoor

T0= 36.10 °C Tgw= 34.90 °C Δ °C=1.20

25th of August h 14:00 Universal Thermal Comfort outdoor

T0= 36.79 Tgw= 35.47 Δ °C=1.32

25th of August h 14:00 dry bulb temperature indoor

T0= 35.68 °C Tgw= 32.05 °C Δ°C=3.63

25th of August h 14:00 mean radiant temperature indoor

T0= 36.96 °C Tgw= 31.53 °C Δ °C=5.43

Responsiveness:

Life period:

Period of installation:

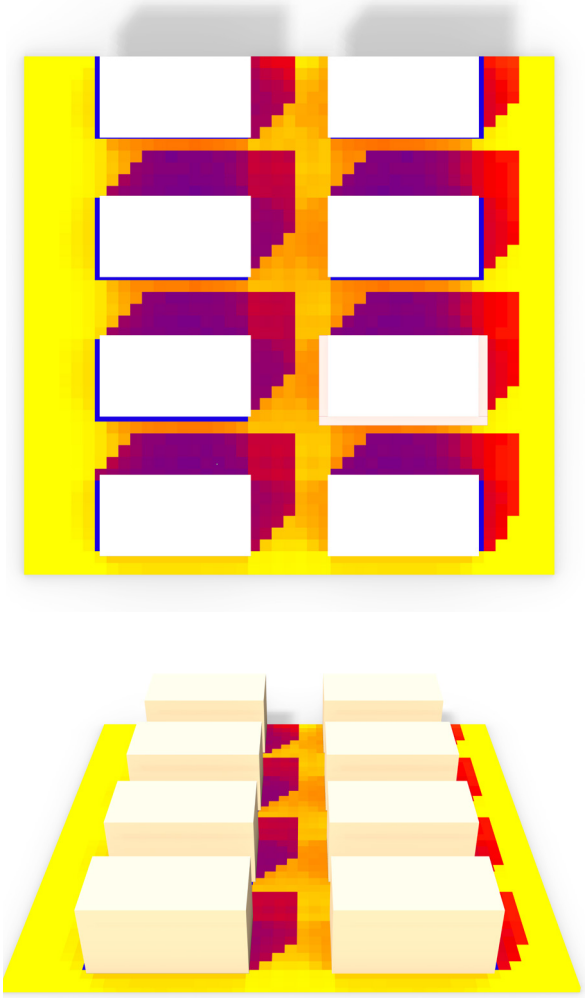
Maintenance:

! ! !

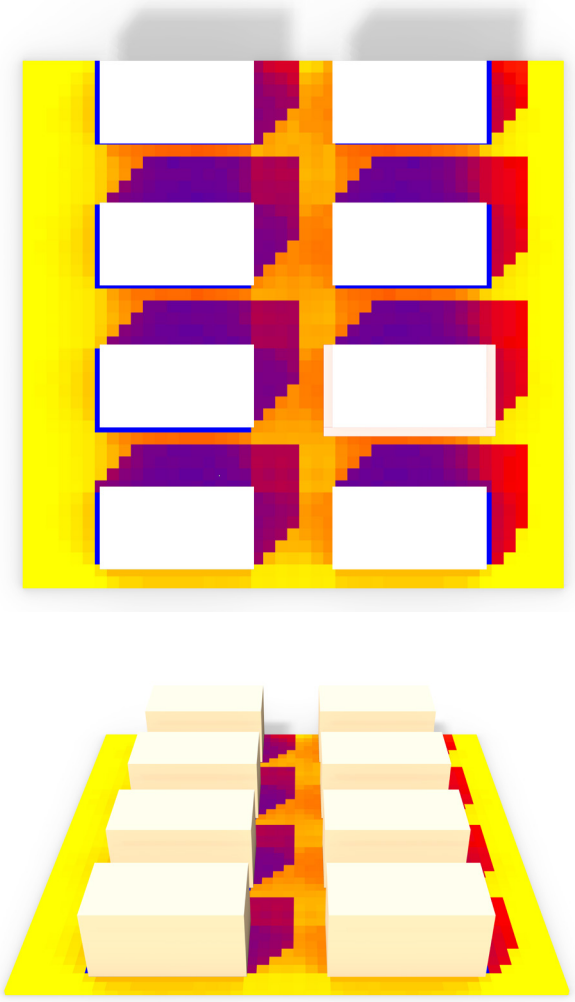
Life span:

Return environmental period:

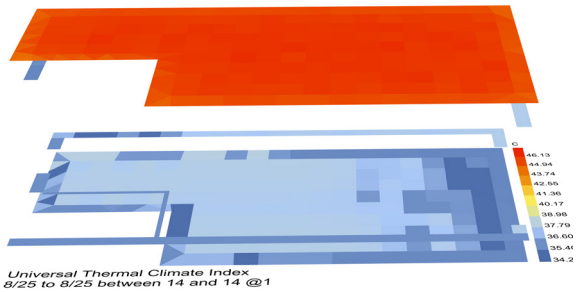
25th of August 14:00 Universal thermal comfort outdoor with no actions



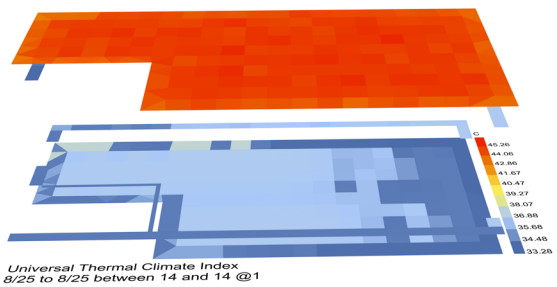
25th of August 14:00 Universal thermal comfort outdoor with green walls



25th of August 14:00 Universal thermal comfort indoor with no actions

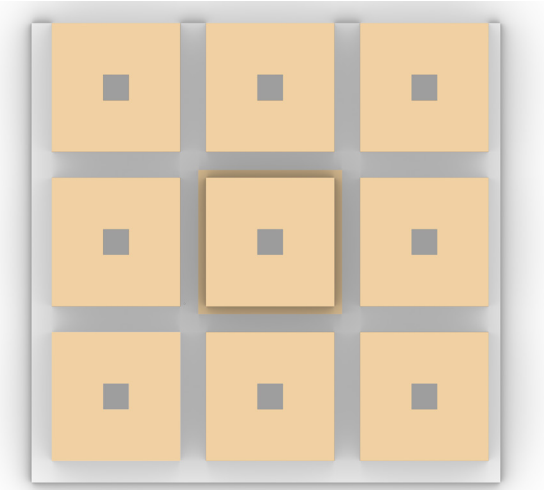


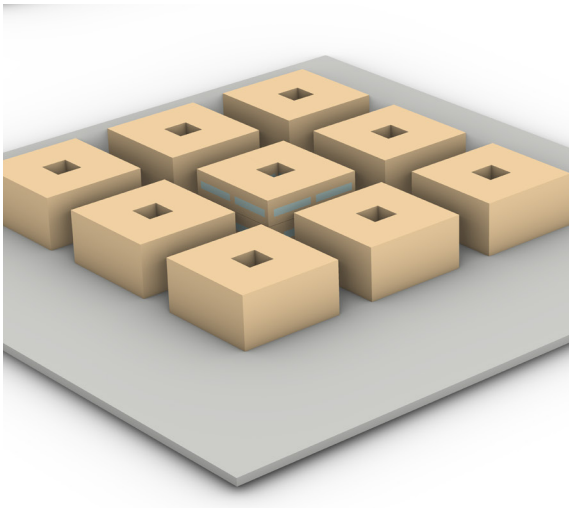
25th of August 14:00 Universal thermal comfort with green walls



OUTPUT COURT

Cool materials:





Input data setting:

- DF Building from solid:
  - Floor to floor: 3 floors with 3m height
  - program: Midrise Appartment
  - Conditioned: false
- DF Apply facade parameter:
  - ratio wind parameter: 0.34
- DF Assign Building UWG Properties:
  - program: Midrise Appartment
  - vintage: Pre 1980 (CBECS)
  - wall albedo: 0.98
  - roof albedo: 0.98
  - wall vegetation: 0
- terrain:
  - albedo: 0.98
  - thickness: 0.5 m
- DF assign Model UWG properties:
  - traffic: typical mixed use part of Toulouse, France
  - tree cover: 0
  - grass cover: 0
- DF vegetation parameters:
  - albedo: 0.25
  - tree latent: 0.7
  - grass latent: 0.5

EFFECTIVENESS OUTDOOR

Air temperature · UTCI · UR% · mrt

EFFECTIVENESS INDOOR

Air temperature · UTCI · UR% · mrt

25th of August h 14:00 dry bulb temperature outdoor

T_o= 36.10 °C T_c= 34.50 °C Δ °C=1.60

25th of August h 14:00 Universal Thermal Comfort outdoor

T_o= 41.41 T_c= 39.73 Δ °C=1.68

25th of August h 14:00 dry bulb temperature indoor

T_0= 33.68 °C T_c= 32.63 °C Δ°C=1.5

25th of August h 14:00 mean radiant temperature indoor

T_0= 31.39 °C T_c= 32.28 °C Δ °C=0.11

Responsiveness:

Life period:

Period of installation:

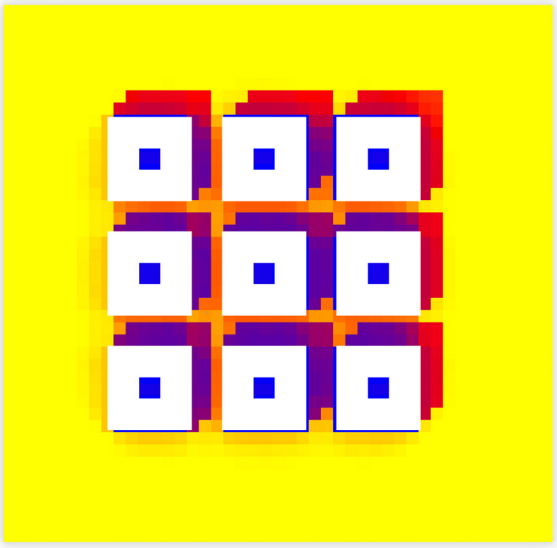
Maintenance:

!

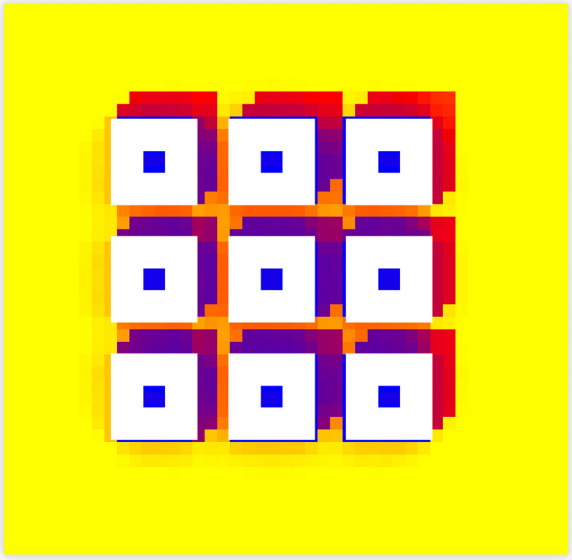
Life span:

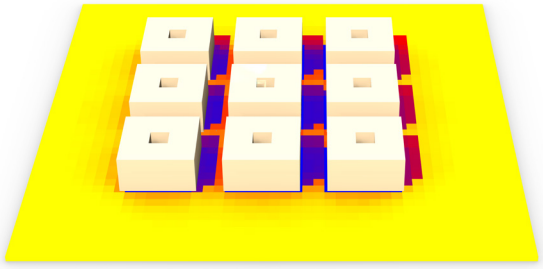
Return environmental period:

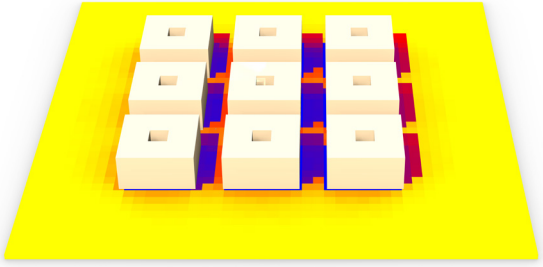
25th of August 14:00 Universal thermal comfort outdoor with no actions



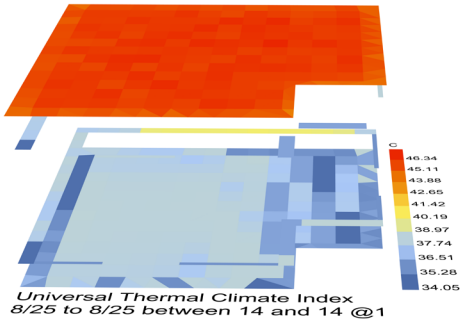
25th of August 14:00 Universal thermal comfort outdoor with cool materials



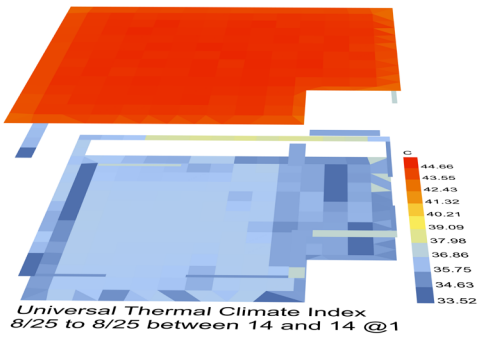




25th of August 14:00 Universal thermal comfort indoor with no actions

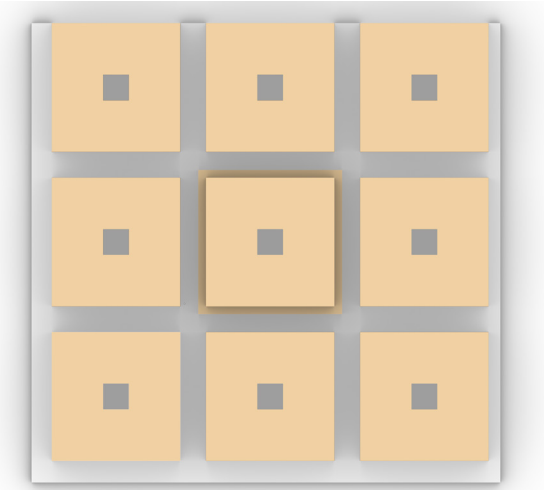


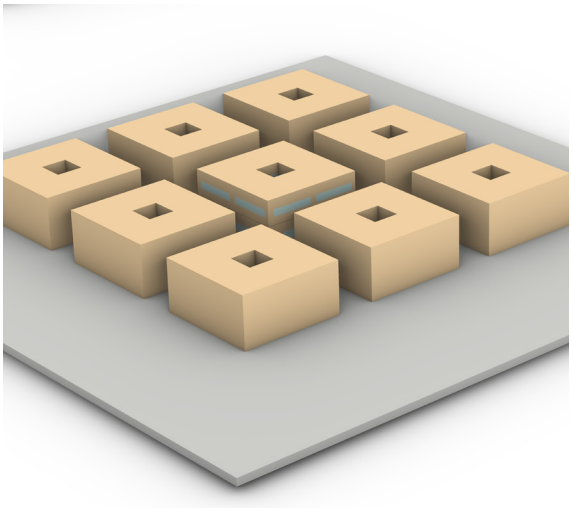
25th of August 14:00 Universal thermal comfort with cool materials



OUTPUT COURT

Greening:





Input data setting:

- DF Building from solid:
  - Floor to floor: 5 floors with 3m height
  - program: Midrise Appartment
  - Conditioned: false
- DF Apply facade parameter:
  - ratio wind parameter: 0.34
- DF Assign Building UWG Properties:
  - program: Midrise Appartment
  - vintage: Pre 1980 (CBECS)
  - wall albedo: 0.2
  - roof albedo: 0.2
  - roof vegetation: 0
- terrain:
  - albedo: 0.1
  - thickness: 0.5 m
- DF assign Model UWG properties:
  - traffic: typical mixed use part of Toulouse, France
  - tree cover: 0.5
  - grass cover: 0.6
- DF vegetation parameters:
  - albedo: 0.25
  - tree latent: 0.7
  - grass latent: 0.5

EFFECTIVENESS OUTDOOR

Air temperature ● UTCI ●● UR% ●● mrt ●●

EFFECTIVENESS INDOOR

Air temperature ● UTCI ● UR% ● mrt ●

25th of August h 14:00 dry bulb temperature outdoor

T_0= 36.10 °C T_g= 34.70 °C Δ °C=1.40

25th of August h 14:00 Universal Thermal Comfort outdoor

T_0= 41.41 T_g= 39.96 Δ °C=1.45

25th of August h 14:00 dry bulb temperature indoor

T_0= 33.68 °C T_g= 32.77 °C Δ°C=0.91

25th of August h 14:00 mean radiant temperature indoor

T_0= 31.39 °C T_g= 31.38 °C Δ °C= 0.01

Responsiveness:

Life period:

Period of installation:



Maintenance:

! ! !

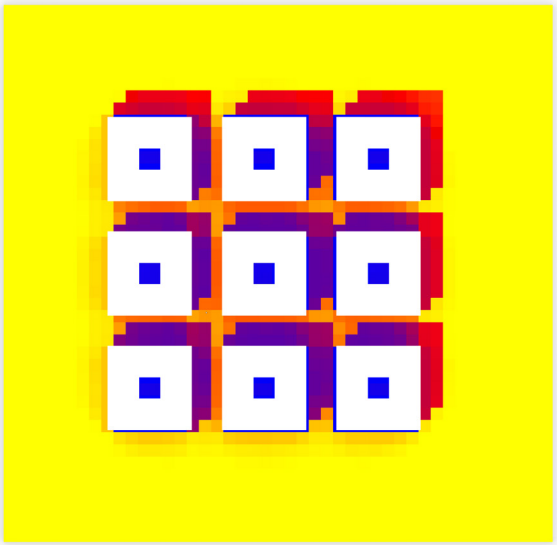
Life span:



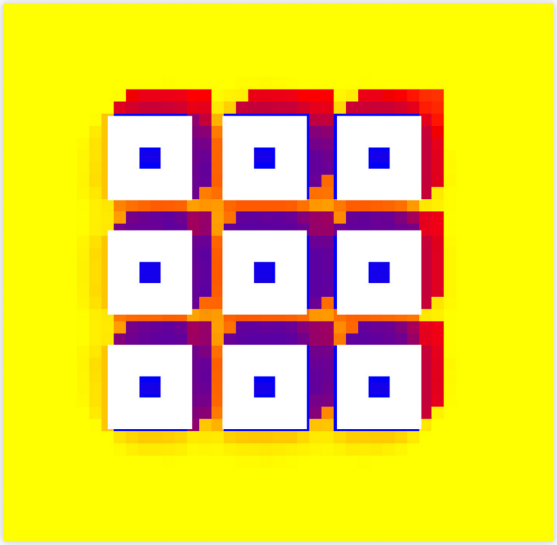
Return environmental period:

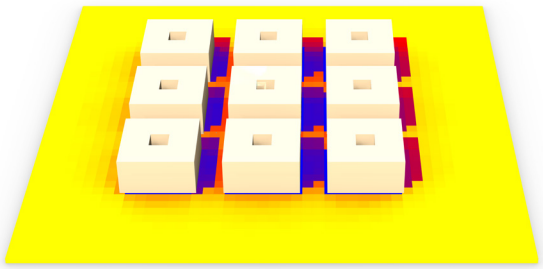


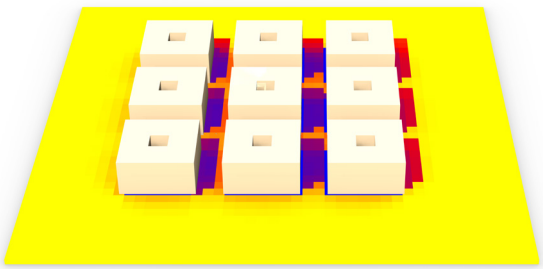
25th of August 14:00 Universal thermal comfort outdoor with no actions



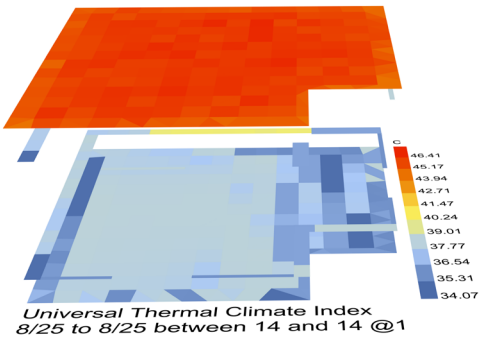
25th of August 14:00 Universal thermal comfort outdoor with greening



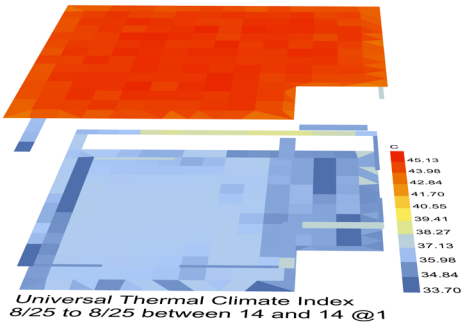




25th of August 14:00 Universal thermal comfort indoor with no actions

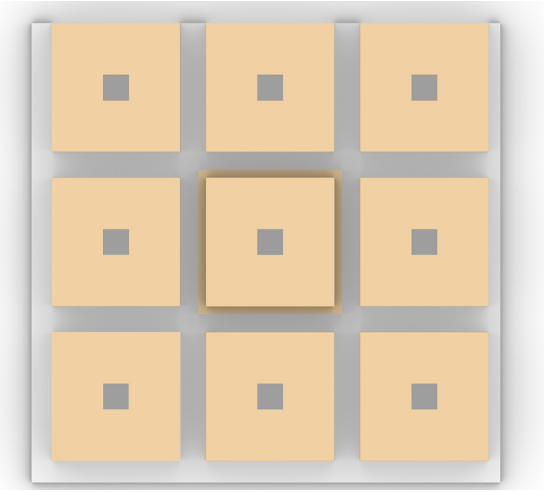


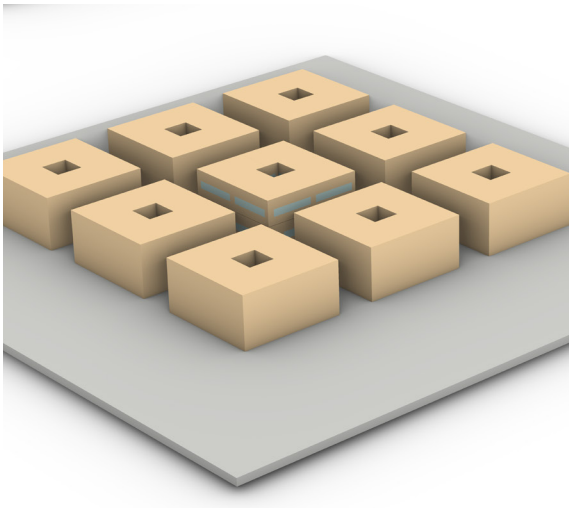
25th of August 14:00 Universal thermal comfort with greening



OUTPUT COURT

Green roofs:





Input data setting:

- DF Building from solid:
  - Floor to floor: 5 floors with 3m height
  - program: Midrise Appartment
  - Conditioned: false
- DF Apply facade parameter:
  - ratio wind parameter: 0.34
- DF Assign Building UWG Properties:
  - program: Midrise Appartment
  - vintage: Pre 1980 (CBECS)
  - wall albedo: 0.2
  - roof albedo: 0.2
  - roof vegetation: 1
- terrain:
  - albedo: 0.1
  - thickness: 0.5 m
- DF assign Model UWG properties:
  - traffic: typical mixed use part of Toulouse, France
  - tree cover: 0
  - grass cover: 0
- DF vegetation parameters:
  - albedo: 0.25
  - tree latent: 0.7
  - grass latent: 0.5

EFFECTIVENESS OUTDOOR

Air temperature · UTCI · UR% · mrt

EFFECTIVENESS INDOOR

Air temperature · UTCI · UR% · mrt

25th of August h 14:00 dry bulb temperature outdoor

T_o= 36.10 °C T_{gr} = 34.90 °C Δ °C=1.20

25th of August h 14:00 Universal Thermal Comfort outdoor

T_o= 41.41 T_{gr} = 40.13 Δ °C= 1.28

25th of August h 14:00 dry bulb temperature indoor

T_o= 33.68 °C T_{gr} = 32.81 °C Δ°C=0.87

25th of August h 14:00 mean radiant temperature indoor

T_o= 31.39 °C T_{gr} = 31.37 °C Δ °C=0.03

Responsiveness:

Life period:

Period of installation:

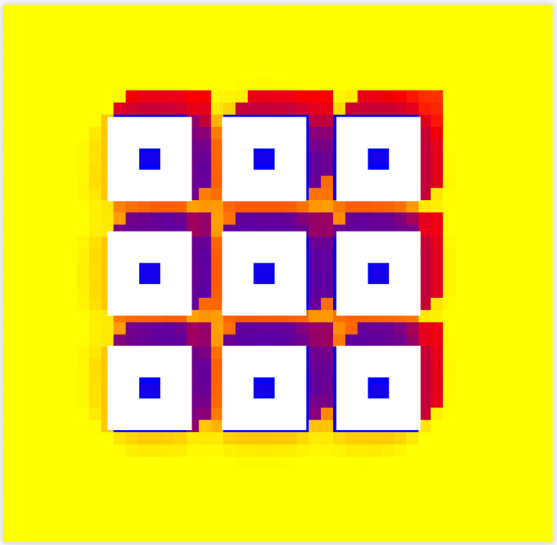
Maintenance:

! ! !

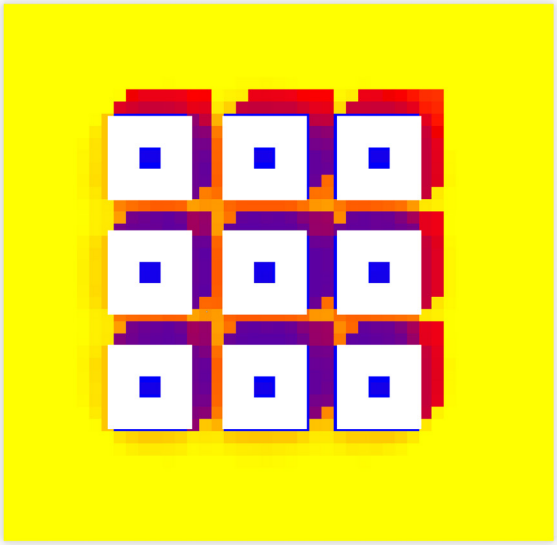
Life span:

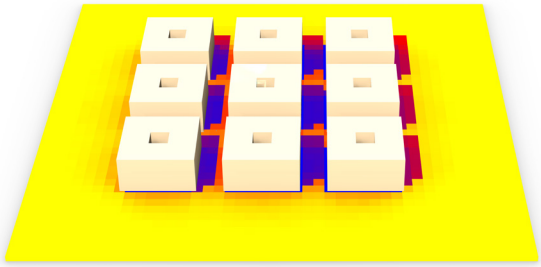
Return environmental period:

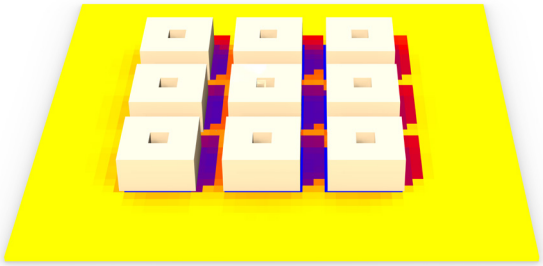
25th of August 14:00 Universal thermal comfort outdoor with no actions



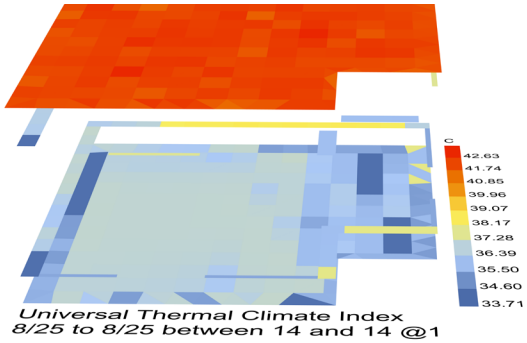
25th of August 14:00 Universal thermal comfort outdoor with green roofs:



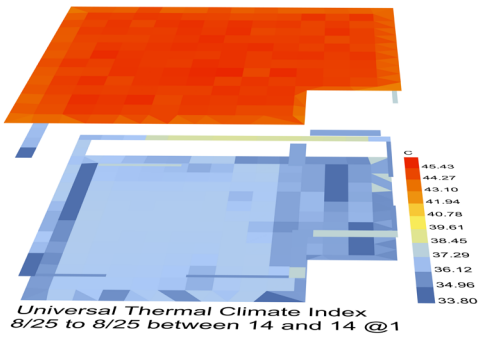




25th of August 14:00 Universal thermal comfort indoor with no actions

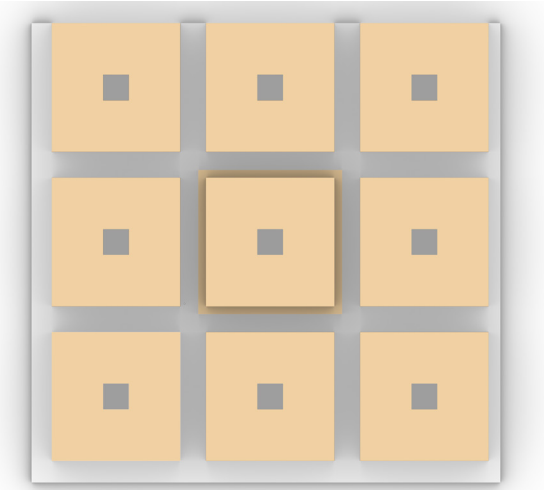


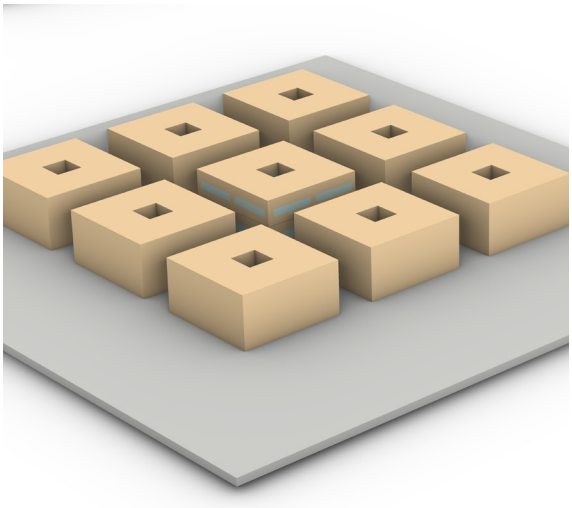
25th of August 14:00 Universal thermal comfort with green roofs



OUTPUT COURT

Green walls:





Input data setting:

- DF Building from solid:
  - Floor to floor: 3 floors with 3m height
  - program: Midrise Appartment
  - Conditioned: false
- DF Apply facade parameter:
  - ratio wind parameter: 0.34
- DF Assign Building UWG Properties:
  - program: Midrise Appartment
  - vintage: Pre 1980 (CBECS)
  - wall albedo: 0.2
  - roof albedo: 0.2
  - roof vegetation: 0
- terrain:
  - albedo: 0.1
  - thickness: 0.5 m
- DF assign Model UWG properties:
  - traffic: typical mixed use part of Toulouse, France
  - tree cover: 0
  - grass cover: 0
- DF vegetation parameters:
  - albedo: 0.25
  - tree latent: 0.7
  - grass latent: 0.5

EFFECTIVENESS OUTDOOR

Air temperature ●

UTCI ●

UR% ●●

mrt ●●

EFFECTIVENESS INDOOR

Air temperature ●●

UTCI ●●

UR% ●●●

mrt ●●

25th of August h 14:00 dry bulb temperature outdoor

T_0= 36.1 °C T_{gw}= 34.9 °C Δ°C=1.60

25th of August h 14:00 Universal Thermal Comfort outdoor

T_0= 37.61 T_{gw}= 36.29 Δ °C=1.20

25th of August h 14:00 dry bulb temperature indoor

T_0= 33.68 °C T_{gw}= 31.83 °C Δ°C=1.85

25th of August h 14:00 mean radiant temperature indoor

T_0= 31.39 °C T_{gw}= 30.06 °C Δ °C=1.33

Responsiveness:

Life period:

Period of installation:



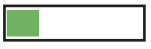
Maintenance:

! ! !

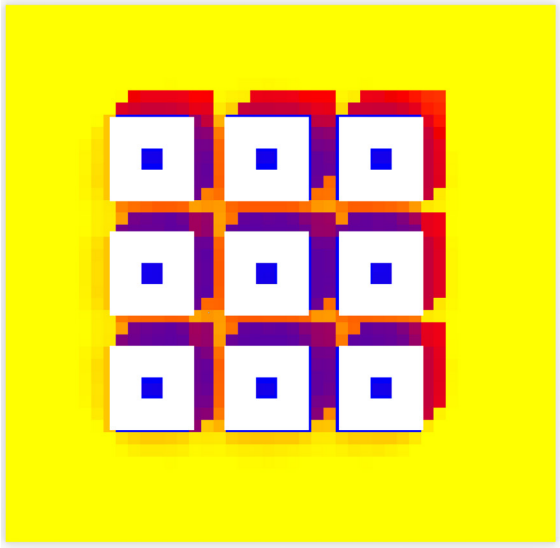
Life span:



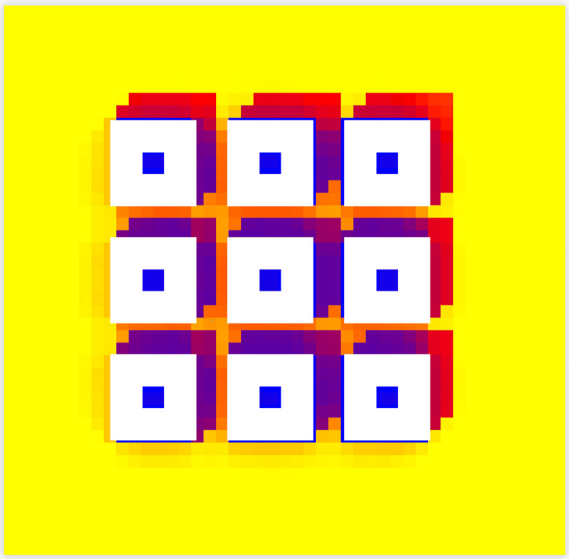
Return environmental period:

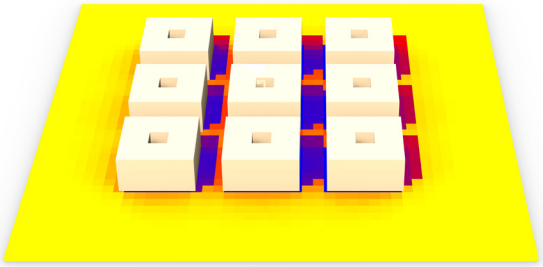


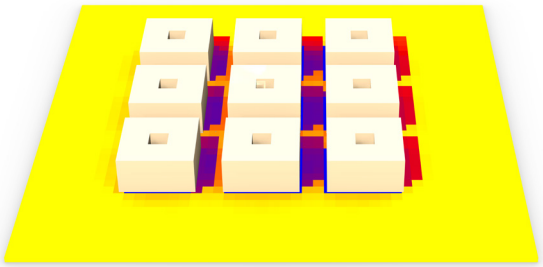
25th of August 14:00 Universal thermal comfort outdoor with no actions



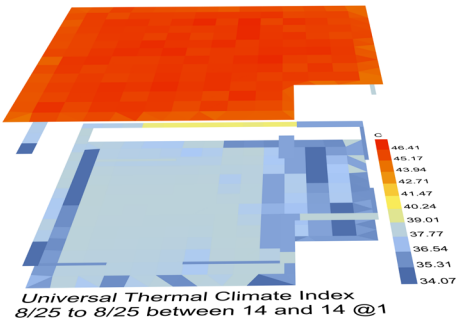
25th of August 14:00 Universal thermal comfort outdoor with green walls:



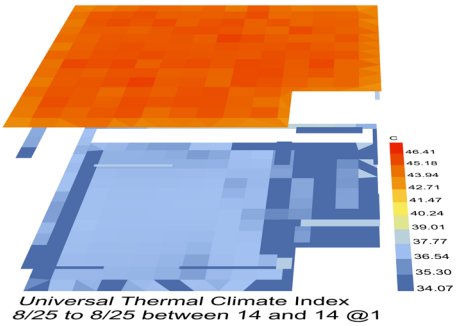




25th of August 14:00 Universal thermal comfort indoor with no actions

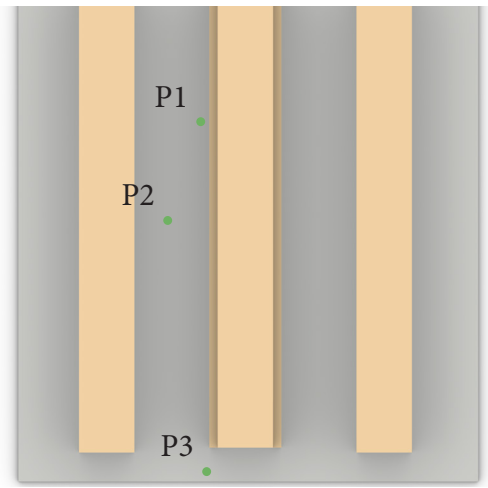


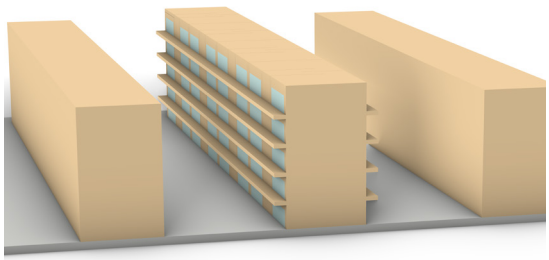
25th of August 14:00 Universal thermal comfort with green walls:



OUTPUT LINE

Cool materials:





Input data setting:

- DF Building from solid:
  - Floor to floor: 5 floors with 3m height
  - program: Midrise Appartment
  - Conditioned: false
- DF Apply facade parameter:
  - ratio wind parameter: 0.34
- DF Assign Building UWG Properties:
  - program: Midrise Appartment
  - vintage: Pre 1980 (CBECS)
  - wall albedo: 0.98
  - roof albedo: 0.98
  - wall vegetation: 0
- terrain:
  - albedo: 0.98
  - thickness: 0.5 m
- DF assign Model UWG properties:
  - traffic: typical mixed use part of Toulouse, France
  - tree cover: 0
  - grass cover: 0
- DF vegetation parameters:
  - albedo: 0.25
  - tree latent: 0.7
  - grass latent: 0.5

EFFECTIVENESS OUTDOOR

Air temperature ● UTCI ● UR% ●● mrt ●●

EFFECTIVENESS INDOOR

Air temperature ● UTCI ● UR% ● mrt ●

25th of August h 14:00 dry bulb temperature outdoor

T_0= 36.1 °C T_c= 34.8 °C Δ °C=1.3

25th of August h 14:00 Universal Thermal Comfort outdoor

T_0= 37.61 T_c= 36.17 Δ °C=1.3

25th of August h 14:00 dry bulb temperature indoor

T_0= 35.13 °C T_c= 34.78 °C Δ°C=0. 492

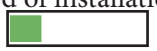
25th of August h 14:00 mean radiant temperature indoor

T_0= 40.22 °C T_c= 39.96 °C Δ °C=0.491

Responsiveness:

Life period:

Period of installation:



Maintenance:

!

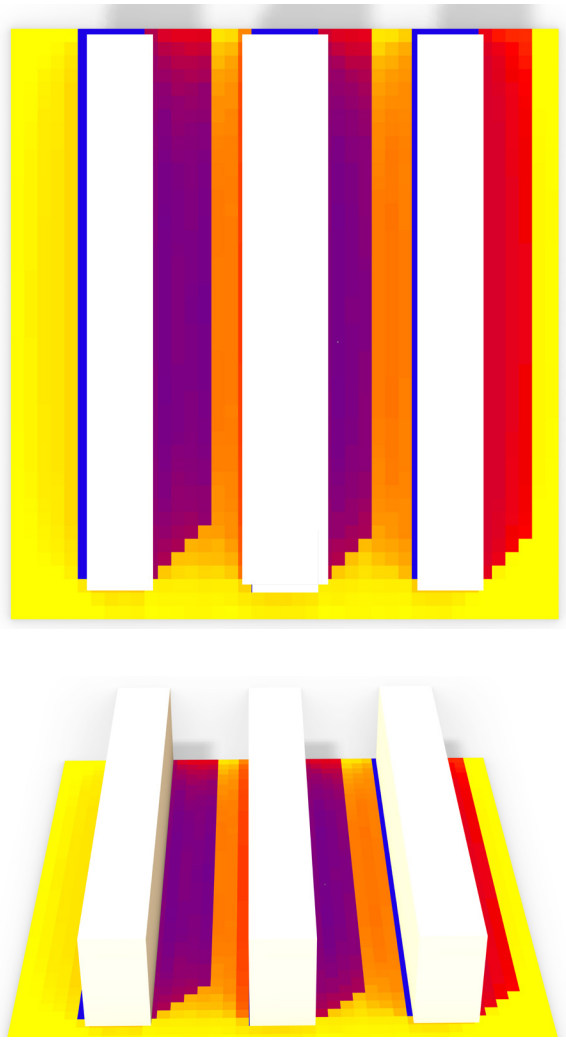
Life span:



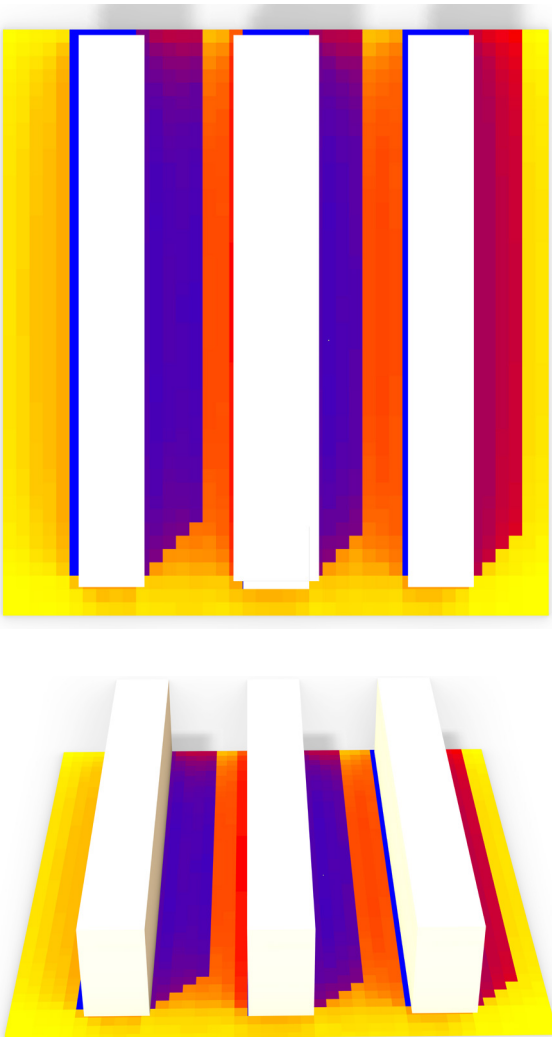
Return environmental period:



25th of August 14:00 Universal thermal comfort outdoor with no actions

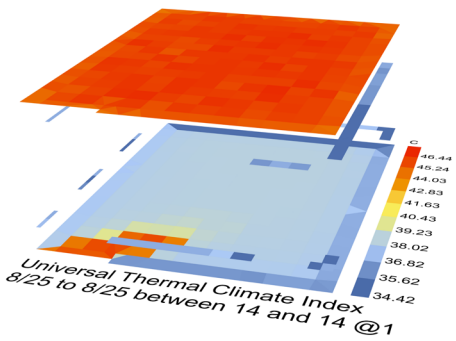


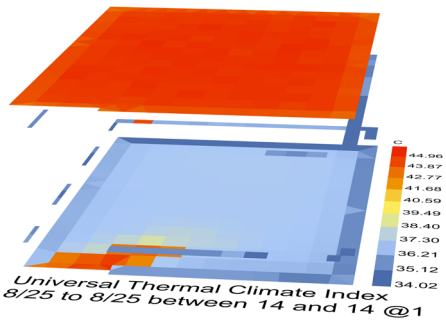
25th of August 14:00 Universal thermal comfort outdoor with cool materials:



25th of August 14:00 Universal thermal comfort indoor with no actions

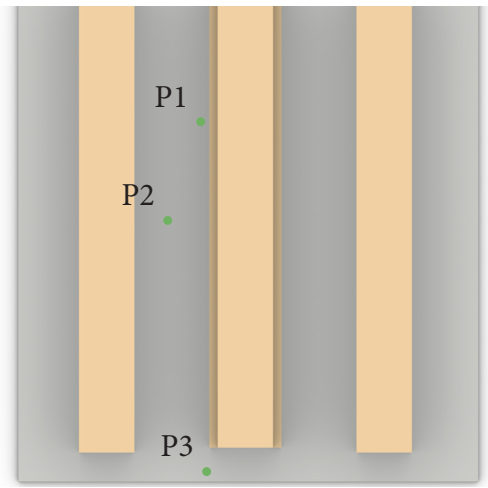
25th of August 14:00 Universal thermal comfort with cool materials:

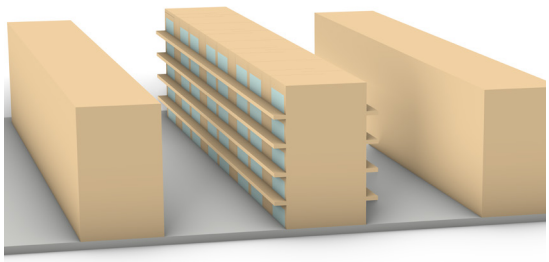




OUTPUT LINE

Greening:





Input data setting:

- DF Building from solid:
  - Floor to floor: 5 floors with 3m height
  - program: Midrise Appartment
  - Conditioned: false
- DF Apply facade parameter:
  - ratio wind parameter: 0.34
- DF Assign Building UWG Properties:
  - program: Midrise Appartment
  - vintage: Pre 1980 (CBECS)
  - wall albedo: 0.2
  - roof albedo: 0.2
  - roof vegetation: 0
- terrain:
  - albedo: 0.1
  - thickness: 0.5 m
- DF assign Model UWG properties:
  - traffic: typical mixed use part of Toulouse, France
  - tree cover: 0.8
  - grass cover: 0.9
- DF vegetation parameters:
  - albedo: 0.25
  - tree latent: 0.7
  - grass latent: 0.5

EFFECTIVENESS OUTDOOR

Air temperature · UTCI · UR% · mrt

EFFECTIVENESS INDOOR

Air temperature · UTCI · UR% · mrt

25th of August h 14:00 dry bulb temperature outdoor

T_0= 36.1 °C T_g= 34.8 °C Δ °C=1.3

25th of August h 14:00 Universal Thermal Comfort outdoor

T_0= 37.61 T_g= 36.17 Δ °C=1.3

25th of August h 14:00 dry bulb temperature indoor

T_0= 35.13 °C T_g= 34.8 °C Δ°C=0.35

25th of August h 14:00 mean radiant temperature indoor

T_0= 40.22 °C T_g= 40.01 °C Δ °C= 0.20

Responsiveness:

Life period:

Period of installation:

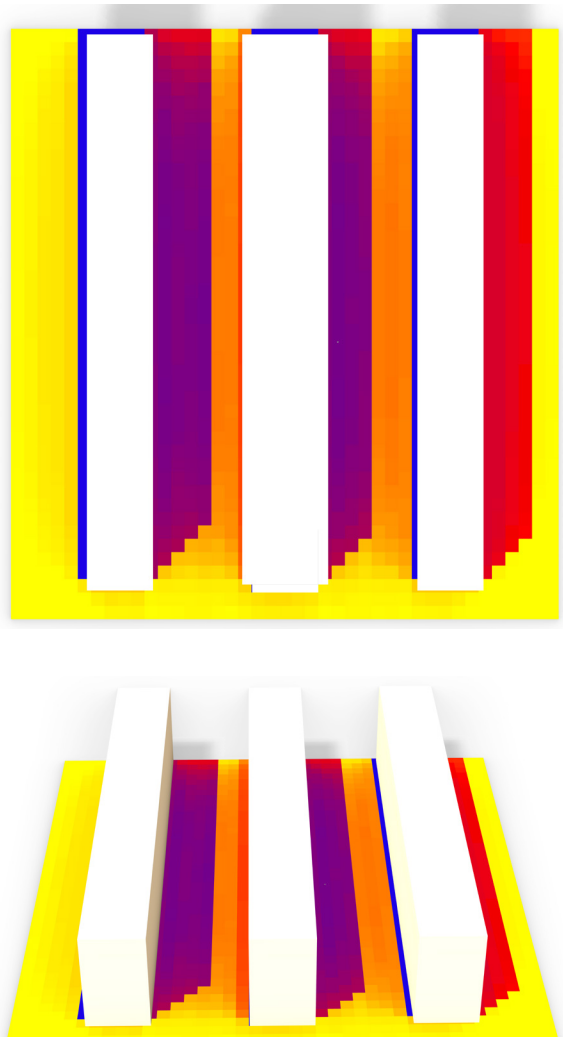
Maintenance:

! ! !

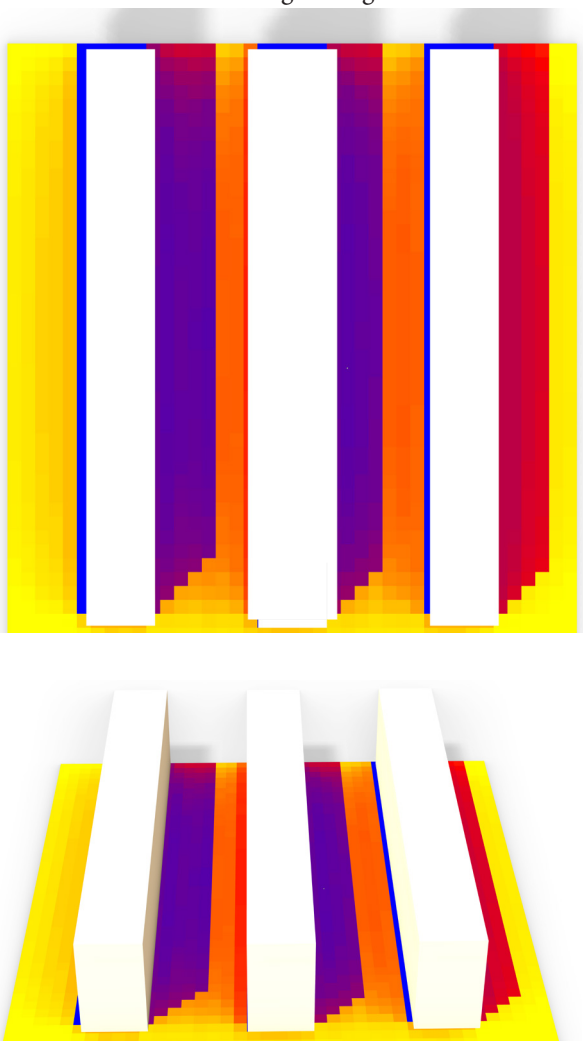
Life span:

Return environmental period:

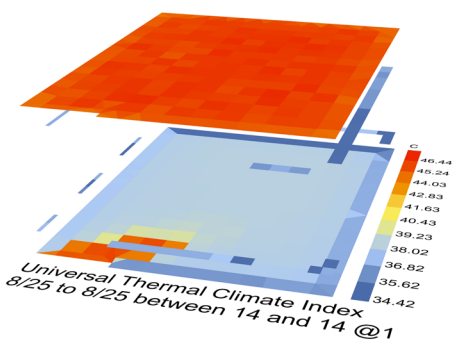
25th of August 14:00 Universal thermal comfort outdoor with no actions



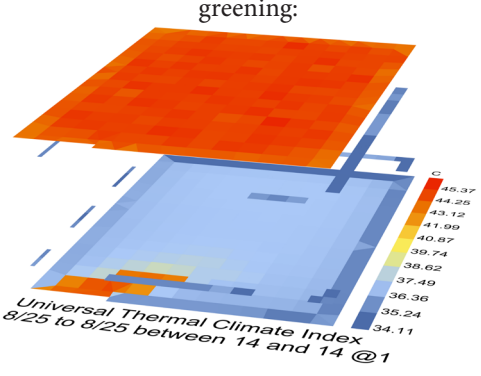
25th of August 14:00 Universal thermal comfort outdoor with greening:



25th of August 14:00 Universal thermal comfort indoor with no actions

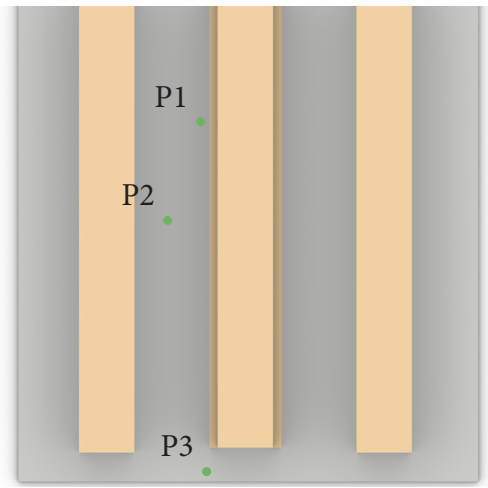


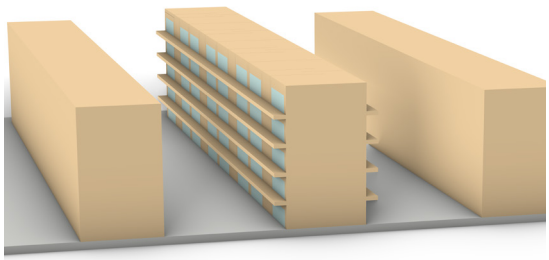
25th of August 14:00 Universal thermal comfort with greening:



OUTPUT LINE

Green roofs:





Input data setting:

- DF Building from solid:
  - Floor to floor: 5 floors with 3m height
  - program: Midrise Appartment
  - Conditioned: false
- DF Apply facade parameter:
  - ratio wind parameter: 0.34
- DF Assign Building UWG Properties:
  - program: Midrise Appartment
  - vintage: Pre 1980 (CBECS)
  - wall albedo: 0.2
  - roof albedo: 0.2
  - roof vegetation: 1
- terrain:
  - albedo: 0.1
  - thickness: 0.5 m
- DF assign Model UWG properties:
  - traffic: typical mixed use part of Toulouse, France
  - tree cover: 0
  - grass cover: 0
- DF vegetation parameters:
  - albedo: 0.25
  - tree latent: 0.7
  - grass latent: 0.5

EFFECTIVENESS OUTDOOR

Air temperature ● UTCI ● UR% ●● mrt ●

EFFECTIVENESS INDOOR

Air temperature ●● UTCI ● UR% ● mrt ●

25th of August h 14:00 dry bulb temperature outdoor

T_o= 36.1 °C T_{gr}= 34.9 °C Δ °C=1.2

25th of August h 14:00 Universal Thermal Comfort outdoor

T_o= 37.61 T_{gr}= 36.29 Δ °C=1.3

25th of August h 14:00 dry bulb temperature indoor

T_o= 35.13 °C T_{gr}= 33.89 °C Δ°C=1.24

25th of August h 14:00 mean radiant temperature indoor

T_o= 40.22 °C T_{gr}= 40.07 °C Δ °C=0.15

Responsiveness:

Life period:

Period of installation:



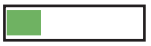
Maintenance:

! ! !

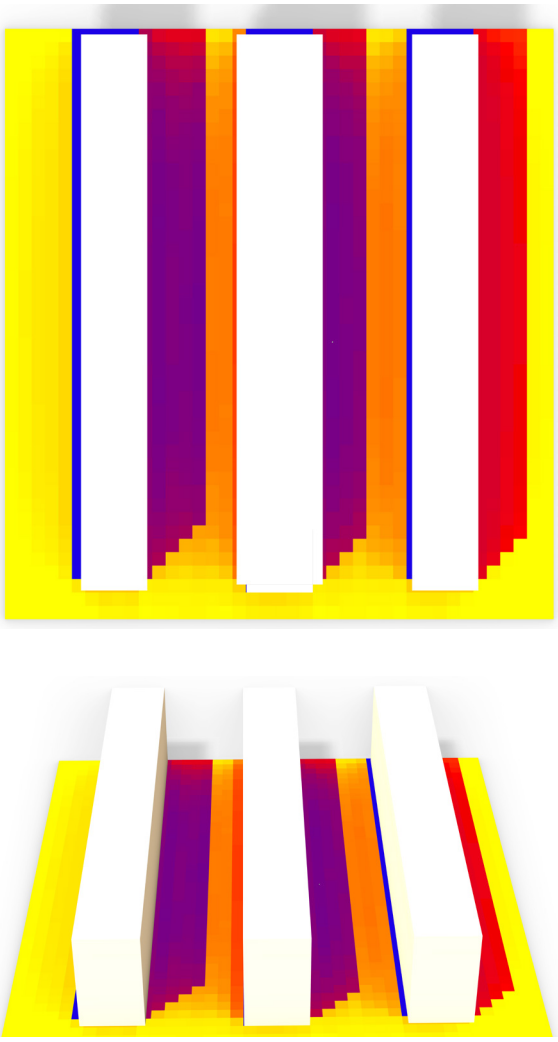
Life span:



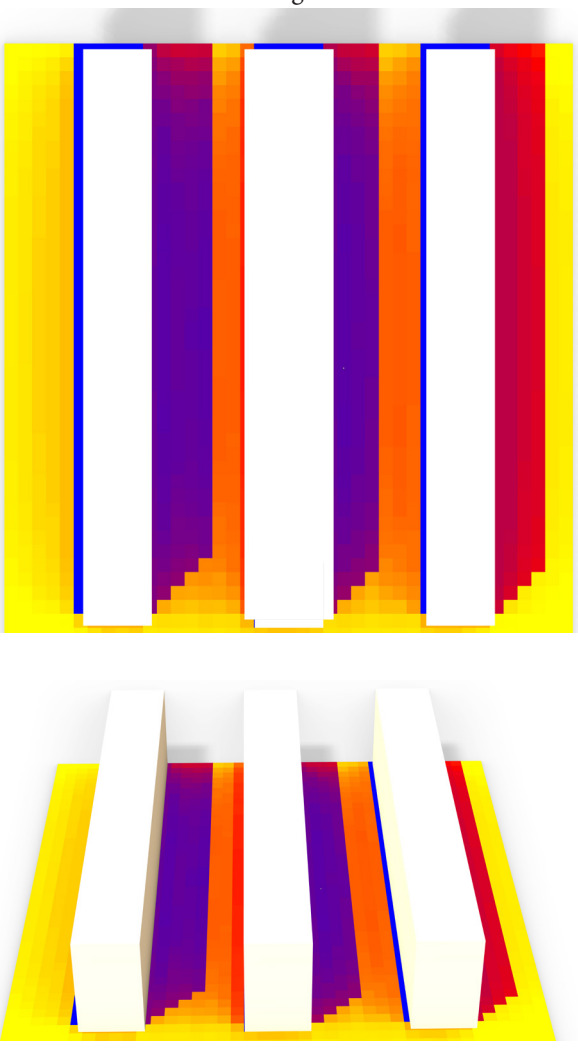
Return environmental period:



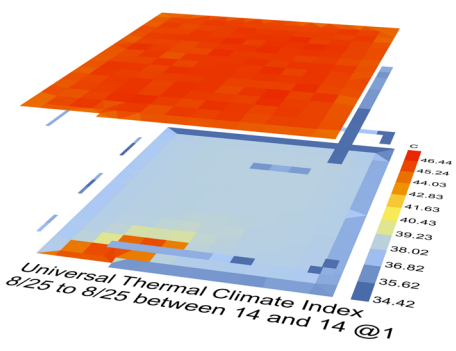
25th of August 14:00 Universal thermal comfort outdoor with no actions



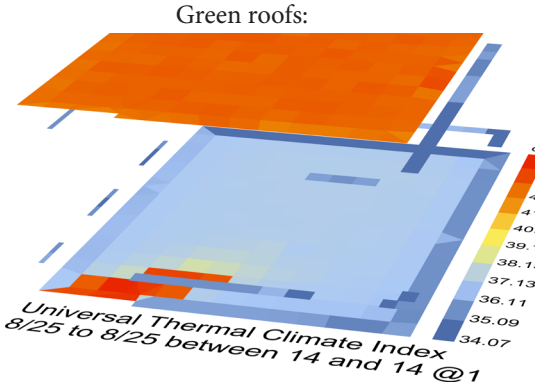
25th of August 14:00 Universal thermal comfort outdoor with green roofs:



25th of August 14:00 Universal thermal comfort indoor with no actions

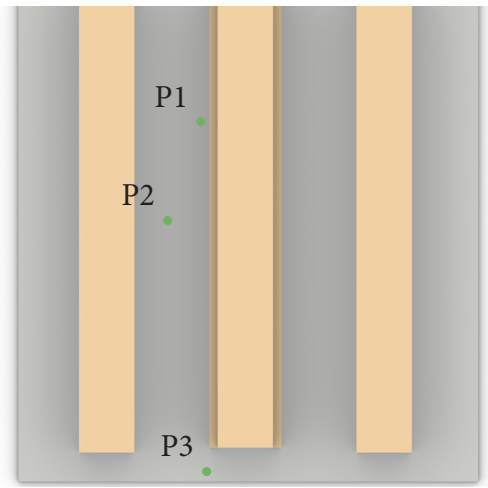


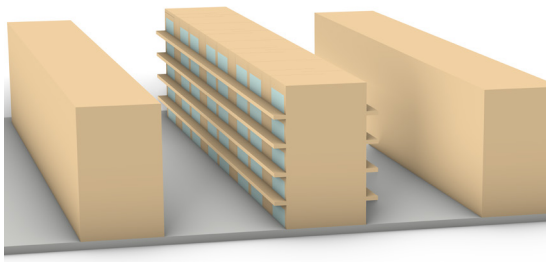
25th of August 14:00 Universal thermal comfort with Green roofs:



OUTPUT LINE

Green walls:





Input data setting:

- DF Building from solid:
  - Floor to floor: 5 floors with 3m height
  - program: Midrise Appartment
  - Conditioned: false
- DF Apply facade parameter:
  - ratio wind parameter: 0.34
- DF Assign Building UWG Properties:
  - program: Midrise Appartment
  - vintage: Pre 1980 (CBECS)
  - wall albedo: 0.2
  - roof albedo: 0.2
  - roof vegetation: 0
- terrain:
  - albedo: 0.1
  - thickness: 0.5 m
- DF assign Model UWG properties:
  - traffic: typical mixed use part of Toulouse, France
  - tree cover: 0
  - grass cover: 0
- DF vegetation parameters:
  - albedo: 0.25
  - tree latent: 0.7
  - grass latent: 0.5

EFFECTIVENESS OUTDOOR

Air temperature · UTCI · UR% · mrt

EFFECTIVENESS INDOOR

Air temperature · UTCI · UR% · mrt

25th of August h 14:00 dry bulb temperature outdoor

T_0= 36.1 °C T_{gw}= 34.9 °C -1.2

25th of August h 14:00 Universal Thermal Comfort outdoor

T_0= 37.61 T_{gw}= 36.29 -1.31

25th of August h 14:00 dry bulb temperature indoor

T_0= 35.13 °C T_{gw}= 34.73 °C -0.40

25th of August h 14:00 mean radiant temperature indoor

T_0= 40.22 °C T_{gw}= 40.05 °C -0.16

Responsiveness:

Life period:

Period of installation:

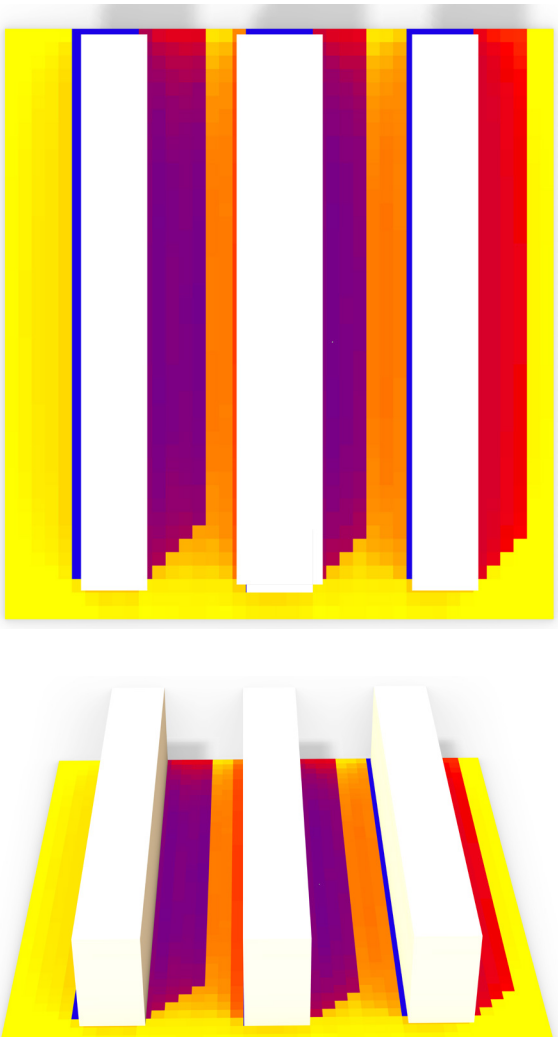
Maintenance:

! ! !

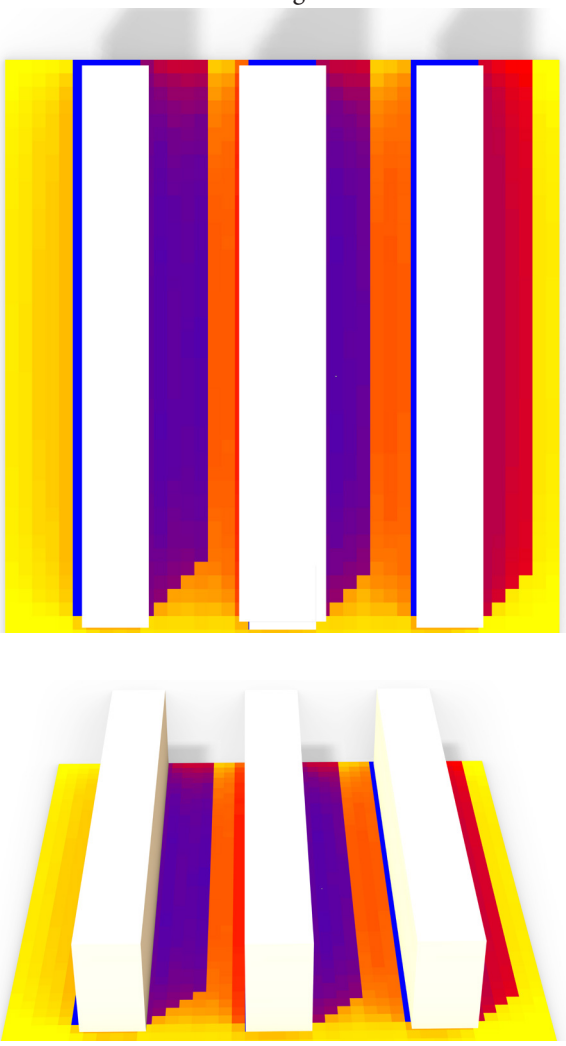
Life span:

Return environmental period:

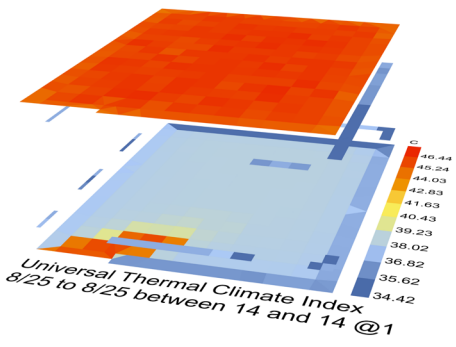
25th of August 14:00 Universal thermal comfort outdoor with no actions



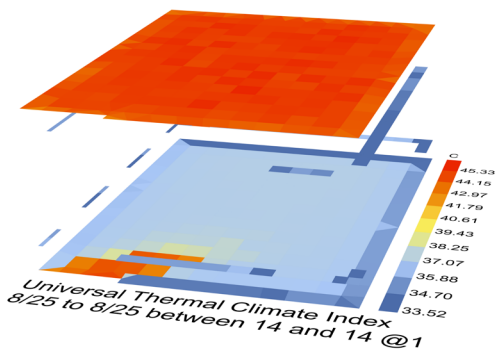
25th of August 14:00 Universal thermal comfort outdoor with green walls:



25th of August 14:00 Universal thermal comfort indoor with no actions

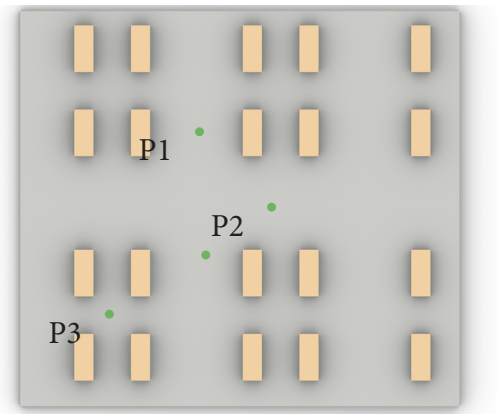


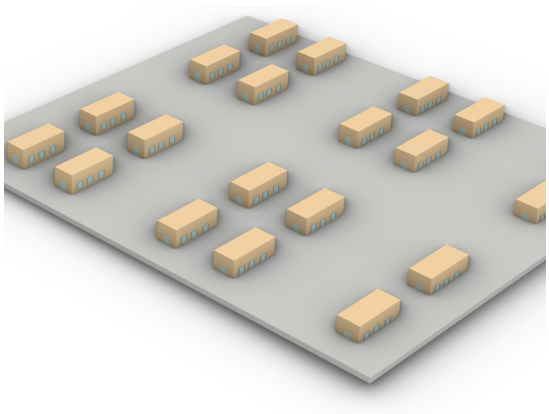
25th of August 14:00 Universal thermal comfort with Green roofs:



OUTPUT ISOLATED

Cool materials:





Input data setting:

- DF Building from solid:
  - Floor to floor: 5 floors with 3m height
  - program: Midrise Appartment
  - Conditioned: false
- DF Apply facade parameter:
  - ratio wind parameter: 0.34
- DF Assign Building UWG Properties:
  - program: Midrise Appartment
  - vintage: Pre 1980 (CBECS)
  - wall albedo: 0.2
  - roof albedo: 0.2
  - roof vegetation: 0
- terrain:
  - albedo: 0.1
  - thickness: 0.5 m
- DF assign Model UWG properties:
  - traffic: typical mixed use part of Toulouse, France
  - tree cover: 0
  - grass cover: 0
- DF vegetation parameters:
  - albedo: 0.25
  - tree latent: 0.7
  - grass latent: 0.5

EFFECTIVENESS OUTDOOR

Air temperature · UTCI · UR% · mrt

EFFECTIVENESS INDOOR

Air temperature · UTCI · UR% · mrt

25th of August h 14:00 dry bulb temperature outdoor

T_0= 36.10 °C T_c= 34.30 °C Δ °C= 1.80

25th of August h 14:00 Universal Thermal Comfort outdoor

T_0= 42.78 T_c= 40.98 Δ °C= 1.80

25th of August h 14:00 dry bulb temperature indoor

T_0= 34.36 °C T_c= 33.82 °C Δ °C= 0.50

25th of August h 14:00 mean radiant temperature indoor

T_0= 32.79 °C T_c= 32.65 °C Δ °C= 0.14

Responsiveness:

Life period:

Period of installation:

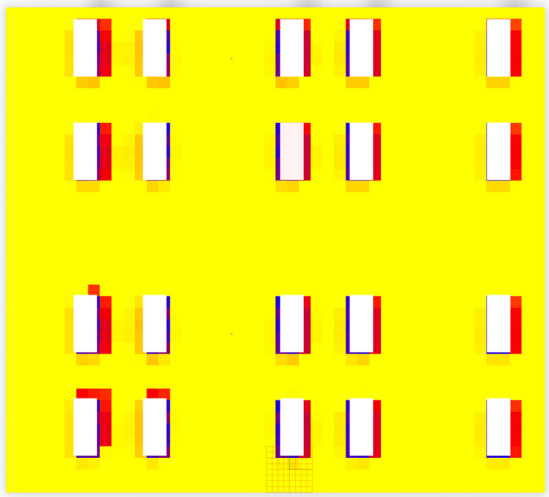
Maintenance:

!

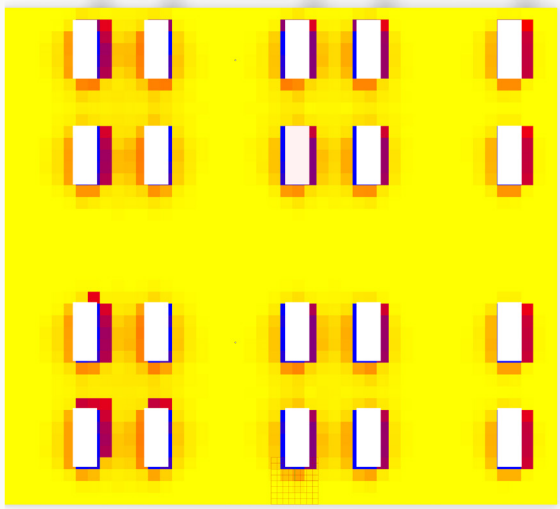
Life span:

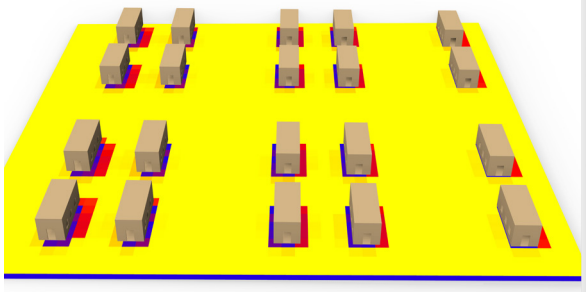
Return environmental period:

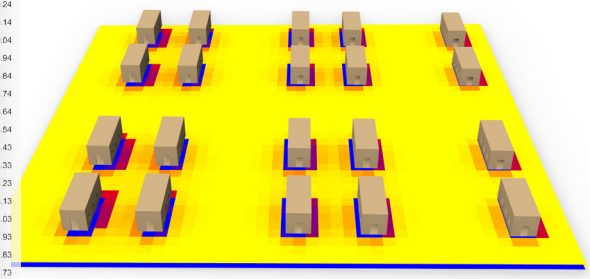
25th of August 14:00 Universal thermal comfort outdoor with no actions



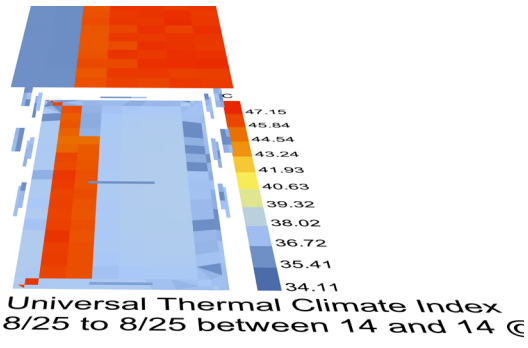
25th of August 14:00 Universal thermal comfort outdoor with cool materials:



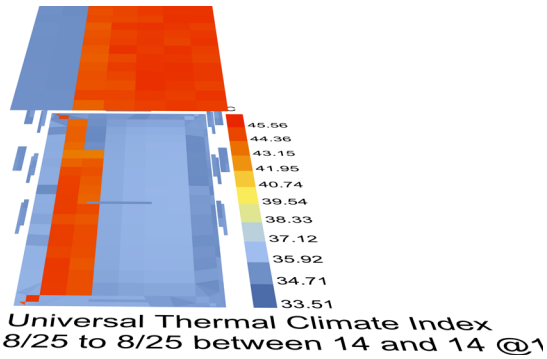




25th of August 14:00 Universal thermal comfort indoor with no actions

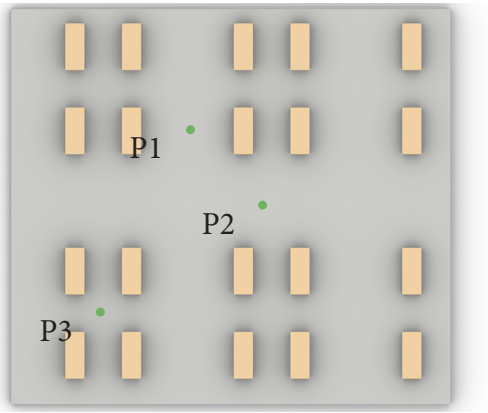


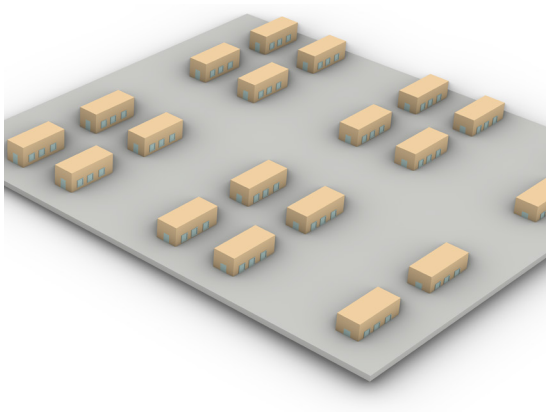
25th of August 14:00 Universal thermal comfort with cool materials:



OUTPUT ISOLATED

Greening:





Input data setting:

- DF Building from solid:
  - Floor to floor: 1 floors with 3m height
  - program: Midrise Appartment
  - Conditioned: false
- DF Apply facade parameter:
  - ratio wind parameter: 0.34
- DF Assign Building UWG Properties:
  - program: Midrise Appartment
  - vintage: Pre 1980 (CBECS)
  - wall albedo: 0.2
  - roof albedo: 0.2
  - roof vegetation: 0
- terrain:
  - albedo: 0.1
  - thickness: 0.5 m
- DF assign Model UWG properties:
  - traffic: typical mixed use part of Toulouse, France
  - tree cover: 0.8
  - grass cover: 0.9
- DF vegetation parameters:
  - albedo: 0.25
  - tree latent: 0.7
  - grass latent: 0.5

EFFECTIVENESS OUTDOOR

Air temperature · UTCI · UR% · mrt

EFFECTIVENESS INDOOR

Air temperature · UTCI · UR% · mrt

25th of August h 14:00 dry bulb temperature outdoor

T_0= 36.10 °C T_g= 34.70 °C Δ °C=1.40

25th of August h 14:00 Universal Thermal Comfort outdoor

T_0= 42.78 T_g= 41.42 Δ =1.36

25th of August h 14:00 dry bulb temperature indoor

T_0= 34.36 °C T_g= 34.08 °C Δ°C=0.28

25th of August h 14:00 mean radiant temperature indoor

T_0= 32.79 °C T_g= 32.78 °C Δ °C= 0.01

Responsiveness:

Life period:

Period of installation:

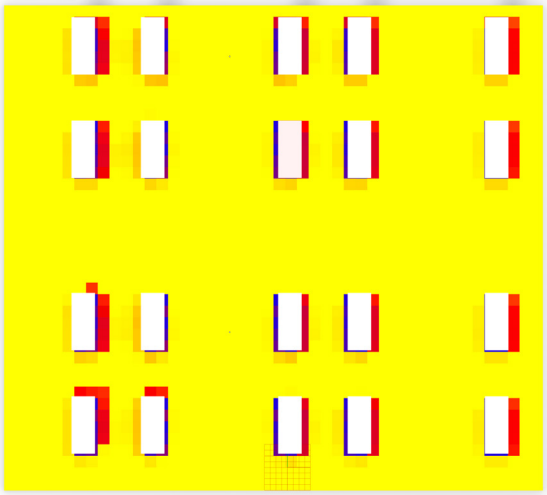
Maintenance:

! ! !

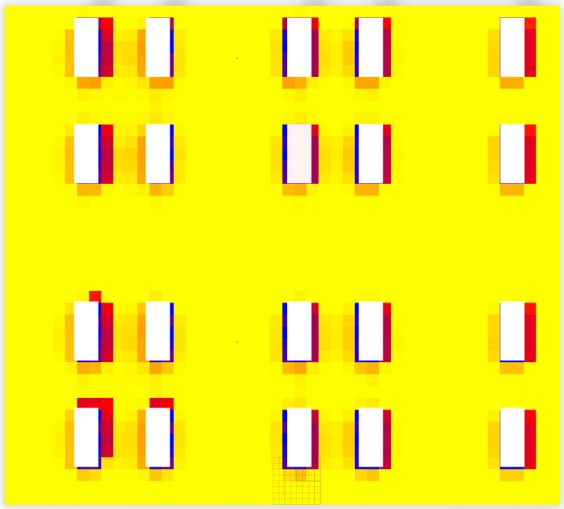
Life span:

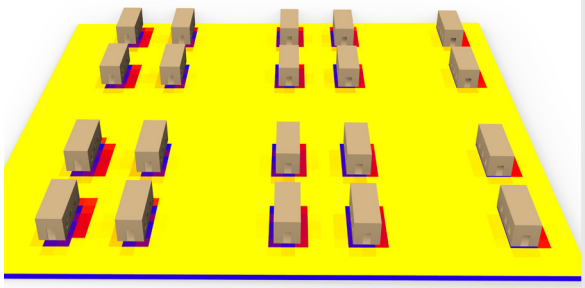
Return environmental period:

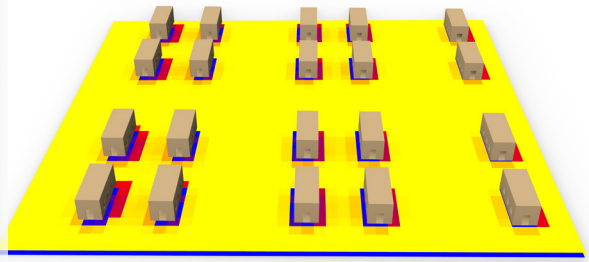
25th of August 14:00 Universal thermal comfort outdoor with no actions



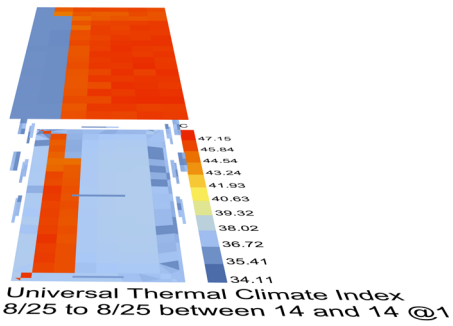
25th of August 14:00 Universal thermal comfort outdoor with greening:



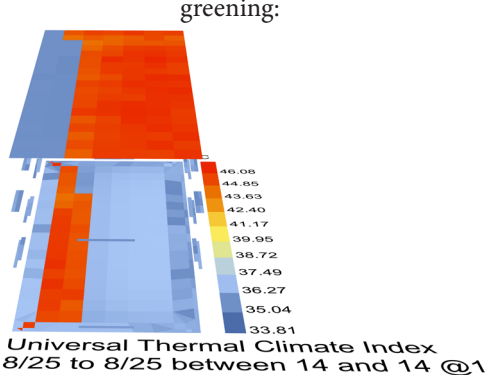




25th of August 14:00 Universal thermal comfort indoor with no actions

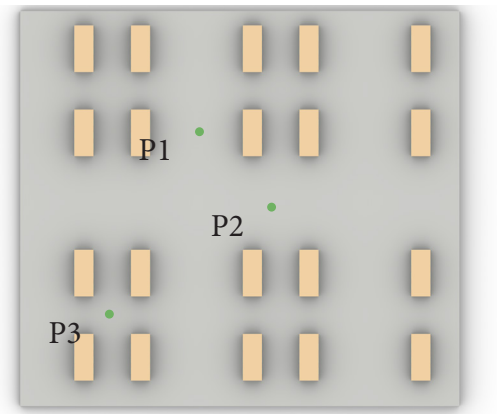


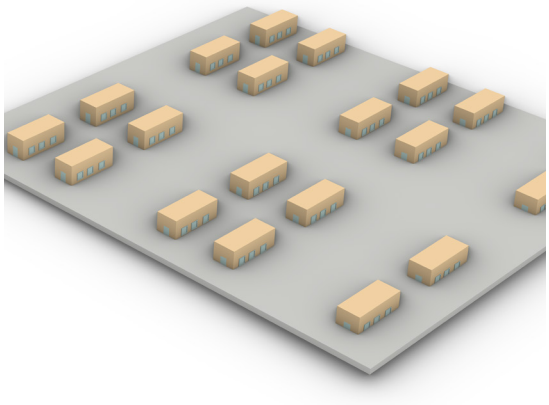
25th of August 14:00 Universal thermal comfort with greening:



OUTPUT ISOLATED

Green roofs:





Input data setting:

- DF Building from solid:
  - Floor to floor: 5 floors with 3m height
  - program: Midrise Appartment
  - Conditioned: false
- DF Apply facade parameter:
  - ratio wind parameter: 0.34
- DF Assign Building UWG Properties:
  - program: Midrise Appartment
  - vintage: Pre 1980 (CBECS)
  - wall albedo: 0.2
  - roof albedo: 0.2
  - roof vegetation: 1
- terrain:
  - albedo: 0.1
  - thickness: 0.5 m
- DF assign Model UWG properties:
  - traffic: typical mixed use part of Toulouse, France
  - tree cover: 0
  - grass cover: 0
- DF vegetation parameters:
  - albedo: 0.25
  - tree latent: 0.7
  - grass latent: 0.5

EFFECTIVENESS OUTDOOR

Air temperature · UTCI · UR% · mrt

EFFECTIVENESS INDOOR

Air temperature · UTCI · UR% · mrt

25th of August h 14:00 dry bulb temperature outdoor

T_o= 36.10 °C T_{gr}= 34.90 °C Δ °C=1.20

25th of August h 14:00 Universal Thermal Comfort outdoor

T_o= 42.78 T_{gr}= 41.58 Δ =1.20

25th of August h 14:00 dry bulb temperature indoor

T_o= 34.36 °C T_{gr}= 33.44 °C Δ°C=0.91

25th of August h 14:00 mean radiant temperature indoor

T_o= 32.79 °C T_{gr}= 31.98 °C Δ °C=0.80

Responsiveness:

Life period:

Period of installation:

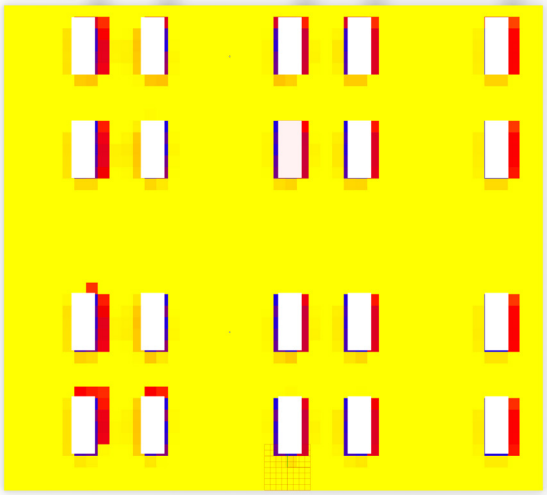
Maintenance:

! ! !

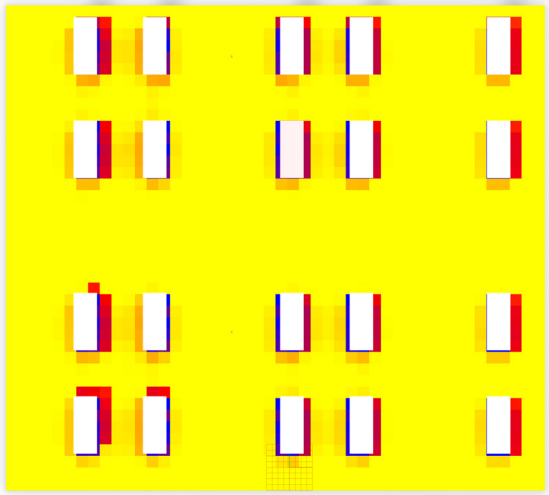
Life span:

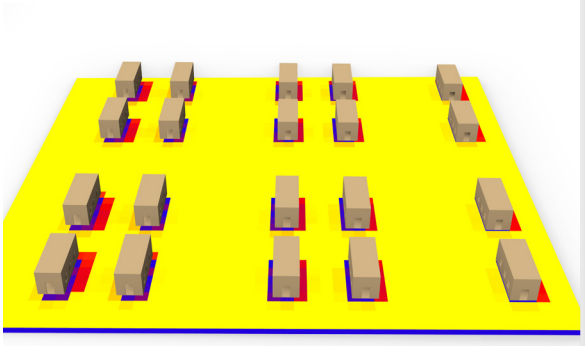
Return environmental period:

25th of August 14:00 Universal thermal comfort outdoor with no actions

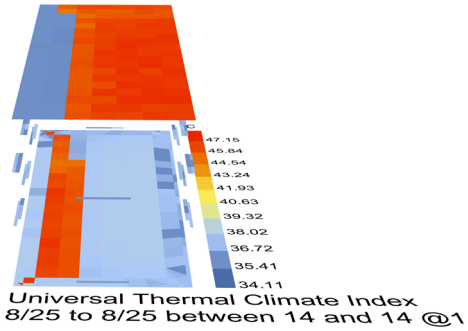


25th of August 14:00 Universal thermal comfort outdoor with green roofs:

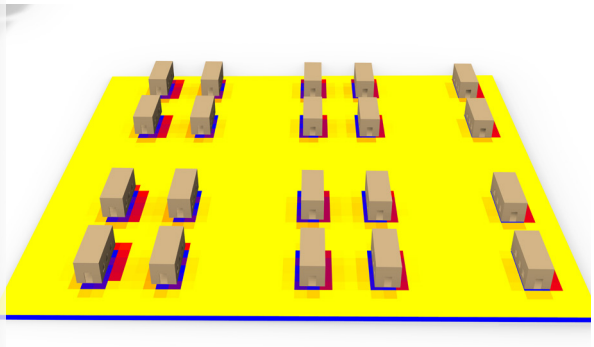


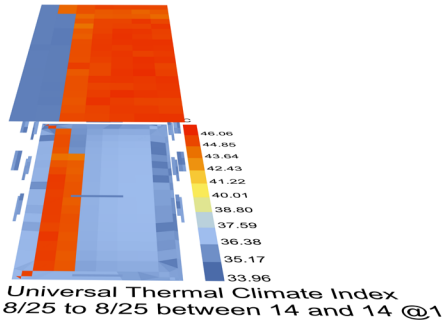


25th of August 14:00 Universal thermal comfort indoor with no actions



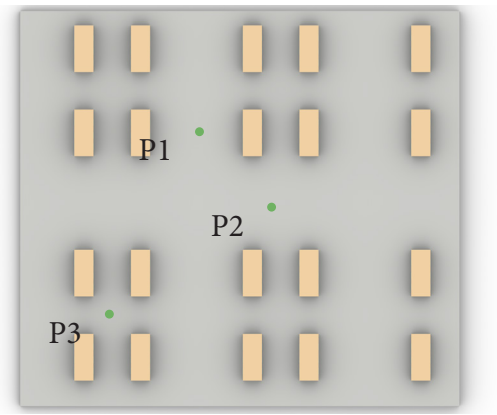
25th of August 14:00 Universal thermal comfort with green roofs:

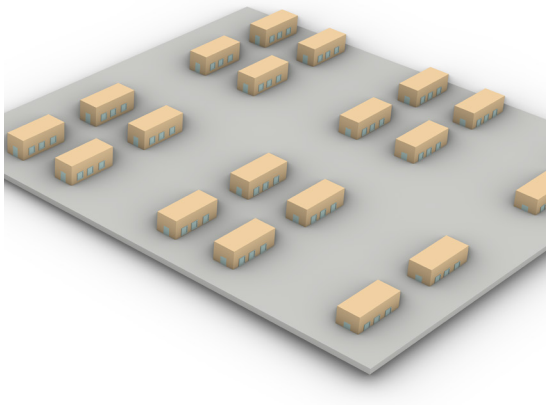




OUTPUT ISOLATED

Green walls:





Data:

- DF Building from solid:
  - Floor to floor: 5 floors with 3m height
  - program: Midrise Appartment
  - Conditioned: false
- DF Apply facade parameter:
  - ratio wind parameter: 0.34
- DF Assign Building UWG Properties:
  - program: Midrise Appartment
  - vintage: Pre 1980 (CBECS)
  - wall albedo: 0.2
  - roof albedo: 0.2
  - roof vegetation: 1
- terrain:
  - albedo: 0.1
  - thickness: 0.5 m
- DF assign Model UWG properties:
  - traffic: typical mixed use part of Toulouse, France
  - tree cover: 0
  - grass cover: 0
- DF vegetation parameters:
  - albedo: 0.25
  - tree latent: 0.7
  - grass latent: 0.5

EFFECTIVENESS OUTDOOR

Air temperature	UTCI	UR%	mrt
●	●	●●	●

EFFECTIVENESS INDOOR

Air temperature	UTCI	UR%	mrt
●●	●	●●●	●●

25th of August h 14:00 dry bulb temperature outdoor

T_o= 36.10 °C T_{gw}= 34.90 °C Δ °C=1.20

25th of August h 14:00 Universal Thermal Comfort outdoor

T_o= 42.78 T_{gw}= 41.58 Δ =1.20

25th of August h 14:00 dry bulb temperature indoor

T_o= 34.36 °C T_{gw}= 33.48 °C Δ°C=0.87

25th of August h 14:00 mean radiant temperature indoor

T_o= 32.79 °C T_{gw}= 31.65 °C Δ °C=1.14

Responsiveness:

Life period:

Period of installation:



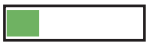
Maintenance:

! ! !

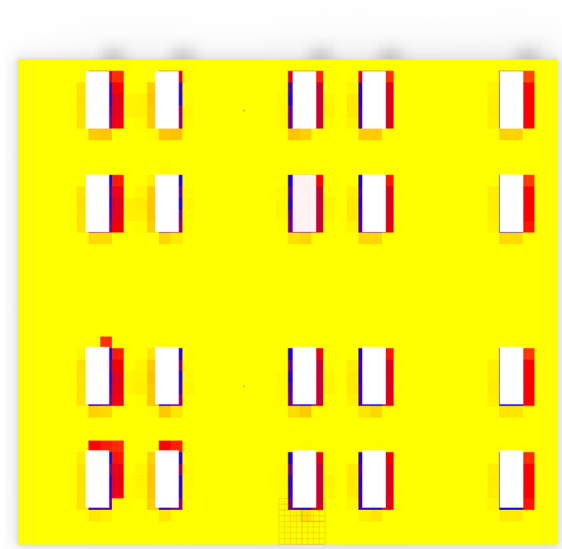
Life span:



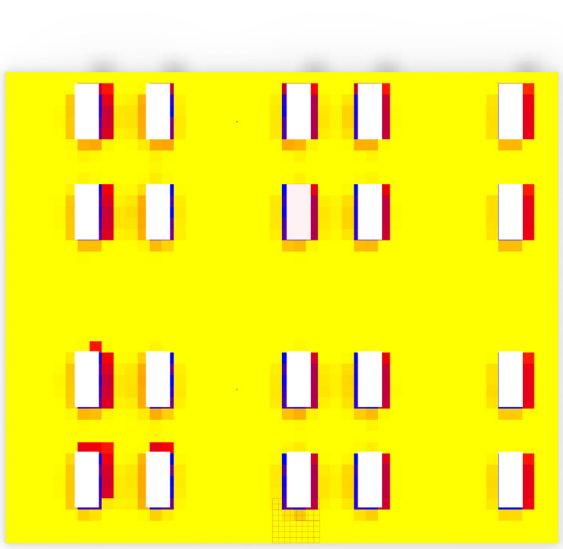
Return environmental period:

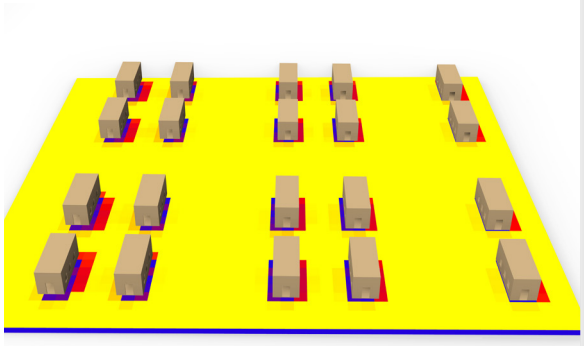


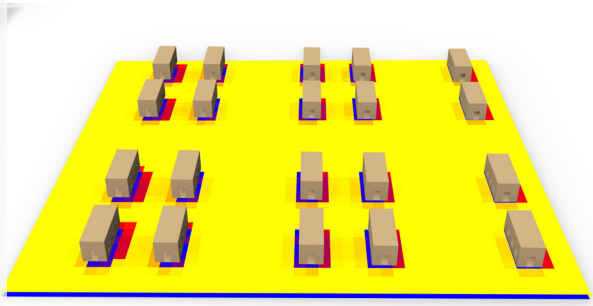
25th of August 14:00 Universal thermal comfort outdoor with no actions



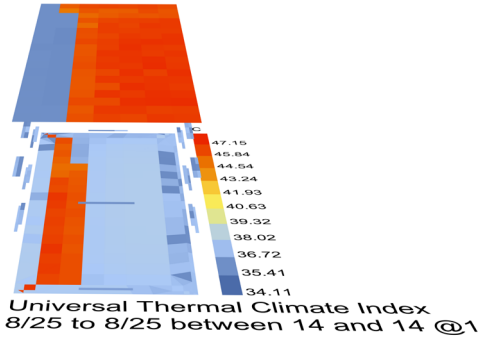
25th of August 14:00 Universal thermal comfort outdoor with green walls:



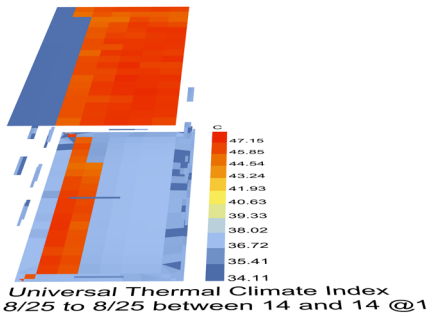




25th of August 14:00 Universal thermal comfort indoor with no actions



25th of August 14:00 Universal thermal comfort with green walls:



Tab. VI a, b, c, d. The tables show the effectiveness levels derived from the simulations carried out using the UWG generator tool and averaged over three different points for each simulation (see section 2.4.1). The results of the simulations can be consulted by scanning the QR code below. Author's elaboration.

Outlines and conclusions.

The UWG generator results align with the literature review regarding technological solutions in section 2.3.2.
In particular, the table explicitly compares the results from the effectiveness perspective. This summary of the results is based on the analysis of the simulations obtained, which can be consulted by scanning the QR code in the caption (TAB VI a, b, c, d).

Tab. VIa

	Block							
	Out				In			
	T(°C)	UR%	UTCI	mrt (°C)	T	UR%	mrt (°C)	UTCI
Cool materials	●	●	●	●●	●●	●●●	●●	●●●
	Δ=-0.5	Δ=+2	Δ=-0.63		Δ=-3.42	Δ=+8.69	Δ=-4.47	
Greening	●	●●	●	●	●●	●●●	●●●	●●
	Δ=-1.40	Δ=+5	Δ=-1.49		Δ=-3.30	Δ=+8.58	Δ=-4.31	
Green roofs	●	●●	●	●	●	●●	●	●
	Δ=-1.20	Δ=+4	Δ=-1.32		Δ=-3.30	Δ=+8.58	Δ=-4.31	
Green walls	●	●●	●	●	●●	●●●	●●	●●●
	Δ=-1.20	Δ=+4	Δ=-1.32		Δ=-5.42	Δ=+10.67	Δ=-7.80	

Tab. VIb

	Court							
	Out				In			
	T(°C)	UR%	UTCI	mrt (°C)	T	UR%	mrt (°C)	UTCI
Cool materials	●	●●	●	●●	●	●	●	●
	Δ=-1.6	Δ=+5	Δ=-0.56		Δ=-1.07	Δ=+1.96	Δ=-0.24	
Greening	●	●●	●●	●●	●	●	●	●
	Δ=-1.4	Δ=+5	Δ=-1.81		Δ=-1.36	Δ=+1.56	Δ=-0.12	
Green roofs	●	●	●●	●	●	●	●	●
	Δ=-0.4	Δ=+1	Δ=-1.77		Δ=-1.69	Δ=+1.09	Δ=-0.25	
Green walls	●	●●	●	●●	●●	●●●	●●	●●
	Δ=-0.4	Δ=+4	Δ=-0.43		Δ=-15.23	Δ=+9.81	Δ=-5.49	

Tab. VIc

	Line							
	Out				In			
	T(°C)	UR%	UTCI	mrt (°C)	T	UR%	mrt (°C)	UTCI
Cool materials	●	●●	●	●●	●	●	●	●
	Δ=-1.3	Δ=+4	Δ=-1.43		Δ=-0.49	Δ=+1.45	Δ=-0.49	
Greening	●	●	●	●●	●	●	●	●
	Δ=-1.3	Δ=+1	Δ=-1.43		Δ=-0.46	Δ=+1.42	Δ=-0.44	
Green roofs	●	●●	●	●	●●	●	●	●
	Δ=-1.2	Δ=+4	Δ=-1.31		Δ=-3.26	Δ=+1.16	Δ=-0.38	
Green walls	●	●●	●	●	●	●	●	●
	Δ=-1.2	Δ=+4	Δ=-1.31		Δ=-0.53	Δ=+1.17	Δ=-0.04	

Tab. VId

	Isolated							
	Out				In			
	T(°C)	UR%	UTCI	mrt (°C)	T	UR%	mrt (°C)	UTCI
Cool materials	●	●●	●	●	●	●	●	●
	Δ=-1.8	Δ=+5	Δ=-1.80		Δ=-0.74	Δ=+1.86	Δ=-0.27	
Greening	●	●●	●	●	●	●	●	●
	Δ=-1.5	Δ=+5	Δ=-1.45		Δ=-0.28	Δ=+1.33	Δ=-0.06	
Green roofs	●	●●	●	●	●	●●	●	●
	Δ=-1.20	Δ=+4	Δ=-1.20		Δ=-1.84	Δ=+4.84	Δ=-2.76	
Green walls	●	●●	●	●	●●	●●●	●●	●
	Δ=-1.20	Δ=+4	Δ=-1.20		Δ=-2.72	Δ=+14.98	Δ=-3.79	

The results are as follows:

- In **block morphology,** the effectiveness of the technological solutions studied varies, provided the values are not too far apart, as the actions considered differ. In the outdoor configuration, there is a decrease in air temperature, ranging from 0.50 °C to 1.47 °C, achieved through the use of cool materials. The relative humidity registers a general increase following the addition of the technological solutions. In particular, the increase varies between +1% for cool materials and +5% compared to the initial values, due to the increase in urban greenery. Comfort levels increase, registering differences ranging from -0.63 (cool materials) to -1.49 (urban green spaces) compared to initial values, thus increasing the comfort level. Green façades and green roofs are intermediate when all the KPIs considered vary. At the indoor level, more significant variations occur. The indoor air temperature decreases by -0.61 °C with the application of vegetated walls and by -5.42 °C with the application of vegetated roofs. Relative humidity increases with values between +5.14% and +10.67%. The average indoor radiant temperature undergoes significant decreases ranging from -2.47 °C through green walls to -7.80 °C with vegetated roofs. In general, it can be stated that at the outdoor level, the difference between the values of the pre- and post-KPIs varies homogeneously for all simulated actions, including cool materials, urban green walls, and green roofs. At the indoor level, there are more significant variations.
- The **courtyard** shows temperature reductions of similar magnitude, regardless of the technology used. In particular, at the outdoor level, the temperature reduction varies between -0.40 °C, achieved through green roofs and green walls, and -1.06 °C, with cool materials, compared to the initial values. The relative humidity presents a general increase, ranging from +1% with green walls to +5% with cool materials and the increase of urban green. The UTCI index following the simulations with the above-mentioned technological solutions decreases from -1.28 °C (with green roofs) to 5.44 °C (with the addition of urban green). The air temperature generally decreases indoors after adding cool materials, urban greenery, and vegetated walls and roofs. In particular, the air temperature decreases between -1.13 °C (with vegetated walls) and 3.69 °C (with vegetated roofs). Relative humidity values

increase from a minimum of +1.09% with vegetated walls to a maximum of +9.81% with vegetated covers. Generally, it can be stated that the differences in values assumed by the various KPIs vary at the indoor level, with orders of magnitude similar for cool materials, greening, and green walls, while achieving significant levels of effectiveness with green roofs. At the outdoor level, the different simulated solutions provide heterogeneous variations. This heterogeneity is understandable, considering that the different solutions behave very differently from one another and that morphological density, being more significant than other configurations, significantly affects the technologies in various ways (for example, through shading).

- In the outdoor environment, the **line model** predicts a decrease in air temperature of approximately 1°C, accompanied by increases in relative humidity of around 1% and decreases in UTCI values that slightly exceed the initial values by 1. At the indoor level, the air temperature varies evenly, except for the vegetated walls, which cause higher decreases than the other simulated technologies. The remaining KPIs show uniform variations as the technologies change. In particular, at the outdoor level, the decrease in air temperature varies from a minimum of -1.20 °C - through the use of vegetated façades, the relative humidity increase varies from a minimum of 1% with green to a maximum of 4% with the addition of cool materials, green roofs and green walls. The UTCI index decreases from a minimum of -1.31, with vegetated roofs and façades, to a maximum of -1.43 by adding increased urban greenery and cool materials. At the indoor level, air temperature decreases from a minimum of -0.46 °C through the increase of urban greenery to a maximum of -3.26 °C by installing green facades. Relative humidity increases from a minimum of -1.16% (green walls) to a maximum of -1.45% (cool materials). Finally, the average indoor radiant temperature decreases from a minimum of -0.38 °C to a maximum of -0.49 °C by installing green roofs and increasing cool materials.
- In the **isolated building configuration**, there is a certain homogeneity in the technologies' outdoor and indoor responses. Only the vegetated walls exhibit significant variations in KPIs between indoor and outdoor environments. In particular, at the outdoor level, the decrease in air temperature varies from

a minimum of -1.20 °C, with green walls and roofs, to a maximum of -1.80 °C, using cool materials. Relative humidity increases from a minimum of +4% with vegetated roofs and walls to a maximum of +5% with the increase in urban real estate and cool surfaces. On the contrary, the UTCI index decreases from a minimum of -1.20 °C, with vegetated roofs and walls, to a maximum of -1.80 °C with the increase of cool surfaces. Indoor air temperature decreases from a minimum of -0.28 °C with the increase of greenery to a maximum of -2.72 °C with the inclusion of vegetated roofs. Relative humidity undergoes an increase that varies from a minimum of +1.33% with the addition of urban greenery to a maximum of +14.94% with the installation of green covers. Finally, the mean radiant temperature decreases from a minimum of - 0.06 °C through urban green spaces and - 3.79 °C through the insertion of vegetated covers.

Analysing the single technologies, however, it emerges:

- The effectiveness of **cool materials** at the outdoor level varies while maintaining the same orders of magnitude: for air temperature, decreases range from -0.50 °C (block morphology) to -1.80 °C (isolated buildings). Relative humidity levels increase between +2% and +5% for isolated and courtyard buildings. The UTCI index decreases from -0.56 for a morphology consisting of courtyard buildings to -1.80 for isolated buildings. In general, at the outdoor level, it can be stated that isolated buildings present the highest levels of effectiveness. There is a higher effectiveness on block morphology at the indoor level than on the other types. In particular, air temperature decreases between -0.49 °C and - line morphology and -3.42 °C - block morphology. Relative humidity increases with initial values ranging from +1.86 (isolated buildings) to +8.69 (block buildings). The mean radiant temperature decreases from 0.24 - courtyard morphology - to -4.47 - block morphology. In addition to these effectiveness data, there are concerns regarding response times: cool materials have short installation times and a long lifespan, with instantaneous payback times.
- The effectiveness of solutions such as increasing **urban greenery** outdoors varies as morphological configurations change. In particular, air temperature decreases from -1.30 °C - for morphologies with in-line buildings - to 1.50 °C for insulated buildings. Relative humidity levels increase from a minimum

of +1% for in-line buildings to a maximum of +5% for all three remaining configurations. The UTCI comfort index decreases from a minimum of -1.43 in in-line buildings to a maximum of -1.81 in courtyard configuration. Generally, at the outdoor level, the morphology with in-line buildings presents a slightly lower effectiveness and minor variations in all KPI values compared to the other configurations considered at the initial levels. It is worth noting that these results do not account for the fluid-dynamic flows that occur within the various morphological configurations. From the indoor perspective, the air temperature decreases from -0.28 °C for the isolated building configuration to -3.30 °C for the block configuration. The increase in relative humidity varies, ranging from a minimum of +1.33% in isolated buildings to +8.58% in block buildings. Finally, the average indoor radiant temperature decreases from a minimum of -0.06 in the isolated buildings to a maximum of -4.31 in the block buildings. At the indoor level, therefore, the increase of urban green presents the highest levels of effectiveness in the presence of morphologies consisting of block buildings. Regarding response times, it is worth noting that outdoor urban green augmentation has longer installation times and periodic maintenance requirements, but offers a more extended lifespan and instantaneous payback.

- The effectiveness of solutions such as **green roofs** exhibits similar variations to morphological conformations, which vary indoors and outdoors. However, there is a greater effectiveness indoors than outdoors in all the morphological types considered. In particular, at the outdoor level, the temperature decreases, with values ranging from -0.40 °C, recorded in courtyard buildings, to -1.20 °C for all other morphological types. Relative humidity varies from a minimum of +1% in courtyard buildings to a maximum of +4% in all other morphological solutions. The UTCI index decreases from a minimum of -1.20 for isolated buildings to a maximum of 1.77 for courtyard buildings. The indoor air temperature decreases from a minimum of -1.69 °C in the courtyard buildings to a maximum of -3.26 °C in the in-line buildings. Indoor relative humidity increases from a minimum of 1.09% in courtyard buildings to a maximum of 5.14% in block buildings. Finally, the values of the mean radiant temperature of the indoor surfaces decrease, ranging from a minimum of 0.25 °C in the

courtyard buildings to a maximum of -2.76 °C in the morphological block type. Generally speaking, the effectiveness of green roofs in the indoor morphological block type is lower than that of other technological solutions. Analysing the response times of this type of action, it appears that green roofs have medium installation times with periodic maintenance and instantaneous payback times.

- Analysing the response of the **green façades** at an outdoor level, it emerges that the behaviour of the KPIs varies similarly as the morphologies vary, i.e. the deltas of variation to the initial values are not too far apart. In particular, the air temperature can decrease from a minimum of - 0.40 °C in the courtyard buildings to a maximum of - 1.20 °C for the other morphological configurations, returning to the initial values. The relative humidity increases by 4% for all four morphological conformations. The UTCI value decreases from a minimum of -0.43 in the courtyard buildings to a maximum of -1.32 in the block buildings. The simulations show that, at the outdoor level, this type of technology has slightly lower effectiveness in courtyard buildings. At the indoor level, the air temperature decreases with values ranging from a minimum of -0.53 °C in the in-line buildings to a maximum of -15.23 °C in the courtyard buildings. At the indoor level, the air temperature decreases with values ranging from a minimum of -0.53 °C in the in-line buildings to a maximum of -15.23 °C in the courtyard morphology. Relative humidity values increase from a minimum of +1.17% in the morphology with in-line buildings to a maximum of +14.98% in the isolated buildings. The mean radiant temperature values decrease from a minimum of -0.25 °C in courtyard buildings to a maximum of -2.76 °C in detached buildings. The simulations show that green façades respond very effectively to the KPIS considered at the indoor level. Like green roofs, green façades have medium installation times, require periodic maintenance, and offer instantaneous payback. However, the applicability of vegetated façades is lower than that of green roofs, as the former must also meet the need for natural light and require different maintenance systems than green roofs, which are more similar to conventional ones.

Some differences emerge when comparing the data from this research with that presented in Section 2.3.1 (European Environment Agency, 2020b). In particular, the document highlights that applying green façades provides an average level of indoor comfort. According to the simulations, the effectiveness levels of indoor comfort are medium to high in three out of four cases. There is another discrepancy in the effectiveness levels of cool materials: according to the RESIN document, this type of solution does not affect the decrease in surface temperatures. On the contrary, the simulations show medium to low decreases in average surface temperature when using cool materials for all morphological solutions considered. However, all other parameters and solutions coincide with the results obtained from the simulations. These discrepancies may be due to differences in the methods used to quantify effectiveness. The project, taken as an example, is based on extensive case studies, rather than simulations, as is the case here. It is, therefore, likely that the efficiency ranges for each case study analysed are different from the ranges of the simulations carried out.
The subsequent development of this part of the thesis involves testing pilot cases to determine whether, with slight variations in climatic conditions, morphology, and building materials, the effectiveness remains the same or varies. Furthermore, it would be interesting to understand how effectiveness varies in a system of technological solutions aimed at mitigating and adapting to islands and heat waves rather than a single solution.

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3.1| Development of a support tool
p. 499

PART 4

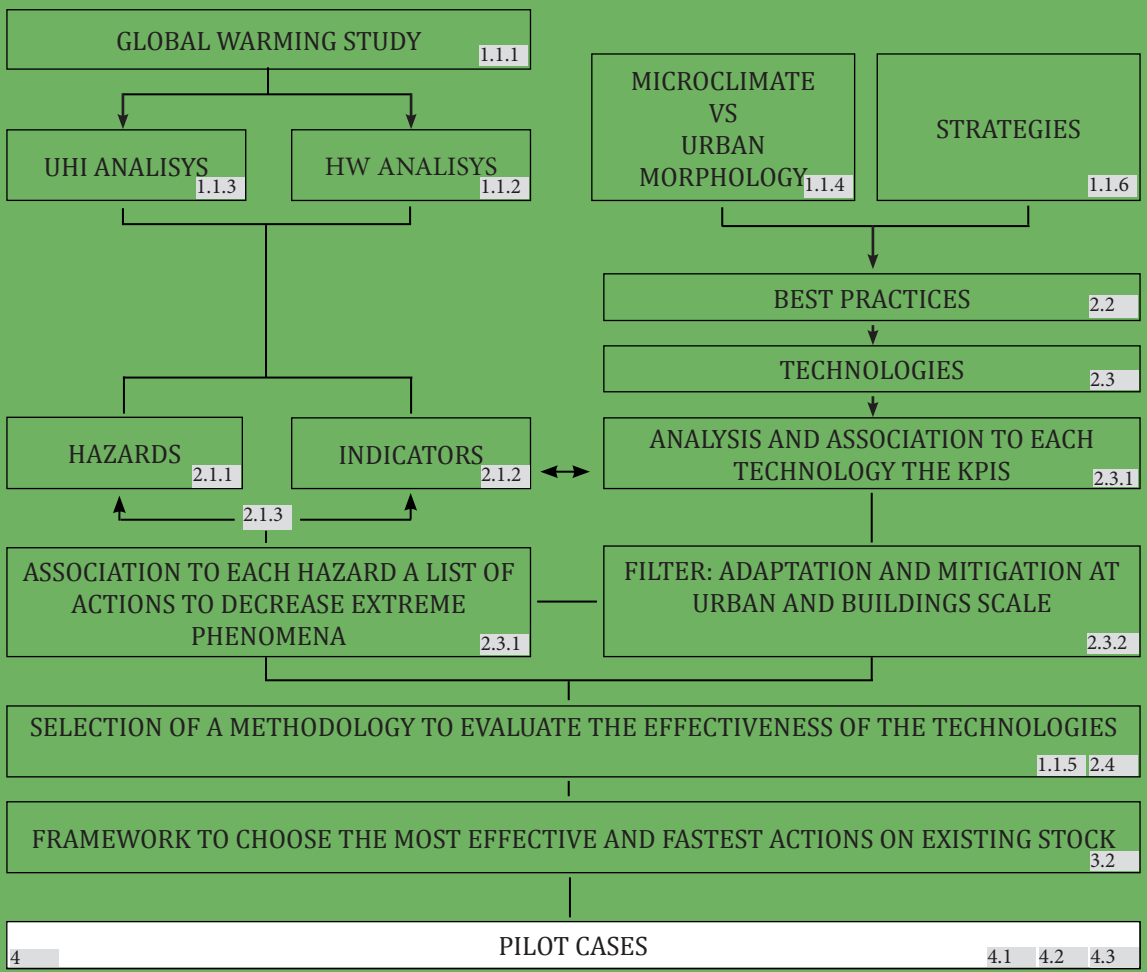
Verification of pilot cases

4 | VERIFICATION OF PILOT CASES

CHAPTER 4

ABSTRACT
So far, the research developments are theoretical, which consist of identifying the most effective and efficient technological solutions for mitigation and adaptation to heat islands and heat waves and an algorithm to aid evaluation. Through the application of these solutions to pilot cases, indoor and outdoor solutions are developed according to the area's identity and climatic and morphological conditions. With the help of the effectiveness evaluation algorithm illustrated above, the effectiveness and efficiency of the solutions in each application context are evaluated. Although not all of the technological solutions outlined in 2.3.2 can be simulated - in these cases, an evaluation is carried out based on the state of the art - it is possible to verify research developments by applying them to different realities with similar climatic conditions.
This methodology proves accurate and valid, adaptable to a wide range of contexts, and able to provide answers quickly, to mitigate the impacts of heat islands and heat waves.
The master plans represent the final output. They are formulated using the tools developed in the thesis according to the area's particular morphological, cultural, and architectural conditions.

KEYPLAN



Outcomes of this chapter:

- **Verification** on pilot cases

Introduction.

The research developments outlined so far are theoretical in nature. An application phase allows the tools and methods developed to be tested. Although the case studies, located in very different geographical contexts, are all in the same climate zone (the warm temperate zone) and face similar problems related to rising temperatures and extreme phenomena associated with climate change in those areas, in particular, the accentuation of the urban heat island phenomenon and the increase in the frequency of heat waves. Furthermore, they represent examples of established neighbourhoods built in the early 1900s, located in critical and hot contexts, and subject to social and physical degradation, while simultaneously preserving their strong historical and cultural background. This aspect is important for subsequent research developments, as further analysis will help us understand which strategies and intervention systems for redevelopment and regeneration are most appropriate for different contexts, primarily cultural ones. It is also interesting to note that the three areas have three different types of relationships between building heights and street widths. In this way, it is possible to compare the performance response to varying morphological-typological and technological-constructive characteristics, in the face of external conditions which, although varying in terms of geographical-cultural aspects, present strong similarities from a climatic point of view and in terms of the categories of climatic-environmental issues associated with them.

An integrated approach, using green, nature-based, grey and blue bioclimatic and energy strategies, is essential for increasing comfort levels and mitigating and adapting existing buildings to urban heat islands and heat waves (Radogna, 2015; Lolasso, et al., 2020).

In particular, the building envelope plays a fundamental role as, by relating directly to external boundary conditions, it increases the availability of natural light: it controls solar loads, uses low-impact materials, controls ventilation, thermally insulates, and improves thermo-hygrometric comfort (Gallo & Romano, 2017; Tucci, 2018). Ventilation influences comfort and environmental conditions: proper control allows for a decrease in energy demand both at the building level and at the urban compartment level (Grosso, 2008). Double-glazed windows with a thermal barrier improve insulation. The strategic arrangement of openings allows good natural ventilation, lowering cooling energy demand by up to half. The need for resilient infrastructure and ecosystems to protect

the existing and diminish the effects of climate change can lead to adopting green infrastructure (Bocanegra et al., 2024). From the bioclimatic point of view, green functions as a screen for solar protection for buildings during the summer season and allows the penetration of the sun's rays during the winter season; it also prevents soil sealing. The presence of vegetation on walking surfaces, roofs and façades increases the insulation and permeability of soils, reducing phenomena such as heat islands, increasing biodiversity and contributing to the mitigation of local thermal effects (European Environmental Agency, 2020). These include 'filter ecosystems', such as wetlands and bioswales, which also contribute to developing site-specific biodiversity. Then there is préverdissement (Guinaudeau, 1987), i.e. a technique that puts the realisation of environmental interventions before that of the works to improve the effectiveness of their insertion in the environment and reduce the pressures due to the construction and operation phases. This is complemented by urban agriculture, which combines processes of cultivation, processing and sale of agricultural products within the city (Gallo et al., 2016). This characteristic allows for green areas that quickly perform ecological functions (Malcevschi & Bisogni, 2016).

The methodology adopted for scientific verification is based on *research through design*, which involves using design as a research tool. The project is seen as 'an integrated set of elements that define the quality of what is to be achieved', used as a real decision-making tool (Ferrante & Gallo, 2024). This approach has already been validated nationally and internationally to identify scenarios for regenerating and redeveloping existing urban heritage building contexts.

In this way, it is possible to derive results, such as quantitative results for each pilot case, to understand the different behaviours of the selected actions. This is important to have a greater control over the project's effects on the existing built stock and consequently to have a more significant influence on decreasing the causes and effects of rising temperatures.

Below is the method used for the design of each pilot case. Next is a small introduction for each district and the results and analysis for each area. Finally, there is a general conclusion.

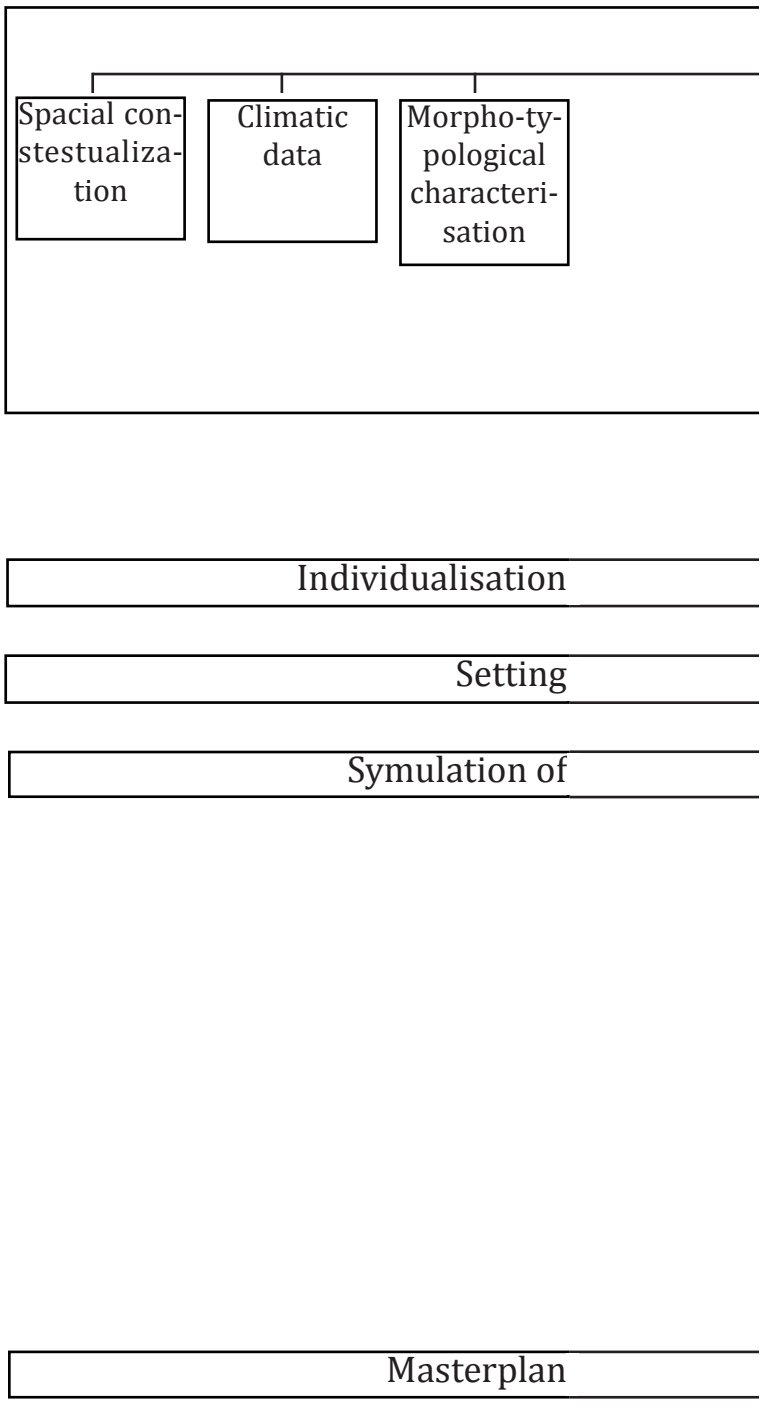
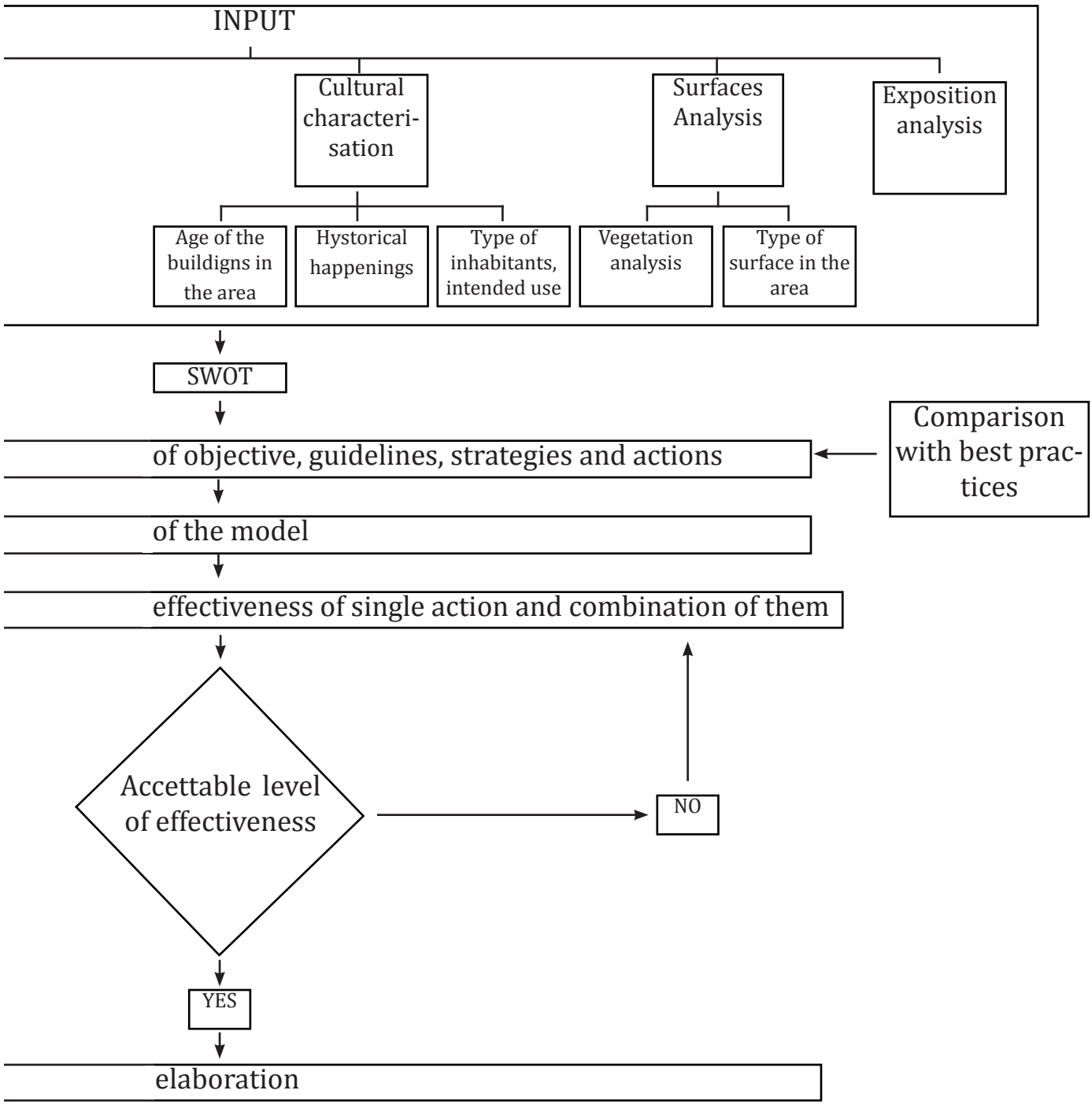


Figure 41. Workflow for the pilot cases. Author's elaboration

Figure 41.


INPUT
Cultural characteri-sation
Surfaces Analysis
Exposition analysis
Age of the buildigns in the area
Hystorical happenings
Type of inhabitants, intended use
Vegetation analysis
Type of surface in the area
SWOT
of objective, guidelines, strategies and actions
Comparison with best prac-tices
of the model
effectiveness of single action and combination of them
Accettable level of effectiveness
NO
YES
elaboration

Methodology.

The research developments are verified by experimental application to pilot cases. Each project is approached as a redevelopment object to improve environmental conditions[36], mitigation, and adaptation to indoor and outdoor comfort levels by islands and heat waves.
The methodology is divided into three phases: analysing the context, selecting the set of potentially usable, highly effective technologies, and elaborating the master plan. In particular, the preliminary study of the areas aimed at formulating each context's strengths, weaknesses and threats leads to formulating objectives, threats and action strategies. By interpolating these results with the hazard matrix developed earlier - Section 2.1.3 -, it is possible to identify the sets of technological solutions that are most suitable. The simulation tool helps assess the effectiveness of the algorithm outlined above. Once the technologies' varying behaviour and systems have been individualised, a master plan is proposed.
The objective is to analyse the influence of different parameters of the built environment on external and internal environmental conditions and human stress: the Quarticciolo neighbourhood in Rome (Italy), the Westside San Antonio neighbourhood in Texas (USA) and the Shuangta Suzhou neighbourhood in China. They are located in very different contexts. However, a comparison is interesting because the three areas have important comparable characteristics:

- They are located in the same climate zone (temperate warm)
- They face problems related to rising temperatures, particularly the intensification of heat islands, which exacerbate climatic conditions during the hottest periods of the year, and the increase in the frequency of heatwaves.
- They are important examples of established local architecture, with a strong historical and cultural background.
- All three date back to the early 1900s and represent critical and hot contexts, areas affected by physical and social degradation.

Furthermore, the three different ratios between height and width of roads and buildings in the three areas allow a comparison of the results obtained, as the morphology and construction characteristics vary, while maintaining the aforementioned similarities.
The effectiveness of the strategies and systems used is assessed

36. Meteoblue.co.uk: This site contains the world histories of precipitation, wind speed, and temperature. It is useful to check for trends and hypothesise solutions that match the specific reality.

using the UWG generator. This software, as highlighted in sections 1.0.4, 2.4.1 and 3.1, has been validated and verified in different contexts in terms of climate zones and building types (Elrefai & Nikolopoulou, 2023; Elwy et al., 2018; Evola et al., 2020; Lopez-Cabeza et al., 2022; Bueno, Norford, Hidalgo, & Pigeon, 2013; Bueno, Roth, Norford, & Li, 2014; Rotach, et al., 2005; Street, Reinhart, Norford, & Ochsendorf, 2013; Masson, et al., 2008; Salvati, 2016). The results obtained in the research highlighted a close correspondence between the findings from on-site surveys and those from simulations carried out using the UWG generator.

1. The first step includes a spatial analysis: the standard features of the three spatial analyses consist of identifying space, climatic characteristics, morpho-constructive, and cultural characteristics in surface analysis. In particular, the analysis of historical and cultural character acts to understand the internal dynamics of the neighbourhood of the type of inhabitants and frequenters and, in general, the characterisation of the area according to the period of construction and major events. Service and morpho-typological analysis delves into the character of individual areas. In particular, these analyses include studying building types at the indoor, outdoor and urban subdivision levels. The analysis of surfaces is helpful for quantifying runoff. Even more in-depth analyses of vegetation aim to define the types of plant species present in the area, those that are native and those that are allochthonous. Land use studies vary the parameters that cause changes in the KPIs (see par 2.1.3). The tools used in this phase consist of the Google Heart platform, graphical rendering through QGIS, Climate Consultant and direct in situ and indirect surveys and inspections.
2. The second step aims to identify potential technological solutions applicable to different contexts. The development of a SWOT analysis allows the identification of objectives, guidelines, strategies and actions for each case considered. This part of the project also includes comparing some best practices with similar characteristics and dangers to the pilot case under consideration. In this phase, ways of resolving the hazards are highlighted. Threats and hazards are interpolated with the matrix developed in Section 2.1.3. In this way, it is possible to identify the technological solutions needed to mitigate the effects of heat waves and heat islands simultaneously. The fi-

nal part of this phase consists of setting up the model to carry out simulations to assess the effectiveness of technologies and technological systems. The tools used consist of the previously identified case studies and the analysis of individual technological solutions, which provides a solid literature base and the hazard matrix.

3. The third step consists of evaluating the effectiveness of the individual technological solutions identified for each pilot case through the algorithm outlined above (see section 3.1). The analysis period, characterised by exceeding a temperature limit of 25 °C, was selected, which in all three cases runs from the beginning of June to the end of August, to examine the most probable periods in which extreme thermal phenomena may occur. A simulation run releases .csv results for each technological solution at the indoor and outdoor levels. The evaluation parameters are dry bulb temperature indoors and outdoors, relative humidity indoors and outdoors, mean radiant temperature indoors and outdoors, and Universal thermal comfort outdoors. For indoors, the potentially worst position in the building is analysed: usually the one coinciding with the top floor, near the window frames. Concerning the outdoors, the evaluation is articulated by averaging three points within the urban compartment. In this way, it is possible to evaluate the effectiveness of different technological solutions, considering the key performance indicators mentioned above and state-of-the-art, the software used for the simulation does not do fluid-dynamic calculations, so it does not take into account the wind movement inside the area. The cool materials are modelled by changing the albedo parameters of the ground, vertical surfaces and roofing. This parameter was always set at 0.9, both for the street and the envelope, thus assuming maximum performance. Green roofs are simulated through the change of the wall package constituting the buildings and the indication of the percentage of green roofs on the total roofs. Green is indicated by inputting the percentage of vegetated areas and trees in the total area. Ventilated facades are simulated through the modification of wall packages. For green façades, there is no specific command to simulate them. Therefore, they are simulated like the ventilated façades, with the last layer of plant material. High levels of plant evapotranspiration are assumed (set at 0.7 for the lawn and 0.9 for the trees). A score point for

each key performance indicator represents the system's effectiveness for each technology, which goes from one to three. One point means that the maximum difference between using a solution or leaving without any environmental technological actions is lower than 1 °C, % in the case of relative humidity, or m/s in the case of the wind. Furthermore, from the data collected by the simulation, some tables were created to understand the behaviour during the day. After that, developing a master plan and indoor solutions for the buildings allowed an unambiguous solution considering the actions applicable to different cases. Several tables are extrapolated from the raw data to assess the change in temperature during the day and the behaviour of the other KPIs. A final summary chart illustrates, for each solution adopted in the master plan, the effectiveness achieved and the efficiency derived from the state-of-the-art study.

4.1| The Westside, (TX) USA

The Westside, located in the city of San Antonio, is a historic neighbourhood characterised by Chicana[37] culture that, despite being in a central area of the city, presents problems of environmental and social degradation. The area is characterised by single-family wooden residential buildings with wooden frames inside and insulating layers. The morphology consists primarily of low, single-storey buildings with an average height of 5 metres, built since the second half of the 19th century. The minimum width of streets varies from a minimum of 7 metres to a maximum of 20 metres, while most streets are around 11 metres wide. Therefore, the ratio of building height to street width varies from 0.25 (in the case of the widest streets in the district connecting it with the rest of the city) to 1 (in the case of small residential streets), although the most common ratio is 0.4. Most buildings have a porch and a small garden in front of the main building. The external envelope consists of wooden uprights joined by transoms, forming frames. The insulation layer is inside the roof; the latter, consisting of wooden beams and joists, is closed by a sheet metal layer.

37. Chicana culture refers to a predominantly Hispanic and Mexican ethnic group. It differs in that it has some influences from other cultures, first and foremost, American culture. Mexican immigrants, first or second generations, are part of this ethnic group. Chicana culture encompasses ways of behaving, art making, stereotypes of beauty, architecture, customs, and traditions that are different from American ones.

Figure 42. San Antonio localization - Autor's elaboration on QGIS

Figure 43. San Antonio area - Autor's elaboration on QGIS

Figure 44. Neighborhood area - Autor's elaboration on QGIS

Figure 45. Autor's elaboration on QGIS

Figure 42.

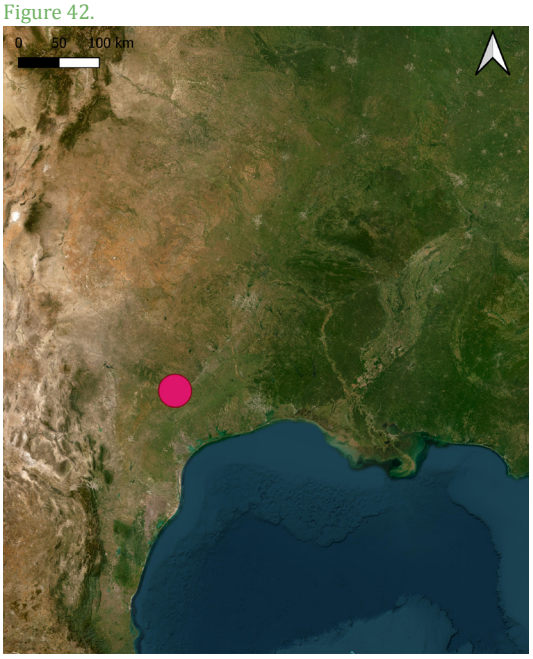


Figure 43.

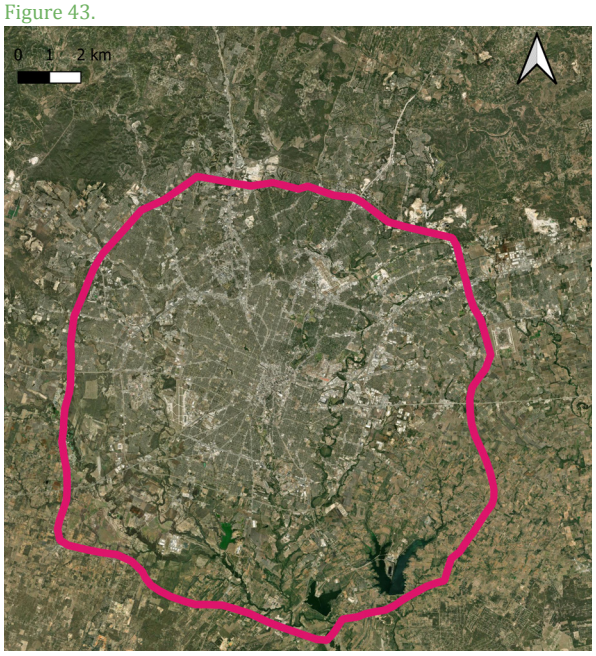


Figure 44.

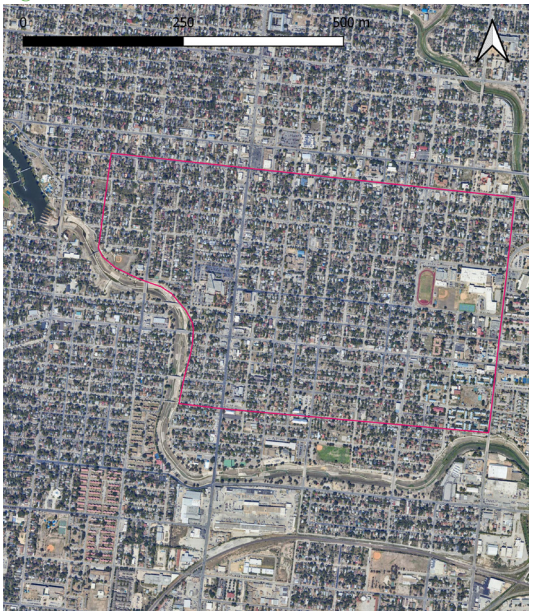


Figure 45.

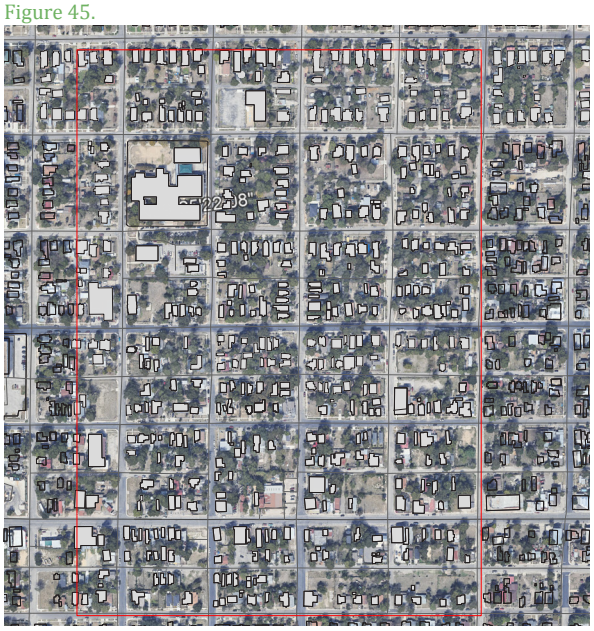


Figure 46.



Figure 47.



Climatic Analysis.

The tables below show that the winds blow mainly from the south, with peak speeds in March, April and May. Rainfall is sporadic, mainly concentrated during mid-season, particularly in May and October. Temperatures in San Antonio remain above 15 °C for most of the year, with relative humidity ranging from 100 % to 9 %.

Figure 48.

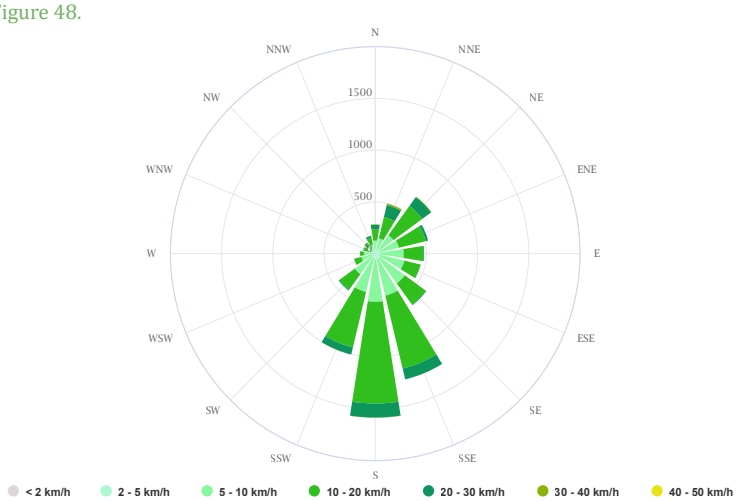


Figure 49.

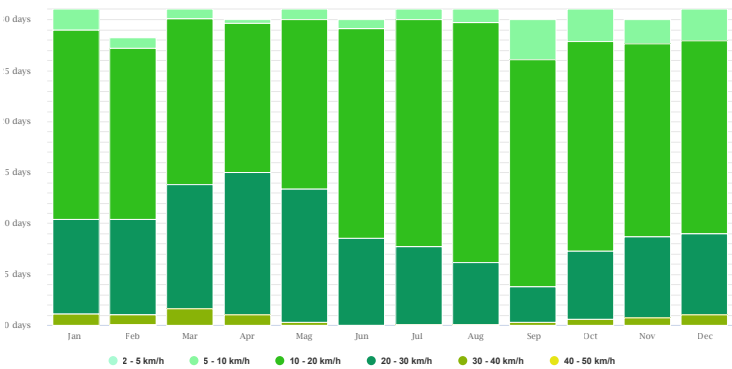


Figure 46. Picture of Westside neighborhood - kept by author

Figure 47. Picture of Westside neighborhood - kept by author

Figure 48. Wind direction - www.meteoblue.it

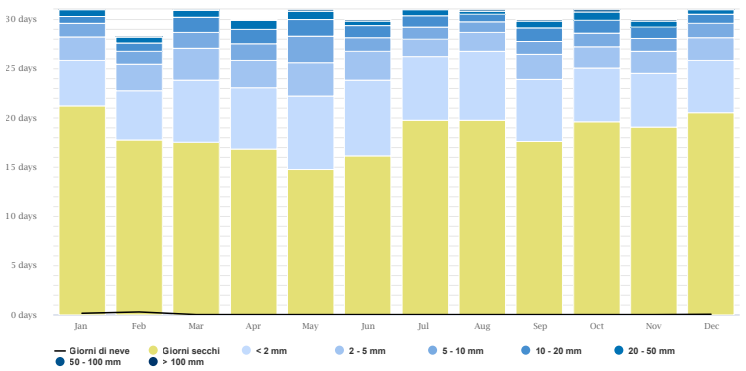
Figure 49. Wind speed - www.meteoblue.it

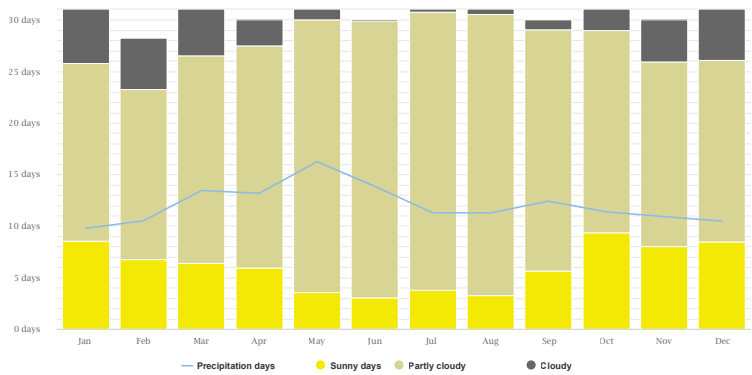
Figure 50. Rainy days - www.meteoblue.it

Figure 51. Sunny days - www.meteoblue.it

Figure 52. Temperatures - www.meteoblue.it

Figure 50.





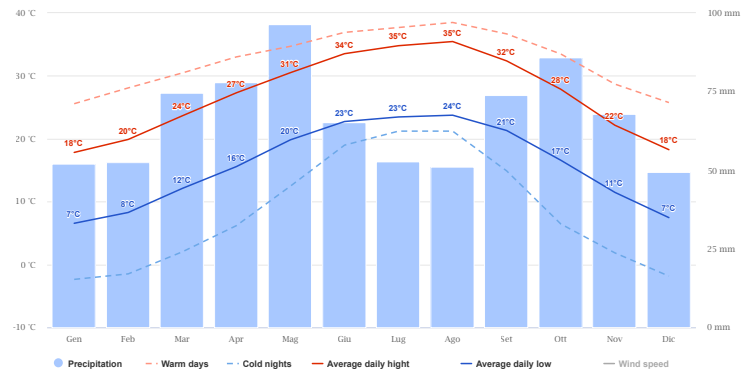


Figure 53. Historical evolution of the neighborhood - Autor's elaboration



Figure 53.

The Westside neighbourhood is located near the Downtown of the city of San Antonio. In the past the name "Westside" meant the West part of San Pedro Creek (San Antonio is crossed by one River -San Antonio river- and several small Creeks). Over the time the neighbourhood's border become less clear: "Westside" began to include all the part not only located in the west of San Pedro Creek, but also the area lived by Hispanic population located between Alazan Creek and Apache Creek.
Despite it is a central neighbourhood, it was always considered ad a "problematic and complex" area. In 1949, the redline maps pointed out the neighbourhood as dangerous for economic investments. From the maps of that period we can deduce that the north San Antonio areas were considered the most "Desirable zones" (so all the banks were encouraged to invest in that zone and not in the Westside).
The mix of factors including the big racial concentration and the fact that the area was considered by the banks an "hazardous area" brought the neighbourhood to become poor and like a "ghetto" for the ethnic minority that lived in the area.
To a lesser extent this happened in others parts of San Antonio such as the East side: also that zone was considered an "hazardous area" were the inhabitants mostly were African American.
From the *Stand born maps* we can understand that the first buildings in the area were built around the 1924 and were concentrated in two principal streets: Guadalupe Street and S. Brazos Street. At the beginning the buildings were spread in small shotgun houses. From the maps of the 1934 we can understand an increase of the houses (in majority small houses). From 1970, instead, we start to see the first residential complexes.

The neighbourhood: cultural aspects.

The culture, the art and the population in the neighbourhood are mixed together creating a mix of Mexican and American culture. The art and the "Chicana" culture (the different stereotypes of beauty, language, traditions, costumes) are recognizable and characterize the neighbourhood both in architecture and in the internal dynamics of the neighbourhood.
The term "Chicano" is used for define people from Mexico, who live in the USA. This term is used also referring to the traditions,

stereotypes of beauty and the art present in the Westside. The term “Chicano”, in the neighbourhood, is often accompanied to the word “Rasquacismo”: this derived from the mexican term “Rasquacio”: to represent the cultural melting and it has a negative meaning. So “Rasquacismo” means a mix of two very different culture apparently unable to overlap and merge. Despite the word etymology, this term, in the Westside, has a positive meaning: it includes indeed the sense of belonging that it is characteristic of the inhabitants of the area. Other morphological characteristics of the area are:

- Regarding the architecture, in addition to the shotgun houses, the buildings assigned to services usually have small windows (this is unusual for European culture used to have big shop windows).
- The plastered walls have beautiful colourful murales.
- Regarding the neighbourhood dynamics: there are a lot of informal landmarks, known by the community as important spaces for “Raquacismo” and “Chicano”’s culture as the anguillar Grocery, the Perla Bakery, the Guadaluper cultural arts center, and la renconcito de Esperanza.



Figure 54.

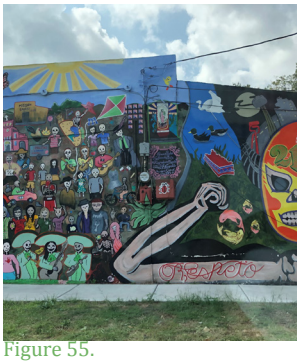


Figure 55.



Figure 56.



Figure 54. The picture represents the neighborhood inhabitants and their will to don’t sell the area to the governemtn in order to don’t change the apperance and the spirit of the neighborhood - https://www.texasobserver.org/public-housing-san-antonio-alazan-apache/

Figure 55. Graffiti in the Westside at San Antonio - Picture taken by the author

Figure 56. Graffiti in the Westside at San Antonio - Picture taken by the author

Figure 57. Guadalupe culture center - Picture taken by the author

Figure 58. Morphological analisys of Westside neighborhood- Author elaboration

Analysis of services and morphotypes.

The area is predominantly residential, characterised by single-family, one-storey wooden dwellings. Along the axes of Buena Vista Street and Guadalupe Street are various services, including food services, cafes, restaurants, elderly care services, supermarkets, hotels, banks, churches, a cultural centre, and shops. On San Louis Street, there are university and school facilities. The library is located to the south of the neighbourhood. The rest of the built-up area is residential and mainly consists of so-called shotgun houses, surrounded by a private, unfenced space belonging to the house. There are also other housing types, such as the residential complexes dating back to 1970, located southeast of the neighbourhood, on the axis of Guadalupe Street. Overall, the area enjoys a low density of built-up areas.

Figure 58.

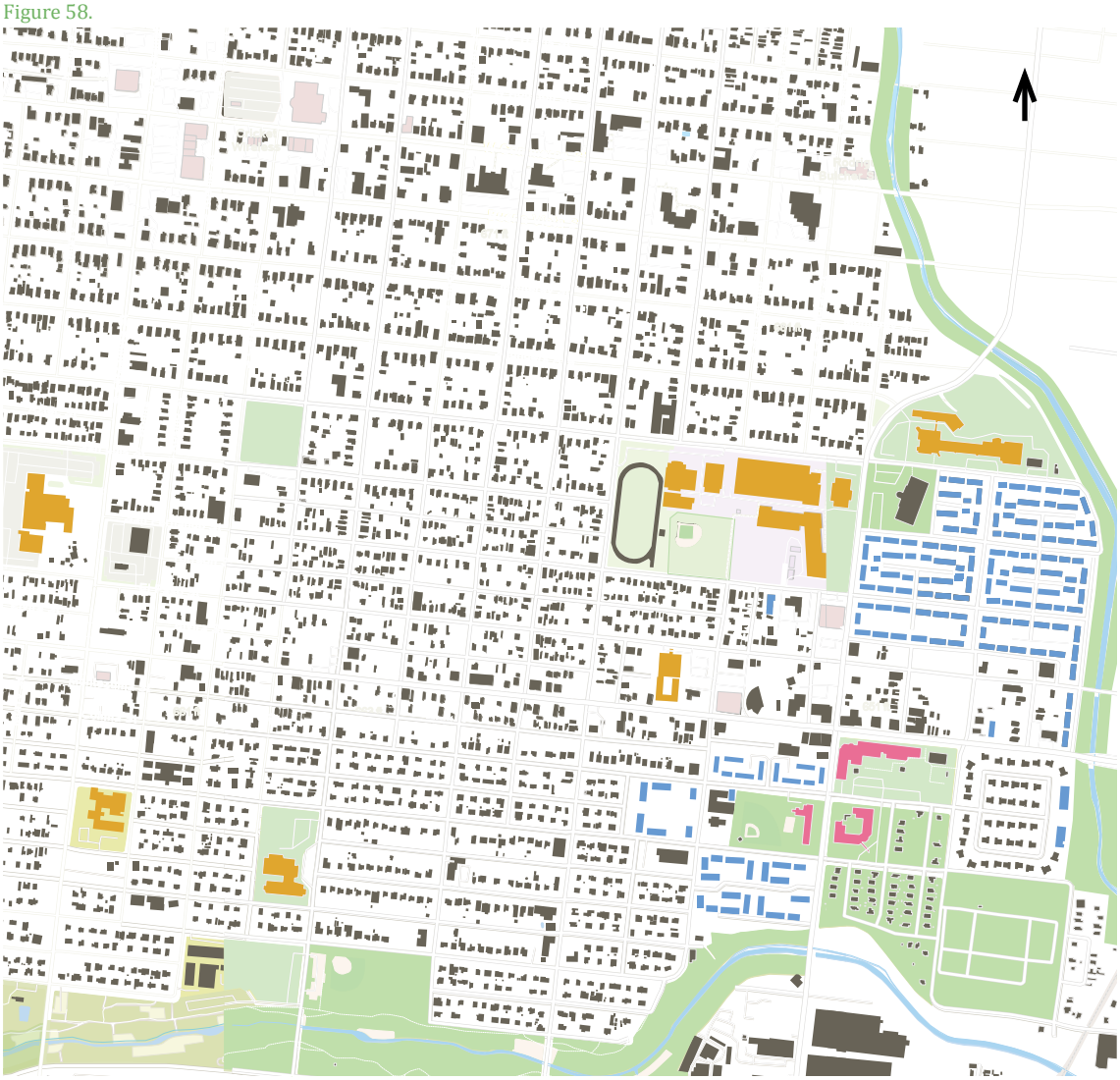

LEGEND:
Shotgun houses
Residencial complex
Aggregation centers
Apartment blocks

Figure 59.



LEGEND:

- Sport
- Cemetery
- Council
- Library
- School
- Achievement center
- Car services
- Residencial
- Shops
- Cultural center
- Churches
- Medical center
- University
- Restaurant
- Pharmacies
- Senior residences
- Food market
- Bank
- Hostels

Shotgun houses in the Westside of San Antonio.

The term “shotgun house” doesn’t mean only a little cheap house built by a vernacular wood structure. Reading from the dictionary (https://www.thefreedictionary.com/shotgun+houses): “A house whose architecture is characterized by several rooms joined in a straight line from the front to the back.”. From the research carried out in the Westside of San Antonio we can notice that this typology of vernacular house always has a front porch placed at the entrance of the building, followed by the living room and the bed rooms. The kitchen is often located in the last room, in front of the internal garden. Other times it was placed after the front porch. In these cases the front porch had also a functional value, becoming a natural continuation of the kitchen and assuming an important social and anthropological value. The restrooms were separated from the house and the windows’ frames were lower than the usual habit and were placed on 1.3 feet up from the floor. In the Westside there are several typologies of shotgun houses. The variations consist in the front porch’s and the roof’s shapes.

Figure 60.

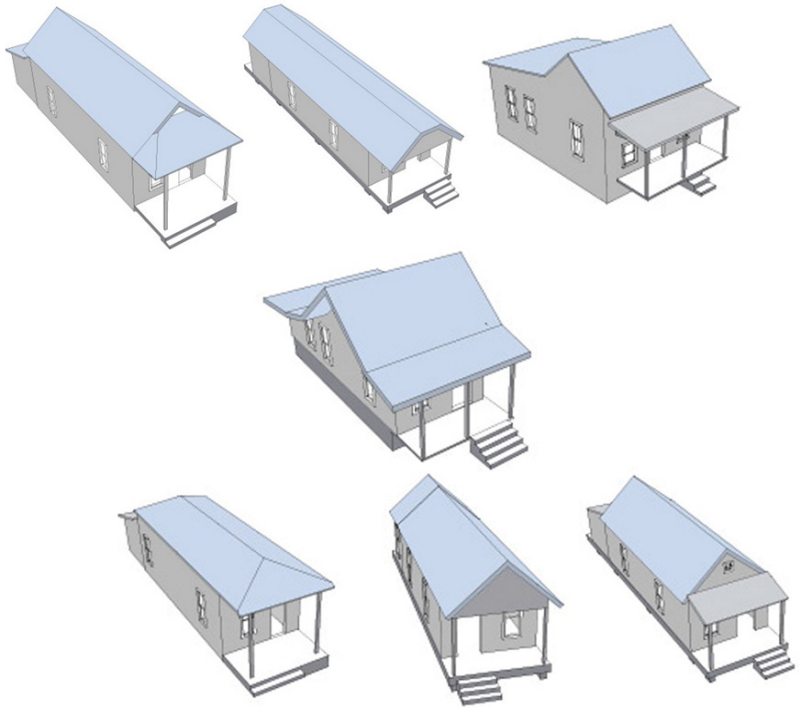


Figure 59. Services analisys of Westside neighborhood- Author elaboration

Figure 60. Shotgun houses roof and poches’ typologies - Autor’s elaboration

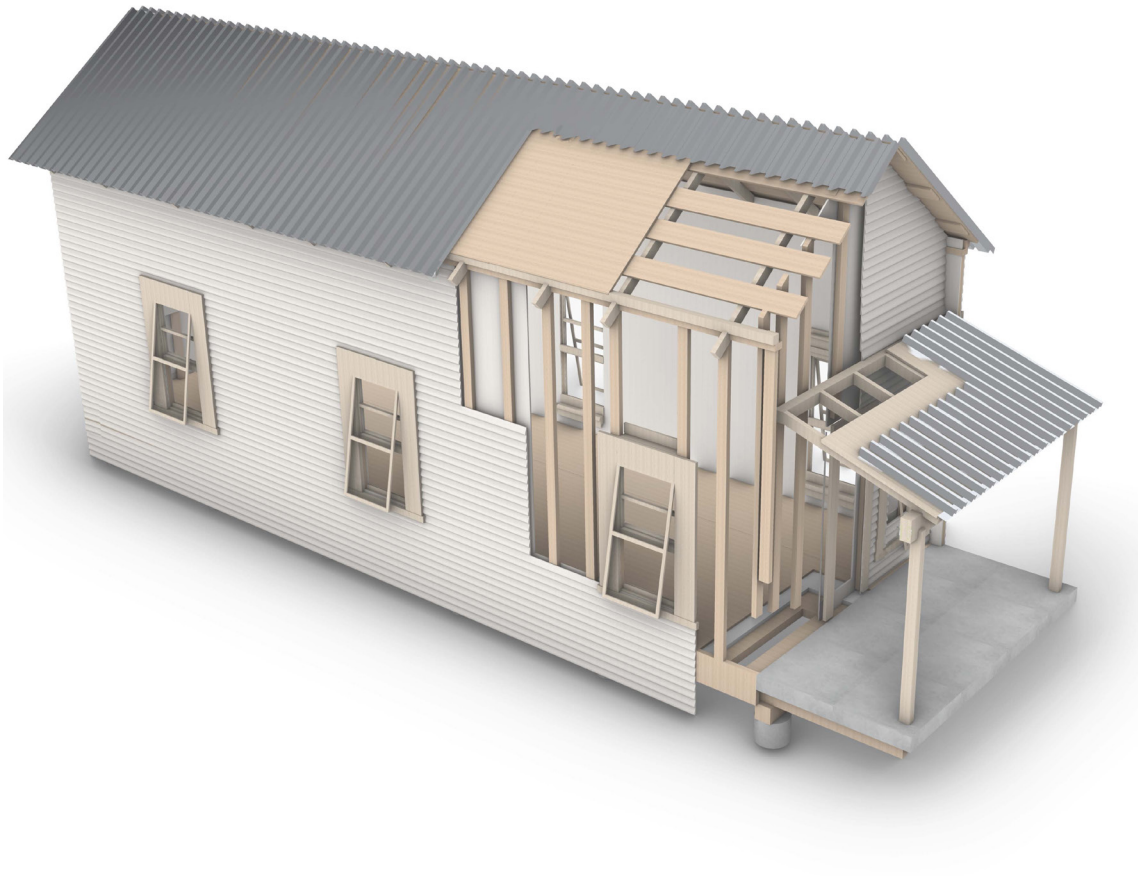


Figure 61.

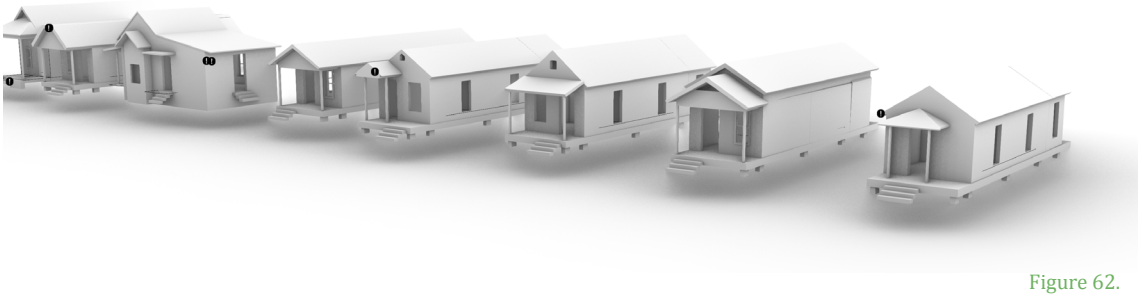


Figure 62.

Surfaces analysis.

Blocks of flats characterise the area, with shotgun houses surrounded by a private garden either left uncultivated or paved and used as an outdoor work and/or leisure space. The area is surrounded on three sides—south, east, and west—by creeks, the edges of which are in a state of decay, consisting of earth or cement. The rest of the area is characterised by asphalt and gravel.

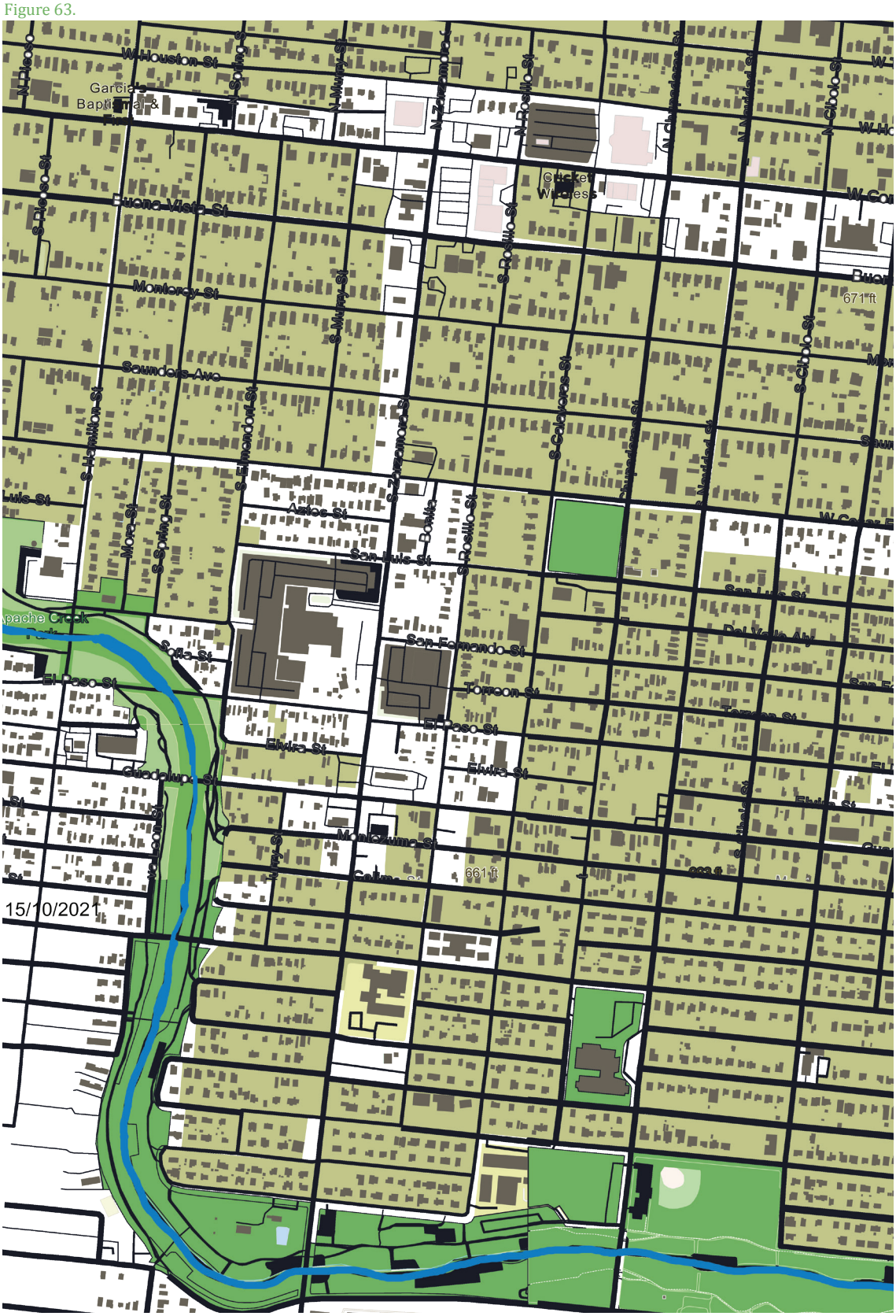
Figure 61. Shotgun house type - Autor's elaboration

Figure 62. Shotgun houses typology model - Autor's elaboration

Innovative and integrated energetic and bioclimatic strategies for adapting existing contexts to climate change and extreme events, aiming to mitigate the environmental impact

p. 526

Figure 63.





LEGEND:
Private green
Public gravel
Asphalt
Concrete

Type of surfaces: Coeff.
- Pavement:
  Asphalt: 1
86558 mq
  Gravel:
99374 mq 1
- Grass: 30243 mq 0.3
- Roofs: 49577 mq 1
- River: 113399 mq 0.1

RUN OFF = 245171

Types of surfaces in the neighborhood

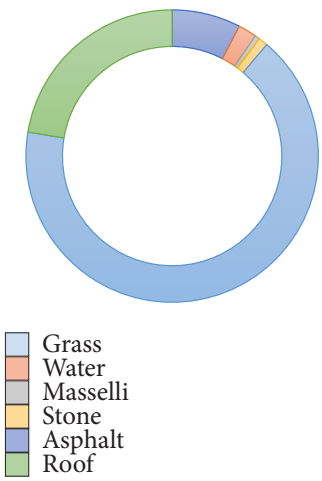


Figure 63. Surface's analysis. Author's elaboration

Vegetation Analysis.

Figure 64. Vegetation analisys of Westside neighborhood- Author elaboration

Despite long periods without rain, Texas's ecosystems are anything but dry, thanks in part to the large number of springs scattered throughout the territory. San Antonio, in particular, is the meeting point of several ecosystems[64]: Black Lands prairies, Edwards Plateau, and South Texas Plains. Below is an analysis of Texas vegetation and these ecosystems.

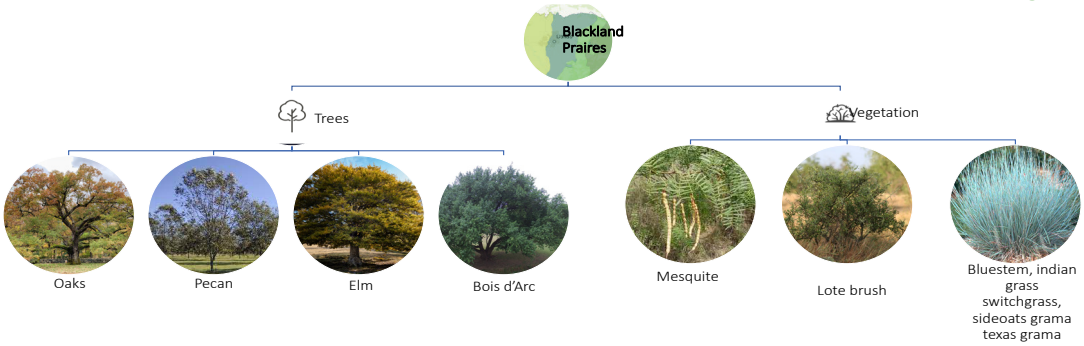
Figure 64.



LEGEND:
- Trans-Pecos Mountains
- High Plains
- Rolling Plains
- Edwards Plateau
- South Texas Plains
- Cross TImber and Prairies
- Blackland Prairies
- Piney Woods
- Post Oak Savannah
- Gulf Prairies and Marshes

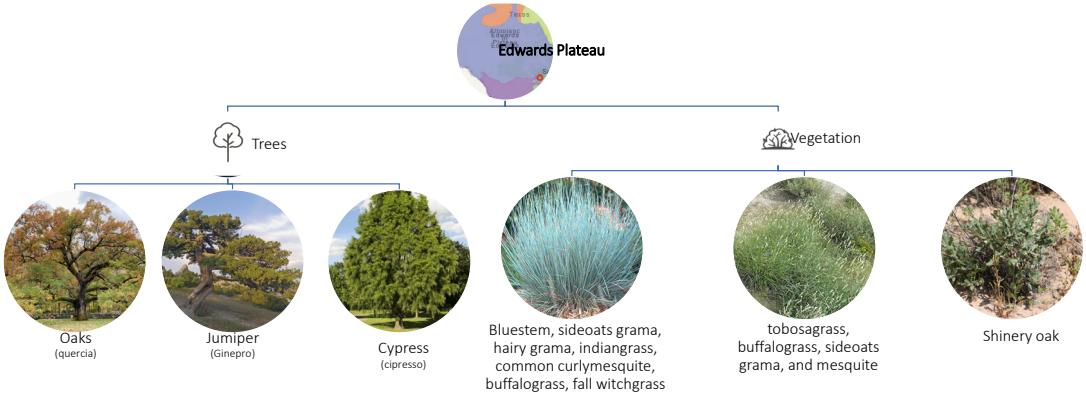
Blackland Prairies: Most of this fertile area has been cultivated, and only small acreages of grassland remain in original vegetation. In heavily grazed pastures, the tall bunchgrass has been replaced by buffalograss, Texas grama, and other less productive grasses. Mesquite, lotebush, and other woody plants have invaded the grasslands.

Figure 65.



Edwards Plateau: This limestone-based area is characterized by the large number of springfed, perennially flowing streams that originate in its interior and flow across the Balcones Escarpment, which bounds it on the south and east. The soils are shallow, ranging from sands to clays, and are calcareous in reaction. This area is predominantly rangeland, with cultivation confined to the deeper soils.

Figure 66.



South Texas Plains: There are distinct differences in the original plant communities on various soils. Dominant grasses on the sandy loam soils are seacoast bluestem, bristlegrass, paspalum, windmillgrass, silver bluestem, big sandbur, and tanglehead. Dominant grasses on the clay and clay loams are silver bluestem, Arizona cottontop, buffalograss, common curlymesquite, bristlegrass, pappusgrass, gramas, plains lovegrass, Texas cupgrass, vinemesquite, other panicums, and Texas wintergrass.

Figure 67.

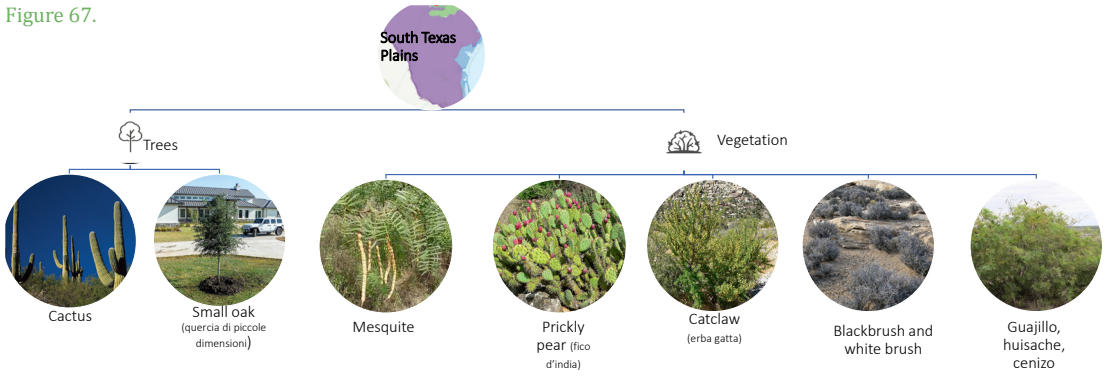


Figure 65. Blackland Prairies' species. Author's elaboration

Figure 66. Edwards Plateau' species. Author's elaboration

Figure 67. South Texas Plains' species. Author's elaboration

36. Google Earth (GE), was launched by Google in 2005 as a 'geobrowser', and Google Earth Engine (GEE) was released in 2010 as a cloud computing platform with substantial computational capabilities (Amani, et al., 2020). GEE enables cloud computing and is an effective tool for analysing global geospatial big data. Compared to other cloud platforms, GEE supports multiple types of geospatial data (e.g. Sentinel and early Landsat data). It provides free services to all users, which is especially important in less developed countries. It has been widely used to process data on a variety of fields concerning environmental changes, including agriculture (Lobell, Thau, Seifert, Engle, & Little, 2015; Teluguntla, et al., 2018), water (Wang, Jia, Chen, & Wang, 2018; Zhou, et al., 2019), land cover and land use ([Huang, et al., 2017; Zurqani, Post, Mikhailova, Schlautman, & Sharp, 2018), disasters (Kakooei & Baleghi, 2020; Meilianda, et al., 2019), climate change (Hao, et al., 2019; Workie & Debella, 2018), soils (Padarian, Minasny, & McBratney, 2015; Padarian, Minasny, & McBratney, Chile and the Chilean soil grid: A contribution to Global Soil Map., 2017), urbanisation (Goldblatt, et al., 2018) and other fields (Tamiminia, et al., 2020). GEE provides users with publicly downloadable Earth observation data on a petabyte scale, advanced algorithms for analysing geographical big data and an interactive programming environment. GEE also hosts long time series of Earth observation records and plays a key role in environmental monitoring and analysis (Amani, et al., 2020; Zhao et al., 2021).

Exposition Analysis.

The analysis of the exposure in the city of San Antonio is carried out through the Google Earth engine platform[36]. This platform allows the user to perform geospatial surveys through different interaction methods. The platform runs algorithms on georeferenced images on Google infrastructure. Below are satellite analyses of vegetation in various seasons and temperature analyses. It is possible to note a certain temperature homogeneity, which, according to the graph, lies between 50 °C and 54 °C, analysing the ground temperature (fig. 69). This information is supported by the morphological typology in the area, which has a low building density and is made up of low dwellings on extremely regular square plots, and by the type of surface, mainly asphalted or topsoil. Only in the western part of the area do temperatures drop. This temperature difference is due to the presence of the Zarzamora Creek. The vegetation is concentrated within the individual plots and constitutes primarily private gardens belonging to dwellings. The lighter colouring shows the absence of green infrastructure, such as tree-lined avenues or green and public-shaded areas.
Next is a graph depicting the heat island during the hours of the

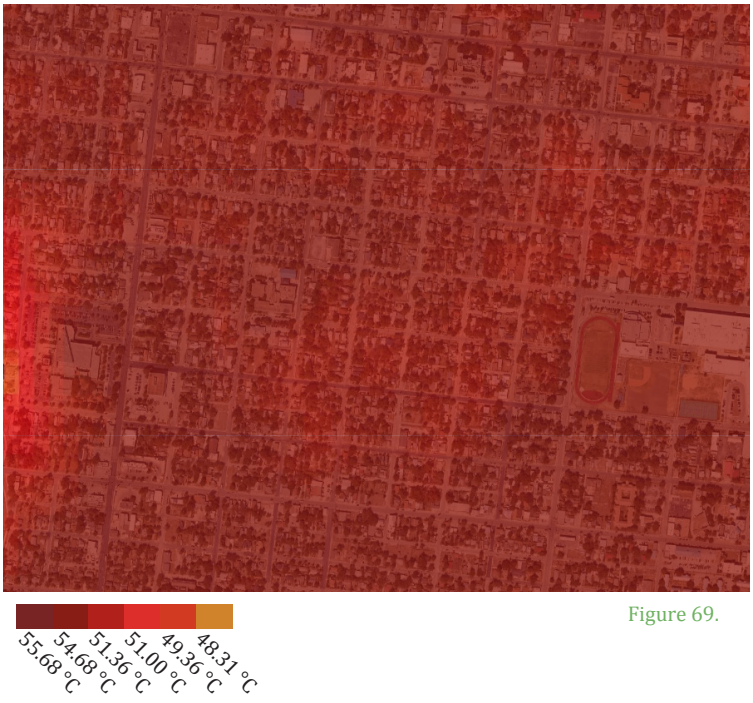


Figure 69.

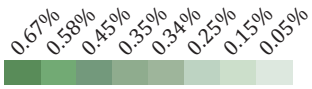


Figure 70.



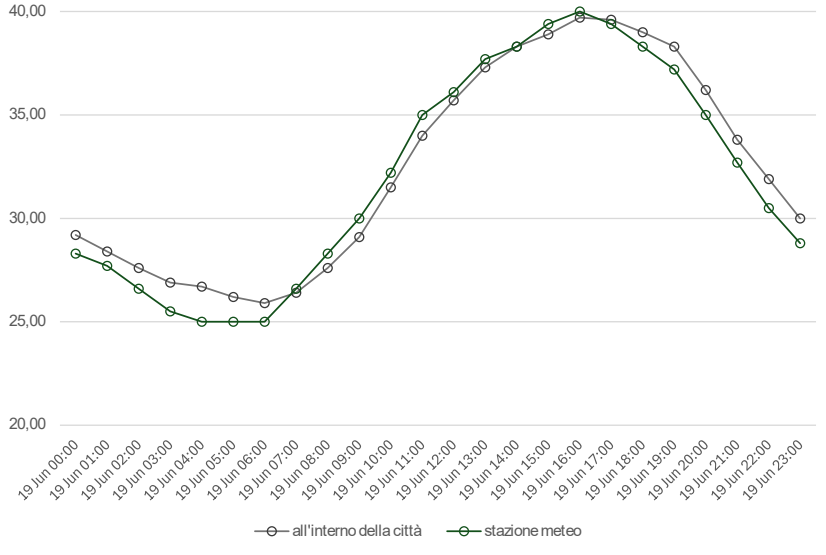
Figure 68. Graphical representation of the heat island in San Antonio. Graphic processing is carried out through the UWG generator. Author's elaboration

Figure 69. Graphical representation of the ground temperature in the analysed Westside area. Elaborated with the help of architect Stefano Urbinati.

Figure 70. Graphic representation of the percentage of green areas in the analysed Westside area. Elaborated with the help of architect Stefano Urbinati.

statistically hottest day in San Antonio (19 June). The graph, processed through Ladybug, uses the UWG generator tool to process the microclimate within the city, which is then compared with the weather station. From the image, the presence of the heat island at night is evident, while the temperatures are very similar during the day.

Figure 68.



Analysis of case studies and individualization of the actions .

Once the cognitive analyses have been carried out, the elaboration of a SWOT analysis helps identify the area's main characteristics. The district's strengths include the large number of indigenous species, the wide availability of open spaces, although these are private, the presence of aggregation and cultural points and complexes, and the regularity of the planimetric structure. Weaknesses include the dilapidated state of public greenery, structures and infrastructures, the massive presence of impermeable surfaces, the absence of equipped areas, the lack of maintenance of private greenery, the absence of a functional and social mix, the difficulty of walking and the dangerousness of the area, the lack of cleanliness and shady spots, and the lack of night lighting. Among the opportunities are broad road sections that allow the installation of ecosystem infrastructures, large unused municipal spaces, the possibility of inserting public services in disused premises, and significant residual areas to be integrated into the ecological network to regenerate the river banks. Among the most dangerous threats are the continuous increase in the area's degradation, involving structures and infrastructures, encouraging depopulation processes in the neighbourhood, negatively impacting structures, decreasing air quality, and soil impoverishment.
From this analysis, we derive macro-objectives on adaptation and mitigation to islands and heat waves and objectives on the city that consist of decreasing the degradation rate of structures and infrastructure, decreasing soil, air and surface temperatures, managing alien species, and redeveloping existing buildings. The objectives concerning the natural network are to decrease the risk of hydrogeological, fire, drought and/or soil aridity, mitigate impacts due to flooding and reduce climate-altering species. From the individual's point of view, the objectives consist of increasing comfort inside and outside the buildings and enabling greater enjoyment of the area through improved thermo-hydro comfort.
This pilot case presents aspects similar to and comparable to two other case studies previously analysed, from which it can take an example. Seaholm eco-district in Austin had heat island problems and was in disrepair. The designers responded to the problem by using materials with a high albedo index, planting vegetated roofs and parks, and increasing the green system. Similarly, the eco-neighbourhood of Limerick presented similar problems to the pilot

case under consideration: a decaying housing stock, insufficient to meet the needs of the population, a lack of a mix of functions and social spaces, a public space dominated by cars, and a high risk of flooding. The solutions that can be adopted consist of both indoor and outdoor actions, such as increasing the airtightness of building envelopes, enhancing the transmittance of walls and windows, implementing mechanical heat recovery, controlling vegetation, and installing an energy monitoring system. The final step in selecting the actions underlying the redevelopment project consists of using Climate Consultant software to confirm the effectiveness of the previously selected actions. This software is a free tool that helps users gain an in-depth understanding of the climate context and choose technological solutions tailored to their specific needs, thereby increasing user comfort. The proposed solutions align with specific characteristics of the vernacular architecture of the area. This aspect reinforces the choice and, therefore, the solutions used, which are based on the same operating principles. The principles underlying the redevelopment of the Westside pilot case consist of increasing shaded areas, indoor and outdoor cross ventilation, and green infrastructure. In fact, the layout of shotgun houses typically features porches that provide shelter from the sun and windows on all sides. The orientation of the entire neighbourhood promotes wind circulation.

Figure 73.

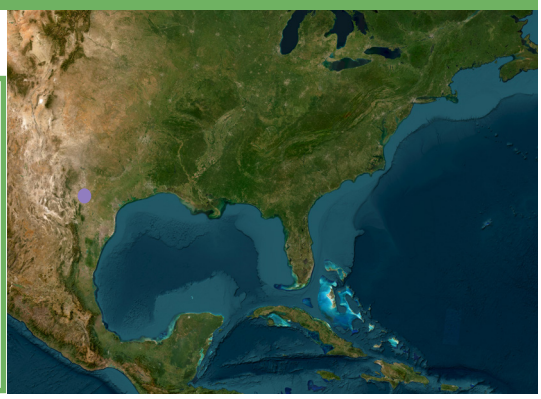
PILOT CASE - WESTSIDE - SAN ANTONIO - (TX) USA

Similar Case study

Seaholm Ecodistrict	Austin	(TX) USA

Cost: \

Designers:	Gail Vittori, Pliny Fisk III
Customers and stake holders:	City of Austin Office of sustainability
Design year:	2012
Construction year:	2014
Completion year:	2017



Geolocalization- Author elaboration on QGIS

Seaholm in the 60's

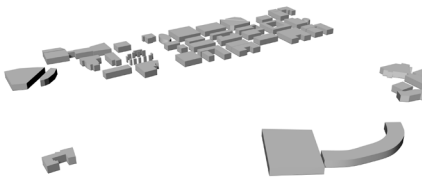


Seaholm today





Inhabitants: 2500
Dimension: 33 ha
Morphology: Centralized
H/L: 0.2



Similar issues to the case study:

- Presence of heat island phenomena
- The area was in a state of neglect

Solutions adopted:

- Surfaces with high albedo index
- Presence of green roofs
- Adoption of green-based solutions
- Construction of new parks
- Increase of vegetation systems for rainwater treatment

PILOT CASE - WESTSIDE - SAN ANTONIO - (TX) USA

Figure 74.

Similar Case study

Limerick	Limerick	Ireland

Cost: 24 M Euro (finanziamento per ricerca e innovazione dell'UE) + 40 M Euro di nuovi investimenti

Designers:	+CITYXCHANGE Norwegian University of Science and Technology (NTNU), Limerick
Customers and stake holders:	
Design year:	2012
Construction year:	2014
Completion year:	2017



Limerick in the 70's

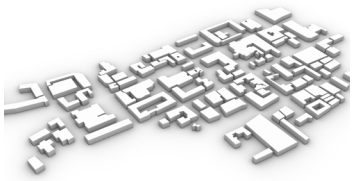


Limerick today





Inhabitants: 194899
Dimension: 1,5 ha
Morphology: Centralized
H/L: 0.86



Similar issues to the case study:

- High unemployment rate
- Insufficient housing stock
- Lack of functional and social mix
- Public space dominated by cars
- Risk of flooding

Solutions adopted:

- Increased air tightness
- Increased transmittance of walls
  Increased transmittance of window frames
- Mechanical heat recovery
- Increased ventilation control
- Installation within buildings of Building
- Energy management systems

Figure 71.

Figure 71. SWOT of Westside neighborhood- Author elaboration

Strenghts:

- A large variety of native species
- Significant presence of land, given by parks and courtyards
- Presence of Colorado Creek
- Presence of pre-existing and versatile buildings
- Presence of cultural complexes and meeting points
- Presence of indoor and outdoor sports facilities
- Regular morphological and planimetric configuration

S

Opportunities:

O

- Broad road sections to ensure increased vegetation/bike lanes, built through highly permeable materials
- Possibility of redevelopment of many shotgun houses
- The presence of large unused commercial spaces
- Possibility of incorporating public services in various disused premises
- Presence of residual areas to be integrated into the ecological network
- Possibility of inserting tree rows
- Possibility of regenerating river banks
- Possibility of setting up infrastructure and equipped green areas
- Possibility of installing night lightin

Weaknesses:

- The presence of the heat island was detected
- Public green areas in a state of disrepair
- Low maintenance and deterioration of infrastructure
- Low presence of equipped green areas
- Lack of equipped public spaces
- Intensive presence of concrete and poorly cohesive soil
- Lack of maintenance of private green areas
- High state of degradation of buildings and surroundings
- Lack of functional and social mix
- Lack of green infrastructure
- Difficulty in travelling by soft mobility
- Lack of cleanliness of public spaces and waste collection
- Unused aggregation points
- Lack of shadow points
- Lack of night lighting
- Presence of many deciduous species
- Excessive solar radiation
- Usually, the downtown areas of cities are characterised by lower vegetation density than residential areas. A more detailed investigation shows that a remarkably large percentage of West Side vegetation is grass or dirt, with no shade production.

W

Threats:

T

- It is impossible to walk or cycle on roads both during the day and at night, as they are dangerous
- Increased degradation of structures and infrastructure
- Stress on structures and infrastructure
- Increase in invasive species
- Increased soil poverty
- Increased mortality and decreased well-being
- Increased maintenance and rehabilitation costs
- Increased neglect of neighbourhoods and buildings
- Increase in crime
- Decrease in air quality
- Increased outdoor temperatures
- Increased fire danger
- Increased drought

Figure 72. Elaboration of strategies and action scenario of Westside neighborhood- Author elaboration

Figure 72.

Objective:

MACRO OBJECTIVES
- Adaptation and mitigation of the urban heat island
- Adaptation and mitigation of extreme temperatures
- Adaptation and mitigation to heat waves

ANTHROPIC SYSTEM
- Decrease in the rate of degradation of structures and infrastructure due to continued high temperatures
- Decrease in soil, air and surface temperatures
- Management and reduction of alien species
- Restoration and enhancement of natural habitats
- Reforestation
- Redevelopment of existing consolidated buildings, environmental heritage

NATURAL SYSTEM
- Hydrogeological risk adaptation and mitigation
- Fire risk adaptation and mitigation
- Drought/aridity risk adaptation and mitigation
- Adaptation to flood risk
- Reduction of climate-altering emissions

WELL-BEING
- Increasing indoor and outdoor comfort also concerns reducing the risk of disasters and extreme events, including increasing prevention/ response capabilities
- Encouragement of the use of the neighbourhood

Guidelines:

- Use of effective strategies in the short-term
- Use of effective strategies that solve the most problems with the least amount of resources
- Reducing emissions in buildings
- Increasing outdoor ventilation and indoor cross-ventilation during peak periods
- Developing innovative land governance models that also involve the local community

Strategies and actions:

- soil management with performance, drainage or cool materials passive cooling
- Control of solar radiation
- Promotion of soft mobility systems
- Management of light capture on a morpho-technological level
- Management of indoor and outdoor air flows using natural and artificial devices
- Management of rainwater collection and storage
- Interventions on morphology and management levels to avoid further degradation situations
- Use and enhancement of green and grey infrastructure at different scales
- Use of effective and efficient solutions that have an impact both indoors and outdoors
- Use and enhancement of green infrastructure for bioclimatic effects at different scales
- Involvement of residents
- Increase in public green-equipped evergreen areas
- Increase in green infrastructure
- Involvement of residents

Actions scenarios:

- Use of cool materials
- Use of reflective materials
- Use of vegetated roofs
- Application of green wall and façade systems
- Application of green systems inside buildings
- Draining roof systems
- Use of draining pavements
- Increasing the urban green system
- Increased shading points through green and grey devices and increased shading of buildings

Innovative and integrated energetic and bioclimatic strategies for adapting existing contexts to climate change and extreme events, aiming to mitigate the environmental impact
p. 542
Figure 75.
SELECTION OF ACTIONS

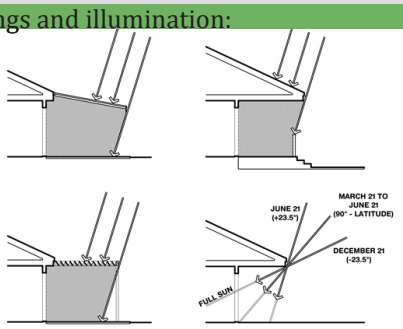
Wildfires	Parks, garden squares, pocket gardens, and urban farmings, trees and green corridors
Drought	Parks, garden squares, pocket gardens, and urban farmings, trees and green corridors
Stress of structures	Water surfaces, rain garden and phytodepuration, wetland ad bioswales, parks, garden squares, pocket gardens, and urban farmings, trees and green corridors, Cooling towers, green systems embedded in buildings, green houses and winter gardens, external coat, green roofs, green walls, ventilated roofs/floors, permeable surfaces, ponds on roof/ground floor, cool materials
Stress of infrastructures	Evaporative cooling, water surfaces, rain garden and phytodepuration, wetland ad bioswales, parks, garden squares, pocket gardens, and urban farmings, trees and green corridors, permeable surfaces, ponds on roof/ground floor, cool materials
Problems with finishing materials	External coat, Parks, garden squares, pocket gardens, and urban farmings, trees and green corridors, green roofs/walls, permeable surfaces, cool materials, cooling towers, green systems embedded in buildings, ventilated roofs/walls
Increasing indoor temperature	Artificial and natural urban devicesfor guide wind flows, parks, garden squares, pocket gardens, and urban farmings, trees and green corridors, bioclimatic atria, cooling towers, green houses and winter gardens
Increasing mortality	Parks, garden squares, pocket gardens, and urban farmings, trees and green corridors, bioclimatic atria, wind chimney, reen houses and winter gardens
Rainfall	Parks, garden squares, pocket gardens, and urban farmings, trees and green corridors
Decreasing of comfort conditions	Parks, garden squares, pocket gardens, and urban farmings, trees and green corridors, bioclimatic atria, wind chimney, reen houses and winter gardens
Energy transmission losses and facilities	Artificial and natural urban devicesfor guide wind flows, artificial shade systems, natural shade systems, Parks, garden squares, pocket gardens, and urban farmings, trees and green corridors, buffer zones, external coat, green roofs, permeable surfaces, ponds on roof/ground floor, phasechange and thermocromic materials, thermal mass

Figure 75. Matrix of hazards related to urban heat island and heat waves and technologies sets that can decrease all the KPI related to each hazard - Author elaboration

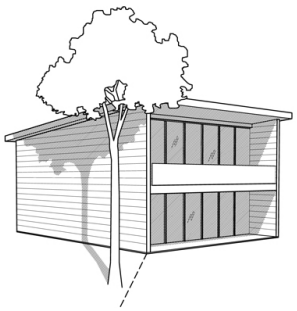
 Negative impact for renewerable energies	Evaporative cooling, water surfaces, rain garden and phytodepuration, wetland ad bioswales, Parks, garden squares, pocket gardens, and urban farmings, trees and green corridors, green roofs/walls, permeable surfaces, ponds on roof/ground floor, cool materials, external coat, ventilated roofs/walls
 Increasing costs for preventing measures	Water surfaces, raingardens and phytodepuration, wetlands and bioswales, parks, garden squares, pocket gardens, and urban farmings, trees and green corridors, cooling towers, green systems embedded in buildings, green houses and winter gardens, cool materials, green roofs/walls, permeable surfaces, ponds on roofs/ground floors, ventilated roofs/walls, green systems embedded in buildings
 Neighborhoods abandonement	Parks, garden squares, pocket gardens, and urban farmings, trees and green corridors
 Buildings abandonement	Parks, garden squares, pocket gardens, and urban farmings, trees and green corridors, bioclimatic atria, cooling towers
 Increasing maintenace costs	Water surfaces, rain garden and phytodepuration, wetland ad bioswales, parks, garden squares, pocket gardens, and urban farmings, trees and green corridors, green systems embedded in buildings, green walls, green roofs, permeable surfaces, ponds on roof/ground floor, photocatalityc materials, cool materials, cooling towers, ventilated roofs/walls
 Increasing recovery costs	Water surfaces, rain garden and phytodepuration, wetland ad bioswales, parks, garden squares, pocket gardens, and urban farmings, trees and green corridors, green systems embedded in buildings, green walls, green roofs, permeable surfaces, ponds on roof/ground floor, photocatalityc materials, cool materials, cooling towers, ventilated roofs/walls
 Increasing deterioration rate of systems and materials	Water surfaces, rain garden and phytodepuration, wetland ad bioswales, parks, garden squares, pocket gardens, and urban farmings, trees and green corridors, green systems embedded in buildings, green walls, green roofs, permeable surfaces, ponds on roof/ground floor, photocatalityc materials, cool materials, cooling towers, ventilated roofs/walls
 Increasing deterioration rate of infrastructures	Rain garden and phytodepuration, wetland ad bioswales, parks, garden squares, pocket gardens, and urban farmings, trees and green corridors, permeable surfaces, ponds on roof/ground floor, photocatalityc materials, cool materials, cooling towers, ventilated roofs/walls
 Buildings may became unsuitable for use	Parks, garden squares, pocket gardens, and urban farmings, trees and green corridors, bioclimatic atria, cooling towers
 Infrastructures may became unsutaible for use	Parks, garden squares, pocket gardens, and urban farmings, trees and green corridors
 Decrease of air quality	Artificial and natural urban devicesfor guide wind flows, parks, garden squares, pocket gardens, and urban farmings, trees and green corridors

CLIMATE CONSULTANT

Shandings and illumination:

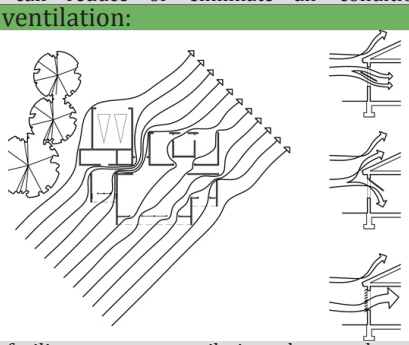


Window overhangs (designed for this latidude) or operable sunshades (awnings that extend in summer) can reduce or eliminate air conditioning

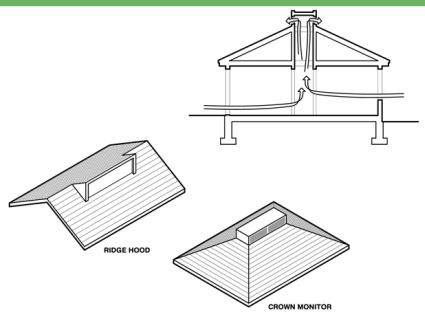


Minimize or eliminate west facing glazing to reduce summer and fall afternoon heat gain

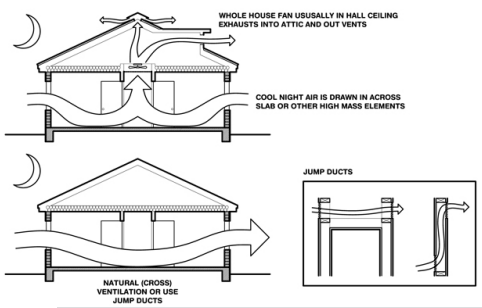
Cross ventilation:



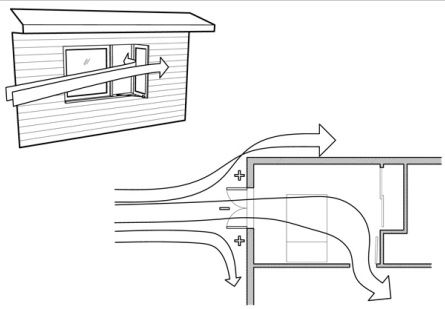
To facilitate cross ventilation, locate door and window openings on opposite sides of building with larger openings facing up-wind if possible



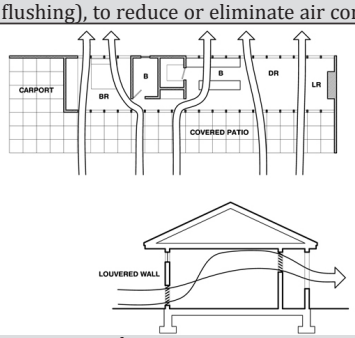
To produce stack ventilation, even when wind speeds are low, maximize vertical height between air inlet and outlet (open stairwells, two story spaces, roofs)



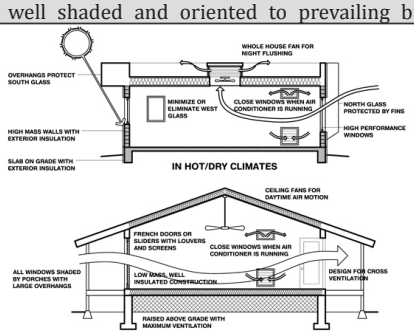
A whole-house fan or natural ventilation can store nighttime "coolth" in high mass interior surfaces (night flushing), to reduce or eliminate air conditioning



Good natural ventilation can reduce or eliminate air conditioning in warm weather, if windows are well shaded and oriented to prevailing breezes



Use open plan interiors to promote natural cross ventilation, or use louvered



In this climate air conditioning will always be needed, but can be greatly reduced if building design minimizes overheating

VERNACULAR ARCHITECTURE

Graphs made by the author.

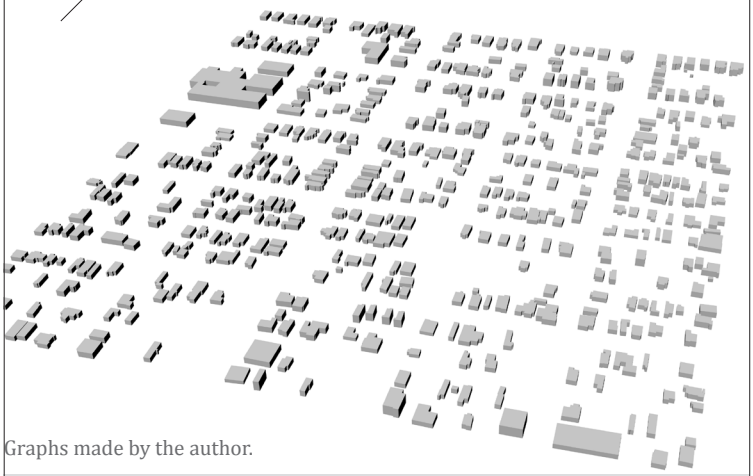


Picture taken by the author.



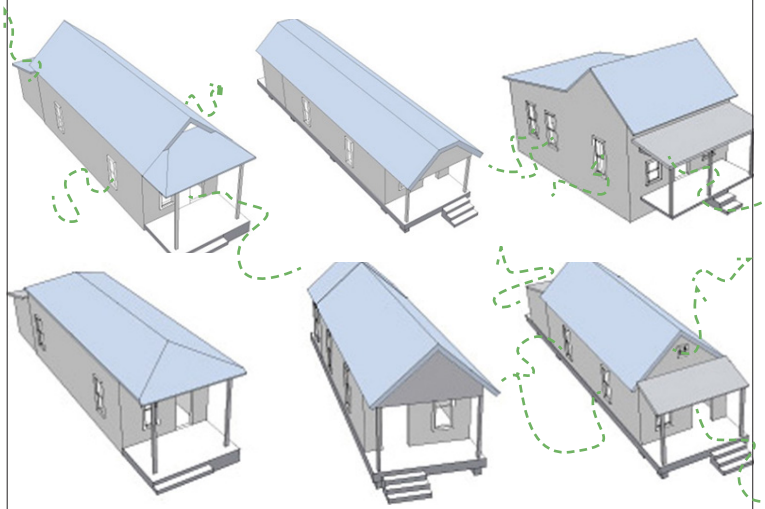
Types of porches of vernacular houses

N



Graphs made by the author.

Orinentation of the neighborhood.



Graphs made by the author.

Cross ventilation in vernacular houses

ACTIONS USED

The redevelopment project includes various green and grey shaded areas.

The redevelopment project includes green and grey screens that promote ventilation.

Model setting.

In conclusion, the analyses carried out allow us to identify the most serious dangers for the Westside neighbourhood, which consist of the possibility of fires due to the presence of often discarded wood materials in the streets and within the spaces of the buildings, drought, due to the presence of periods of complete absence of rainfall an increase in the stress of structures and infrastructures, due to the presence of long periods where temperatures are very high and the almost complete lack of building maintenance, an increase in mortality and a decrease in comfort levels, an increase in costs for preventive measures, the abandonment of buildings and the neighbourhood, and a reduction in air quality. Potential actions applicable to this context, by the SWOT matrix, the objectives and the hazards found on the city's fabric, consist of installing green infrastructures, cooling towers, wetlands and bioswales, water squares, cool materials, buffer zones and bioclimatic atria. Due to the punctual and historical conformation of the buildings, which does not allow the installation of bioclimatic atria, cooling towers or, in general, the aesthetic change of the building, the solutions evaluated concern the use of cool materials, green infrastructures, water squares and bioswales.
Then, the model is set up to perform simulations to understand which set of technologies is most effective and efficient in the context under consideration: The indoor and outdoor indicators affecting heat island and heat wave phenomena (air temperature, airspeed, RH%, and mean radiant temperature) and the UTCI comfort index are illustrated below. This evaluation is done through the Ladybug plug-in, which runs on the Grasshopper software described in Chapter 3.1 above. The input data concerns the location, the built environment, and the individuals within the area. The area is modelled on Rhinoceros and linked to the algorithm on Grasshopper. The building envelopes entered into the calculation consist of a structure with a wooden roof and sheet metal finish, an envelope composed of wooden mullions and transoms forming the load-bearing structure, a layer of insulation within these frames and a wooden finish.

Figure 76.

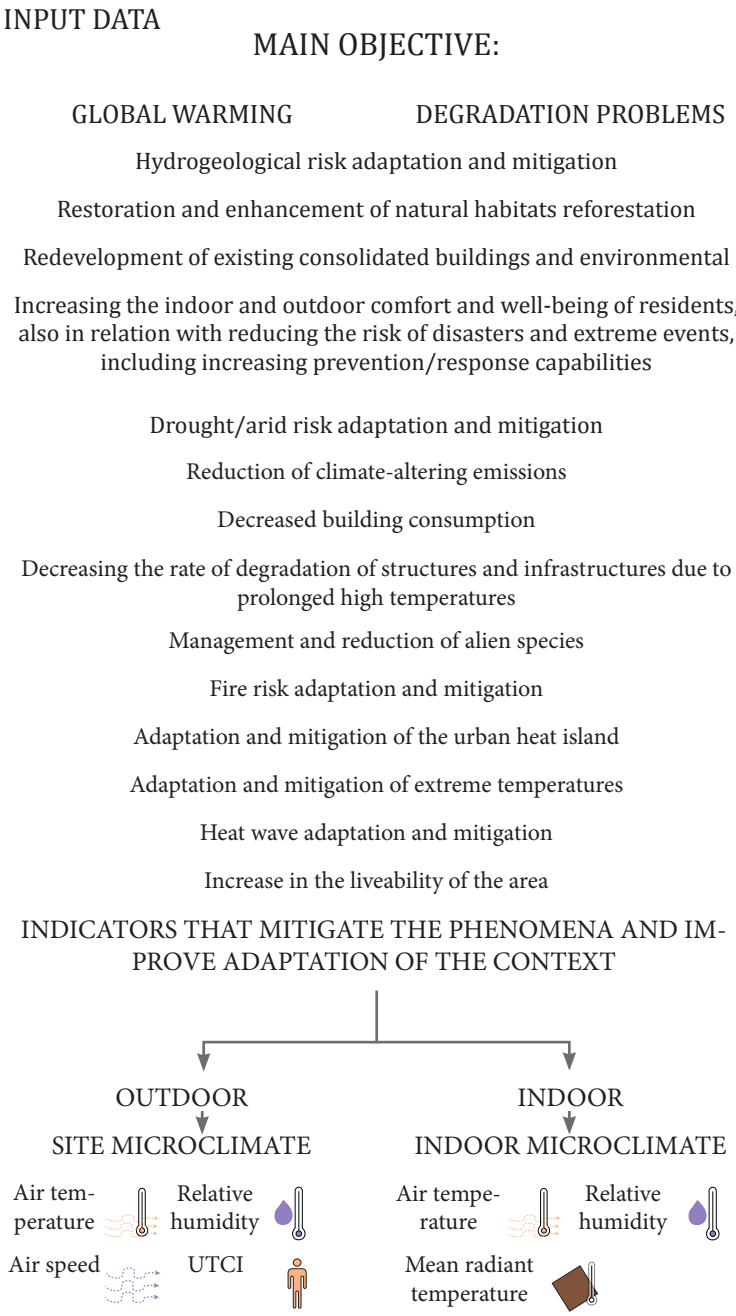


Figure 76. KPIs evaluated on Ladybug tools - Author elaboration

Figure 77.

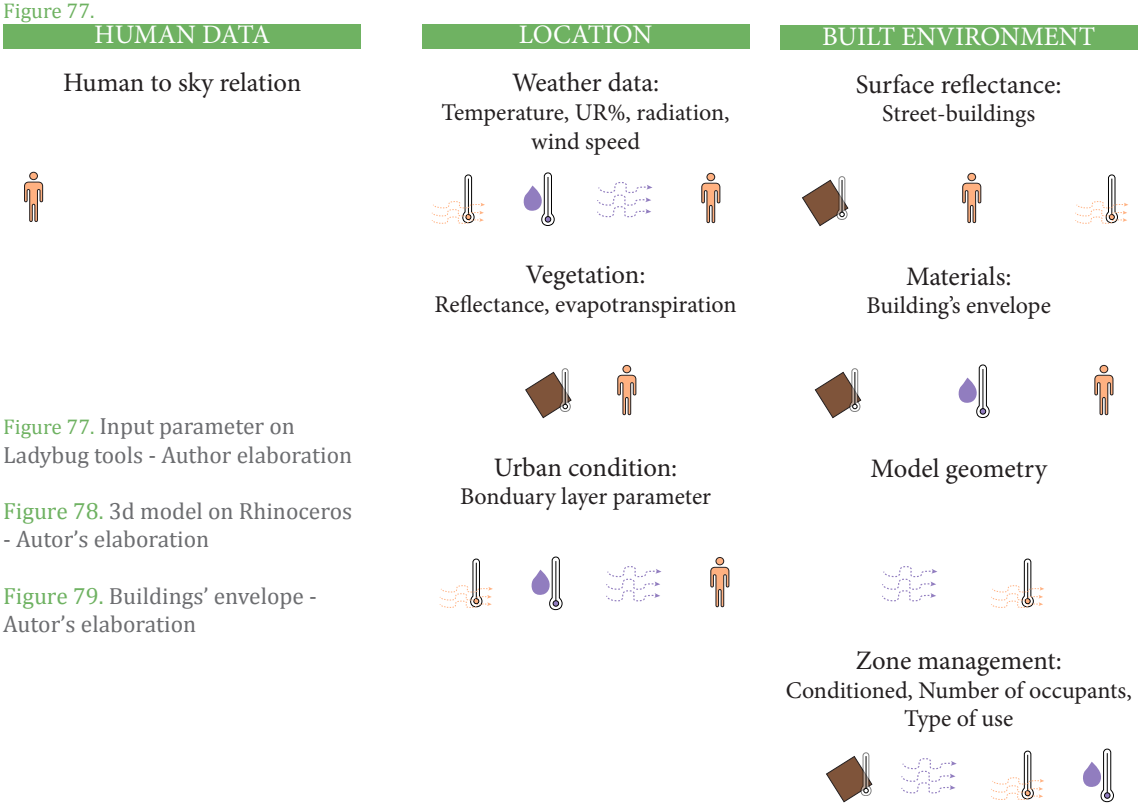


Figure 77. Input parameter on Ladybug tools - Author elaboration

Figure 78. 3d model on Rhinoceros - Autor's elaboration

Figure 79. Buildings' envelope - Autor's elaboration

INPUT DATA

Weather data:

It is usually represented by a .epw file where there are the main values of a region that concernes Temperature, UR%, radiation and wind speed. These type of file s can be dowun loaded from : https://www.ladybug.tools/epwmap/.

Human to sky relation:

Calculate parameters for the relationship between human geometry and the sky given the position of a human subject and context geometry surrounding this position. It represent a Ldybig component and is used to calculate MRT of a certain person inside the model.

Figure 78.

Model Geometry and points of simulation:

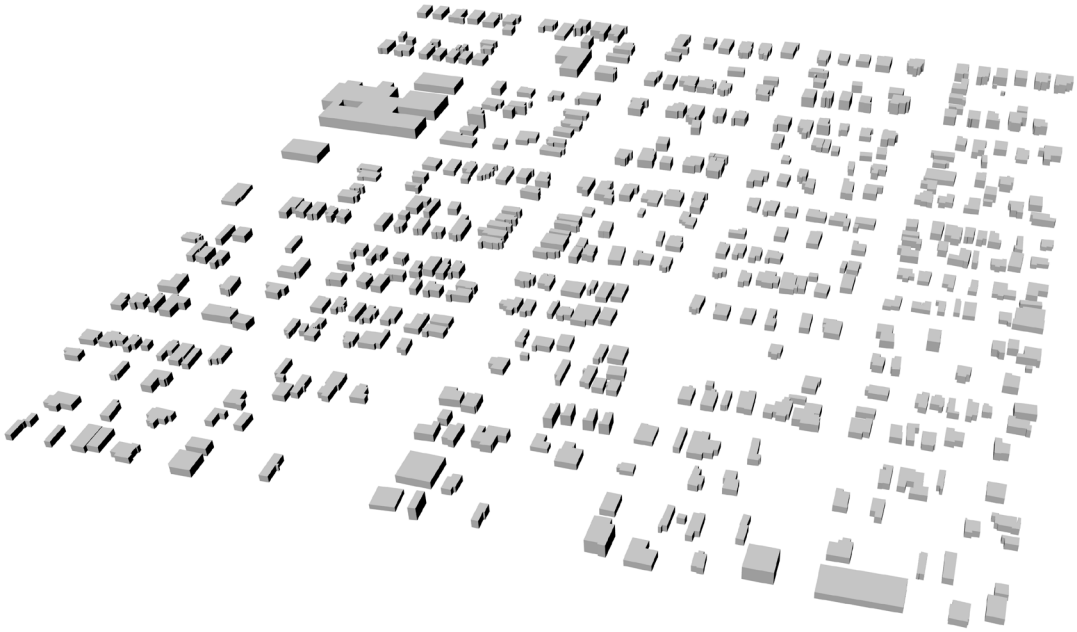
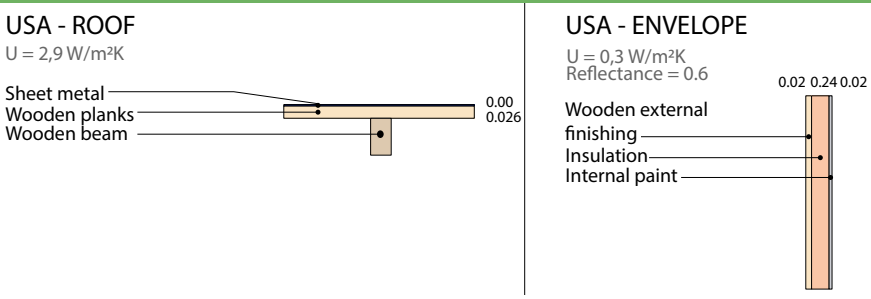


Figure 79.

Building envelope:



Greening:

Figure 78. 3d view of preintervention on Westside neighborhood - Author elaboration

Figure 79. 3d view of the inclusion of green infrastructures in Westside neighborhood - Author elaboration

Figure 80. The graphic compares indoor and outdoor temperatures at 2.00 pm on the hottest day, that from statistic analisys id on the 19th of June - Author elaboration

Figure 81. The graph illustrates the different types of surfaces present before the intervention.

Figure 82. The graph illustrates the different types of surfaces present following the redevelopment work.

Figure 83. Plan of preintervention on Westside neighborhood - Author elaboration

Figure 84. The graphic compares outdoor temperatures at 2.00 pm on the hottest day, that from statistic analisys id on the 19th of June - Author elaboration

Figure 85. Inclusion of green infrastructure on Westside neighborhood- Author elaboration

Pre

Figure 78.



Post

Figure 79.



Greening:

PRE
TOT copertura pre
49577 mq

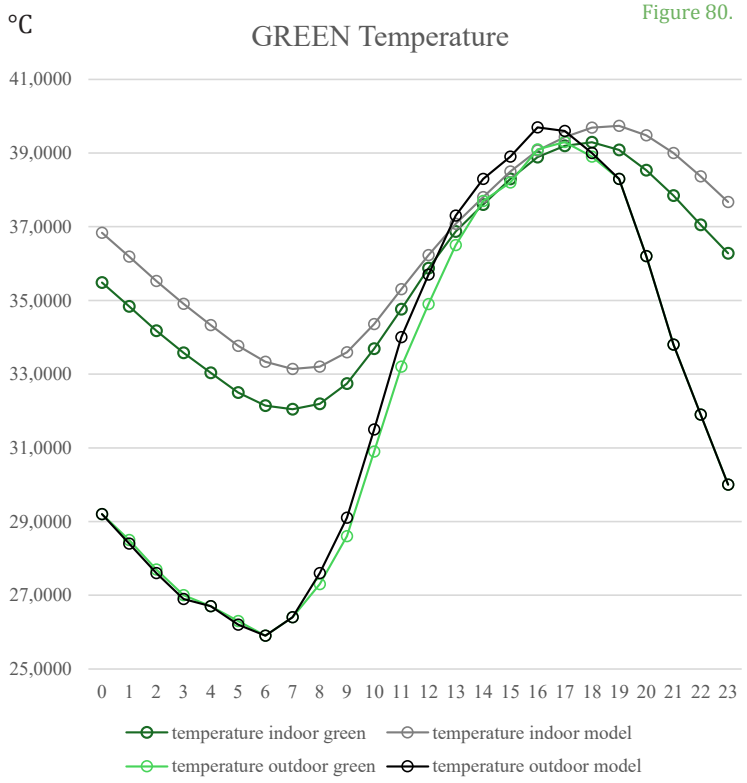
asfalto pre	99374 mq
Gardens pre	30243 mq
terra pre	99374 mq
Trees pre	13684 mq

POST
TOT copertura post
49577 mq

terra post	99374 mq
asfalto post	99374 mq
Gardens post	30879 mq
bioswales	2242 mq
masselli inerbiti	68495 mq
Trees post	29534 mq

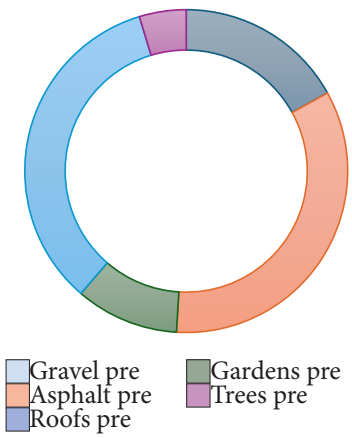
EFFECTIVENESS:
Outdoor:
Wind speed:●●●
UTCI: ●
Temperature●●●
UR%: ●●●
Indoor:
Wind speed:●●
UTCI: ●●
mrt indoor:●●
UR%: ●●●
Temperature:●

Figure 80.



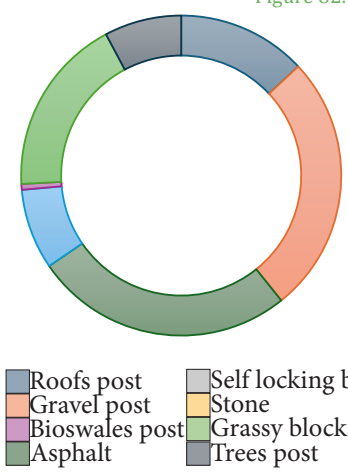
Pre:

Figure 81.



Post:

Figure 82.



Greening:

Figure 83.



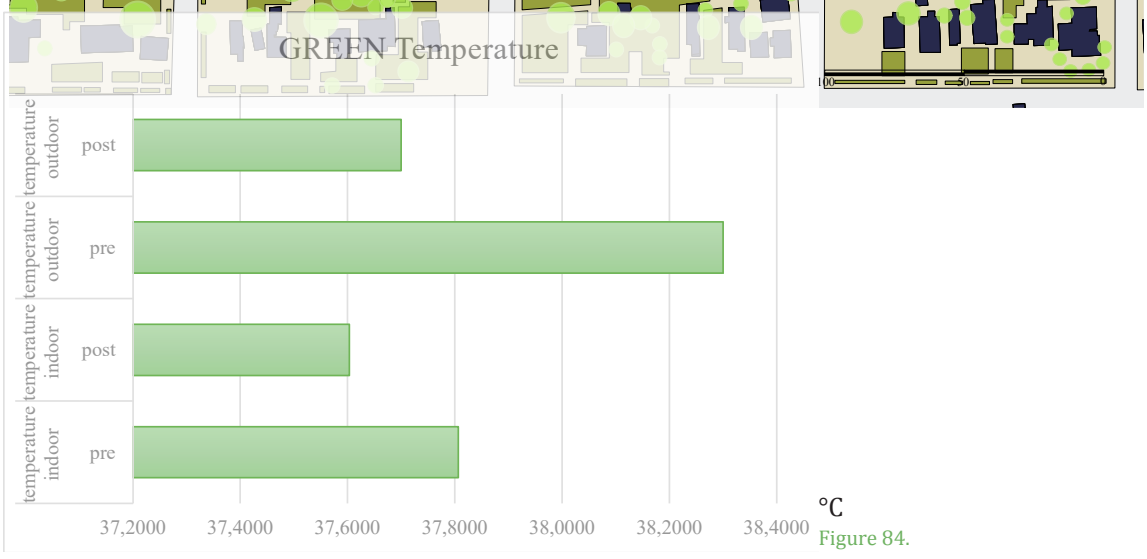
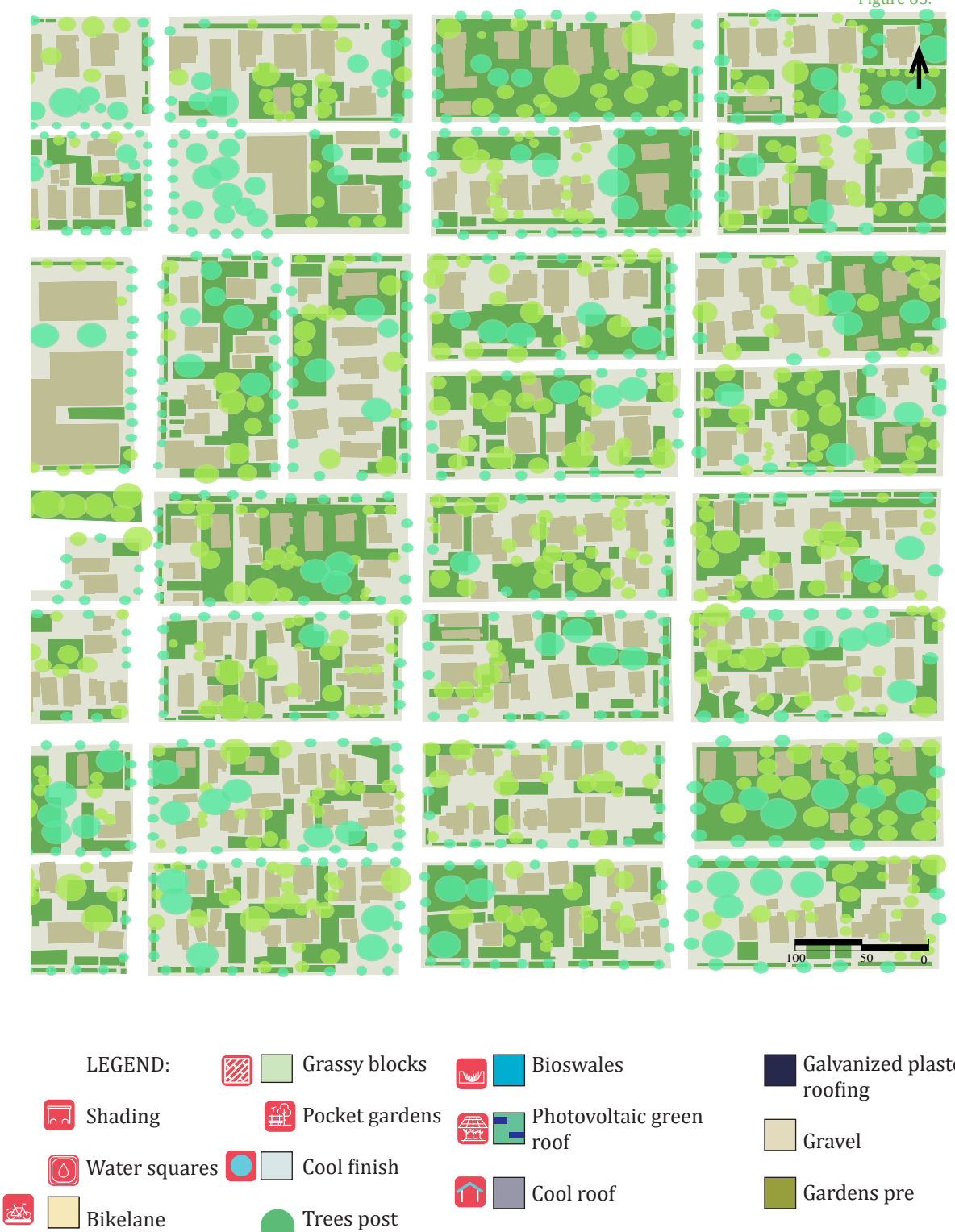


Figure 84.

Greening:

Figure 85.



Cool materials:

Pre

Figure 78.

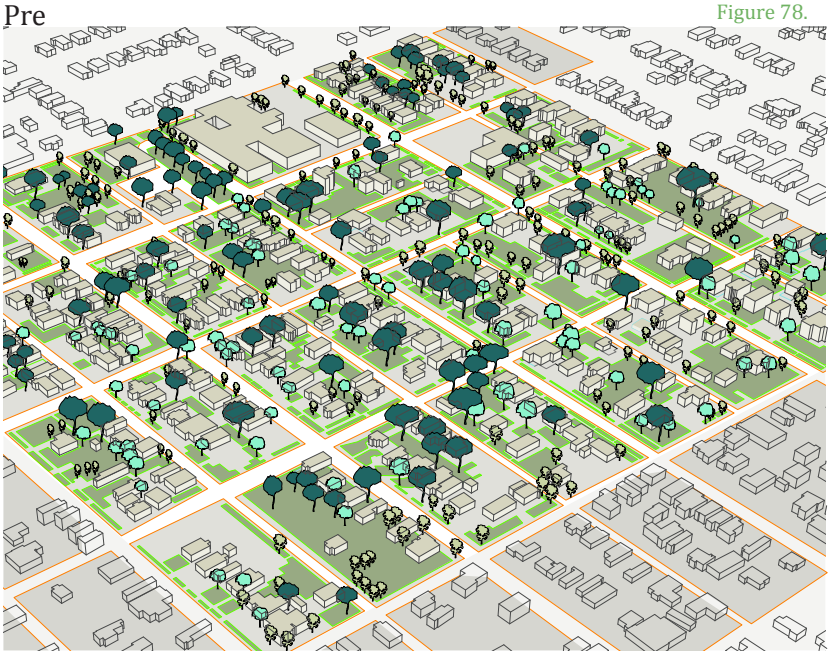


Figure 78. 3d view of preintervention on Westside neighborhood - Author elaboration

Post

Figure 86.



Figure 86. 3d view of the inclusion of cool materials in Westside neighborhood - Author elaboration

Figure 87. The graphic compares indoor and outdoor temperatures at 2.00 pm on the hottest day, that from statistic analisys id on the 19th of June - Author elaboration

Figure 89. The graph illustrates the different types of surfaces present following the redevelopment work.

Figure 90. Plant of preintervention on Westside neighborhood - Author elaboration

Figure 91. The graphic compares indoor and outdoor temperatures at 2.00 pm on the hottest day, that from statistic analisys id on the 19th of June - Author elaboration

Figure 92. Inclusion of cool materials on Westside neighborhood- Author elaboration

Cool materials:

COOL		POST	
PRE		TOT copertura cool post	
TOT copertura pre		49577 mq (100%)	
49577 mq		terra post	99374 mq
asfalto pre	86558 mq	asfalto cool post	
Gardens pre	30243 mq	86558 mq (100%)	
terra pre	99374 mq	Gardens post	30243 mq

EFFECTIVENESS:

Outdoor:

Wind speed:

UTCI: ●

Temperature: ●●●

UR%: ●●●

Indoor:

Wind speed:

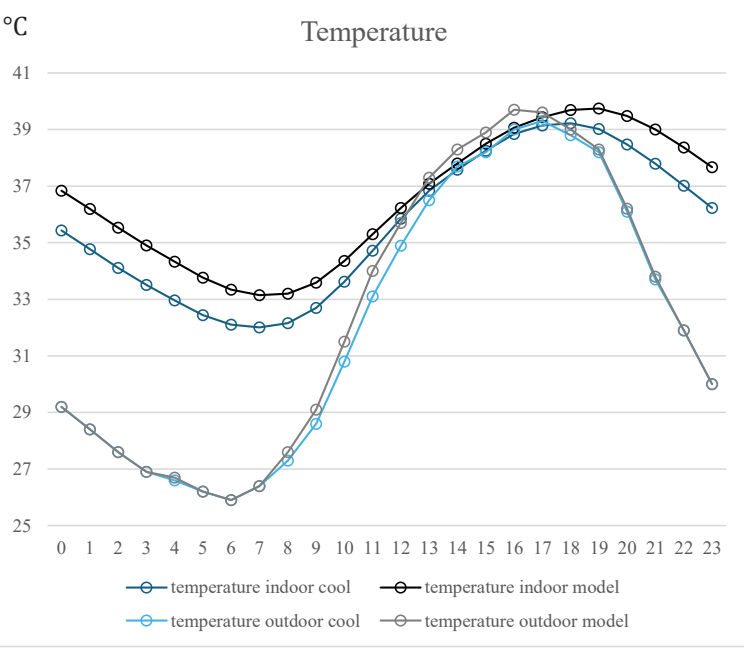
UTCI: ●

mrt indoor: ●●

UR%: ●●●

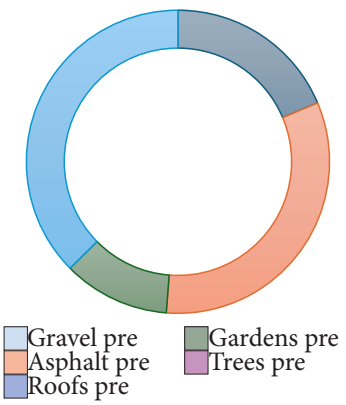
Temperature: ●●

Figure 87.



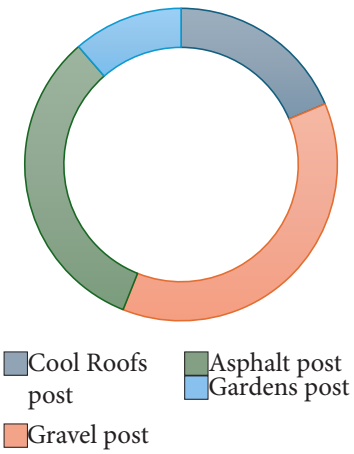
Pre:

Figure 81.



Post:

Figure 89.



Cool materials

Figure 83.

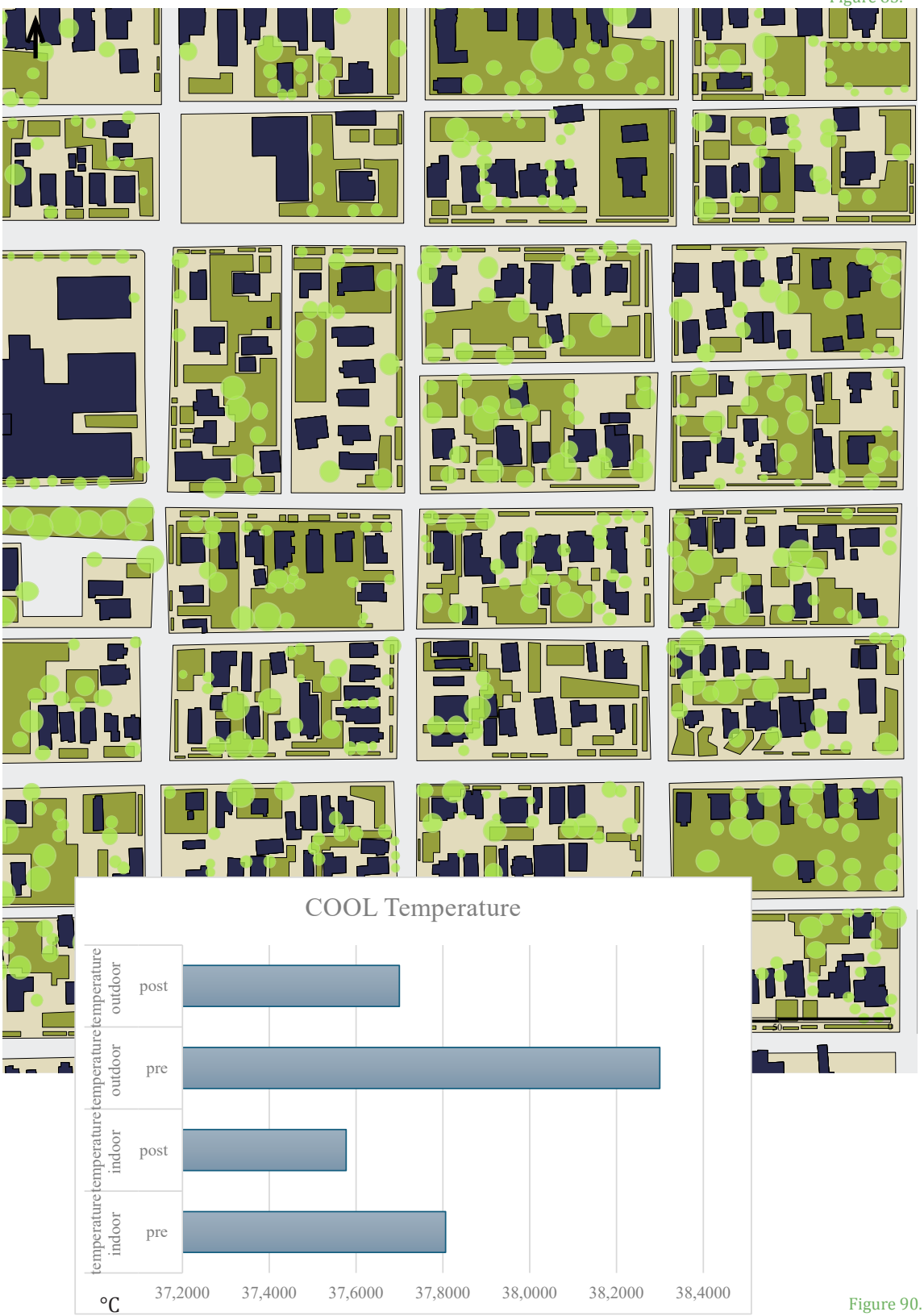


Figure 90.

Cool materials

Figure 91



Cool materials and greening:

Figure 92. 3d view of the inclusion of green infrastructures and cool materials and cool materials in Westside neighborhood - Author elaboration

Figure 78. Plant of preintervention on Westside neighborhood - Author elaboration

Figure 93. Surfaces analisys pre

Figure 94. The graphic compares indoor and outdoor temperatures at 2.00 pm on the hottest day, that from statistic analisys id on the 19th of June - Author elaboration

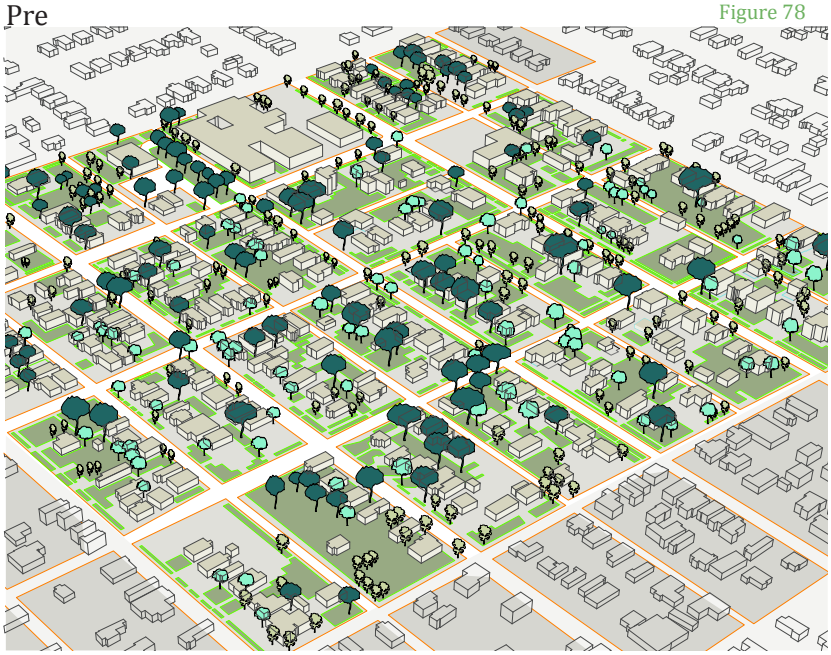
Figure 95. The graph illustrates the different types of surfaces present following the redevelopment work.

Figure 96. Plan with the inclusion of cool materials and greening - Author elaboration

Figure 97. Inclusion of cool materials and green infrastructure on Westside neighborhood- Author elaboration

Pre

Figure 78



Post

Figure 92



Cool materials and greening:

PRE			POST		
TOT copertura pre 49577 mq			TOT copertura cool post 49577 mq		
asfalto pre mq	116715,9202		terra post	99374	mq
Gardens pre	30243	mq	asfalto cool post	17427	mq
terra pre	99374	mq	Gardens post	30879	mq
Trees pre	13684	mq	bioswales	2242	mq
			masselli inerbiti	68495	mq
			Trees post	29534	mq

EFFECTIVENESS:

Outdoor:

Wind speed: ●●●

UTCI: ●

Temperature: ●●●

UR%: ●●●

Indoor:

Wind speed: ●●

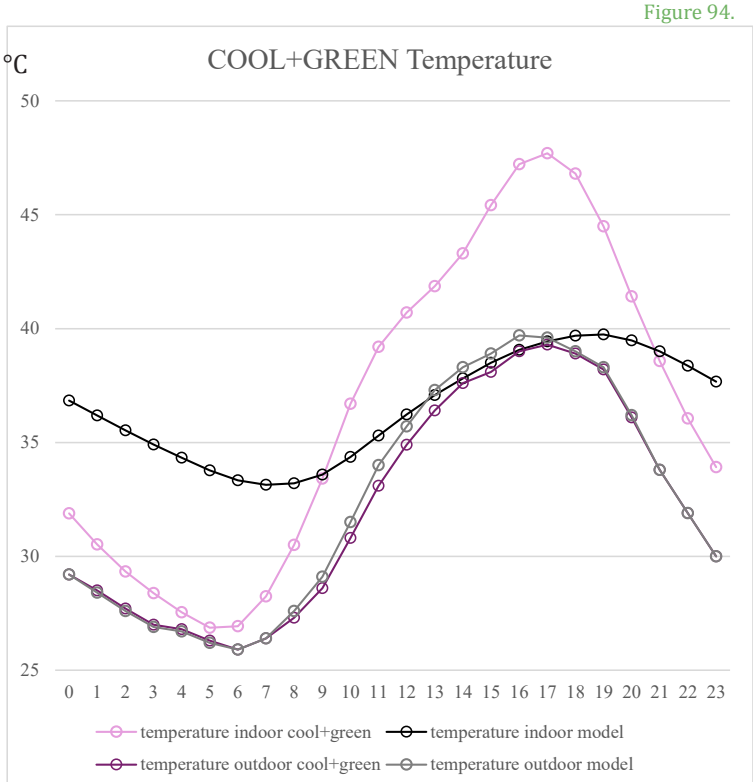
UTCI: ●

mrt indoor: ●●

UR%: ●●●

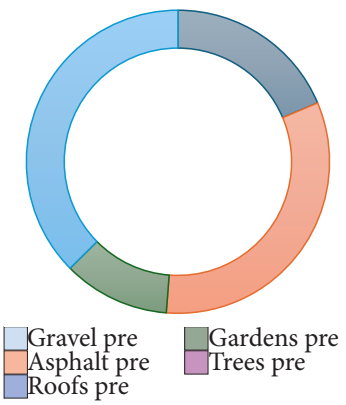
Temperature ●

Figure 94.



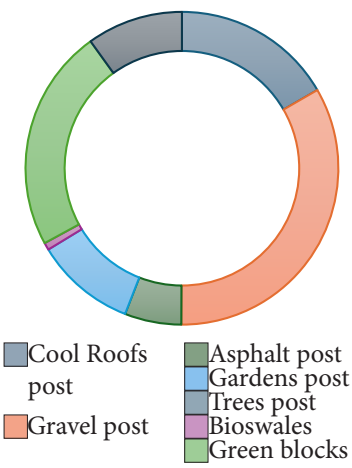
Pre:

Figure 93



Post:

Figure 95.



Cool materials and greening

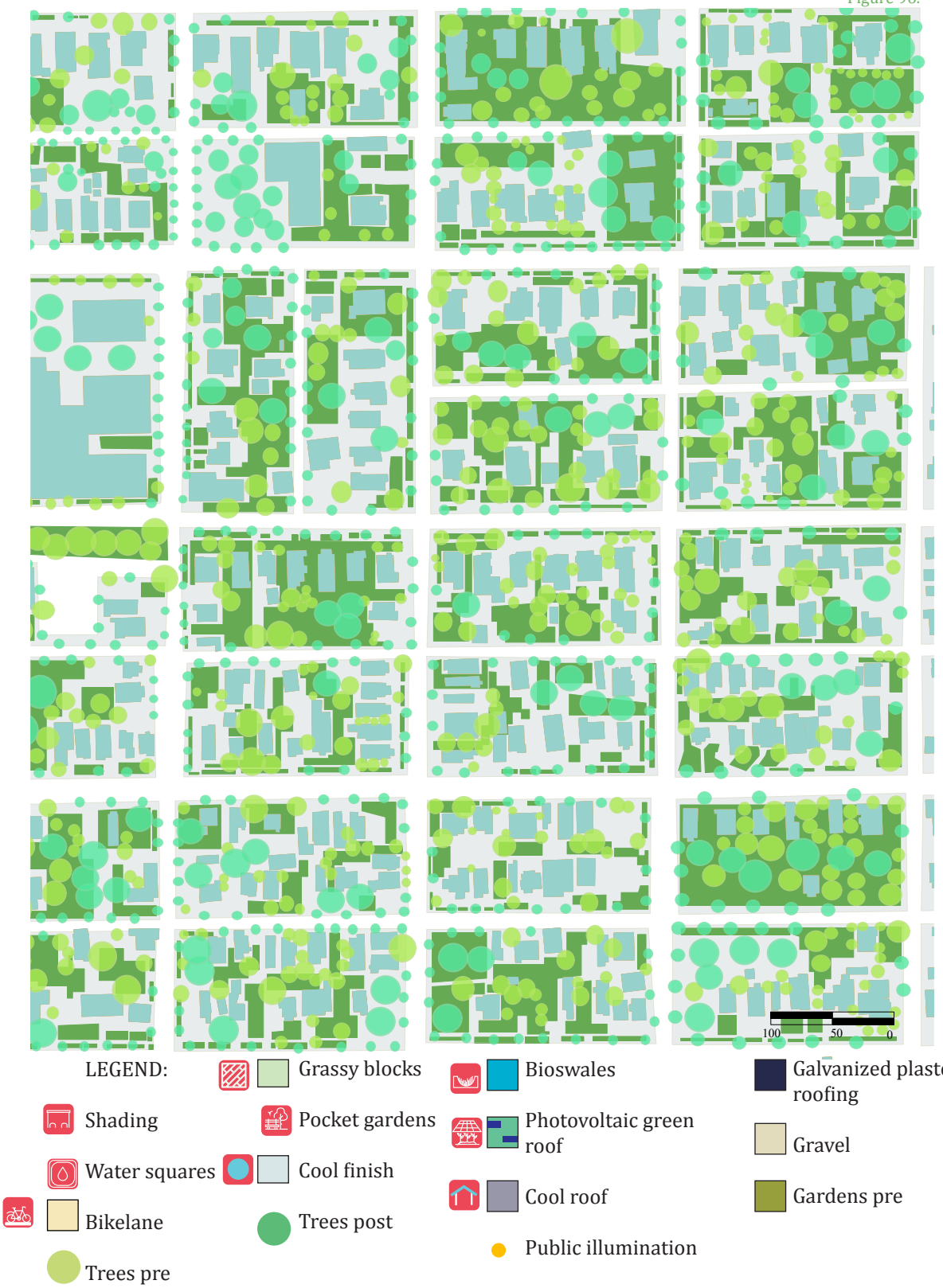
Figure 83.



Figure 97

Cool materials and greening

Figure 96.



Masterplan:

Figure 78 3d view of the inclusion of green infrastructures and cool materials in Westside neighborhood - Author elaboration

Figure 97. Plant of preintervention on Westside neighborhood - Author elaboration

Figure 98 3D view of a typical shotgun houses - Author elaboration

Figure 99. D view of a typical shotgun houses with bioclimatic and energetic solution post- Author elaboration

Figure 96. Plan pre - Author elaboration

Figure 100 MASTERPLAN POST- Author elaboration

Figure 101 a, b, c, d. Quantitative analysis of the type of surfaces, trees and type of roofing used

Figure 103. Schematic representation of the type of surfaces used in the master plan

Tab. VII. Analysis of the effectiveness of the technological solutions adopted

Figure 78.

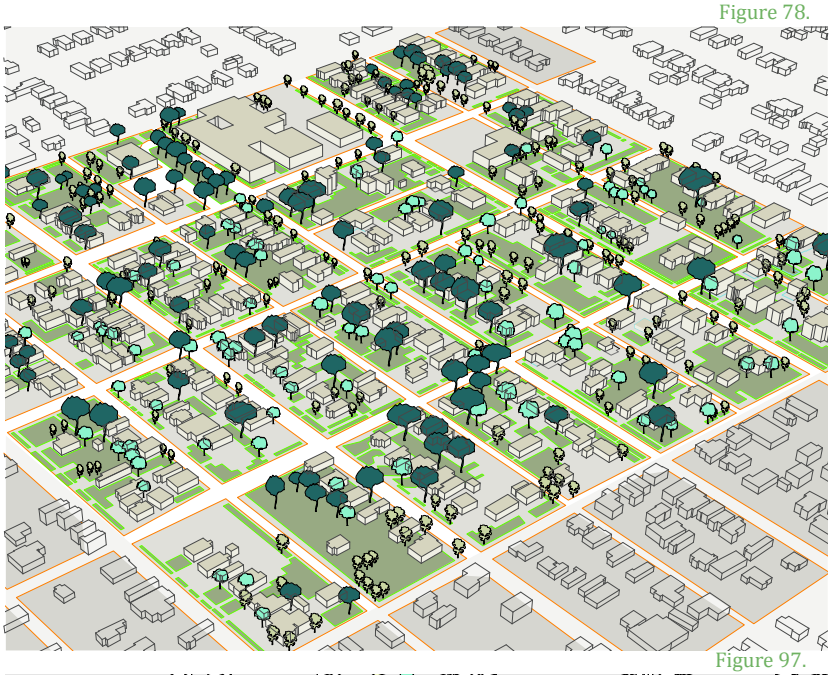
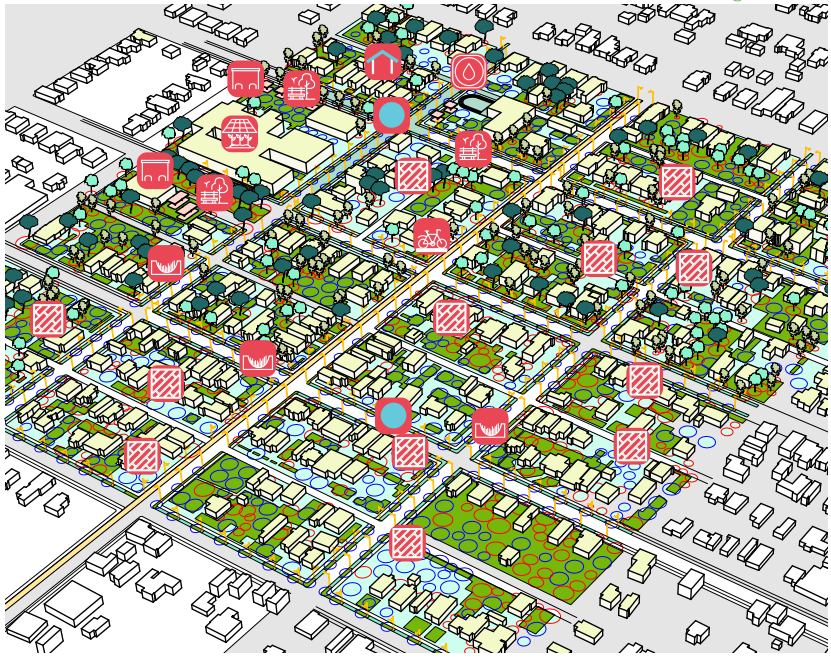


Figure 97.



Masterplan

Masterplan:

Figure 98.

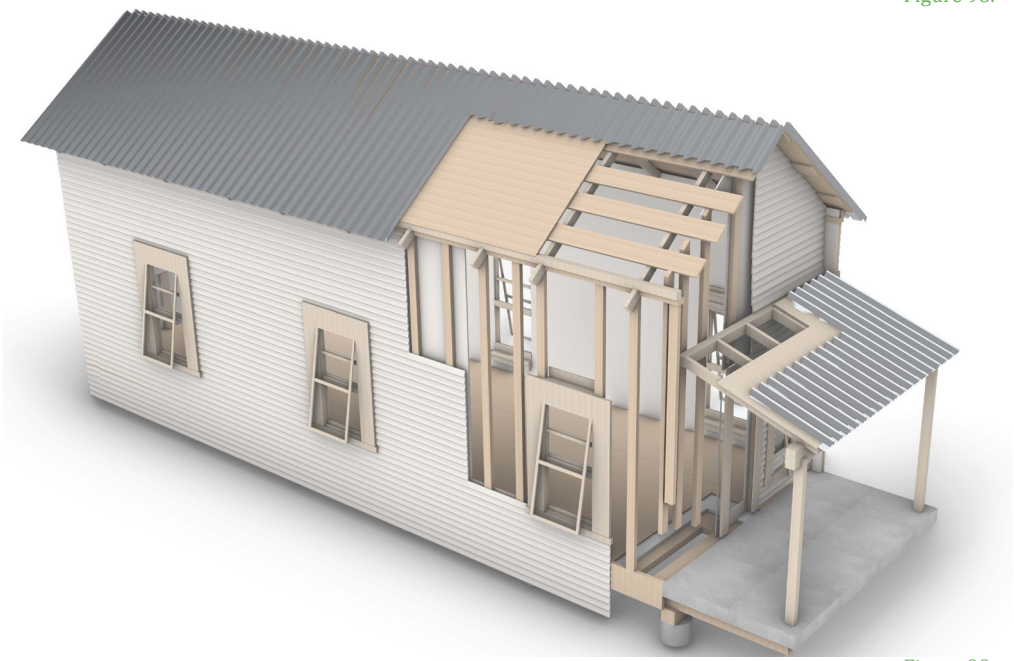


Figure 99.

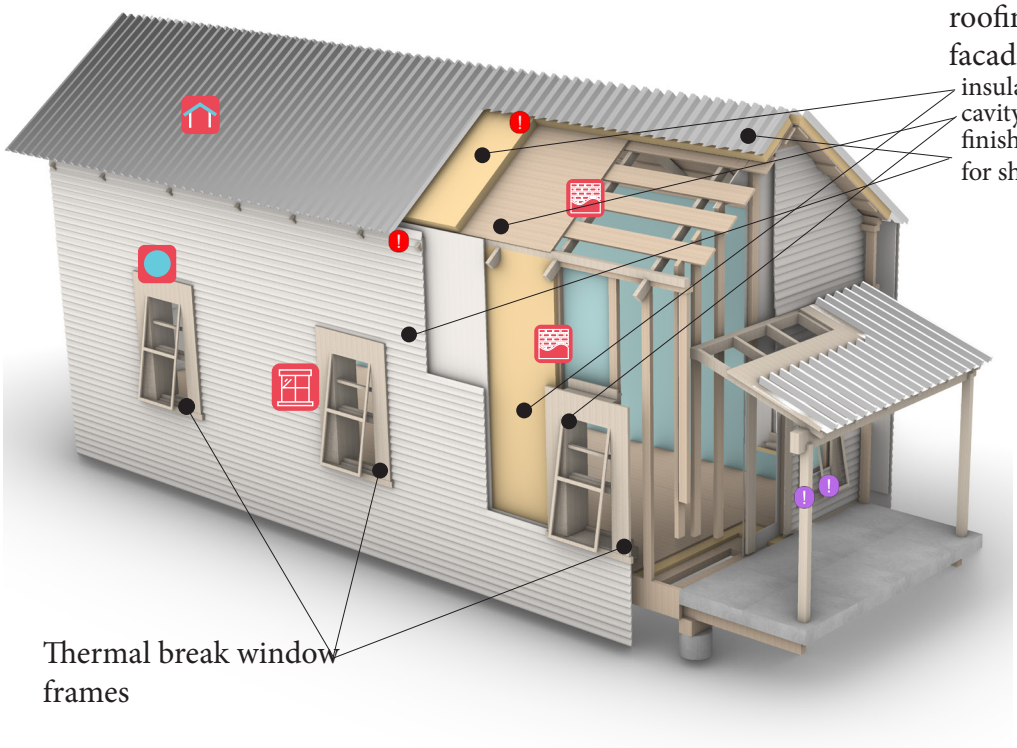
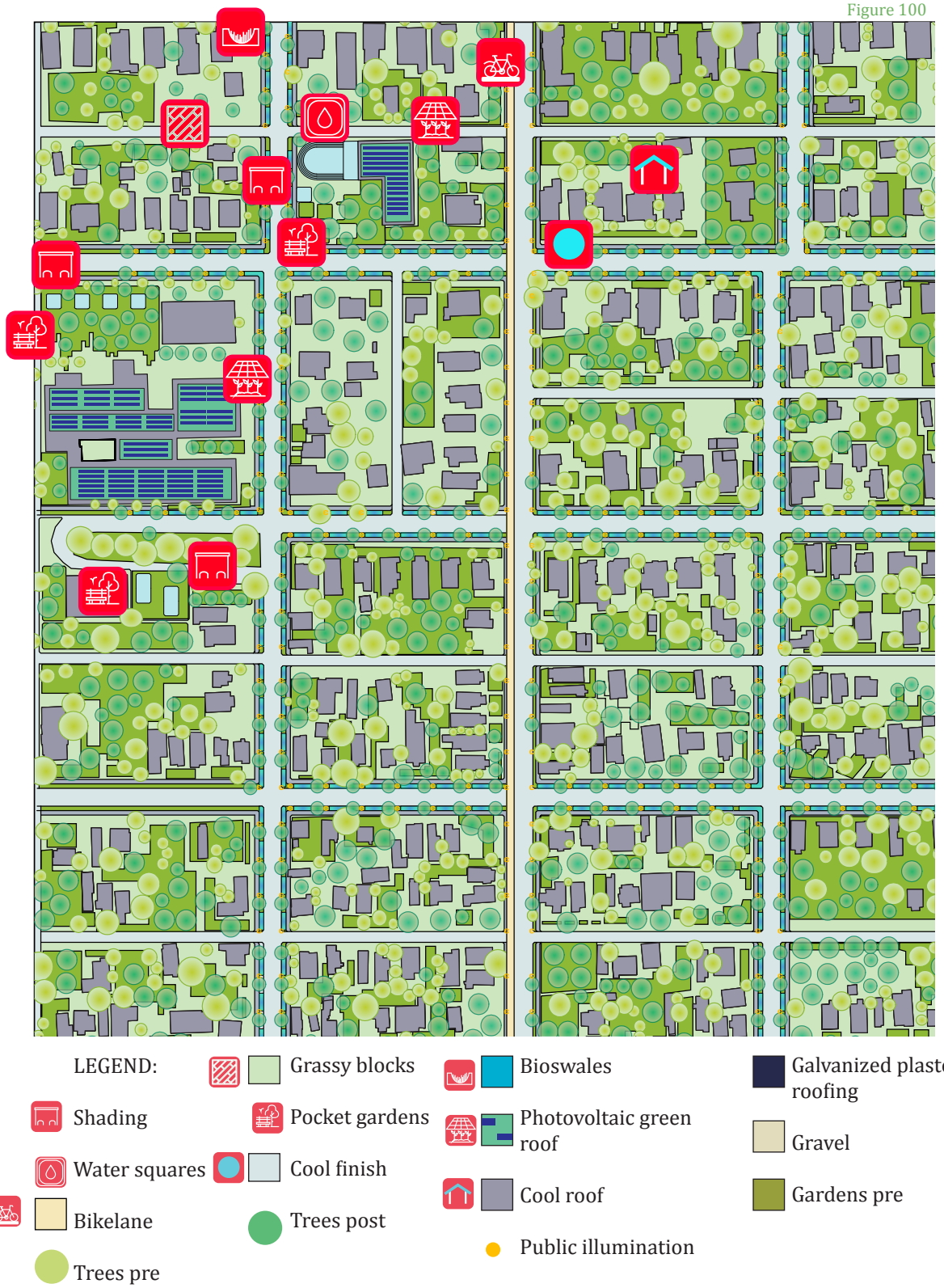


Figure 83.



Masterplan

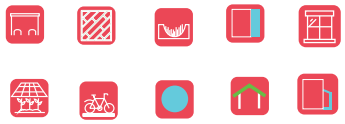
Figure 100



Objective:

MACRO OBJECTIVES

- Adaptation and mitigation of the urban heat island
- Adaptation and mitigation of extreme temperatures
- Adaptation and mitigation to heat waves



ANTHROPIC SYSTEM

- Decrease in the rate of degradation of structures and infrastructure due to continued high temperatures
- Decrease in soil, air and surface temperatures
- Management and reduction of alien species
- Restoration and enhancement of natural habitats
- Reforestation
- Redevelopment of existing consolidated buildings, environmental heritage



NATURAL SYSTEM

- Hydrogeological risk adaptation and mitigation
- Fire risk adaptation and mitigation
- Drought/aridity risk adaptation and mitigation
- Adaptation to flood risk
- Reduction of climate-altering emissions



WELL-BEING

- Increasing indoor and outdoor comfort also concerns reducing the risk of disasters and extreme events, including increasing prevention/ response capabilities
- Encouragement of the use of the neighbourhood

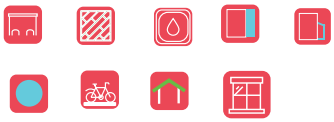


Figure 101 a.

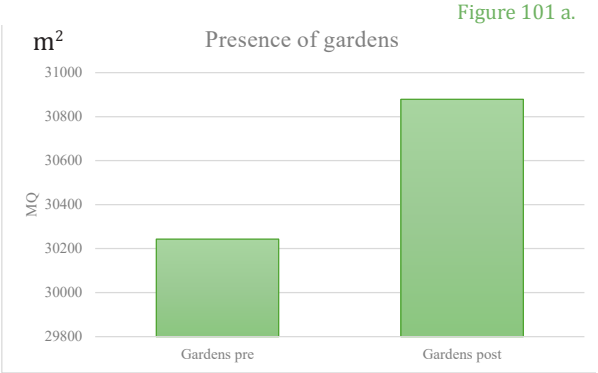


Figure 101 b.

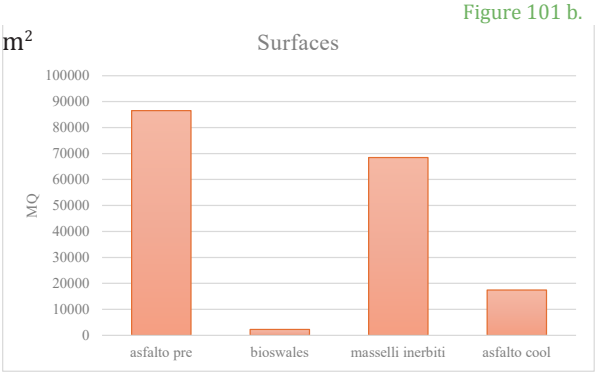


Figure 101 c.

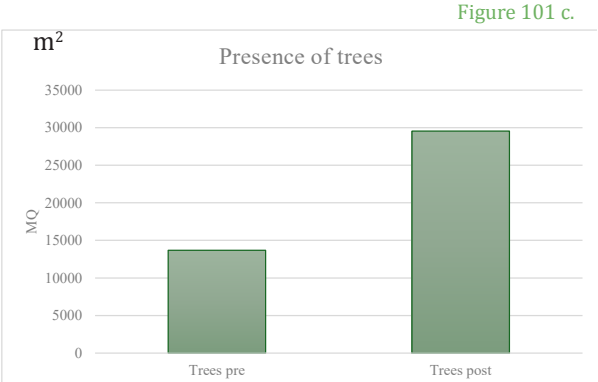
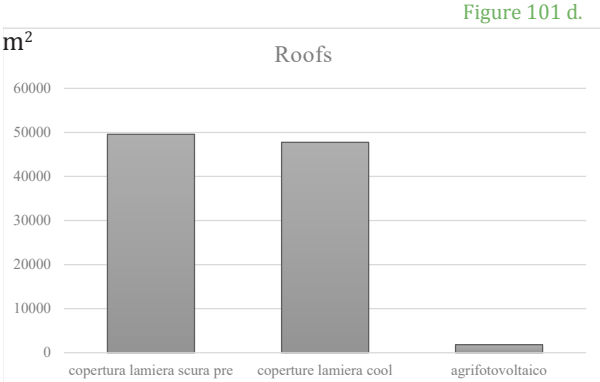


Figure 101 d.



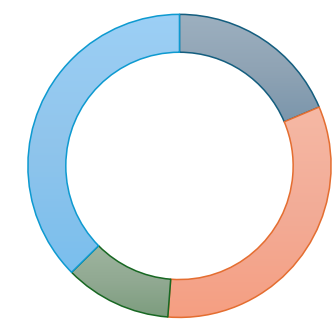
Tab VII.

p. 567

	EFFECTIVENESS:								RESPONSIVENESS			
	OUTDOOR				INDOOR				LIFE PERIOD			
	T	UR%	mrt	wind speed	T	UR%	mrt	wind speed	Period of installa-tion	Mainte-nace	Life span	Return en-vironemntal period
	●	●	●●	●	\	\	\	\	▭	!	▭	▭
	●	●●●	●●	●	\	\	\	\	▭	!!	▭	▭
	●	●●●	●●	●	\	\	\	\	▭	!!	▭	▭
	●●●	●●●	●●	●●●	●●	●●	●●	●	▭	!!!	▭	▭
	●●	●●●	●●	●●	●	●	●	\	▭	!!!	▭	▭
	●	●●	●●	\	●●●	●●●	●●	\	▭	!!!	▭	▭
	●●	●	●●●	●	●●	●●	●●●	\	▭	!	▭	▭
	●●	●	●●●	●	●●	●●	●●●	\	▭	!	▭	▭
	\	\	\	\	●●●	●●	●●●	\	▭	!	▭	▭
	\	\	\	\	●●●	●●	●●●	\	▭	!	▭	▭

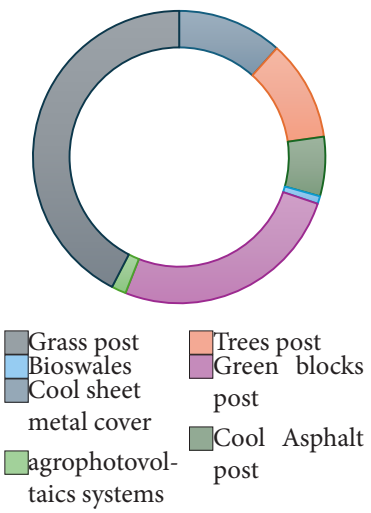
Pre:

Figure 93



Masterplan:

Figure 103.



Summary:

Figure 104. Indoor and outdoor temperature trends on the statistically warmest day of the year pre- and post-intervention. Author's elaboration

Figure 105. Maximum tempeature at 2 p.m. on the hottest day of the year indoors and oudoor pre- and post-intervention. Author's elaboration

Figure. 106 a, b, c, d. Trends in indoor and outdoor relative humidity, indoor mean radiant temperature and outdoor UTCI on the statistically warmest day of the year pre- and post-intervention. Author's elaboration

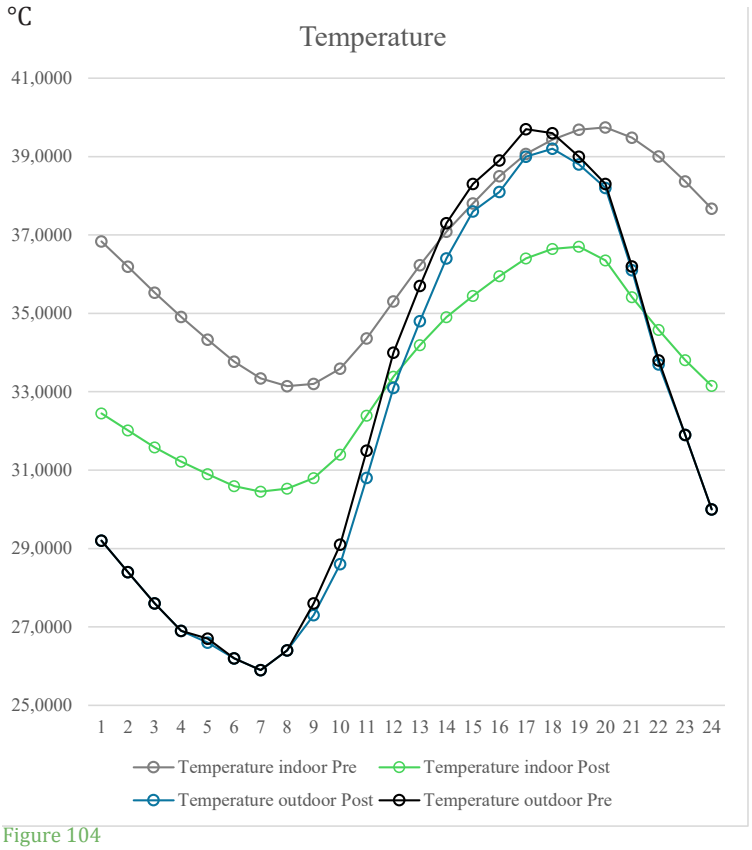


Figure 104

Figure 105

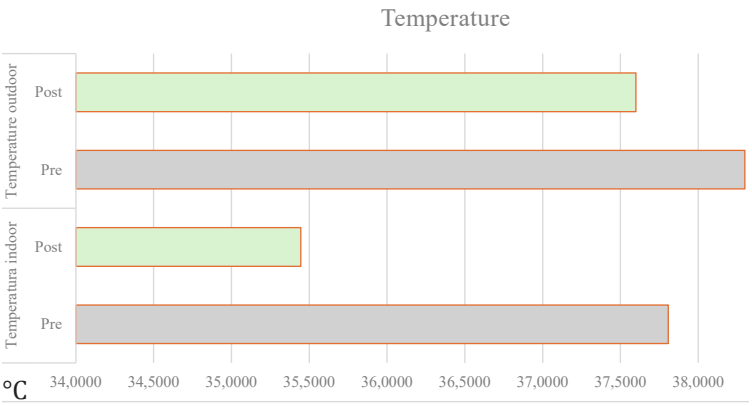


Figure 106a.

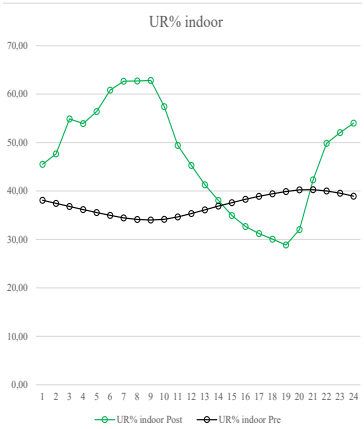


Figure 106b.

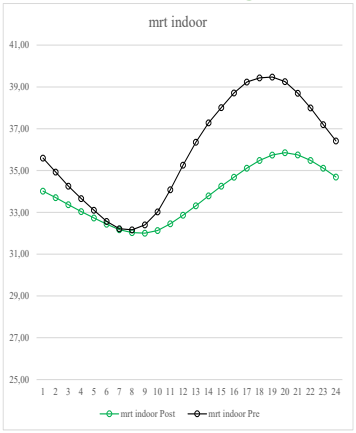


Figure 106c.

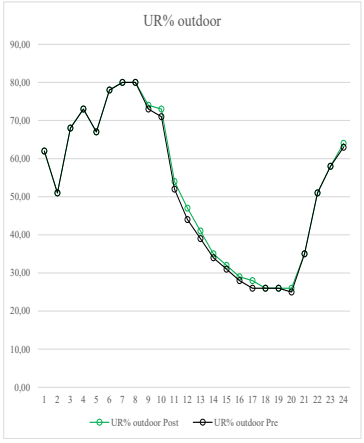
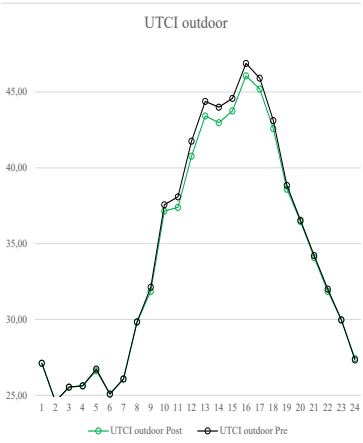


Figure 106d.



Masterplan and results.

Figures 81, 82, 89, 95, 103 illustrate the composition of surfaces in relation to the total intervention area before and after mitigation and adaptation measures and systems were implemented. The technologies used belong to those that affect the hazards highlighted in the matrix above. The selection is made according to the area's physical, cultural and architectural characteristics. In this case, for example, wind towers cannot be used because the buildings in the neighbourhood are too small. The actions selected consist of setting up pocket gardens and shady spots, increasing the number of trees, transforming surfaces into usable green areas, installing driveway paving slabs within the area, using cool finishes and roofing, thermal break window frames, ventilated façades, installing agri-photovoltaic systems on the roofs of public buildings, and installing water squares. Once the most effective actions within the district and their combinations are determined, they are tested by simulating them with the input of individual actions and combinations before elaborating on the final master plan. The technological solutions in the master plan have short payback periods: they all bring benefits immediately after installation. Despite being the most maintenance-intensive, the greenery solutions cover the most KPIs, followed by cold surfaces.

Tab VIII. Table summarising the effectiveness of the solutions through simulations carried out on the Westside neighbourhood. Author's elaboration

	T_{out}	T_{in}	$UTCI_{out}$	mrt_{in}	$UR\%_{out}$	$UR\%_{in}$
Cool	6.50	1.55	1.50	6	6.50	61.65
Green	6.50	1.53	1.56	5	6.50	61.43
Cool + Green	6.50	7.70	6.30	6	6.50	70.53
Masterplan	6.50	5.11	4.69	6	6.50	58.99

Tab VIII.

As shown in Table IV, on the bioclimatic level, the solutions adopted in the outdoor master plan consist of the installation of bioswales on the sides of the streets of pocket gardens with shady spots, water squares, the use of grassy cold surfaces, and an increase in the number of trees within the district. From the indoor point of view, the author proposes to increase the performance of the external envelope through the construction of ventilated façades, the installation of thermal break window frames, and the use of finishing materials with a high albedo index. In terms of energy, agro photovoltaic roofing is installed on public buildings. Cool materials alone allow the temperature to drop to a maximum of 6.50 °C in summer. The presence of green solutions alone, such as pocket gardens, bioswales or tree-lined avenues, also decreases the temperature to 6.50 °C. By combining the two solutions, the temperature decrease does not change. On the contrary, the relative humidity level increases and decreases with the internal temperature up to 7.70 °C. The simulation of the master plan predicts a decrease in air temperature of up to 6.50 °C for a better perception of comfort than with the use of greening and cool materials alone. At the indoor level, the temperature decreases to 1.55 °C using cool materials and 1.53 °C with the greening solutions.

4.2| Quarticciolo, Rome, IT

Figure107. Rome localization - Autor's elaboration on QGIS

Figure 108. Rome area - Autor's elaboration on QGIS

Figure 109. Autor's elaboration on QGIS

Figure 110. Neighborhood area - Autor's elaboration on QGIS

Contextualisation in the urban fabric.

The suburb is located along Via Prenestina, beyond the 19th-century fortress, near the General Markets and Slaughterhouse area, on a plot of approximately 390 hectares. It consists of eleven lots, with 3- to 5-storey buildings for residential and partly for commercial use. Quarticciolo is a district of Rome that belongs to the fifth municipality in the eastern part of the city. In the urban development plan, the area corresponds to the twentieth-century type of expansion with continuous fronts. The area has mainly residential spaces, open spaces, a twentieth-century expansion fabric with free-standing buildings, and medium settlement density.

Figure 107.



Figure 108.

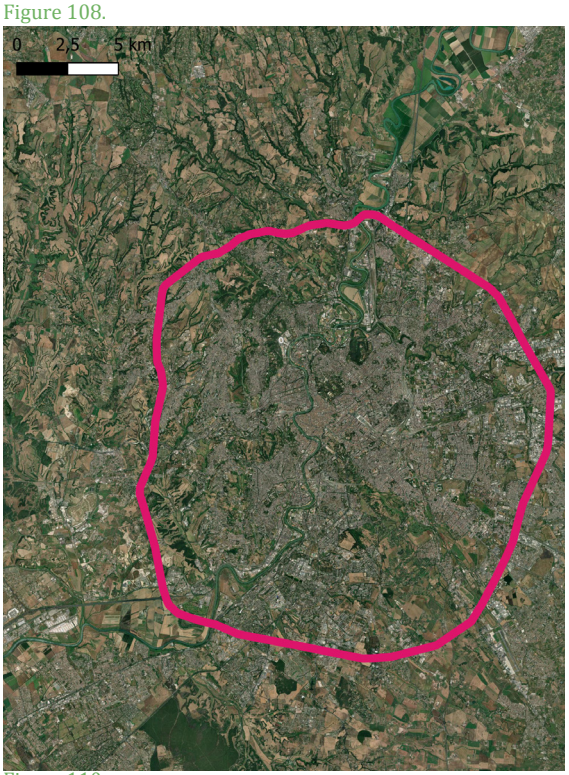


Figure 109.



Figure 110.

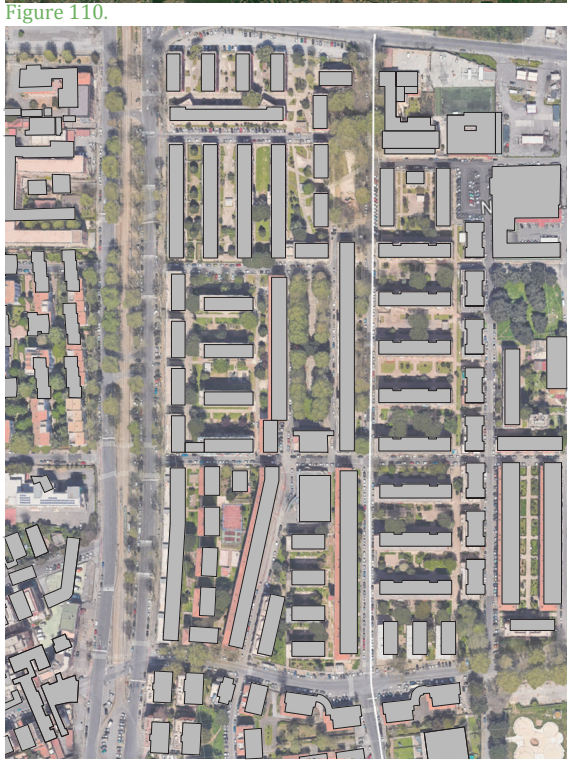


Figure111 a, b, c. Picture of Quarticciolo plaza, made by the autor (08/06/2025)

Figure 112. Picture of Quarticciolo neighborhood, made by the autor (08/06/2025)



Figure 111 a.

Figure 111 b.



Figure 112.



Figure 111 c.





GENERAL ANALYSIS

PRG Framework

Figure 113.



Sistema insediativo

CITTÀ STORICA
Tessuti vedi tavole 1:5000
T5 Espansione otto-novecentesca a lottizzazione edilizia puntiforme
T6 Espansione novecentesca a fronti continue
T7 Espansione novecentesca a lottizzazione edilizia puntiforme
T8 Espansione novecentesca a impianto moderno e unitario
T10 Nuclei storici isolati
Edifici e complessi speciali
Centro archeologico monumentale
Capisaldi architettonici e urbani
Ville storiche
Grandi attrezzature e impianti post-unitari
Edifici speciali isolati di interesse storico-architettonico e monumentale
Spazi aperti vedi tavole 1:5000
Spazi verdi privati di valore storico-morfologico-ambientale
Ambiti di valorizzazione
An Spazi aperti di valore ambientale
Bn Tessuti, edifici e spazi aperti
Cn Aree dismesse e insediamenti prevalentemente non residenziali
Dn Ostia Lido

CITTÀ CONSOLIDATA
Tessuti di espansione novecentesca a tipologia edilizia definita e a media densità insediativa - T1
Tessuti di espansione novecentesca a tipologia edilizia definita e ad alta densità insediativa - T2
Tessuti di espansione novecentesca a tipologia edilizia libera - T3
Verde privato
Programmi integrati
Pn codice identificativo

CITTÀ DA RISTRUTTURARE
Tessuti
prevalentemente residenziali
prevalentemente per attività
Programmi integrati
n codice identificativo
Spazi pubblici da riqualificare
Proposte programmi di recupero urbano art. 11, L 493/93
Individuazione dei nuclei di edilizia ex abusiva da recuperare

CITTÀ DELLA TRASFORMAZIONE
Ambiti di trasformazione ordinaria
Rn prevalentemente residenziali
In integrati
Ambiti a pianificazione particolareggiata definita

PROGETTI STRUTTURANTI
Centralità urbane e metropolitane
a pianificazione definita
da pianificare
Centralità locali
Spazi pubblici da riqualificare

AMBITI DI RISERVA
Ambiti di riserva a trasformabilità vincolata

Sistema ambientale

ACQUE
Fiumi e laghi

PARCHI
Parchi istituiti e tenuta di Castel Porziano

AGRO ROMANO
Aree agricole

Sistema dei servizi e delle infrastrutture

SERVIZI
Verde pubblico e servizi pubblici di livello locale
Servizi pubblici di livello urbano
ci cimiteri
æ aeroporti
Verde privato attrezzato
Servizi privati
Campeggi

INFRASTRUTTURE PER LA MOBILITÀ
Ferrovie nazionali, metropolitane e in concessione, aree di rispetto
Metropolitane
Stazioni
Strade
Nodi di scambio
Porti
pc commerciali
pt turistici

INFRASTRUTTURE TECNOLOGICHE
Infrastrutture tecnologiche
Confine comunale

GENERAL ANALYSIS

Figure 114.

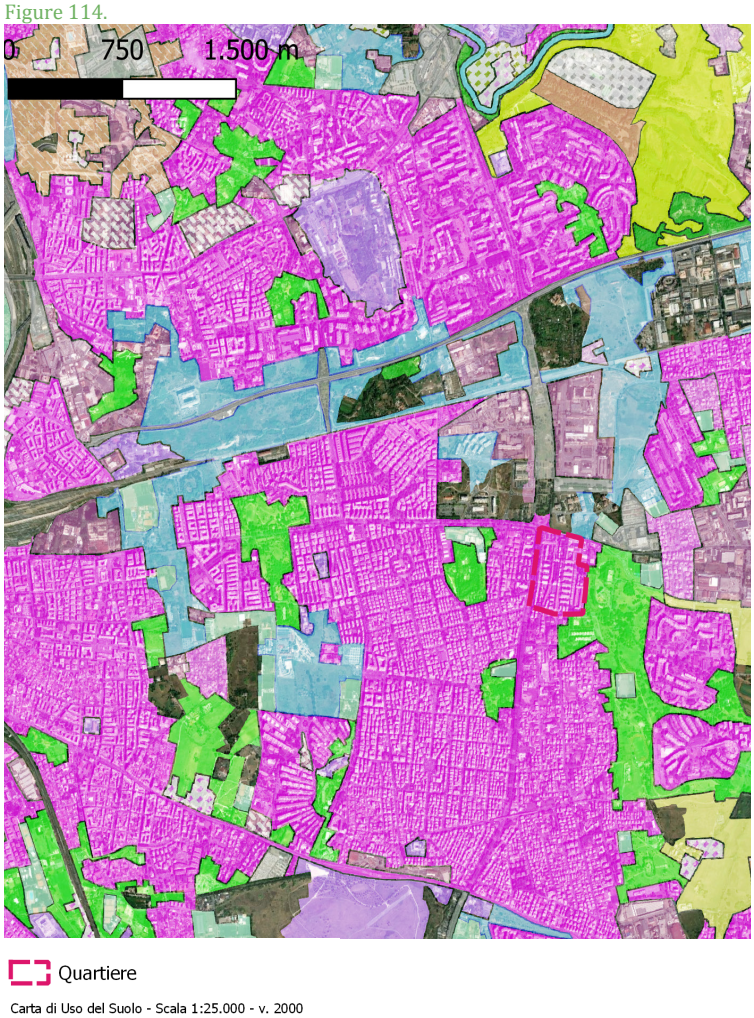


Figure 114. Excerpt from the master plan of Rome. The figure shows the location and use of the area. Author elaboration on QGIS.

Climatic analysis.

The climatic picture of the Roman landscape includes rainfall averaging around 11 days per month, with peaks in April and November. In the summer months, rainfall decreases. The city is characterised by partly cloudy days and only sporadic overcast skies. Winds blow mainly from the east and northeast. Temperatures in Rome during the year vary from 40 °C in summer to 0 °C in winter, with a few days of frost that do not exceed 5 per month, concentrated in December, January and February, and snow phenomena that have a very low probability, statistically concentrated in February. Below are schematically presented average climatic histories, which illustrate in detail the climatic characterisation of the area.

Figure 115. The diagram represents the sky conditions in Rome for different months of the year. www.meteoblue.com

Figure 116. The diagram represents the average temperature in Rome in the various months of the year. www.meteoblue.com

Figure 117. The diagram represents the wind characteristics (direction and speed) in Rome. www.meteoblue.com

Figure 115.

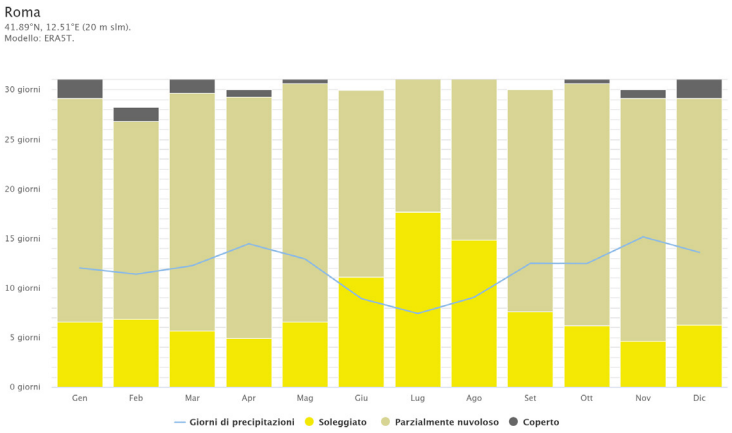


Figure 116.

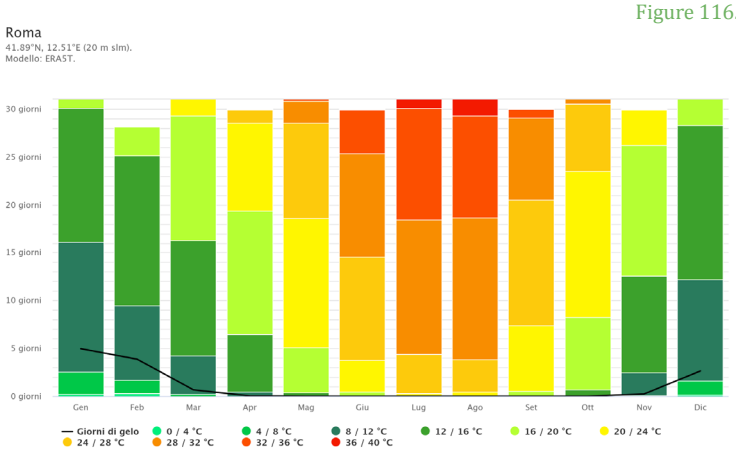


Figure 117.

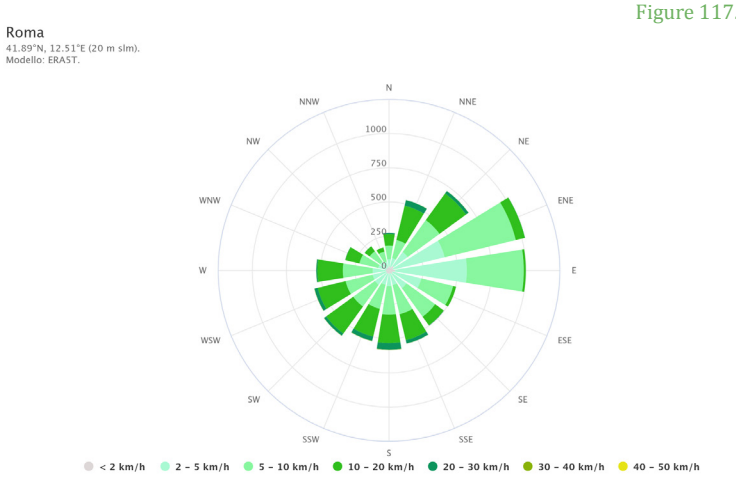


Figure 118.

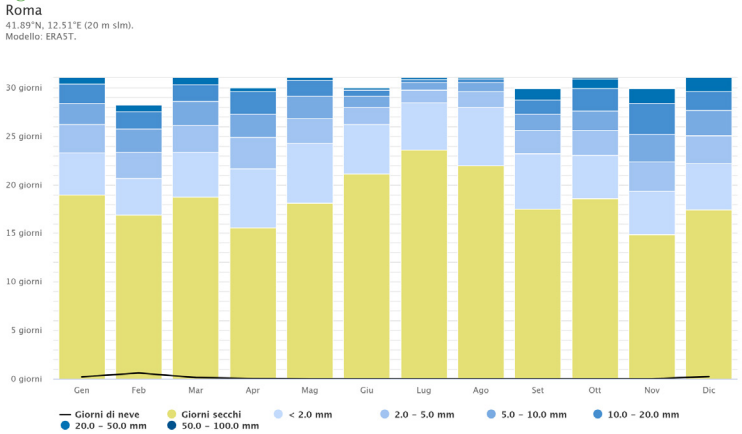


Figure 119.

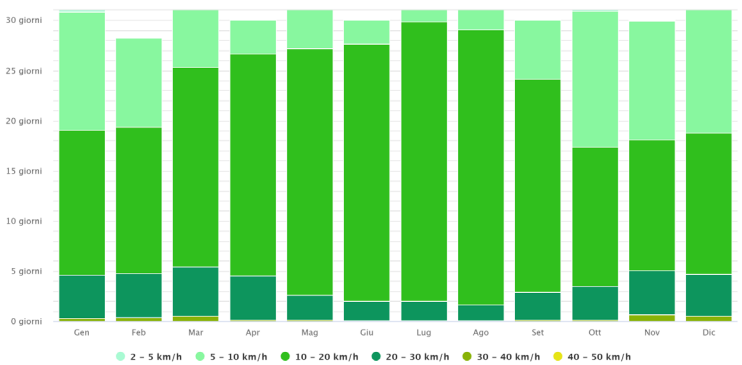


Figure 120.

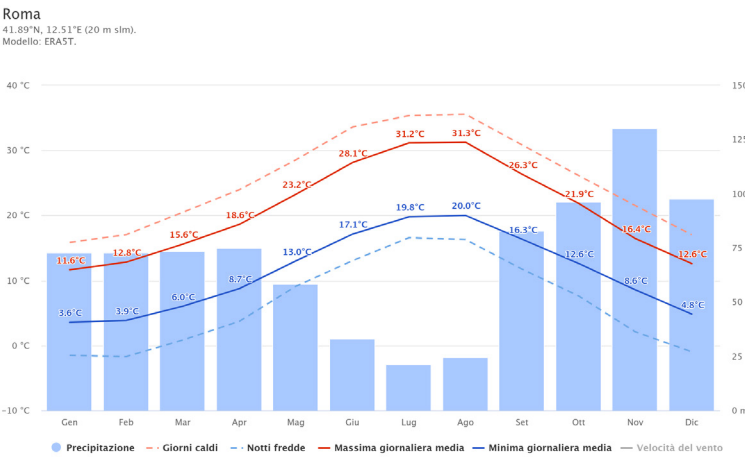


Figure 118. The graph represents the amount of rain that fell and the dry days during the various months of the year. www.meteoblue.com

Figure 119. The graph represents the average wind speed in different months of the year. www.meteoblue.com

Figure 120. The graph represents precipitation, average nighttime and daytime temperatures, maximums, and minimums for the various months of the year. www.meteoblue.com

Welfare and services analysis.

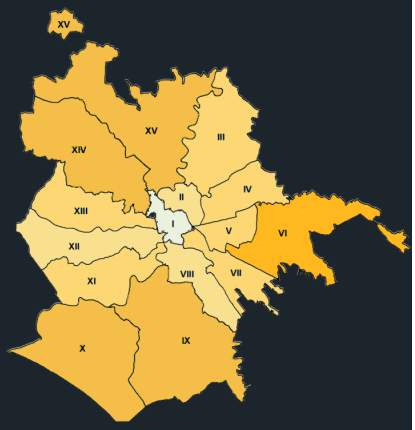
Figure 121. The diagram represents an analysis of kindergarten coverage in the area. Reworked based on Lorenzo Mariani's dissertation.

The area refers, as a hospital service, to the Casilino hospital, which can be reached by public transport (19 minutes), by bicycle (11 minutes) and by personal transport (8 minutes). The data in the tables show a low number of beds for the health sector - currently 219, with an even lower number of places for long-term care. This lack of beds causes overcrowding in healthcare facilities. This problem exacerbates the impacts on the well-being of the islands and heat waves in all segments of the population, particularly the weakest. The average age in the area is around 45/50 years, with 2590 children enrolled in nurseries, most of whom are enrolled in private nurseries managed indirectly by the municipality. The Sapienza, Tor Vergata, and Roma Tre universities can be reached by public transport (50 minutes for the first, 61 minutes for the second and 58 minutes for the third), by bicycle - 30 minutes for the first two and 48 minutes for the third - and by car - 16 minutes for the first two and 14 minutes for the third. The municipal offices are six minutes from the neighbourhood or three minutes by bicycle. Within the neighbourhood are medical offices, restaurants, a gymnasium, places of worship and centres for the elderly. Next to the neighbourhood are police stations and supermarkets, shops and educational facilities. There are critical points that are difficult to cross and potentially dangerous at night, southwest and southeast of the neighbourhood, respectively. In general, journeys to major interchanges are long, and the area is poorly connected to the rest of the city.

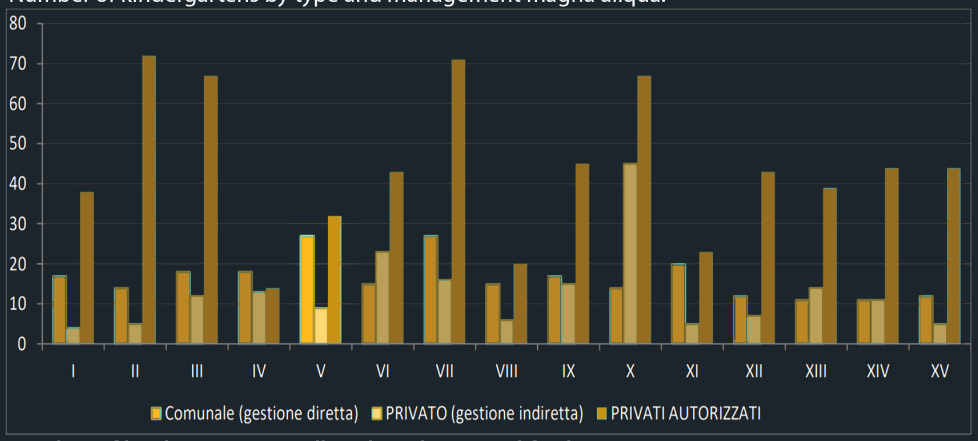
Figure 121.

Analysis of Kindergarten Coverage in Rome's Municipal District 5 (Academic Year 2020/2021)

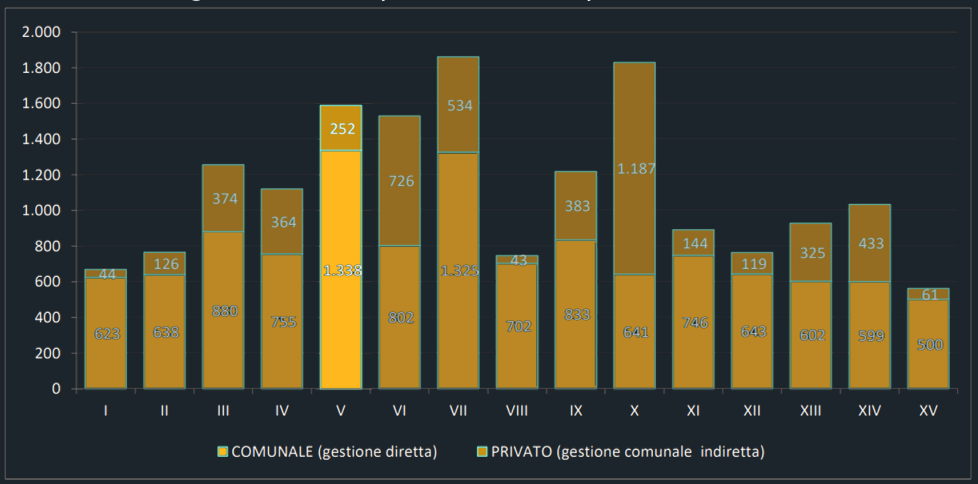
In Rome's Municipal District 5, 2590 children are enrolled in kindergartens, out of an annual average of about 4,000. This figure shows coverage of 64.75%, underscoring the importance of examining strategies and solutions to improve access to educational facilities in the area.



Number of kindergartens by type and management magna aliqua.



Number of kindergarten enrollees by educational facility - 2020/2021



Fonte: Annuario statistico di Roma Capitale, 2021

Figure 122.

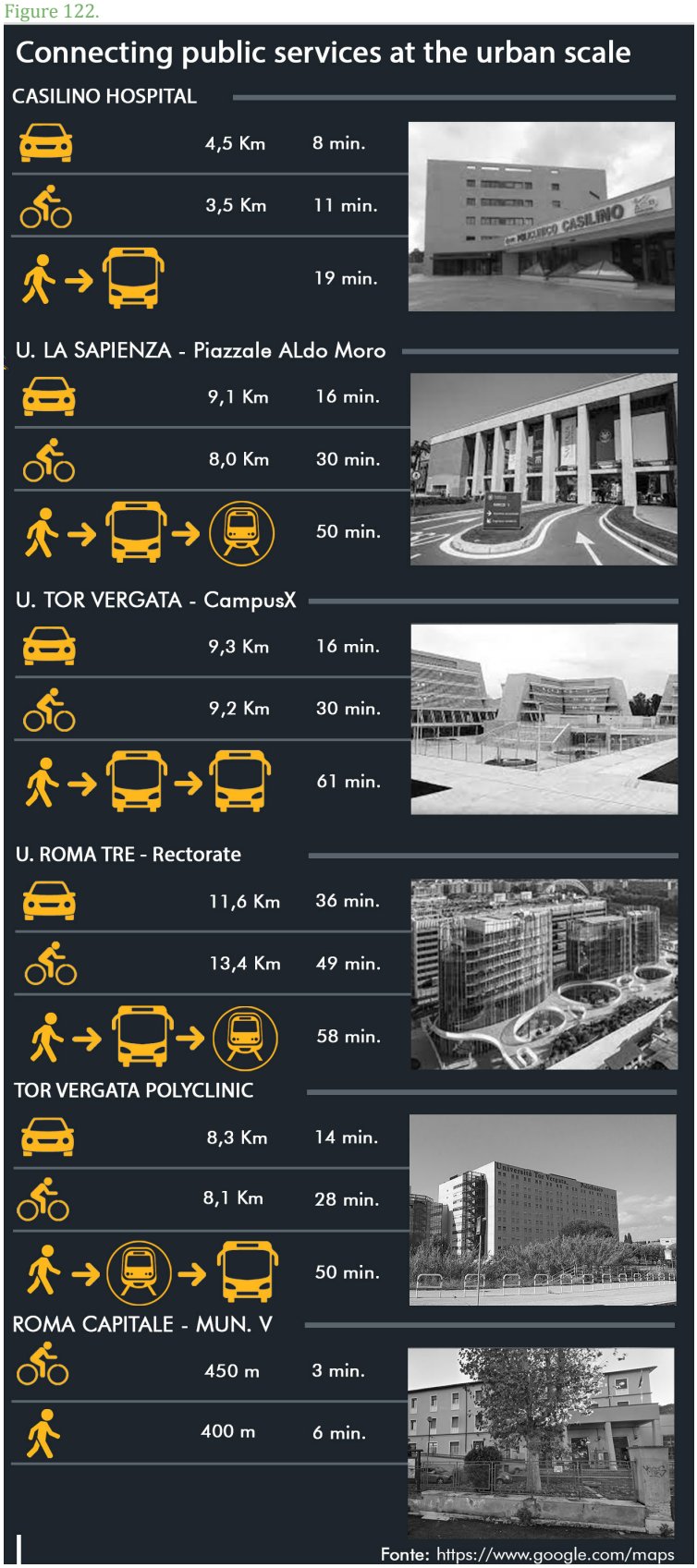


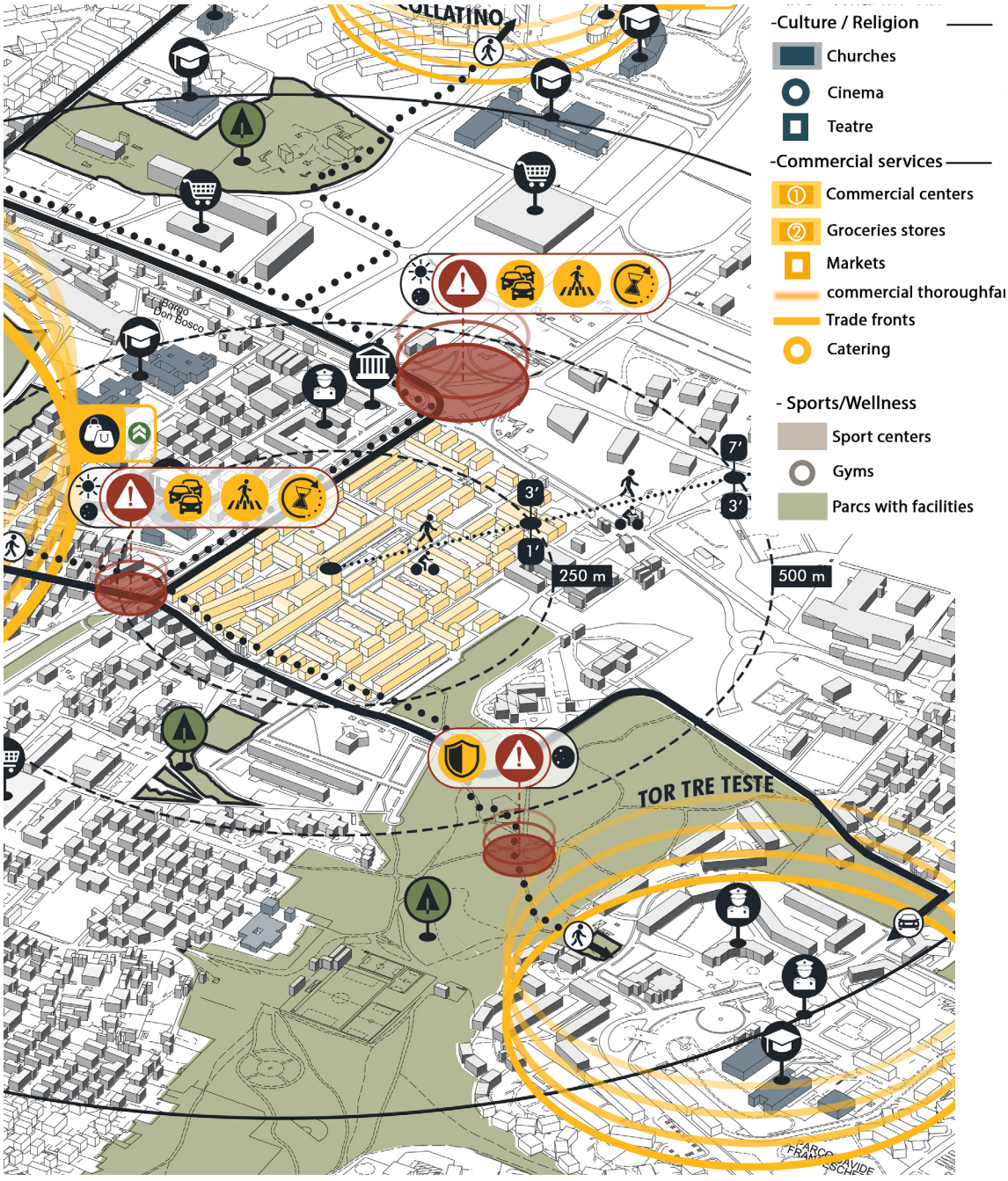
Figure 122. The diagram illustrates the distances to various points of interest located around the pilot case. Reworked based on Lorenzo Mariani's dissertation.

Historical analysis.

The Roman suburb of Quarticciolo, designed by Roberto Nicolini, was built in 1940 and completed between the 1950s and 1960s. The plot belonged to the Quarticciolo estate owned by the chapter of Santa Maria Maggiore, then purchased by the governorate in December 1938. The complex consisted of a vast rural estate close to the strip of vineyards outside the Walls for arable and pastoral use. In each lot, the distribution of the buildings, with a north-south or east-west orientation, leaves space for large courtyards on the residences: semi-public spaces, open to a pedestrian crossing, destined in part for horticultural use (in the eastern sector) and in part for gardens. The green layout outlined in the project elaboration is not realised: the courtyards were fitted out with clotheslines, small fenced-off spaces for play and areas for bicycles and motorbikes to park, while the care of the squares and streets, ceded by the Istituto Autonomo per le case Popolari to the municipality in 1954, became the responsibility of the Garden Service, which in the same year provided for the creation of the necessary 'breathing green spaces' - the garden in Piazza del Quarticciolo, the trees in Largo Mola di Bari and Via Manfredonia, Via Lucera and Via Molfetta. In the 1950s, the township expanded by constructing a 'building complex' comprising the Andrea Dori primary schools, the offices of the municipal delegation, the sanitary station, a public baths building and three groups of affordable housing - about 600 flats. In 1960 a covered market was inaugurated, and a monument to the Fallen in war was erected on the main square. These works were also accompanied by the commitment of the Pontifical Opera through the construction of the parish hall and the Church of the Ascension of Our Lord Jesus Christ by the Opera accompanied these works. In 1947, part of the lot for the school was occupied by the Corallo cinema arena, designed by Renato Marconi. 1959, the cinema was closed, and the premises were used as a warehouse for the local market. In the 1960s, the former cinema was rented to Francesca Rame, who set up a theatre club inside. Film activity at the Corallo cinema then resumed in 1973. In the 1990s, it was purchased and became a supermarket: this change of use was accompanied by demolition and splitting operations that affected its historical and architectural character. In 2007, a new cultural centre was built in the township, represented by the library theatre, the result of the redevelopment of the former district market by the architectural studio F. Pepe & A. Pepe. Pepe & A. Preziosi. Since the 1990s, the neighbourhood has been the subject of intense recovery and redevelopment activities involving changes in materials and the outline of the buildings without altering their historical character (Accorsi & Chiavoni, 2023).

Figure 123. Infrastructure analysis. Reworked based on Lorenzo Mariani's dissertation.




-Culture / Religion
Churches
Cinema
Teatre
-Commercial services
Commercial centers
Groceries stores
Markets
commercial thoroughfai
Trade fronts
Catering
- Sports/Wellness
Sport centers
Gyms
Parcs with facilities
7′
3′
3′
1′
250 m
500 m
TOR TRE TESTE

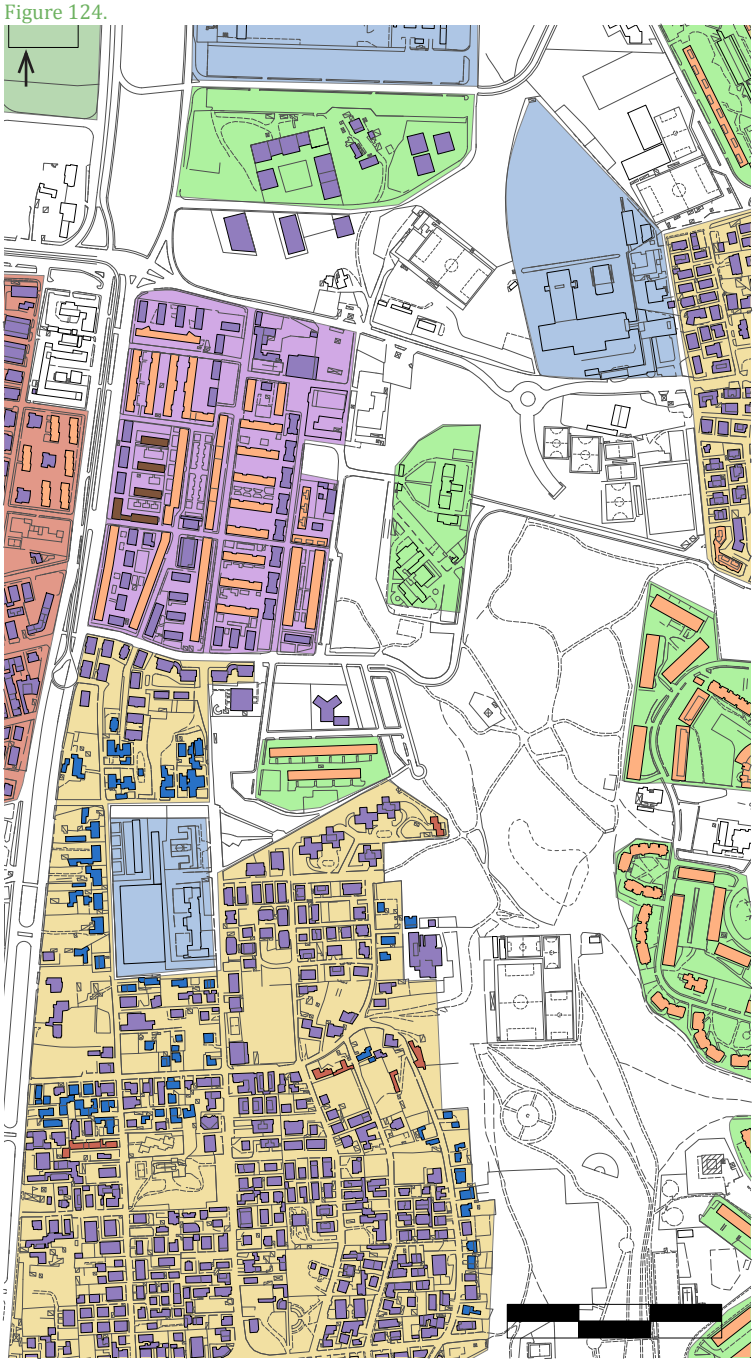
Morpho-typological analysis.

The area, according to the master plan, corresponds to an area with a twentieth-century fabric and high building density. Within it, there are in-line buildings and isolated buildings. The average height of the buildings is 15 metres, and the streets' width varies from a minimum of 8 metres to a maximum of 40 metres. The ratios of building height to street width thus vary from 2.1 in smaller streets parallel to the main street to 0.4 for wider streets, while the average ratio of building to street width is 0.8
The buildings' average height is 15 metres, and their width is around 19 metres. The surveyed masonry is made of tuff 'Roman style' stripes with sparse recurrences of solid bricks extended within the thickness; the roofing is instead made of a cement-lime slab, masonry, and hollow blocks, which was originally intended to create an aerated 'ceiling'[37].

37. The information regarding the wall packages comes from *Azienda Territoriale per l'Edilizia Residenziale Pubblica del Comune di Roma (10/06/2021), Località Quarticciolo, Lotto VII, Fabbricato n. 11, Edificio via Ugento n. 37 - Relazione generale del Progetto definitivo 'Intervento di restauro e risanamento conservativo - Accesso agli incentivi statali previsti dalla legge 17 luglio 2020, n. 77, superbonus 110 per cento per interventi di efficienza energetica e interventi antisismici',* pp. 9 and 10.

Figure 124. Morphotypological analysis of the area. Reworked based on Lorenzo Mariani's dissertation.

Figure 124.



Legend:
BUILDING TYPES
isolated single-family: Type often single-family. This type includes housing units developed from ground to sky with a more or less sizeable private garden.

'terraced': a general typology resulting from the aggregation in a series of several housing units: each dwelling has a wall in common with adjacent units

line: Type generated by the linear aggregation of several multi-storey building units. The line of aggregation is often, but not necessarily, rectilinear.
block: Variant type of line: The course of the main line is deformed according to a break to circumscribe all or part of an internal space

with gallery: Variant type of line: The course of the main line is deformed according to a break to circumscribe all or part of an internal space

Isolated: isolated multi-storey typology, with shared vertical connectives and private and/or common open outdoor areas

SETTLEMENT
T1 - 20th-century expansive fabric with a defined building type and medium settlement density
T2 - Novecetean expansive fabrics with defined building typology and high building density
T3 - twentieth-century expansion fabrics with free-building typology
T4 - fabrics defined by PRG in 'City to be restructured' with predominantly residential character
T8 - fabrics defined by PRG in 'City to be restructured' with predominantly residential character
S1 - private services
S2 - public services

MORPHOTYPOLOGICAL ANALYSIS

Figure 125, 126, 127. The graphs analyse the types and morphologies of buildings in the area under examination. Reworked based on Lorenzo Mariani's dissertation.



Figure 125.

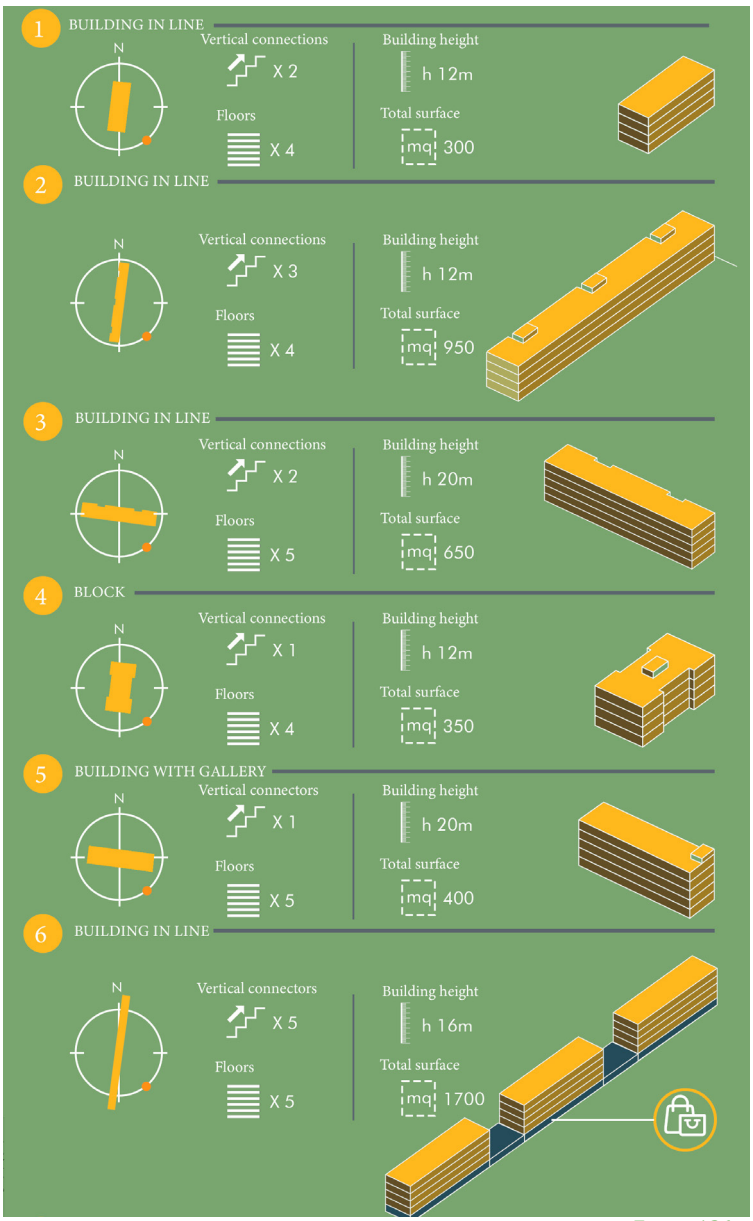

1
BUILDING IN LINE
N
Vertical connections
X 2
Floors
X 4
Building height
h 12m
Total surface
mq 300
2
BUILDING IN LINE
N
Vertical connections
X 3
Floors
X 4
Building height
h 12m
Total surface
mq 950
3
BUILDING IN LINE
N
Vertical connections
X 2
Floors
X 5
Building height
h 20m
Total surface
mq 650
4
BLOCK
N
Vertical connections
X 1
Floors
X 4
Building height
h 12m
Total surface
mq 350
5
BUILDING WITH GALLERY
N
Vertical connectors
X 1
Floors
X 5
Building height
h 20m
Total surface
mq 400
6
BUILDING IN LINE
N
Vertical connectors
X 5
Floors
X 5
Building height
h 16m
Total surface
mq 1700

Figure 126.

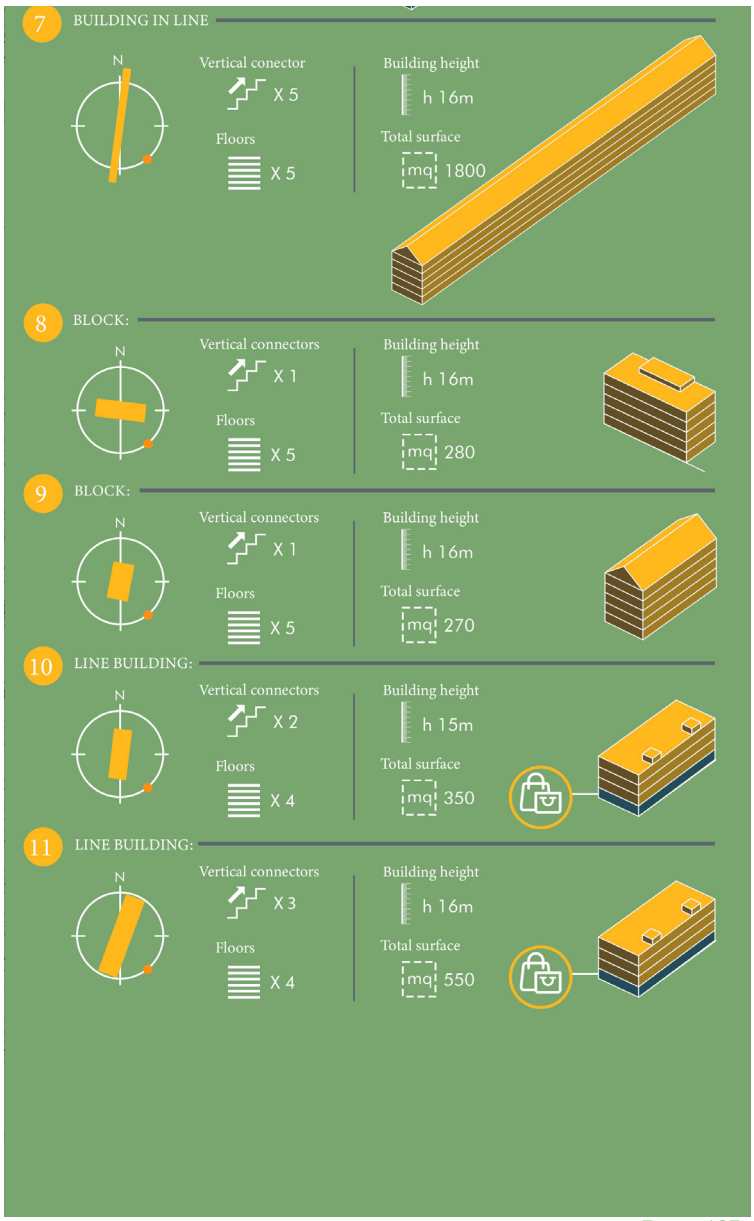

7
BUILDING IN LINE
N
Vertical conector
X 5
Floors
X 5
Building height
h 16m
Total surface
mq 1800
8
BLOCK:
N
Vertical connectors
X 1
Floors
X 5
Building height
h 16m
Total surface
mq 280
9
BLOCK:
N
Vertical connectors
X 1
Floors
X 5
Building height
h 16m
Total surface
mq 270
10
LINE BUILDING:
N
Vertical connectors
X 2
Floors
X 4
Building height
h 15m
Total surface
mq 350
11
LINE BUILDING:
N
Vertical connectors
X 3
Floors
X 4
Building height
h 16m
Total surface
mq 550

Figure 127.

Geology and Hydrogeology.

As can be seen from the figures128, 129, 130, elaborated by QGIS, the Quarticciolo area is located in an amia zone characterised by carbonate units, with low hydrogeological risk, far from buried tectonic lineaments and linear springs. The soil is composed of gravel, sand, and clay, which give the land a good drainage capacity but, at the same time, make it less cohesive. Close to Quarticciolo, considered in the landscape map as an area of urban settlement, there are natural and diffuse historical settlement areas corresponding to the Giovanni Palatucci park the adjacent green zone, and the Torre Angela area.

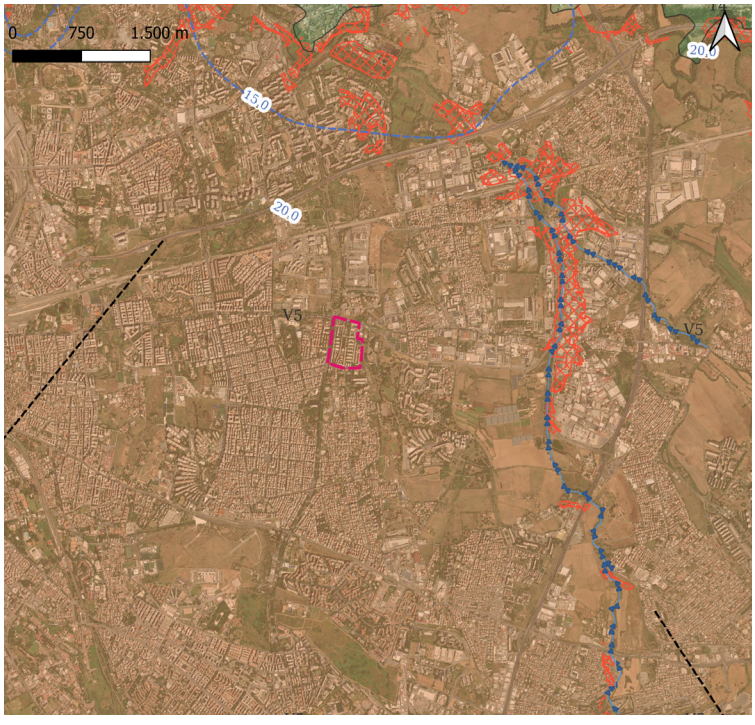


Figure 128.

Figure 128. Hydrogeological analysis. Author's elaboration on QGIS

LEGEND:
Carbonate units
Volcanic units
Detrital - alluvial units

Alluvial Units
Flyslope units
Negligible water resource units labelled

LEGEND:
Buried tectonic lineaments
Hydrogeological risk of landslides and floods
Linear source, flow class 10 to 50 l/s
Isopieze

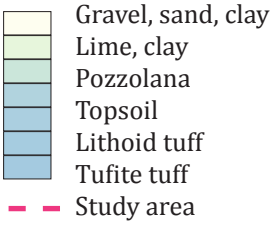


Figure 129. Geological analysis. Author's elaboration on QGIS



Figure 129.

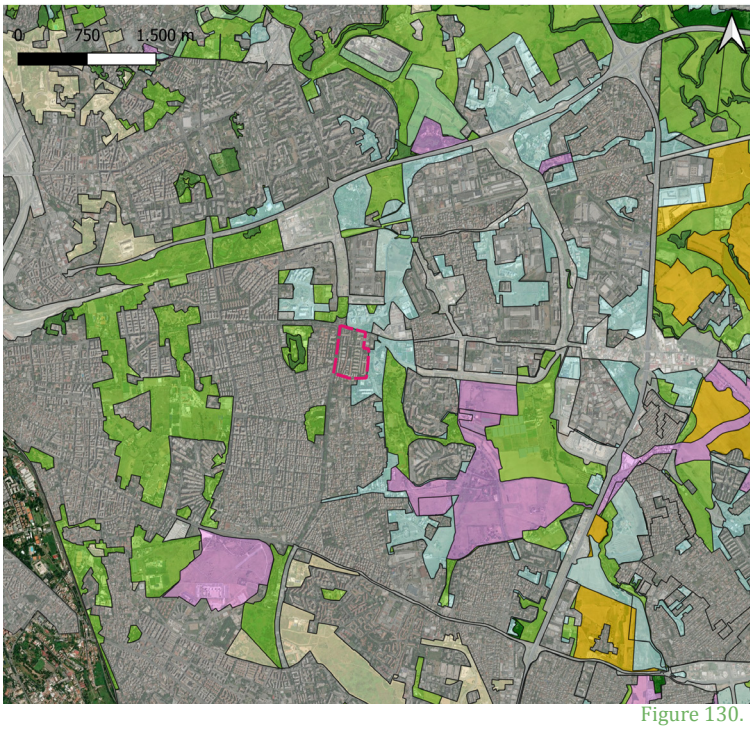


Figure 130.

Figure 130. Landscape planning. Author's elaboration on QGIS

Surface and vegetation analysis .

Various plant species are present within the area. The tree rows are mainly composed of Platanus Hispanica. In the larger green areas are specimens of Quercus Ilex, Pinus Pinea, Acer Negundo and Ulmus Minor. Other plant species present in the area in the squares, courtyards and roadside verges are specimens of Tilia Cordata, Robinia Pseudoacacia, Caprinus Betullus, Olea Europea, Cedrus Deodora, Faxinus Excelsior, Pinus Silvestris, Ligustrum Lucidum, Platicladus Orientalis, Umus Pumilia. All the specimens considered have a medium to large crown that lends itself well to the formation of shady areas. Apart from Cipressus, the root system is also extensive. In contrast to the foliage, this factor is to be considered because wide roots promote road disruption, thus requiring more maintenance than specimens with smaller root systems. Many areas within the neighbourhood are covered with impermeable surfaces such as asphalt, stone and screed surfaces, which prevent rainwater runoff. The roofing of buildings is made of concrete, tiles or sheet metal. Asphalt is the most common type of surface used as a road, surface and roofing material. It is the most present material in the area, with 38.4 per cent of the total surface. The runoff level amounts to 304400, and considering the size of the area, it, therefore, has a low average level of absorption.

Figure 131.

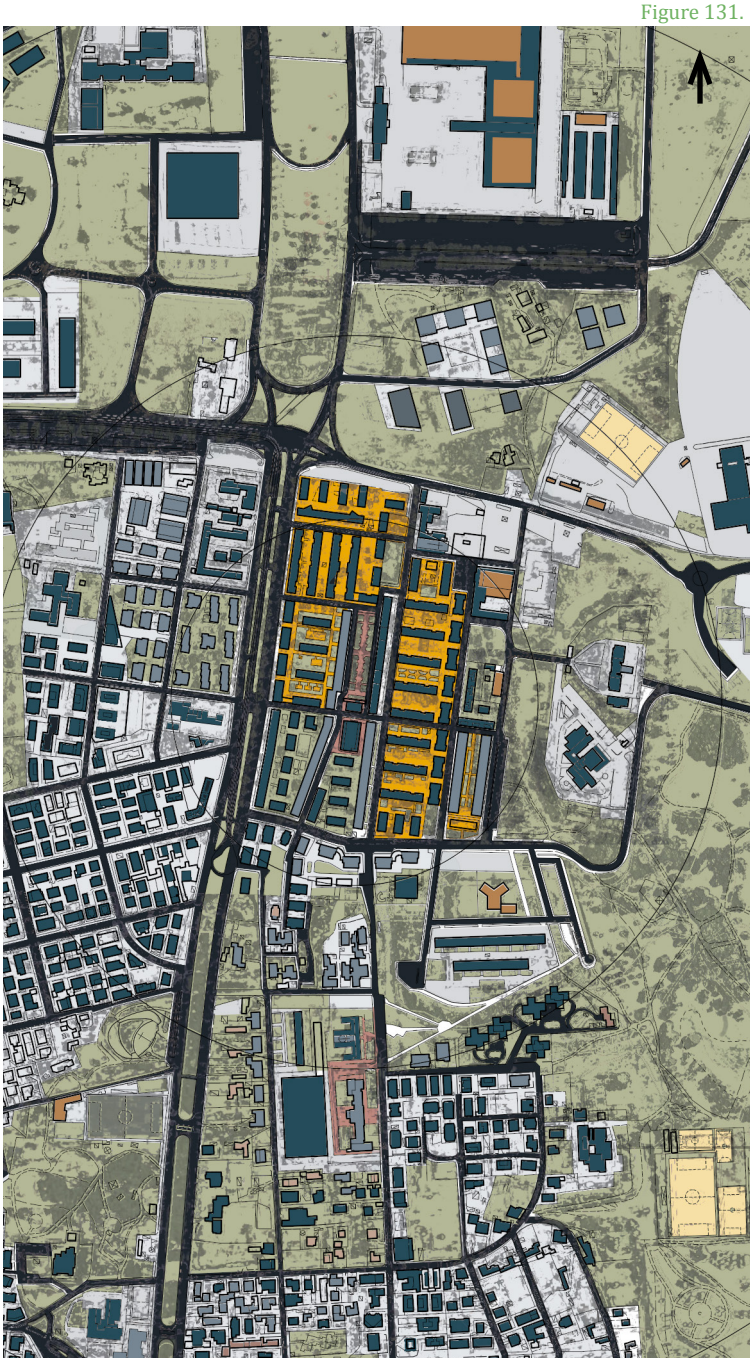


Figure 131. Surfaces analysis. Reworked based on Lorenzo Mariani's dissertation.

Concrete roofs
Asphalt
Greening
Black pavimentation
Tiled roofs

Figure 132.

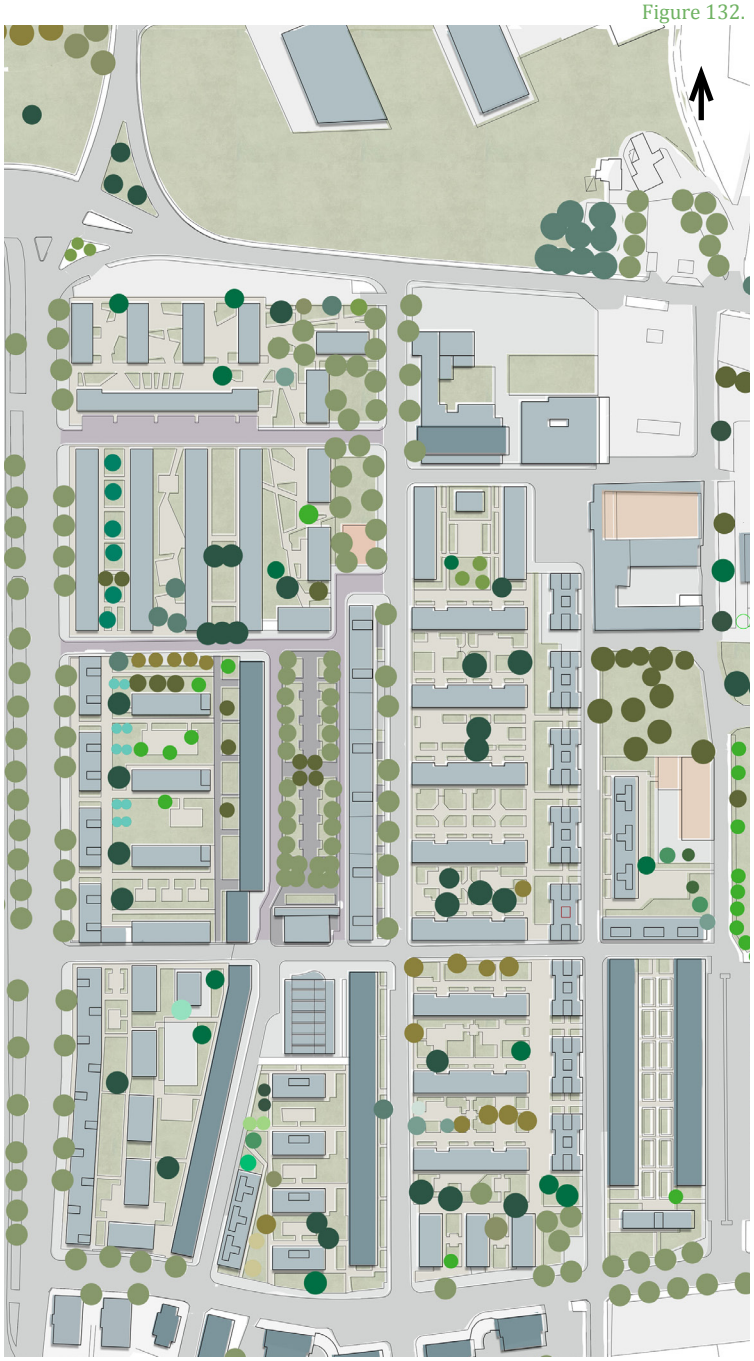


Figure 132. Green system analysis. Reworked based on Lorenzo Mariani's dissertation.

- Permeable

Gravel - Humidity level: MEDIUM
Effects:
- High vapour transfer from soil to air by evaporation from the soil
- Low soil capacity to retain moisture

Grass - Humidity level: HIGHT
Effects:
- Limited soil evaporation due to the surface protection provided by the turf
- Retained rainwater is absorbed very slowly by the soil
- Decreased water flow velocity on steep terrain

Trees and grass (S1) - Humidity level: HIGHT
Effects:
- High moisture retention capacity in the soil
- High and slow absorption of rainwater by the soil
- High moisture content in the areas under the tree canopy, which protects against radiation and ventilation
- Moisture level generally stable over the course of the year, varying only with the occurrence of precipitation

- Impermeable:

Effects:
- High evaporation in the absence of vegetation cover
- Rapid rainwater runoff and no water infiltration into the soil

Cement/asphalt surface (P10) - Moisture level: LOW
Includes all surfaces pertaining to private and public building entities.

Stone surfaces (P9) - Moisture level: LOW

Solid surface (P7) - Moisture level: LOW

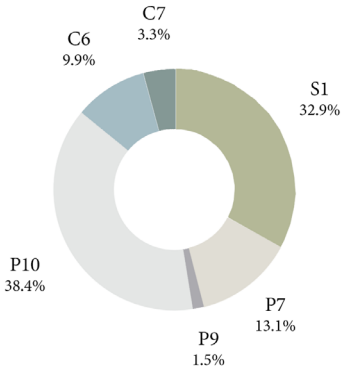
ROOFING

Asphalt roofing (C6)

Tiled roofing (C7)

Metal roofing (C8)

SURFACES
PERCENTAGE:



RUN OFF

VALUE
304400

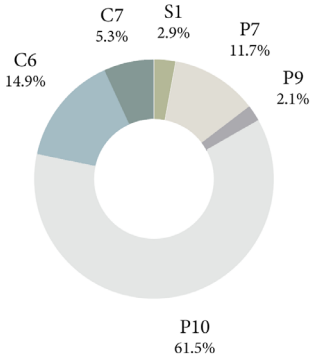
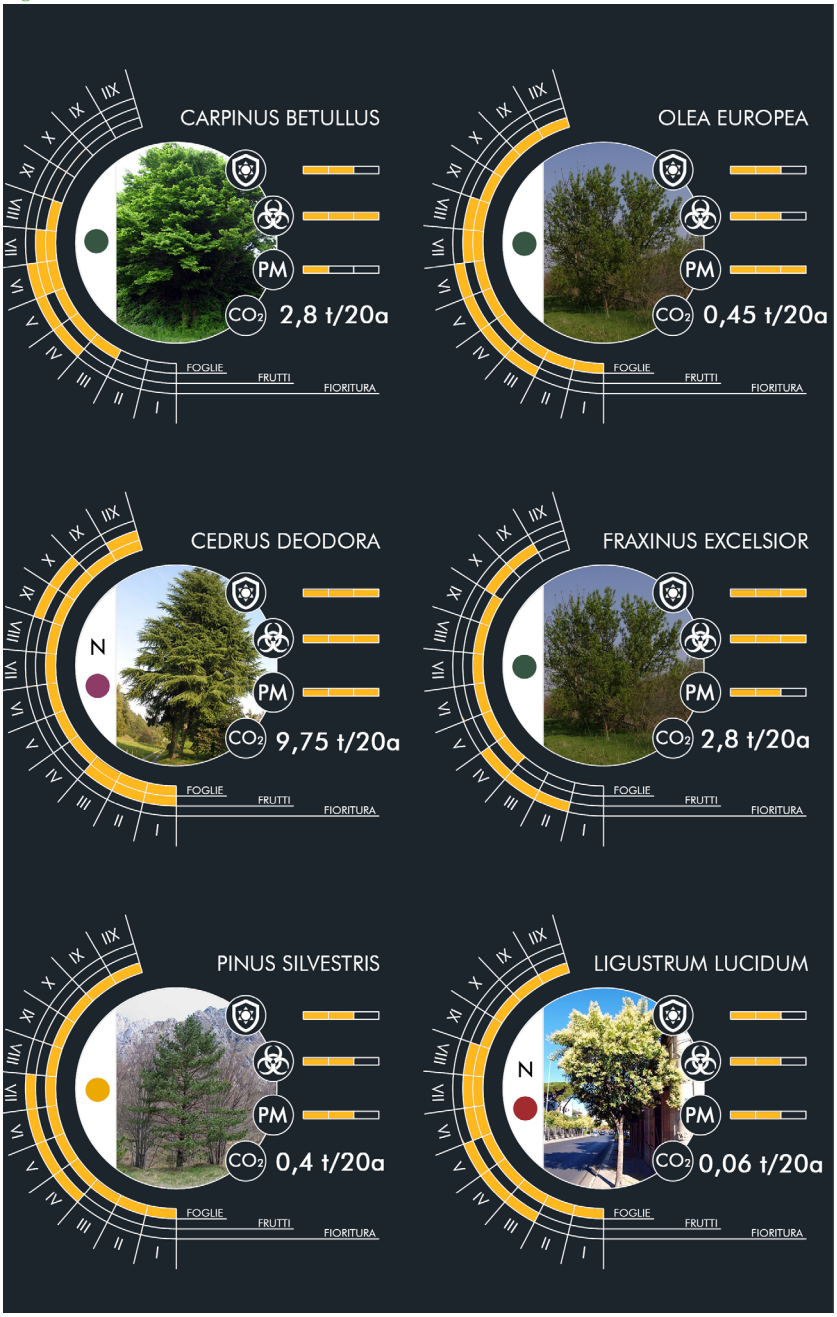


Figure 133 a.



Figure 133 a, b. Trees system analysis. Reworked based on Lorenzo Mariani's dissertation.

Figure 133 b.

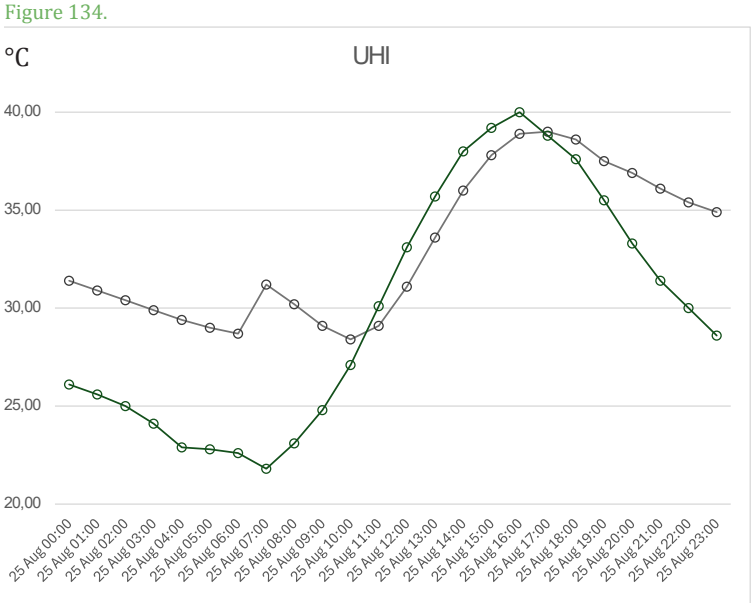

CARPINUS BETULLUS
PM
CO2
2,8 t/20a
FOGLIE
FRUTTI
FIORITURA
OLEA EUROPEA
PM
CO2
0,45 t/20a
FOGLIE
FRUTTI
FIORITURA
CEDRUS DEODORA
N
PM
CO2
9,75 t/20a
FOGLIE
FRUTTI
FIORITURA
FRAXINUS EXCELSIOR
PM
CO2
2,8 t/20a
FOGLIE
FRUTTI
FIORITURA
PINUS SILVESTRIS
PM
CO2
0,4 t/20a
FOGLIE
FRUTTI
FIORITURA
LIGUSTRUM LUCIDUM
N
PM
CO2
0,06 t/20a
FOGLIE
FRUTTI
FIORITURA

Exposition Analysis.

The graph in Figure 134 illustrates the heat island trend within the district on the statistically hottest day (25 August) of the year. The graph shows that the phenomenon occurs more at night, while the heat island phenomenon is absent during the daytime and especially in the morning. The heat absorbed during the day by the building materials is released at night, preventing temperature drops comparable to those recorded at the exact location, but in the countryside. Figures 135 and 136 are elaborations through

Figure 134. The graph illustrates the heat island in the area under investigation. The green break represents the temperatures of a typical day as measured by the nearest weather station. In contrast, the grey break represents the temperatures simulated through modelling on Ladybug, setting up and generating the city microclimate. Author's elaboration

Figure 134.



the Google Earth engine GEE - see the section on the exposure of the Westside pilot case - and respectively represent the ground temperature of the statistically hottest day and the percentage of vegetation in the area. Figure 135 shows that the area under investigation has a surface temperature of around 46-47 °C, which is lower than in the rest of the district. The different surface treatments, the buildings' height with the streets' width, and the presence of tree lines and green squares justify the lower temperature compared to the surrounding areas. Figure 136 shows that the highest concentration of green areas is around 73% and is recorded in correspondence with Viale Palmiro Togliatti, in the square of

Quarticciolo, to the north, in some points of Via Prenestina, and correspondence with the Sacro Cuore San Giovanni Battista Institute to the east. The area is located close to the Tor Tre Teste park. It could benefit from various green infrastructures, which would increase the liveability of the neighbourhood, as it has large public and semi-public spaces set aside for green areas, which are currently in a state of decay.

Figure 135.

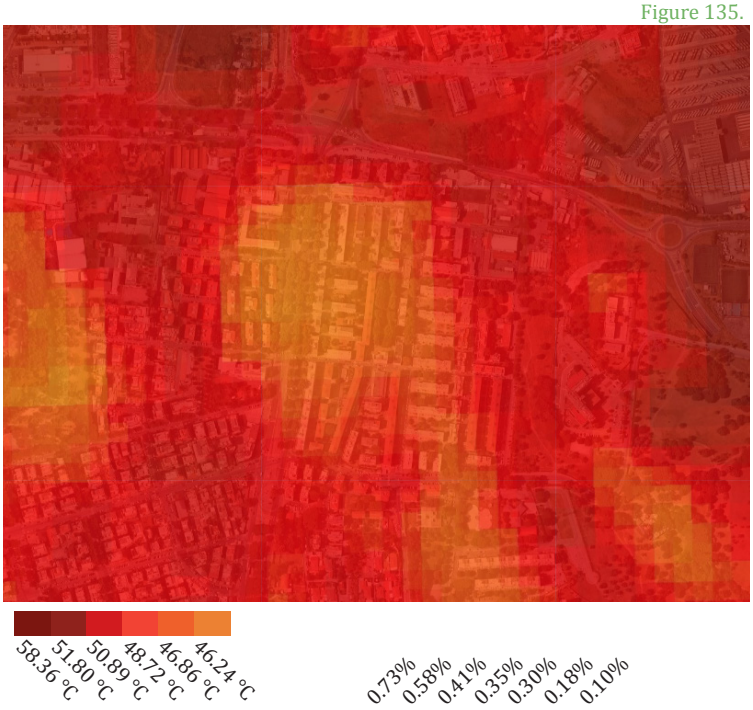


Figure 135. Graphical representation of the ground temperature in the analysed Quarticciolo area. Elaborated with the help of architect Stefano Urbinati.

Figure 136.

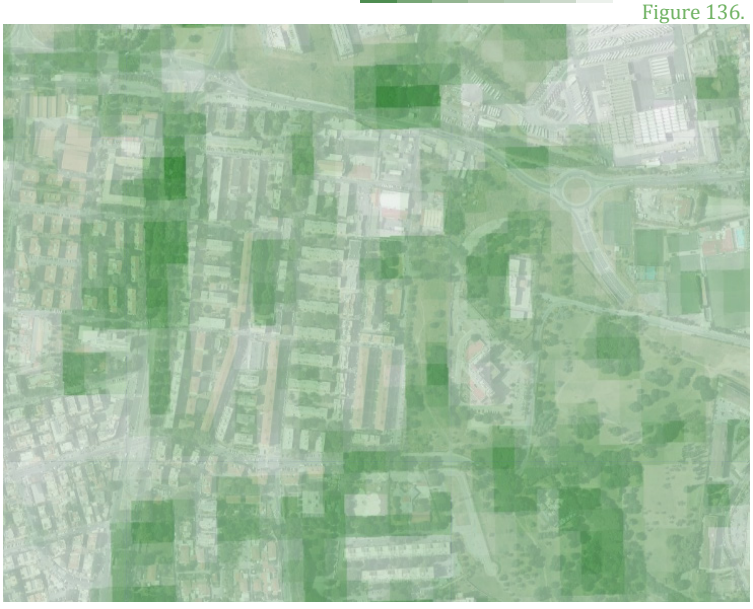


Figure 136. Graphic representation of the percentage of green areas in the analysed Quarticciolo area. Elaborated with the help of architect Stefano Urbinati.

Similar case studies, SWOT and objective individualization.

Quarticciolo has features similar to those of two case studies: the Duchére neighbourhood in Lyon and the Laguna de Duero Torrelago neighbourhood in Valladolid. The former, built in the 1960s for the working class and subject to redevelopment as of 2019, presents as similar traits of the pilot case under analysis of the complex circulation within the neighbourhood, heat island phenomena during the dry season, a non-diversified housing stock, insufficient public spaces and declining aggregation points and shopping centres. The solutions adopted in this context include installing insulation and applying thermal break windows and doors, exploiting cross ventilation and ventilated corridors, installing low-energy systems, and creating a large green area: Parc du Vallon. The second case study, built around 1980, was presented before the redevelopment began in 2004, with very dispersive envelopes, architectural inhomogeneities, urban and mobility problems, and long heat island phenomena during the summer period. The solutions adopted during the redevelopment include installing external insulation systems, renewing the air conditioning systems with more efficient appliances, and redeveloping the green area along the lake.
The critical issues within the two neighbourhoods can also be traced in Quarticciolo. These problems consist of poorly cohesive terrain, heat islands throughout the summer period that exacerbate the already hot temperatures in the entire area around Rome, low maintenance of green spaces, which, although present, are difficult to use, equipped green areas and the lack of connections with adjacent green areas and parks. The morphological configuration, which is very regular, is challenging to modify, with many buildings in decay and closed internal courtyards. The most common material in the area is concrete, with few shaded areas, aggravating the summer heat island phenomenon. Over the years, commercial and/or tertiary services, such as meeting points and public safety and health facilities, have decreased, exponentially increasing the degradation situation in the area. The area's strengths lie in the presence of autochthonous species typical of the Mediterranean maquis, which complement the allochthonous ones that contribute to the greenness of the area. During the summer, the tree canopies contribute to the shading of the public spaces. The courtyards between the complexes are large. Within the

neighbourhood are places of worship, schools, cultural and sports complexes. The area is close to large commercial areas. Potential threats for Quarticciolo consist of the possible occupation of common spaces due to the worsening of the housing crisis, the increase in the degradation and stress of structures and infrastructures, leading to increased danger of collapse, the decrease in welfare levels, the increase in consumption, and the decrease in air quality. In addition, important threats to the neighbourhood consist of increased maintenance costs, increased levels of neglect and the triggering of chain phenomena such as increased fire hazards due to the abandonment of flammable materials and the dryness of the ground caused by high temperatures combined with low rainfall, typical of the summer season. Lack of maintenance causes a potential increase in invasive species and increased degradation of structures, infrastructure and soil. On the contrary, the opportunities found consist of the massive presence of flat roofs, which can be converted into green roofs. The presence of large, unused commercial areas allows for their possible exploitation to increase the functional mix. Despite their decay, the inner courtyards can become important semi-public spaces that the inhabitants can exploit. Many streets already have rows of trees that can be increased.
Ultimately, the objectives envisaged for the district consist of increasing the levels of adaptation and mitigation of the impacts caused by islands and heat waves. Specifically, the objectives envisaged in the anthropic system consist of decreasing the degradation rate of structures and infrastructure, managing and reducing alien species, and reducing building consumption. At the level of the natural system, the project's objectives are to decrease the hydrogeological risk, increased by the impermeability of the area, the risk of fires, the reduction of climate-altering emissions, and the reforestation and reconstitution of a native line habitat. This goal, in particular, has positive implications from various points of view, such as increasing liveability and well-being levels and decreasing air and surface temperatures. Following the analysis, the applicable strategies and actions include draining and cooling materials to decrease surface temperatures and increase drainage. The use of strategies that increase passive cooling allows decreases in consumption and increases the bioclimatic behaviour of the area. Controlling solar radiation contributes to decreasing heat islands and increasing comfort. The increase in soft mobility systems allows for a decrease in traffic and emissions. Enhan-

cing green infrastructures and using ecosithematic actions such as bioswales, communal gardens, green walls and roofs, and tree canopies act broadly on all objectives. Finally, the involvement of the inhabitants in redevelopment operations would increase the durability of the solutions adopted and trigger virtuous circles of neighbourhood promotion, decreasing levels of degradation and increasing actions aimed at increasing thermo-hygro-ecological well-being.

Thanks to the proposed solutions and the hazard matrix developed in section 2.1.3, the identified potentially usable solutions consist of the adoption of green infrastructure, green facades, cool materials, green and blue roofs, wetlands and bioswales, the setting up of bioclimatic atria, buffer zones and ventilation towers.

The final step in selecting the actions underlying the redevelopment project consists in using Climate Consultant software to confirm the effectiveness of the actions selected previously. This software is a free tool that enables users to gain an in-depth understanding of the climate context and select technological solutions tailored to the context, thereby enhancing user comfort. The proposed solutions align with the specific characteristics of the vernacular architecture in the area. This aspect reinforces the choice and, therefore, the solutions used, which are based on the same operating principles. The principles underlying the redevelopment of the Quarticciolo pilot case consist of increasing shaded areas, indoor and outdoor cross ventilation, and green infrastructure. It should be noted that some features that encourage passive bioclimatic behaviour in the area are already present, such as the presence of large windows and flat roofs.

PILOT CASE - QUARTICCIOLO - ROME - ITALY

Similar Case study

La Duchére Lion France

Cost: \

Designers:	Gautier + Conquet
Customers and stake holders:	Grand Lyon Habitat
Design year:	2000
Construction year:	2001
Completion year:	in progress



Geolocalization- Author elaboration on QGIS

La Duchére in the 60's

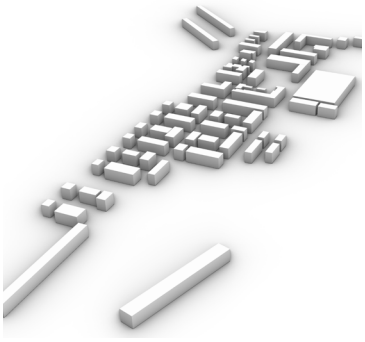


La Duchére today 2018





Inhabitants: 12500 (5500 housing units)
Dimensions: 120ha
Morphology: Centralized
H/L: 1.125



Similar issues to the case study:

- Presence of heat island phenomena
- Complex circulation within the neighbourhood: dead-end streets, complicated pedestrian accesses
- Old and poorly insulated buildings
- Undiversified housing stockInsufficiently developed public spaces
- Declining shopping centre

Solutions adopted:

- Installation of an external coat to increase thermal-acoustic insulation
- Installation of thermal break window frames
- Exploitation of cross-ventilation and ventilated corridors
- Installation of low energy consumption systems
- Establishment of a complex and extensive green system (Parc du Vallon)

PILOT CASE - QUARTICCIOLO - ROME - ITALY

Similar Case study
Laguna de Duero Torrelago | Valladolid | Spain

Cost: 16,07 M Euro

Designers:	CityFIED
Customers and stake holders:	European Commission, Veolia
Design year:	2004
Construction year:	2016
Completion year:	2019



Geolocalization- Author elaboration on QGIS

Laguna de Duero Torrelago in the 70's

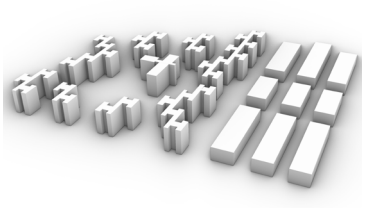


Laguna de Duero Torrelago today





Inhabitants: 5000 (with 1488 housing units and 31 buildings
Dimensions: 14 ha
Morphology: Centralized
H/L: 1



Similar issues to the case study:

- Very dispersive enclosures
- Architecturally uneven neighbourhood
- Urban and mobility issues
- Island and heat wave issues

Solutions adopted:

- Installation of an external coat to increase thermal insulation
- Renewal of air conditioning systems to reduce costs and ensure greater efficiency
- Redevelopment of the green area around the lake

RISK ANALYSIS

Figure 137.

Figure 137. SWOT Analysis. Author's elaboration

Strenghts:

- A large variety of autochthonous, evergreen and deciduous species typical of the Mediterranean maquis
- Significant presence of greenery, given by parks and courtyards
- The high degree of shading of public spaces during summer periods
- The shape of the neighbourhood is inspired by the 'small town/ small city' model
- Predisposition for diversification of functions
- Non-intensive fabric with large courtyards and communal spaces
- Presence of public services of an administrative nature
- Presence of educational and cultural complexes and places of worship
- Presence of public and private spatial facilities
- Proximity to areas of high commercial density

S

Opportunities:

O

- Broad road sections to ensure an increase in vegetation / or bicycle lanes, built using high permeability materials
- Availability of flat roofs so that they can be used as garden roofs or treated with cool materials
- Utilisation of unused commercial spaces
- Possibility of incorporating public services in various disused premises
- Presence of residual areas to be integrated into the ecological network
- Possibility of inserting tree rows
- Possibility of regenerating inner courtyards

RISK ANALYSIS

Weaknesses:

- Poorly cohesive terrain
- Large heat island problem
- Low maintenance of green areas
- Low presence of equipped green areas
- Lack of connections between green areas in the borough and with neighbouring parks
- Intensive presence of concrete and poorly permeable surfaces
- Morphological and planimetric configurations are complex to change
- High state of degradation on buildings and surroundings
- Enclosure of internal courtyards
- Decreasing presence of commercial services and mixité in the neighbourhood over the years
- Lack of cleanliness of public spaces and waste collection
- Lack of a meeting point for residents
- Lack of health and public safety facilities
- Lack of shady spots
- Presence of non-native species
- Excessive solar radiation

W

T Threats:

- Exacerbation of the housing crisis and occupation of service spaces
- Increasing degradation of structures and infrastructure
- Stress on structures and infrastructure
- Increase in invasive species
- Increased mortality and decreased well-being
- Increased maintenance and rehabilitation costs
- Increased neglect of neighbourhoods and buildings
- Decreased air quality
- Increased soil dryness
- increased outdoor temperatures
- increased invasive species
- Increased fire danger

RISK ANALYSIS

Figure 138. Risks analysis. Author's elaboration

Figure 138.

Objective:

- urban heat island adaptation and mitigation
- adaptation to extreme temperatures
- adaptation to heat waves

- hydrogeological risk adaptation
- fire risk adaptation and mitigation
- adaptation to drought/aridity risk
- reduction of climate-altering emissions
- reforestation

- Increasing the indoor and outdoor comfort and well-being of residents, also about reducing the risk of disasters and extreme events, including increasing prevention/response capabilities
- Increasing the level of liveability of the area stimulating community development and growth

- Decreasing the rate of degradation of structures and infrastructure due to continued high temperatures
- management and reduction of alien species
- restoration and enhancement of natural habitats
- redevelopment of existing consolidated buildings and environmental heritage
- decrease in building consumption

Strategies and actions:

- soil management with performance, drainage or cool materials passive cooling
- control of solar radiation
- promotion of soft mobility systems
- management of light capture on a morpho-technological level
- management of indoor and outdoor air flows using natural and artificial devices
- management of rainwater collection and storage
- interventions on morphology, land use and management levels to avoid further degradation situations
- use and enhancement of green and grey infrastructure at different scales
- use of efficient and effective solutions that have an impact both indoors and outdoors
- use and enhancement of green infrastructure for bioclimatic effects at different scales
- involvement of residents

Guidelines:

- use of strategies that are effective in the short-term
- use of effective strategies that solve the most problems with the least amount of resources
- reducing emissions in buildings
- increasing outdoor ventilation and indoor cross-ventilation during peak periods
- development of innovative spatial governance models

Actions scenarios:

- Use of cool materials
- Use of reflective materials
- Use of vegetated roofs
- Application of green wall and façade systems
- Application of green systems inside buildings
- Draining roof systems
- Use of draining pavements
- Increasing the urban green system
- Increased shading points through green and grey devices and increased shading of buildings

Innovative and integrated energetic and bioclimatic strategies for adapting existing contexts to climate change and extreme events, aiming to mitigate the environmental impact
p. 612
Figure 139.
SELECTION OF ACTIONS

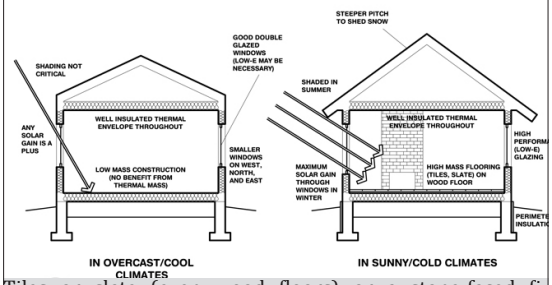
Wildfires	Parks, garden squares, pocket gardens, and urban farmings, trees and green corridors
Drought	Parks, garden squares, pocket gardens, and urban farmings, trees and green corridors
Stress of structures	Water surfaces, rain garden and phytodepuration, wetland ad bioswales, parks, garden squares, pocket gardens, and urban farmings, trees and green corridors, Cooling towers, green systems embedded in buildings, green houses and winter gardens, external coat, green roofs, green walls, ventilated roofs/floors, permeable surfaces, ponds on roof/ground floor, cool materials
Stress of infrastructures	Evaporative cooling, water surfaces, rain garden and phytodepuration, wetland ad bioswales, parks, garden squares, pocket gardens, and urban farmings, trees and green corridors, permeable surfaces, ponds on roof/ground floor, cool materials
Problems with finishing materials	External coat, Parks, garden squares, pocket gardens, and urban farmings, trees and green corridors, green roofs/walls, permeable surfaces, cool materials, cooling towers, green systems embedded in buildings, ventilated roofs/walls
Increasing indoor temperature	Artificial and natural urban devicesfor guide wind flows, parks, garden squares, pocket gardens, and urban farmings, trees and green corridors, bioclimatic atria, cooling towers, green houses and winter gardens
Increasing mortality	Parks, garden squares, pocket gardens, and urban farmings, trees and green corridors, bioclimatic atria, wind chimney, reen houses and winter gardens
Rainfall	Parks, garden squares, pocket gardens, and urban farmings, trees and green corridors
Decreasing of comfort conditions	Parks, garden squares, pocket gardens, and urban farmings, trees and green corridors, bioclimatic atria, wind chimney, reen houses and winter gardens
Energy transmission losses and facilities	Artificial and natural urban devicesfor guide wind flows, artificial shade systems, natural shade systems, Parks, garden squares, pocket gardens, and urban farmings, trees and green corridors, buffer zones, external coat, green roofs, permeable surfaces, ponds on roof/ground floor, phasechange and thermocromic materials, thermal mass

Figure 139. Matrix of hazards related to urban heat island and heat waves and technologies sets that can decrease all the KPI related to each hazard - Author elaboration

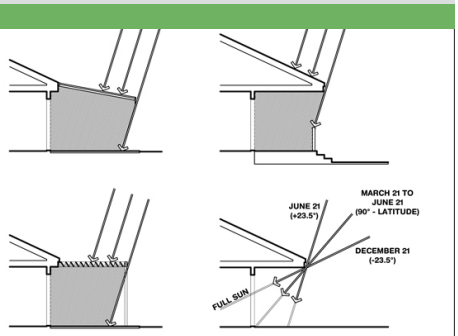
 Negative impact for renewerable energies	Evaporative cooling, water surfaces, rain garden and phytodepuration, wetland ad bioswales, Parks, garden squares, pocket gardens, and urban farmings, trees and green corridors, green roofs/walls, permeable surfaces, ponds on roof/ground floor, cool materials, external coat, ventilated roofs/walls
 Increasing costs for preventing measures	Water surfaces, raingardens and phytodepuration, wetlands and bioswales, parks, garden squares, pocket gardens, and urban farmings, trees and green corridors, cooling towers, green systems embedded in buildings, green houses and winter gardens, cool materials, green roofs/walls, permeable surfaces, ponds on roofs/ground floors, ventilated roofs/walls, green systems embedded in buildings
 Neighborhoods abandonement	Parks, garden squares, pocket gardens, and urban farmings, trees and green corridors
 Buildings abandonement	Parks, garden squares, pocket gardens, and urban farmings, trees and green corridors, bioclimatic atria, cooling towers
 Increasing maintenace costs	Water surfaces, rain garden and phytodepuration, wetland ad bioswales, parks, garden squares, pocket gardens, and urban farmings, trees and green corridors, green systems embedded in buildings, green walls, green roofs, permeable surfaces, ponds on roof/ground floor, photocatalityc materials, cool materials, cooling towers, ventilated roofs/walls
 Increasing recovery costs	Water surfaces, rain garden and phytodepuration, wetland ad bioswales, parks, garden squares, pocket gardens, and urban farmings, trees and green corridors, green systems embedded in buildings, green walls, green roofs, permeable surfaces, ponds on roof/ground floor, photocatalityc materials, cool materials, cooling towers, ventilated roofs/walls
 Increasing deterioration rate of systems and materials	Water surfaces, rain garden and phytodepuration, wetland ad bioswales, parks, garden squares, pocket gardens, and urban farmings, trees and green corridors, green systems embedded in buildings, green walls, green roofs, permeable surfaces, ponds on roof/ground floor, photocatalityc materials, cool materials, cooling towers, ventilated roofs/walls
 Increasing deterioration rate of infrastructures	Rain garden and phytodepuration, wetland ad bioswales, parks, garden squares, pocket gardens, and urban farmings, trees and green corridors, permeable surfaces, ponds on roof/ground floor, photocatalityc materials, cool materials, cooling towers, ventilated roofs/walls
 Buildings may became unsuitable for use	Parks, garden squares, pocket gardens, and urban farmings, trees and green corridors, bioclimatic atria, cooling towers
 Infrastructures may became unsutaible for use	Parks, garden squares, pocket gardens, and urban farmings, trees and green corridors
 Decrease of air quality	Artificial and natural urban devicesfor guide wind flows, parks, garden squares, pocket gardens, and urban farmings, trees and green corridors

CLIMATE CONSULTANT

Shandings and illumination:

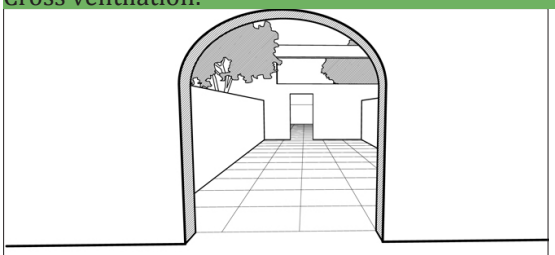


Tiles or slate (even wood floors) or a stone-faced fireplace provides enough surface mass to store winter daytime solar gain and summer nitghttime "coolth"

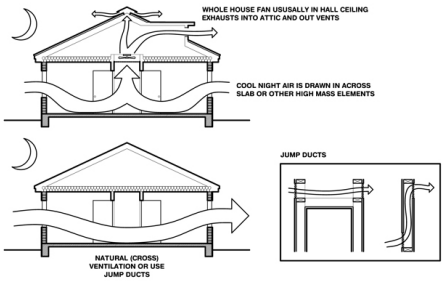


Window overhangs (designed for this latitude) or operable sunshades (awnings that extend in summer) can reduce or eliminate air conditioning

Cross ventilation:



Sunny wind-protected outdoor spaces can extend living areas in cool weather (seasonal sun rooms, enclosed patios, courtyards, or verandahs)

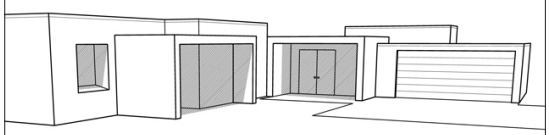


A whole-house fan or natural ventilation can store nighttime "coolth" in high mass interior surfaces (night flushing), to reduce or eliminate air conditiong

Morphology of the buildings

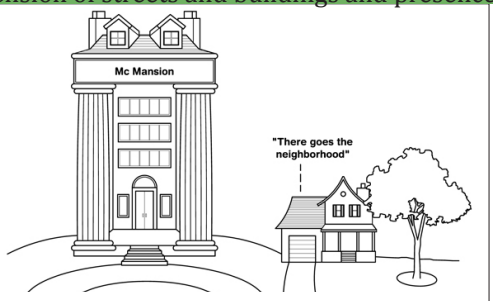


Traditional passive homes in warm humid climates used high ceilings and tall operable (French) windows protected by deep overhangs and verandahs

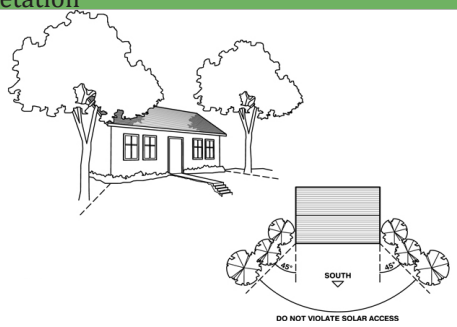


Flat roofs work well in hot dry climates (especially if light colored)

Dimension of streets and buildings and presence of vegetation

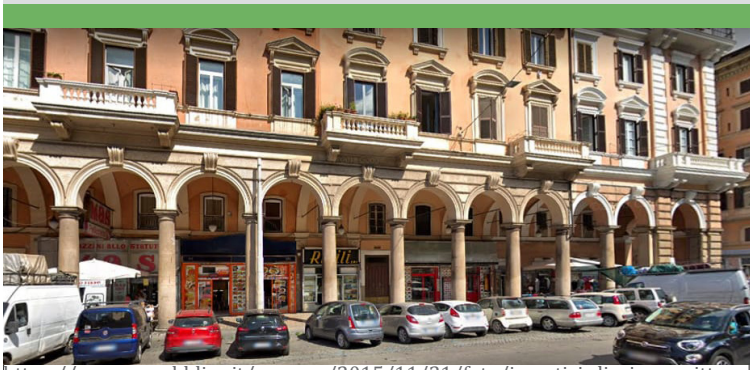


Keep the building small (right-sized) because excessive floor area wastes heating and cooling energy



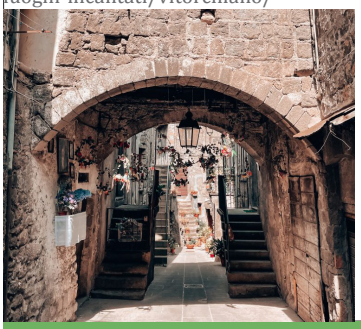
Trees (neither conifer or deciduous) should not be planted in front of passive solar windows, but are OK beyond 45 degrees from each corner

VERNACULAR ARCHITECTURE



https://roma.repubblica.it/cronaca/2015/11/21/foto/i_portici_di_piazza_vittorio_tornano_a_risplendere_grazie_a_retake_roma-127884707/1/

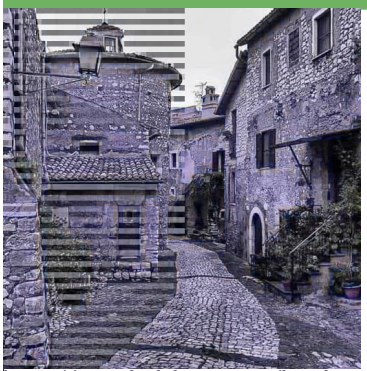
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https://it.wikipedia.org/wiki/Piazza_Borghese_(Roma)





https://www.laglobetrotter.it/borghi-marche-quali-visitare-colli-mare/

ACTIONS USED IN REQUALIFICATION ACTIONS

The redevelopment measures include various waterproofing measures on both buildings and public spaces.

The project includes green and grey urban screens that increase ventilation.

The windows in the neighbourhood are large. Flat roofs are fitted with green roof systems, photovoltaic systems or both.

Urban greenery is being implemented throughout the area through various actions.

Model setting.

With the identification of objectives and actions applicable to the Quarticciolo context, following the matrix developed previously in section 2.3.2, the technologies most suited to the highlighted objectives, respecting the climatic, historical, cultural and architectural characteristics of the area, consisting of the installation of shielding devices, cold surfaces, green infrastructures of various types - green corridors, pocket gardens, bioswales, urban gardens - green walls and roofs. The model's setup is the same as in the other pilot cases: the algorithm consists of the UWG generator tool for creating a city microclimate, explained in parts 2.4.1 and 3.1 of this thesis. Furthermore, the inputs into the system are related to information on the climatic environment and the built environment, such as the reflectance of surfaces, the geometry of the model and the uses. The model is processed on Rhinoceros 6.0 software and then connected to the algorithm on Ladybug, through which indoor and outdoor microclimatic information is obtained. The wall packages loaded on the model correspond to the layers found in the literature - see morpho-typological analysis. The KPIs investigated through the simulation consist of indoor and outdoor air temperature, indoor and outdoor relative humidity, indoor mean radiant temperature and indoor and outdoor UTCI.

Figure 140.

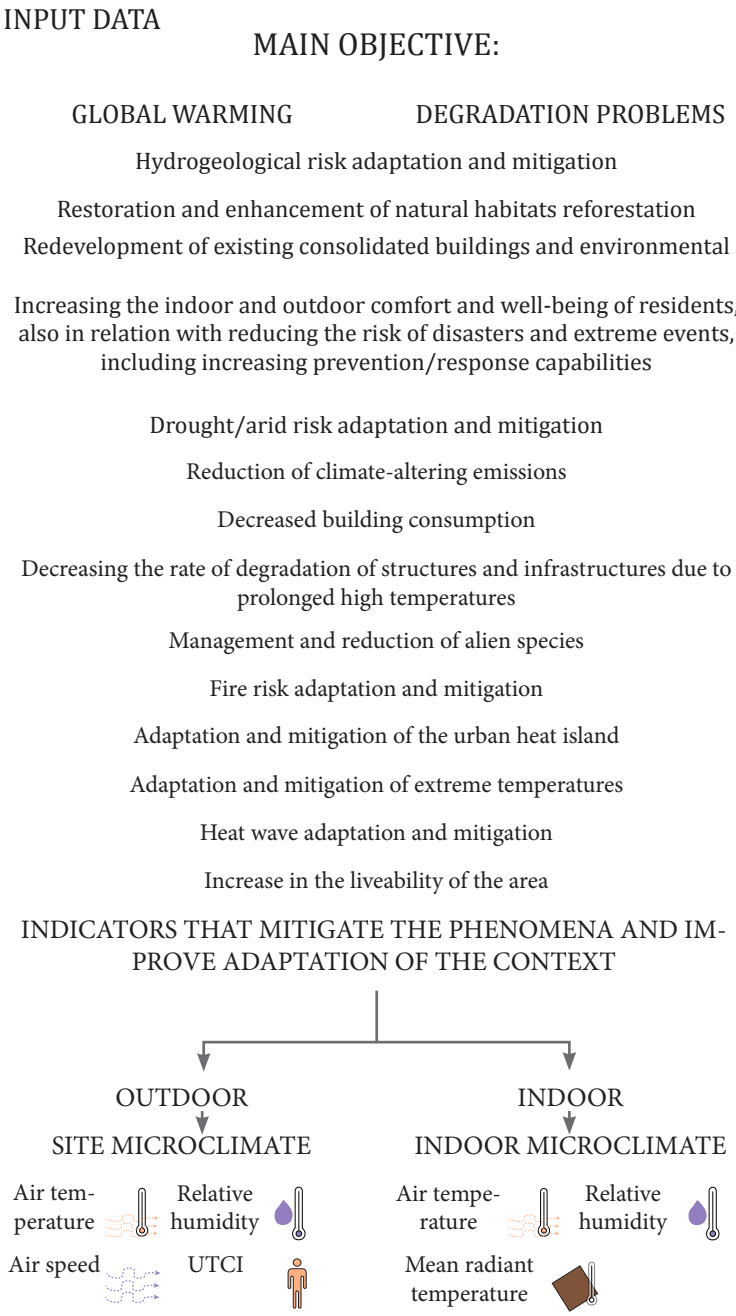


Figure 140. KPIs evaluated on Ladybug tools - Author elaboration

Figure 141.

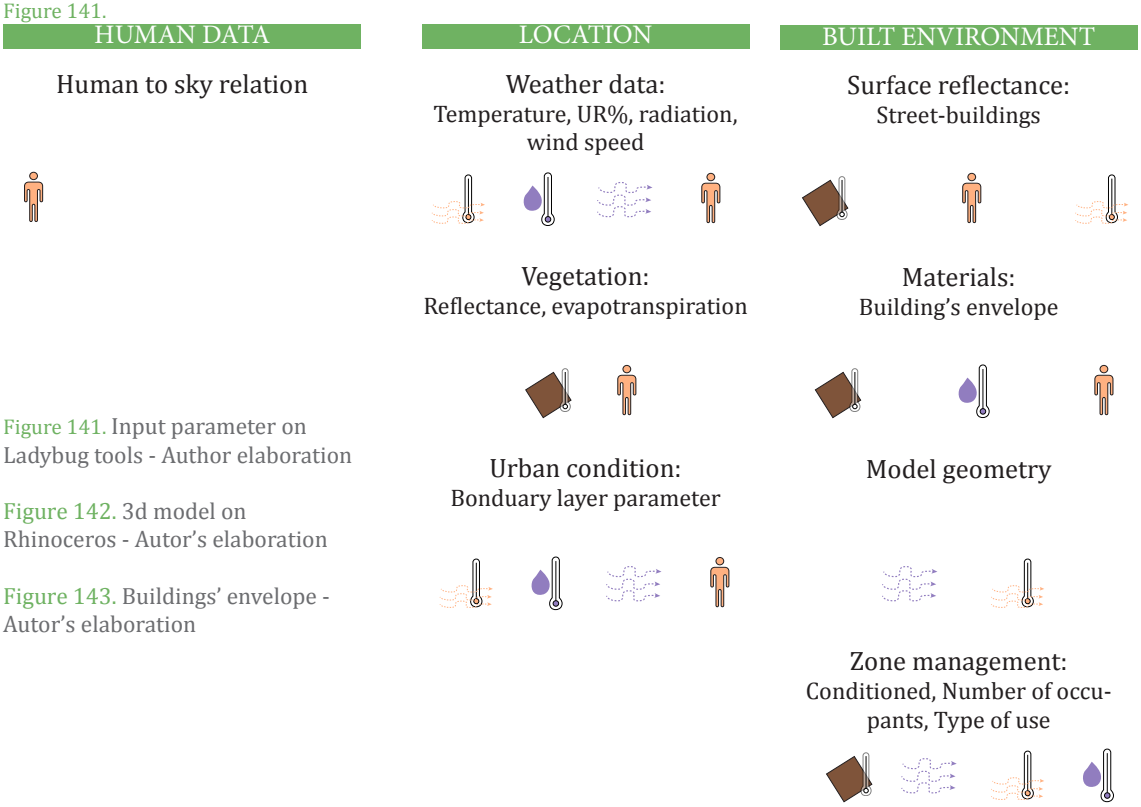


Figure 141. Input parameter on Ladybug tools - Author elaboration

Figure 142. 3d model on Rhinoceros - Autor's elaboration

Figure 143. Buildings' envelope - Autor's elaboration

INPUT DATA

Weather data:

It is usually represented by a .epw file where there are the main values of a region that concernes Temperature, UR%, radiation and wind speed. The-

Human to sky relation:

Calculate parameters for the relationship between human geometry and the sky given the position of a human subject and context geometry surrounding this position. It represent a Ldybig component and is used to calculate MRT of a certain person inside the model.

Figure 142.

Model Geometry and points of simulation:

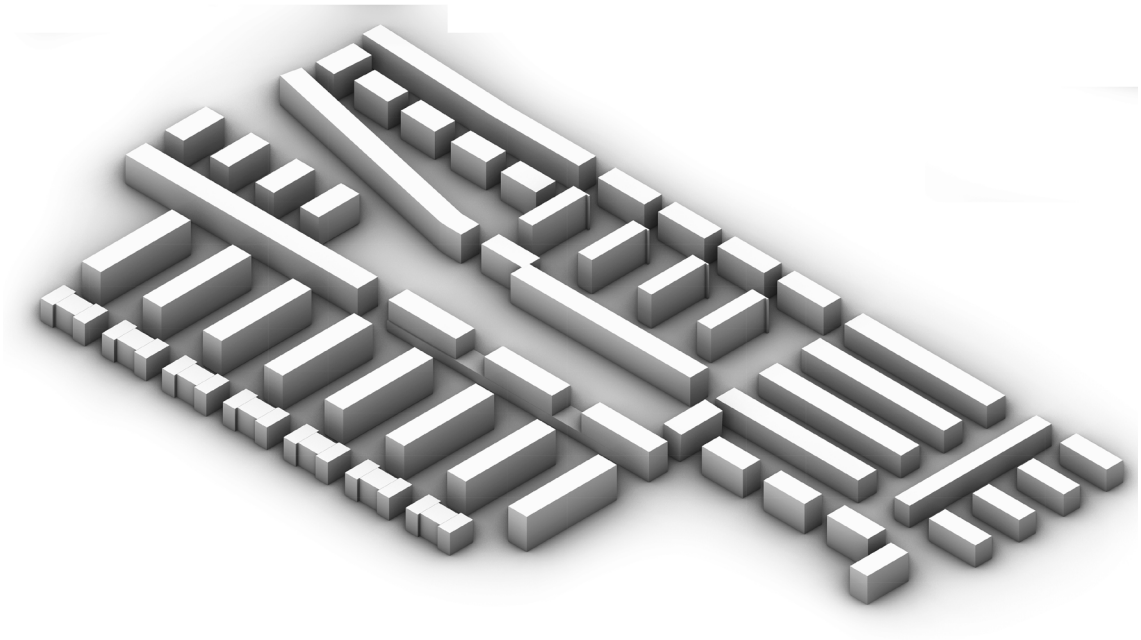
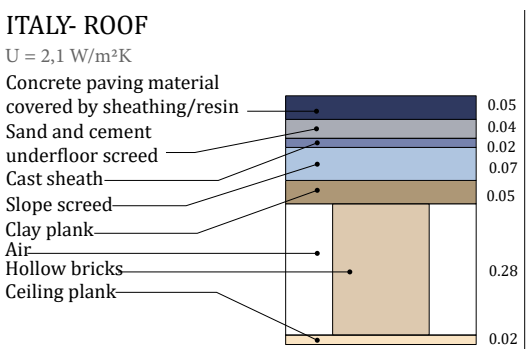
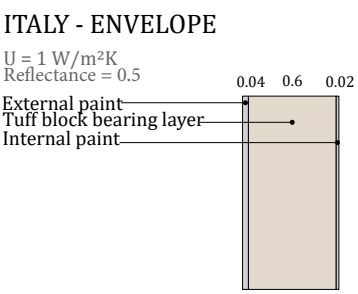


Figure 143.

Building envelope:





Green Roofs:

Pre

Figure 144.



Figure 145.

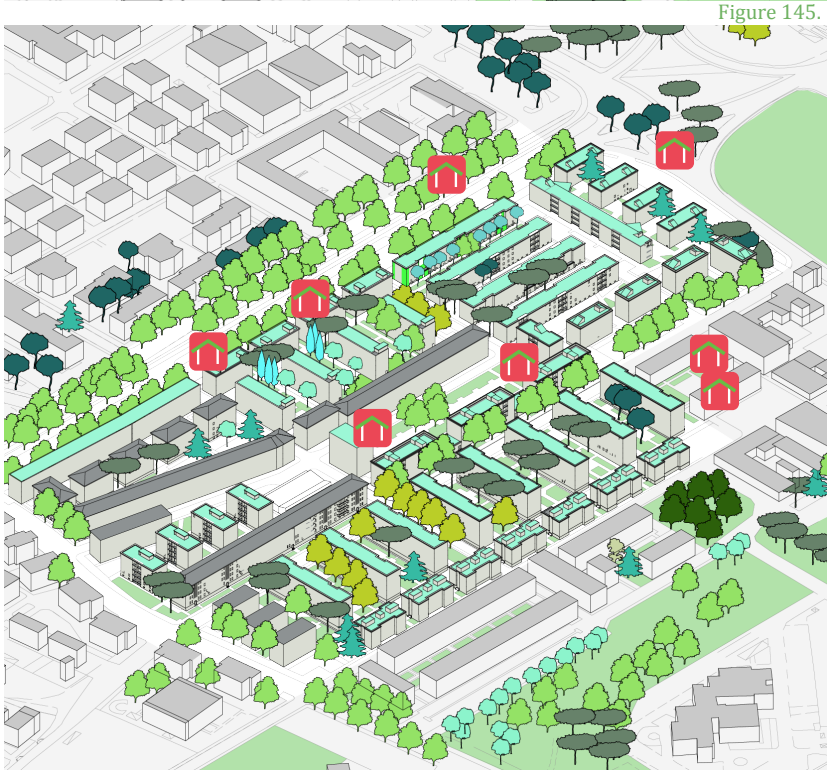


Figure 144. Configuration of Quarticciolo ante operam. Author's elaboration

Figure 145. Configuration of Quarticciolo with the installation of green roofs. Author's elaboration

Figure 146. Representation of the green roof used in the simulation. Author's elaboration

Figure 147. The graph illustrates the different types of surfaces present before the intervention.

Figure 148. The graph illustrates the different types of surfaces present following the redevelopment work.

Figure 149. Analysis of indoor and outdoor temperature trends on a typical day before and after the intervention

Figure 150. Pre-intervention plan of the district. Author's elaboration

Figure 151. Post-intervention plan of the district. Author's elaboration

Figure 152. Variation of indoor and outdoor temperature at 2 p.m. on the statistically hottest day of the year pre- and post-intervention. Author's elaboration

Green Roofs:

PRE
Surfaces tot 397318 mq
streets 358890 mq
tiled roofing 6854,724324 mq
Asphalt roofing 20564,17297 mq
metal roofing 11009,1027 mq
garden pre 3666 mq
tree pre 17300,7 mq

GREEN ROOF
Surfaces tot 397318 mq
sreets 360936,173 mq
tiled roofing 6854,724324 mq
Green roof 18518 mq
garden pre 3666 mq
tree pre 17300,7 mq

EFFECTIVENESS:
Outdoor:
Wind speed: \
UTCI:
Temperature:
UR%:
Indoor:
Wind speed: \
UTCI:
mrt indoor:
UR%:
Temperature:

Figure 146.

ITALY- GREEN ROOF

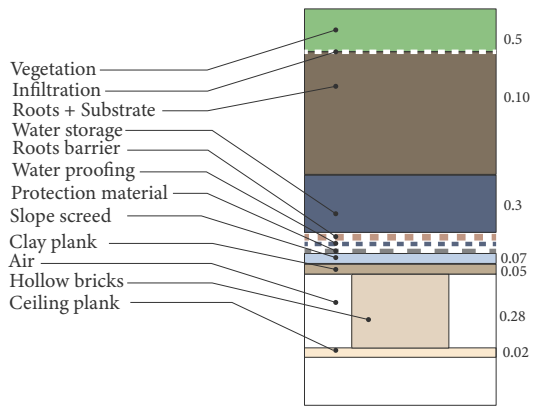
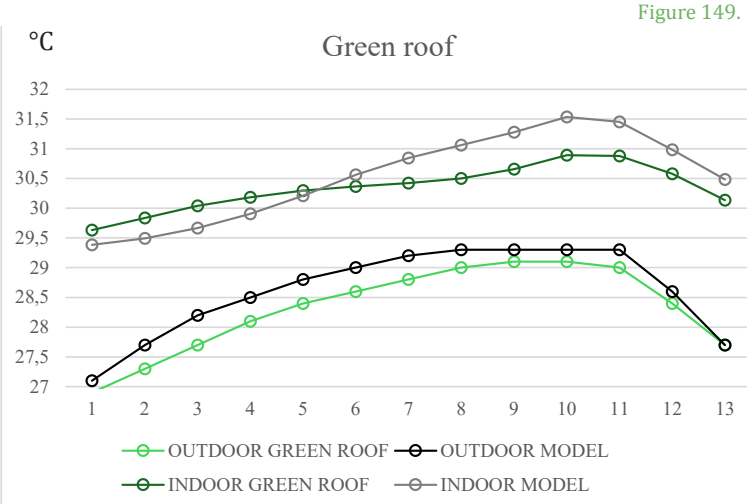
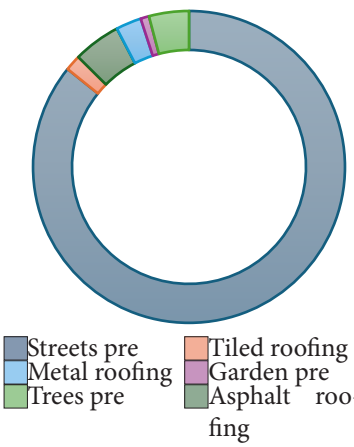


Figure 149.



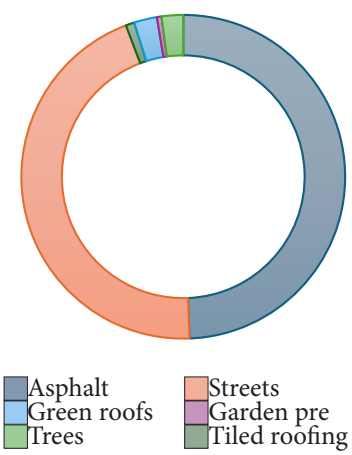
Pre:

Figure 147.



Post:

Figure 148.



Green Roofs:

Figure 150.



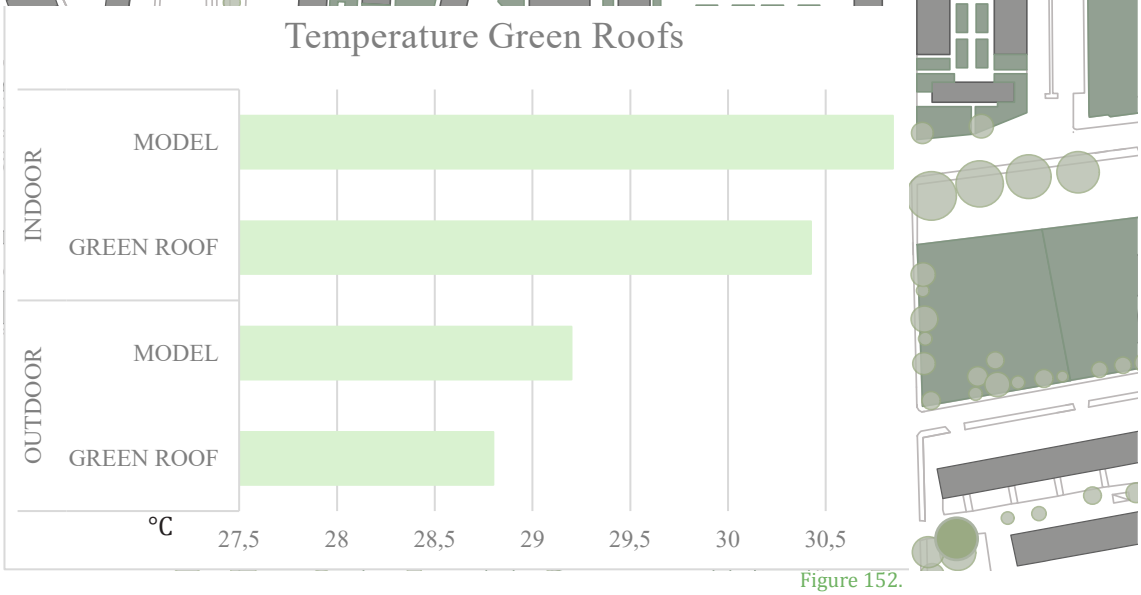


Figure 152.

Green Roofs:

Figure 151.



Green Walls:

Pre



Figure 144.

Post:



Figure 153.

Figure 153. Schematic representation of the Quaticciolo following the installation of green walls. Author's elaboration

Figure 154. Schematic representation of the type of green walls used in the simulations

Figure 155. Pre- and post-intervention indoor and outdoor temperature trends during the statistically hottest day of the year

Figure 156. The graph illustrates the different types of surfaces present following the redevelopment work.

Figure 157. Post-intervention planimetry

Figure 158. Maximum air temperature at 14.00 on the statistically hottest day of the year inside and outside before and after the intervention.

Green Walls:

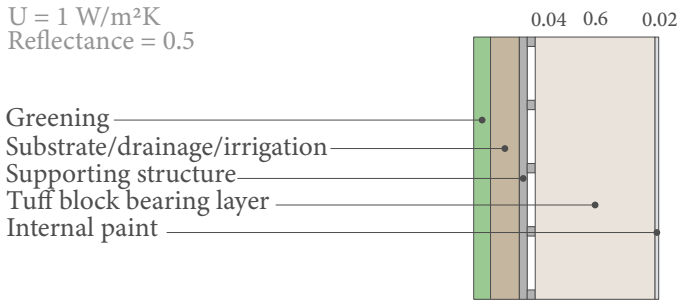
PRE
Surfaces tot 397318 mq
streets 358890 mq
tiled roofing 6854,724324 mq
Asphalt roofing 20564,17297 mq
metal roofing 11009,1027 mq
garden pre 3666 mq
tree pre 17300,7 mq

GREEN FACADES
Surfaces tot 397318 mq
streets 358890 mq
tiled roofing 6854,724324 mq
Asphalt roofing 20564,17297 mq
metal roofing 11009,1027 mq
garden pre 3666 mq
tree pre 17300,7 mq
green facades 149803,5 mq

Figure 154.

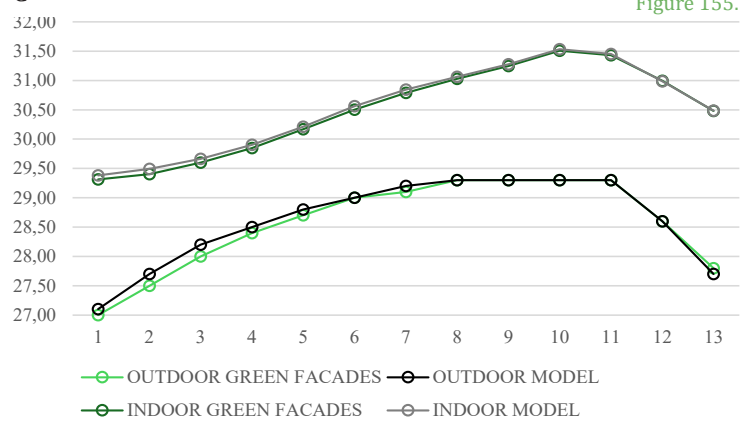
ITALY - ENVELOPE

U = 1 W/m²K
Reflectance = 0.5



°C

Figure 155.



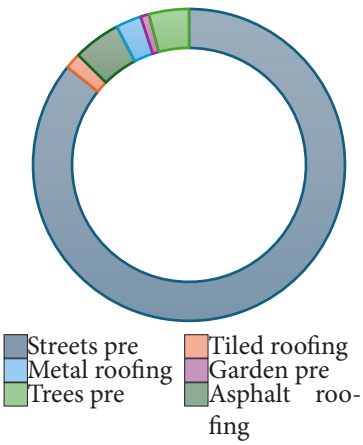
EFFECTIVENESS:

Outdoor:
Wind speed: \
UTCI: ●
Temperature: ●
UR%: ●●●

Indoor:
Wind speed: \
UTCI: ●●
mrt indoor: ●
UR%: ●
Temperature: ●

Pre:

Figure 147.



Post:

Figure 156.

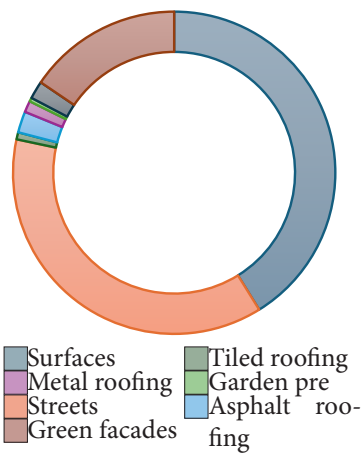


Figure 150.

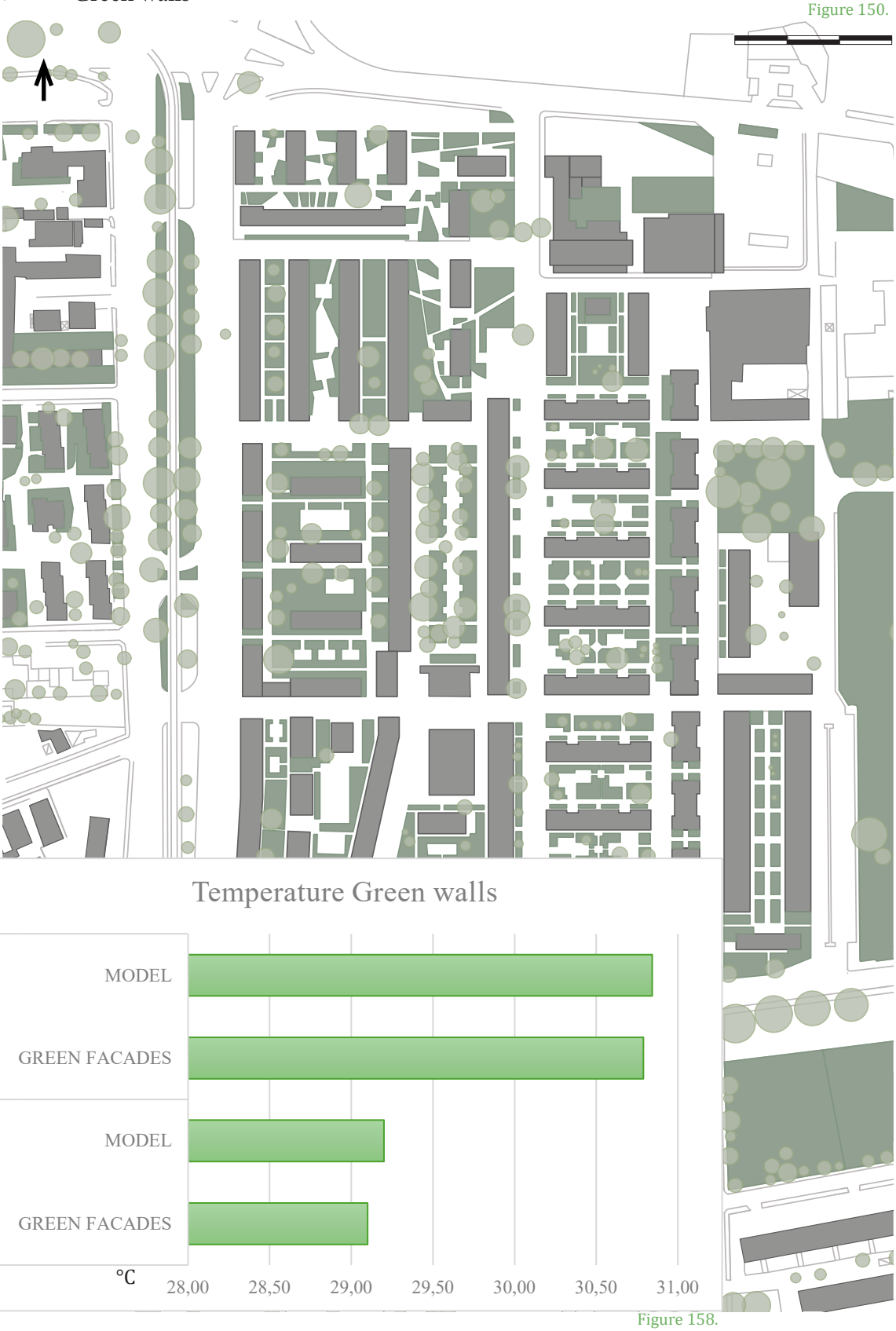


Figure 158.

Green walls

Figure 157.



Cool materials:

Pre

Figure 144.



Post:

Figure 159.



Figure 159. Schematic representation of Quarticciolo with the installation of cool materials

Figure 160. The graph illustrates the different types of surfaces present following the redevelopment work.

Figure 161. Temperature trend during the statistically hottest day of the year, indoor and outdoor pre and post intervention

Figure 162. Maximum temperature at 2 p.m. on the statistically hottest day of the year indoor and outdoor, pre- and post-intervention

Figure 163. Post-intervention planimetry

Cool materials:

PRE		COOL	
Surfaces tot	397318 mq	Surfaces tot	397318 mq
streets	358890 mq	cool asphalt	358890 mq
tiled roofing	6854,724324 mq	cool tiled roofing	6854,724324 mq
Asphalt roofing	20564,17297 mq	Cool Asphalt roofing	20564,17297 mq
metal roofing	11009,1027 mq	cool metal roofing	11009,1027 mq
garden pre	3666 mq	garden pre	3666 mq
tree pre	17300,7 mq	tree pre	17300,7 mq

EFFECTIVENESS:

Outdoor:

Wind speed: \

UTCI: ●●

Temperature: ●●

UR%: ●●●

Indoor:

Wind speed:

UTCI: ●●

mrt indoor: ●●

UR%: ●●●

Temperature: ●

Pre:

Figure 147.

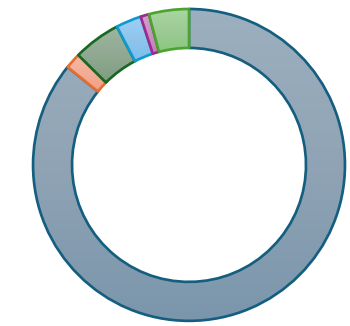
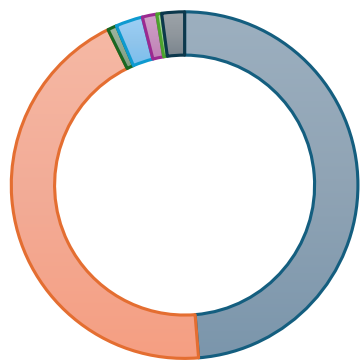
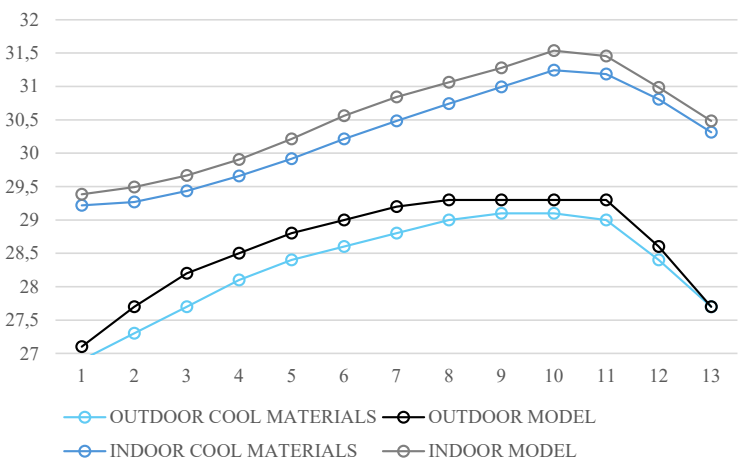


Figure 160.



°C

Figure 161.



Cool materials

Figure 150.

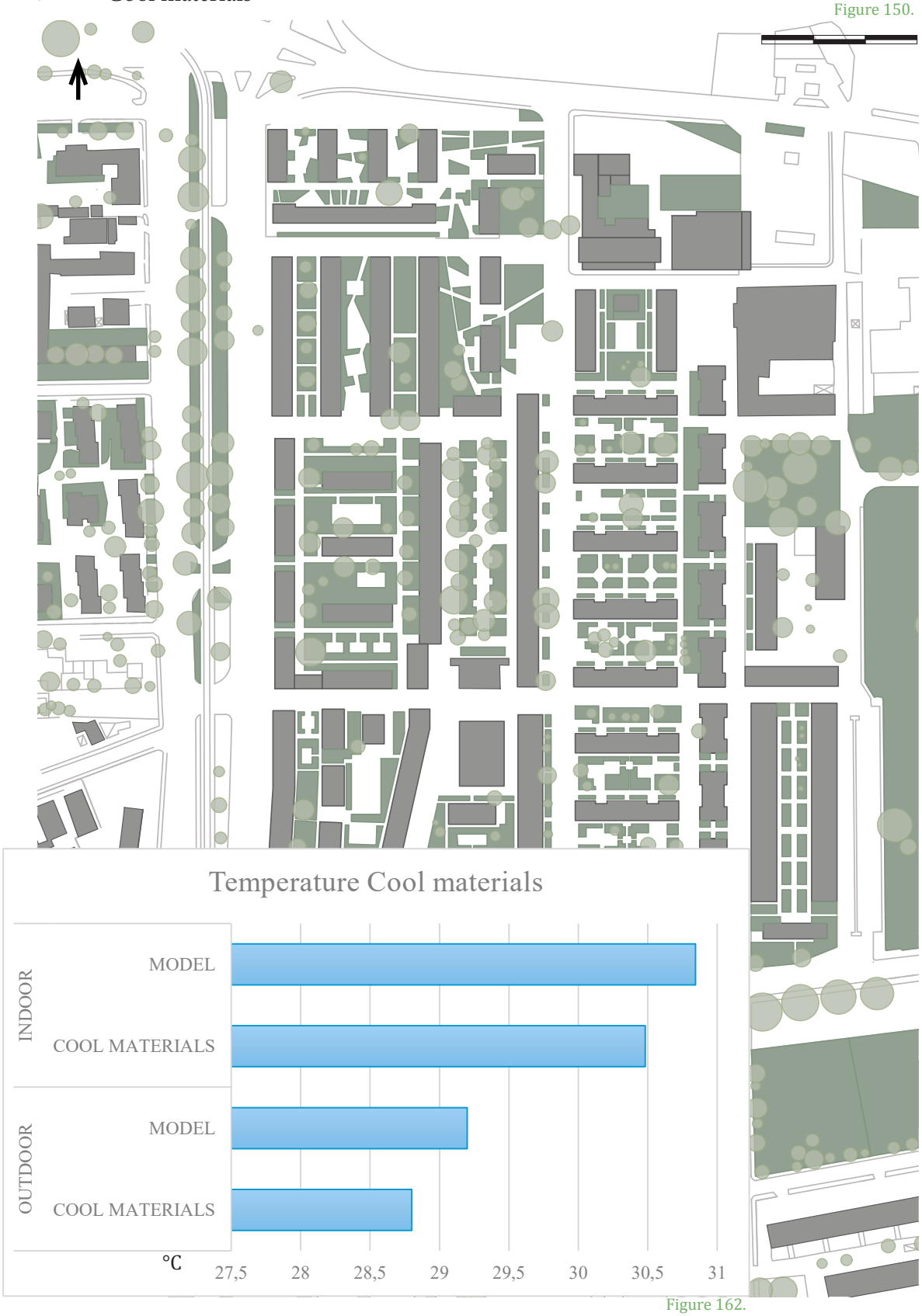


Figure 162.

Cool materials

p. 631
Figure 163.



Greening:

Pre

Figure 144.

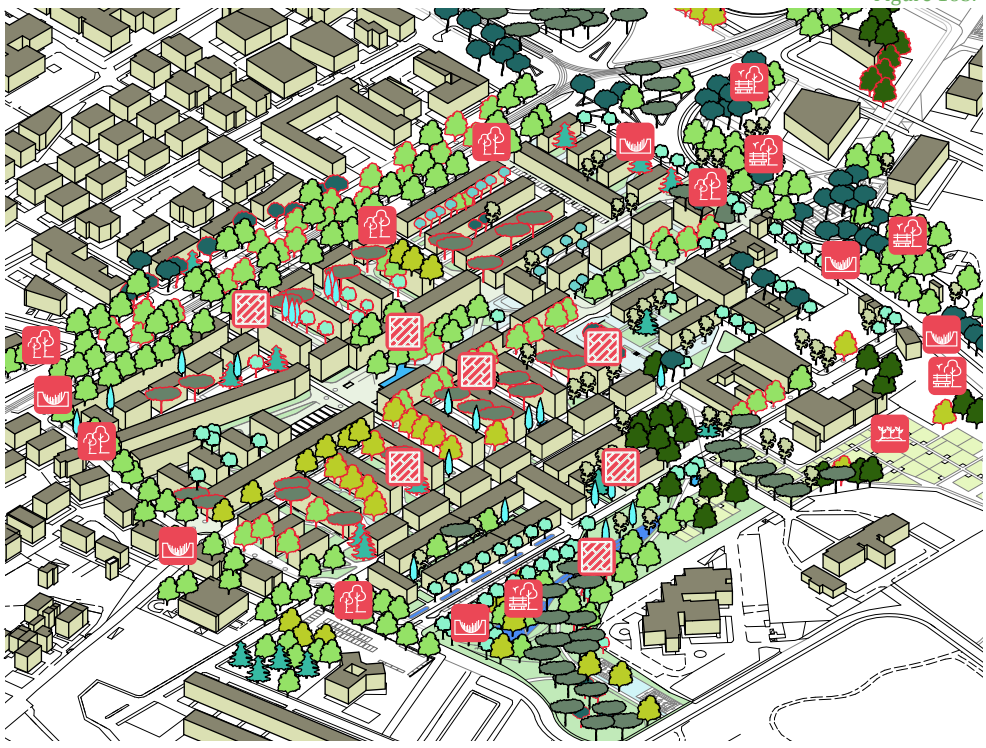


Figure 165.
Schematic representation of Quarticciolo with the installation of green infrastructure

Figure 166.
The graph illustrates the different types of surfaces present following the

Post:

Figure 165.



Greening

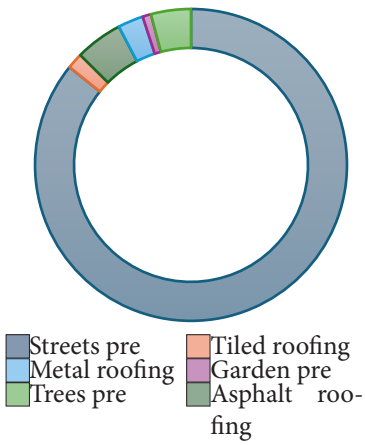
PRE
Surfaces tot 397318 mq
strreets 358890 mq
tiled roofing 6854,724324 mq
Asphalt roofing 20564,17297 mq
metal roofing 11009,1027 mq
garden pre 3666 mq
tree pre 17300,7 mq

GREEN
Surfaces tot 397318 mq
streets 358890 mq
tiled roofing 6854,724324 mq
Asphalt roofing 20564,17297 mq
metal roofing 11009,1027 mq
garden post 21384 mq
tree post 36810 mq
urban farmings 6955 mq
masselli autobloccanti 6662 mq

EFFECTIVENESS:
Outdoor:
Wind speed: ●●●
UTCI: ●
Temperature: ●
UR%: ●●●
Indoor:
Wind speed: ●●●
UTCI: ●
mrt indoor: ●
UR%: ●●●
Temperature: ●

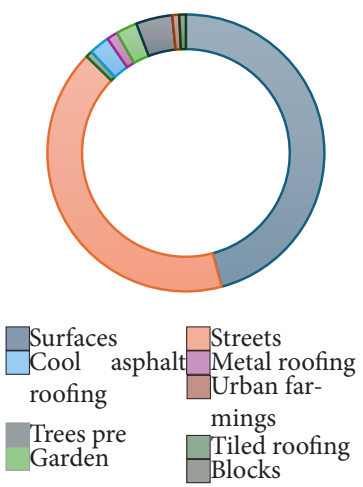
Pre:

Figure 147.



Post:

Figure 166.



°C

Figure 167.

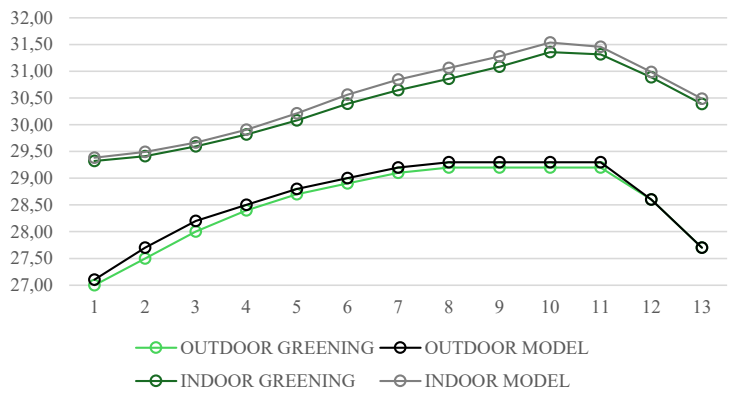


Figure 150.

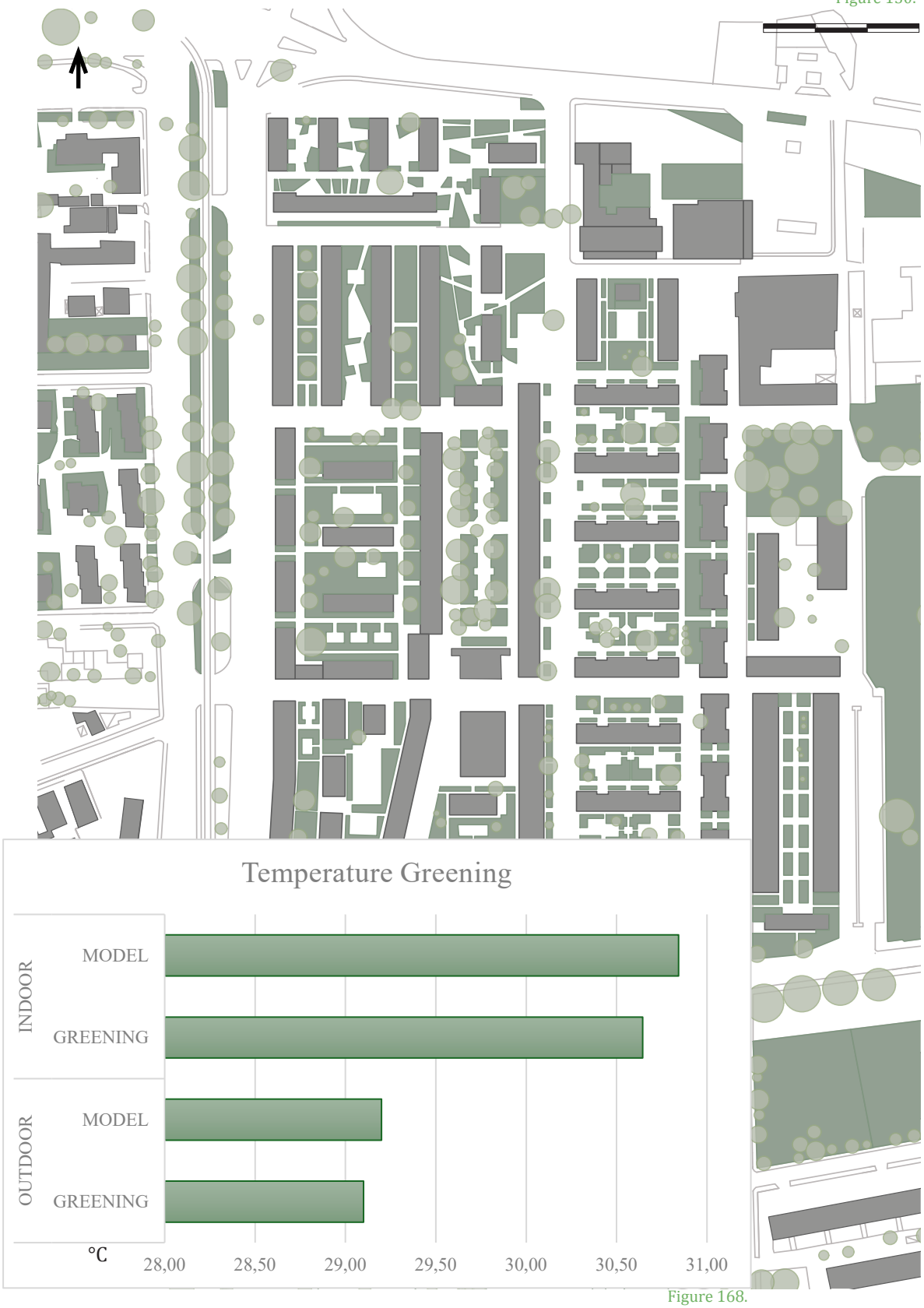


Figure 168.

Greening

Figure 169.



Shading:

Pre

Figure 144.



Figure 171. Schematic representation of Quarticciolo post intervention

Figure 172. The graph illustrates the different types of surfaces present following the redevelopment work.

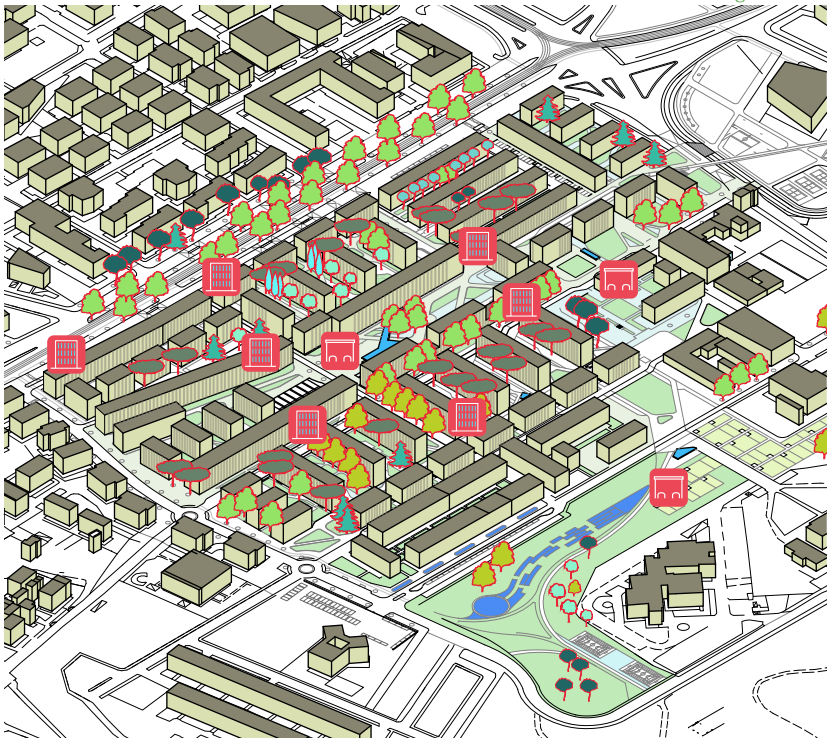
Figure 173. Temperature trend on the statistically hottest day of the year, indoor and outdoor, post intervention

Figure 174. Air temperature on the statistically hottest day of the year, at 2 p.m., indoor and outdoor, pre and post intervention

Figure 175. Post intervention planimetry

Post:

Figure 171.



Shading:

PRE

Surfaces tot	397318 mq
streets	358890 mq
tiled roofing	6854,724324 mq
Asphalt roofing	20564,17297 mq
metal roofing	11009,1027 mq
garden pre	3666 mq
tree pre	17300,7 mq

SHADING:

Surfaces tot	397318 mq
streets	358890 mq
tiled roofing	6854,724324 mq
Asphalt roofing	20564,17297 mq
metal roofing	11009,1027 mq
garden pre	3666 mq
tree pre	17300,7 mq
outdoor shading	1582 mq
indoor shading	1841630,857 mq

EFFECTIVENESS:

Outdoor:

Wind speed: \

UTCI: ●

Temperature: ●

UR%: ●●●

Indoor:

Wind speed: ●

UTCI: ●

mrt indoor: ●

UR%: ●●

Temperature: ●

Pre:

Figure 147.

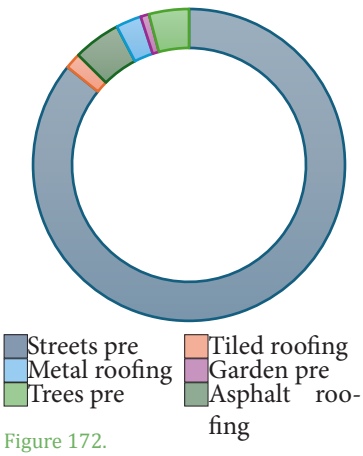
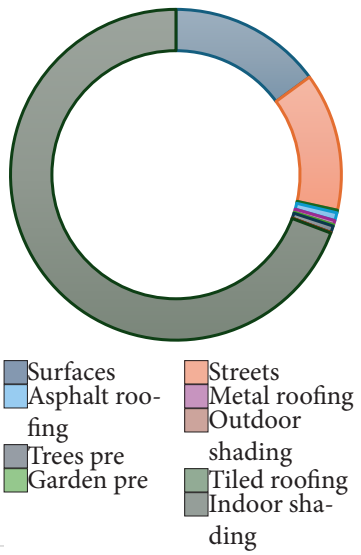
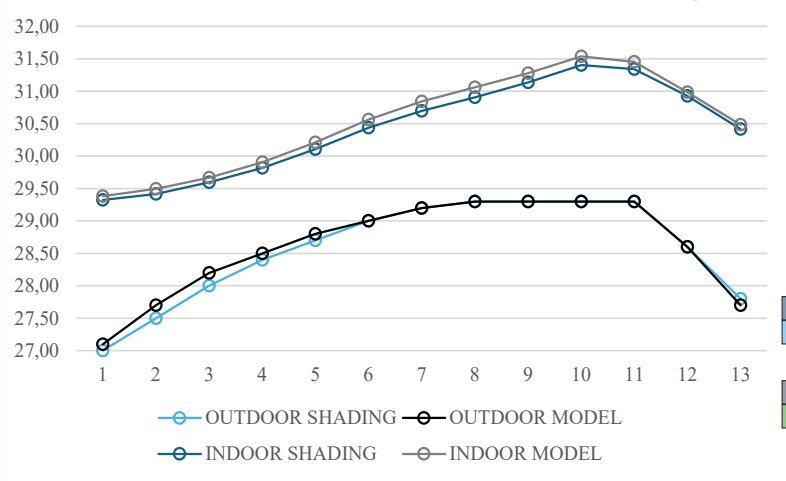


Figure 172.



°C

Figure 173.



Shading

Figure 150.

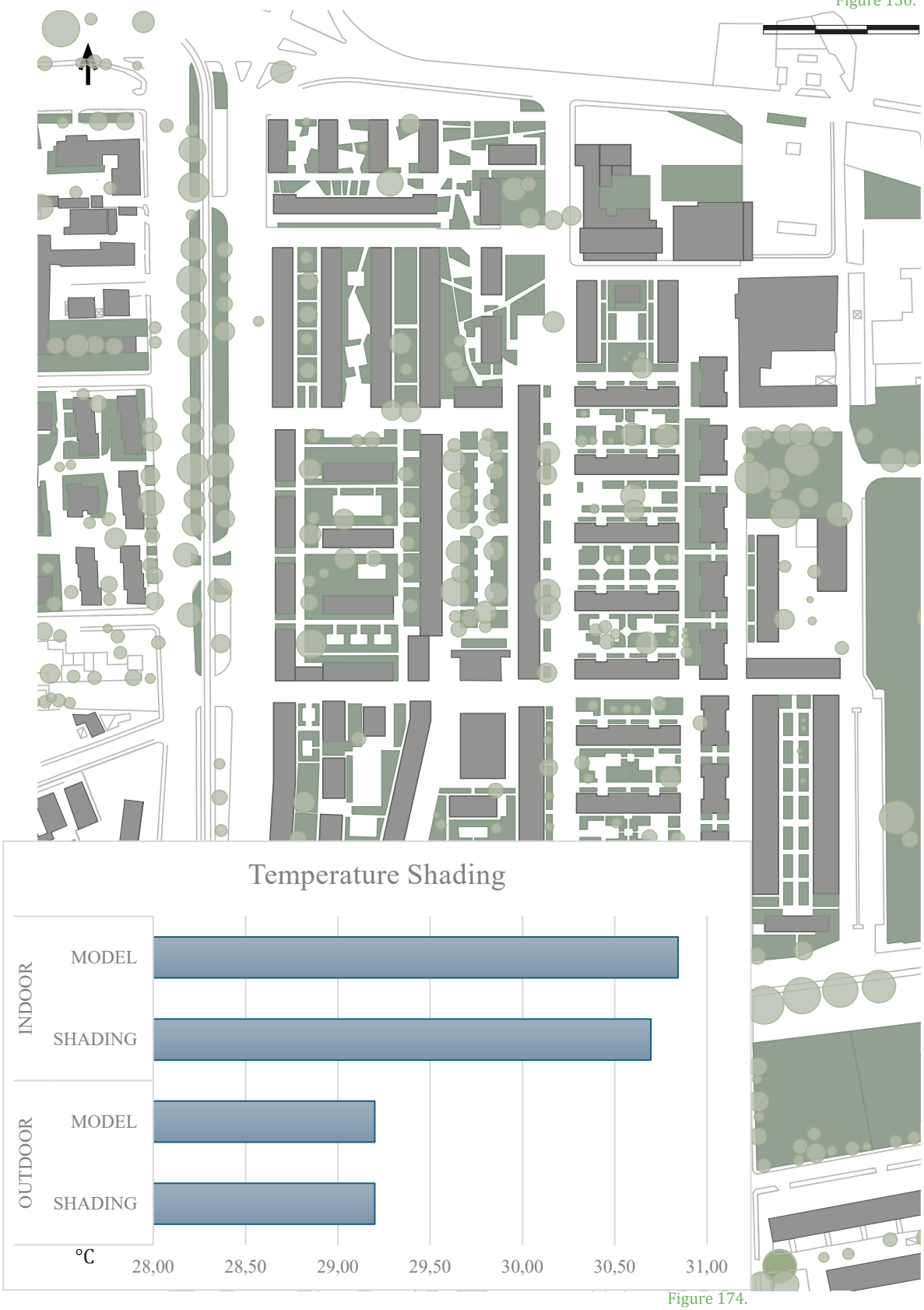


Figure 174.

Shading

Figure 175.



Greening + cool materials:

Pre

Figure 144.

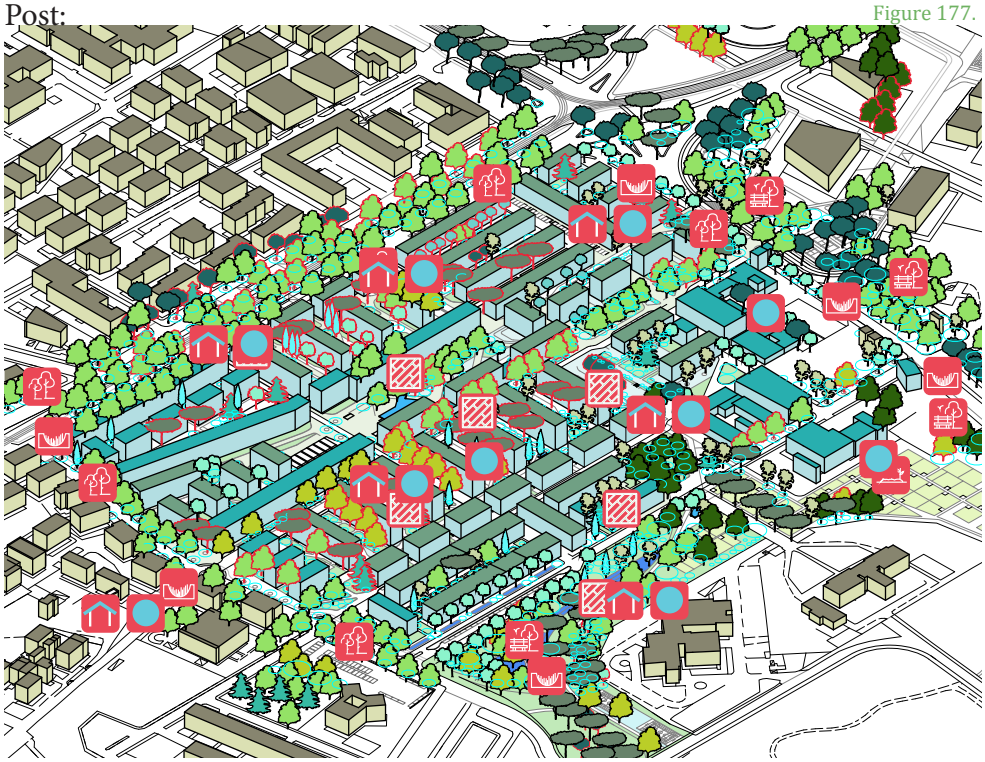


Figure 177.
Schematic representation of Quarticciolo post intervention

Figure 178.
The graph illustrates the different types of surfaces present following the

Post:

Figure 177.



Greening + Cool materials

PRE
Surfaces tot 397318 mq
streets 358890 mq
tiled roofing 6854,724324 mq
Asphalt roofing 20564,17297 mq
metal roofing 11009,1027 mq
garden pre 3666 mq
tree pre 17300,7 mq

GREEN +COOL
Surfaces tot 397318 mq
cool asphalt 358890 mq
cool tiled roofing 6854,724324 mq
Cool Asphalt roofing 20564,17297 mq
cool metal roofing 11009,1027 mq
garden post 21384 mq
tree post 36810 mq
urban farmings 6955 mq
Blocks 6662 mq

EFFECTIVENESS:
Outdoor:
Wind speed: ●●●
UTCI: ●●
Temperature: ●●
UR%: ●●●
Indoor:
Wind speed: ●●
UTCI: ●●
mrt indoor: ●
UR%: ●●●
Temperature: ●

Pre:

Figure 147.

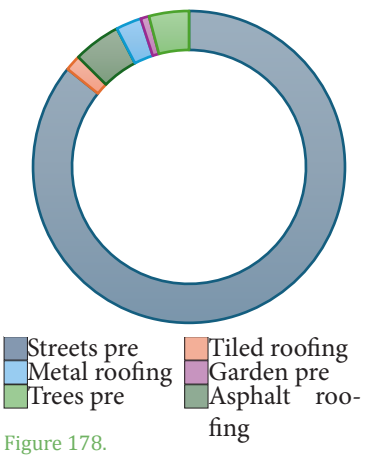


Figure 178.

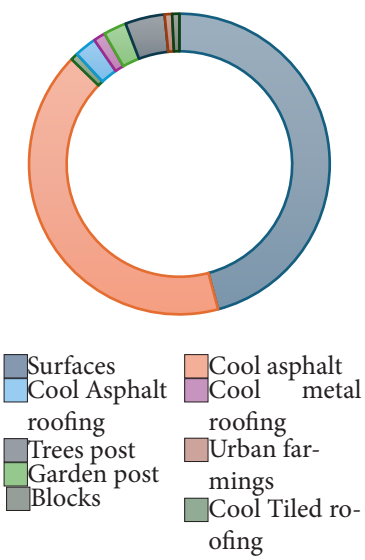
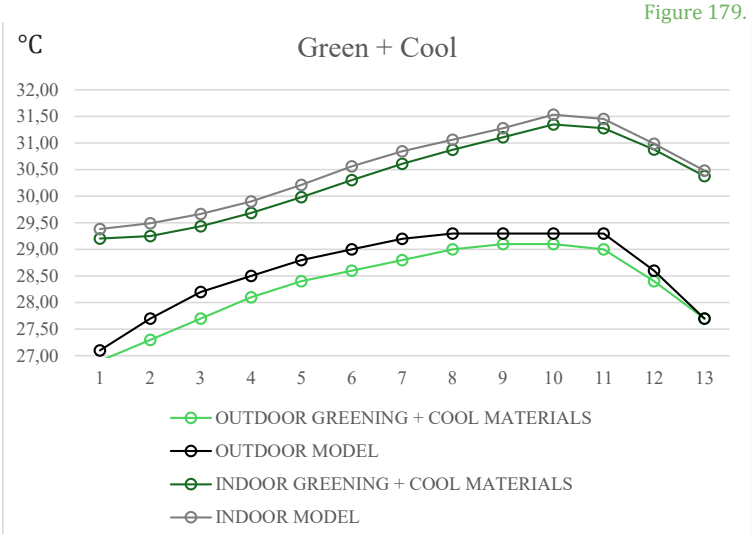


Figure 179.



Greening + Cool materials

Figure 150

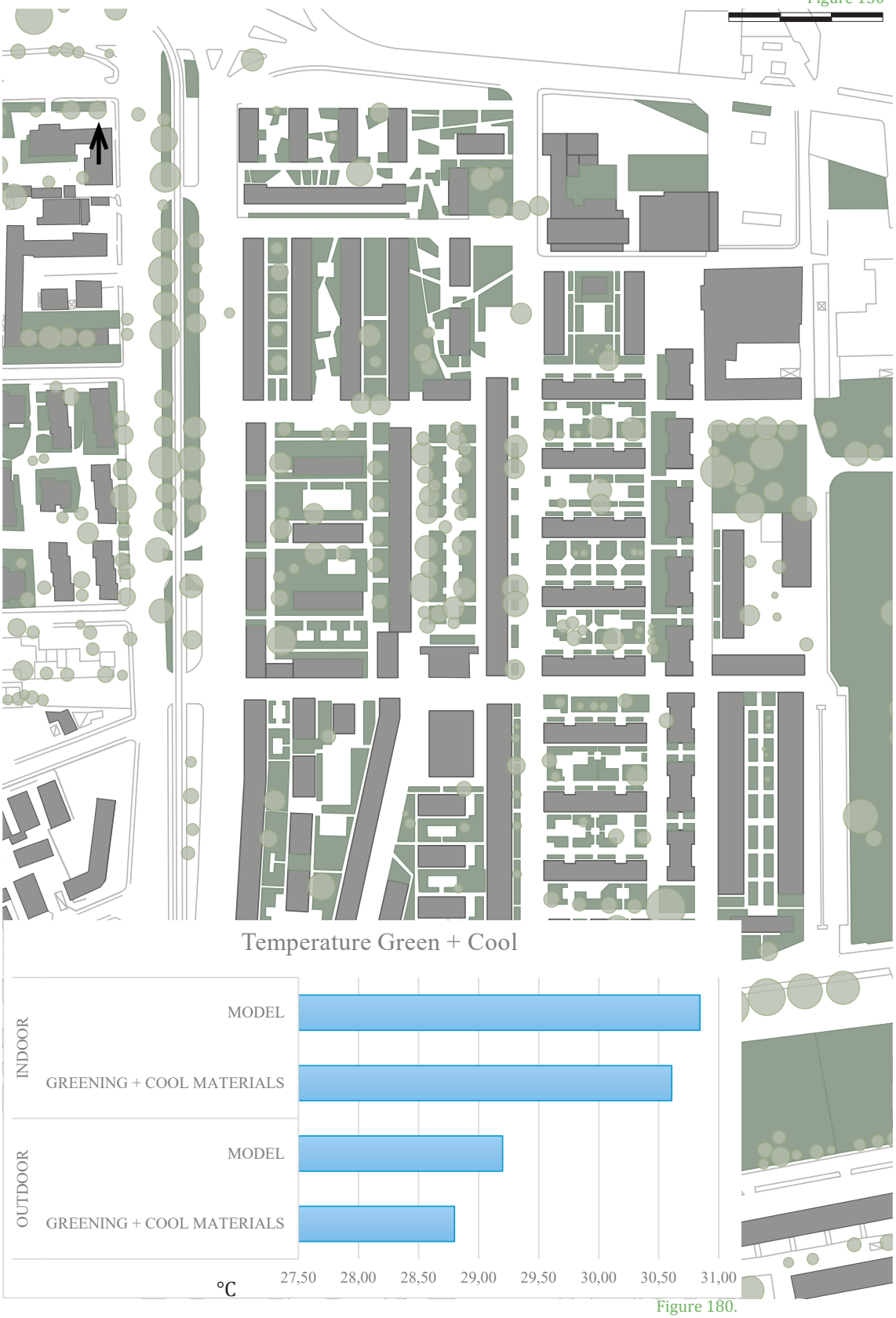
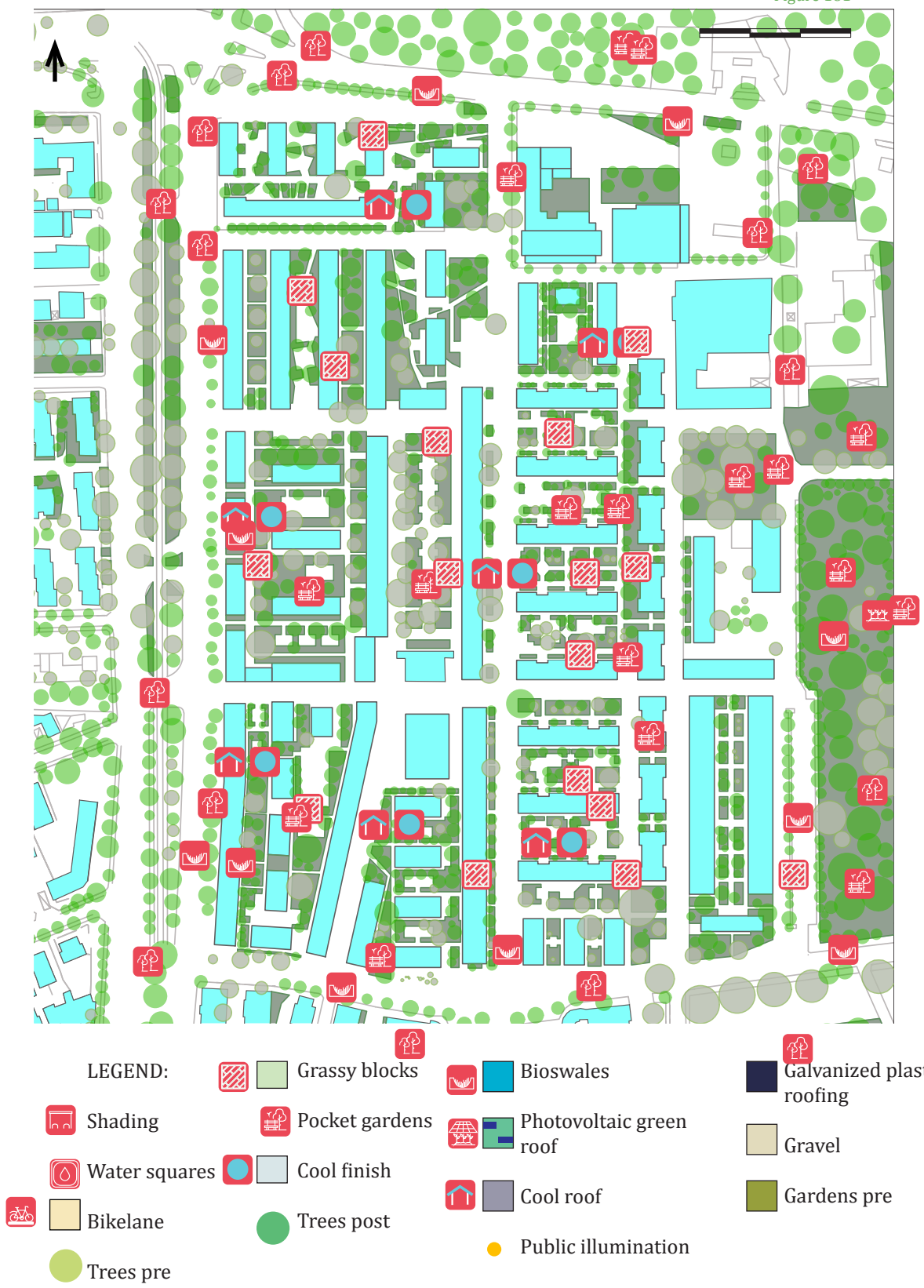


Figure 180.

Greening + Cool materials

Figure 181



Greening + Shading

Pre

Figure 144.



Figure 183. Post-operative schematic representation.

Figure 184. The graph illustrates the different types of surfaces present following the redevelopment work.

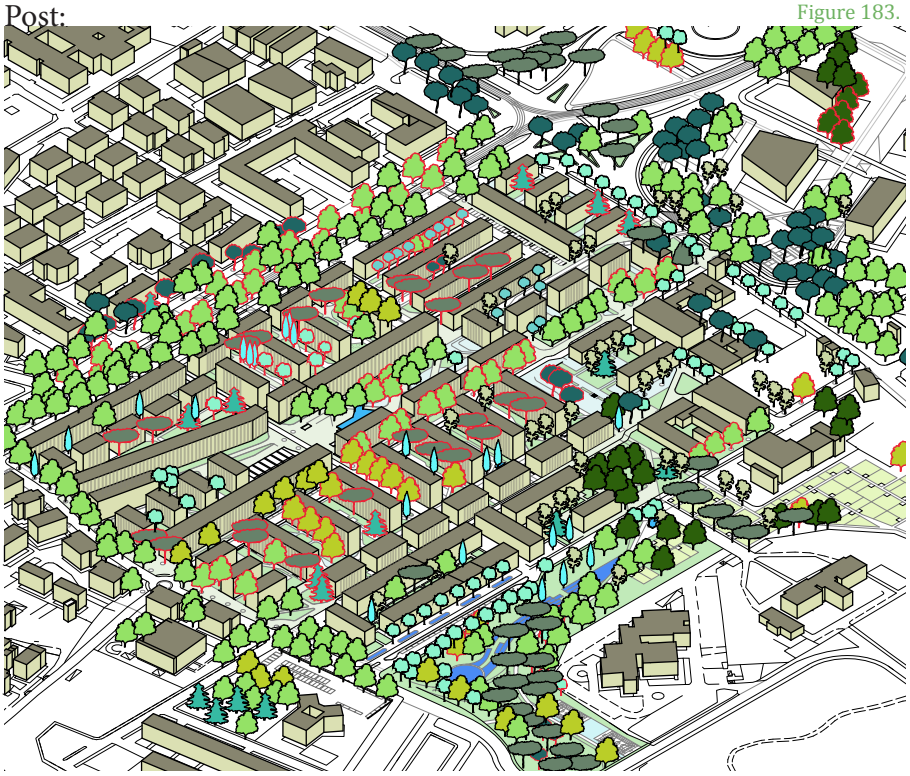
Figure 185. Temperature trend during the statistically hottest day of the year, indoor and outdoor, pre- and post-intervention

Figure 186. Air temperature at 2 p.m., during the statistically hottest day of the year, pre and post intervention, indoor and outdoor

Figure 187. Post intervention plan

Post:

Figure 183.



Greening + Shading

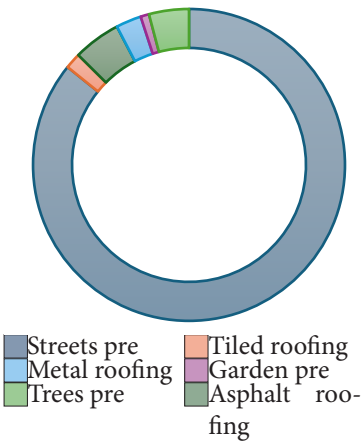
PRE
Surfaces tot 397318 mq
streets 358890 mq
tiled roofing 6854,724324 mq
Asphalt roofing 20564,17297 mq
metal roofing 11009,1027 mq
garden pre 3666 mq
tree pre 17300,7 mq

GREEN + SHADING
Surfaces tot 397318 mq
Streets 358890 mq
tiled roofing 6854,724324 mq
Asphalt roofing 20564,17297 mq
metal roofing 11009,1027 mq
garden post 21384 mq
tree post 36810 mq
urban farmings 6955 mq
Blocks 6662 mq
outdoor shading 1582 mq
indoor shading 1841630,857 mq

EFFECTIVENESS:
Outdoor:
Wind speed: ●●●
UTCI: ●
Temperature: ●
UR%: ●●●
Indoor:
Wind speed: ●●
UTCI: ●
mrt indoor: ●●
UR%: ●●●
Temperature: ●

Pre:

Figure 147.



Post:

Figure 184.

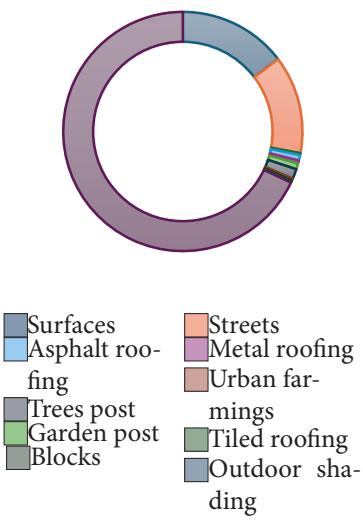
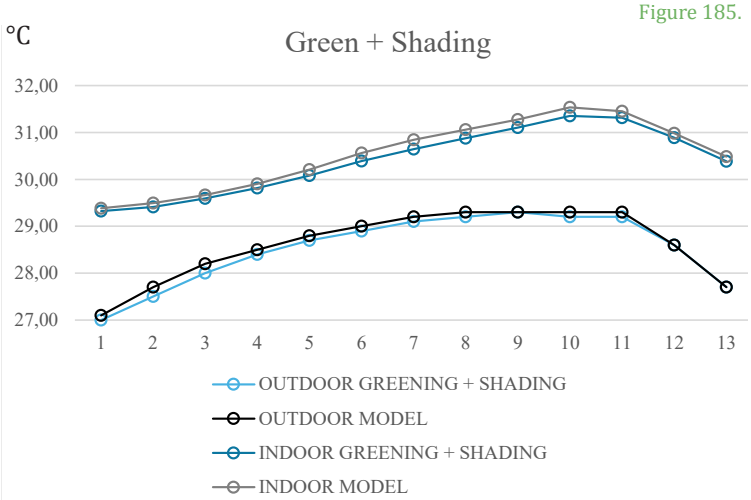


Figure 185.



Greening + Shading

Figure 150.

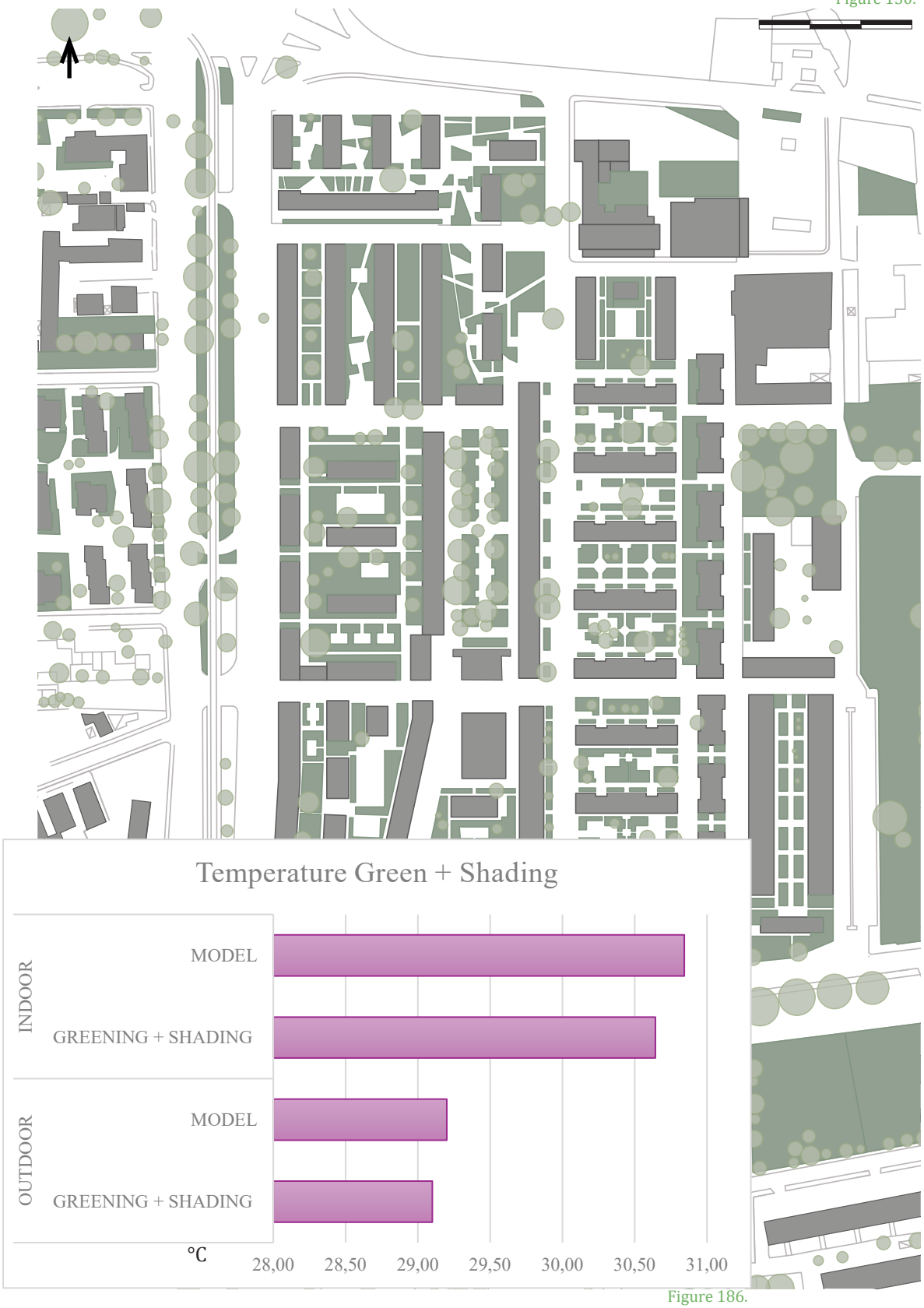


Figure 186.

Greening + Shading

Figure 187.



Greening + Shading + Cool materials

Pre

Figure 144.



Figure 189. Schematic representation of Quarticciolo post intervention

Figure 190. The graph illustrates the different types of surfaces present following the redevelopment work.

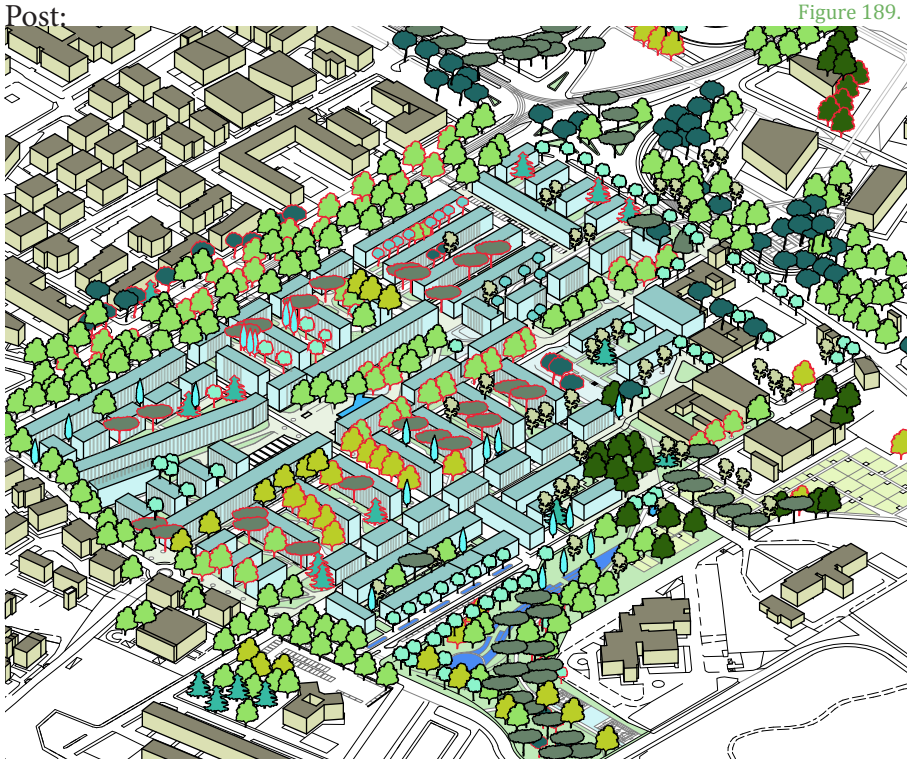
Figure 191. Temperature trend during the statistically hottest day of the year, pre and post intervention, indoor and outdoor

Figure 192. Pre- and post-intervention air temperature at 2 p.m. on the statistically hottest day of the year, indoor and outdoor

Figure 193. Post intervention planimetry

Post:

Figure 189.



Greening + Shading + Cool materials

PRE		GREEN +COOL+SHADING	
Surfaces tot	397318 mq	Surfaces tot	397318 mq
streets	358890 mq	cool asphalt	358890 mq
tiled roofing	6854,724324 mq	cool tiled roofing 6854,724324	mq
Asphalt roofing	20564,17297 mq	Cool Asphalt roofing 20564,17297	mq
metal roofing	11009,1027 mq	cool metal roofing 11009,1027	mq
garden pre	3666 mq	garden post	21384 mq
tree pre	17300,7 mq	tree post	36810 mq
		urban farmings	6955 mq
		Blocks	6662 mq
		outdoor shading	1582 mq
		indoor shading	1841630,857 mq

EFFECTIVENESS:

Outdoor:

Wind speed: ●●●

UTCI: ●●

Temperature: ●●

UR%: ●●●

Indoor:

Wind speed: ●●

UTCI: ●●

mrt indoor: ●

UR%: ●●●

Temperature: ●

Pre:

Figure 147.

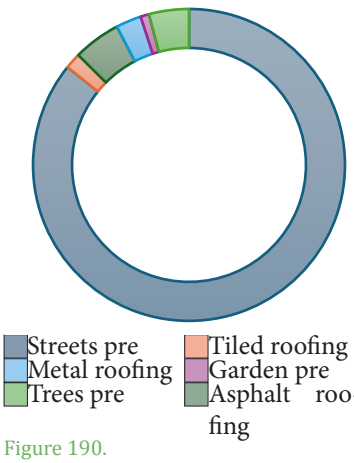


Figure 190.

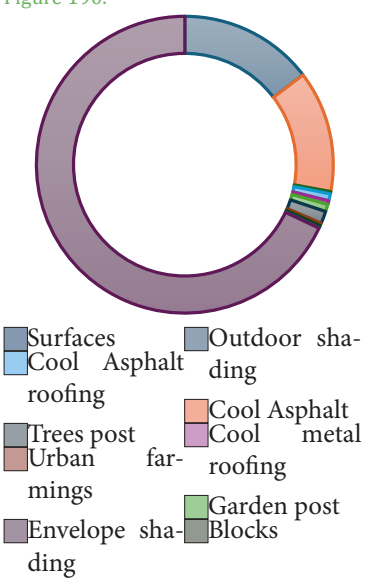
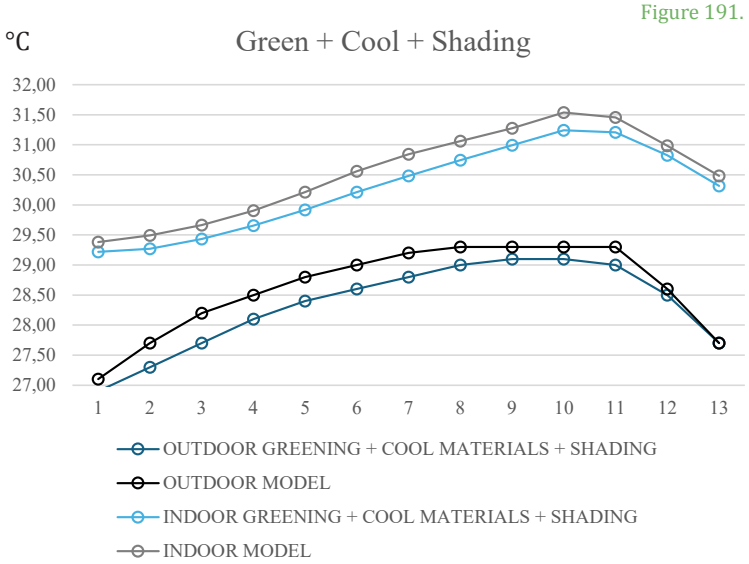


Figure 191.



p. 650

Greening + Shading + Cool materials

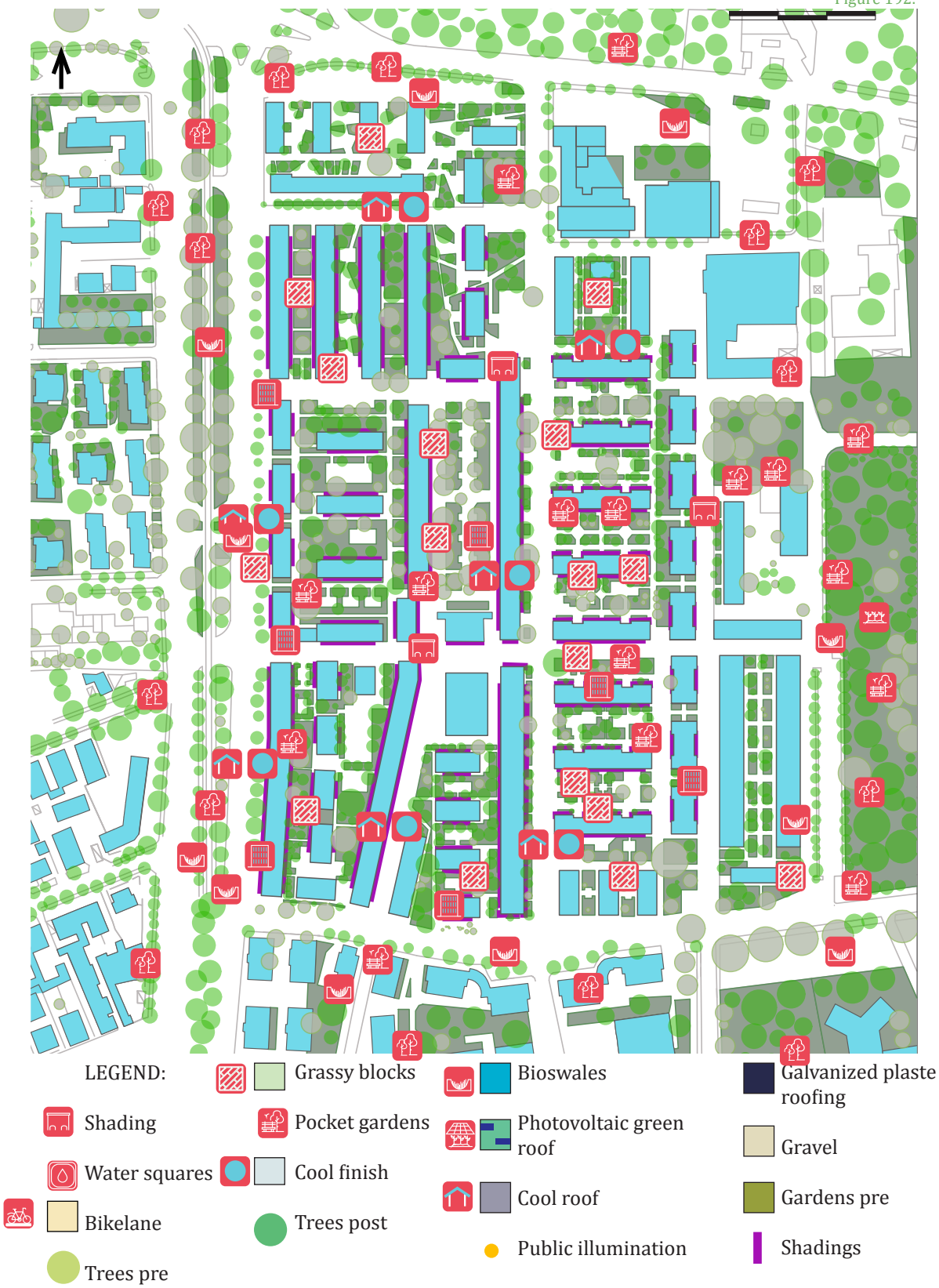
Figure 150.



Figure 192.

Greening + Shading + Cool materials

Figure 192.



Final Masterplan

Pre

Figure 144.



Figure 194. Schematic representation of the post-intervention masterplan

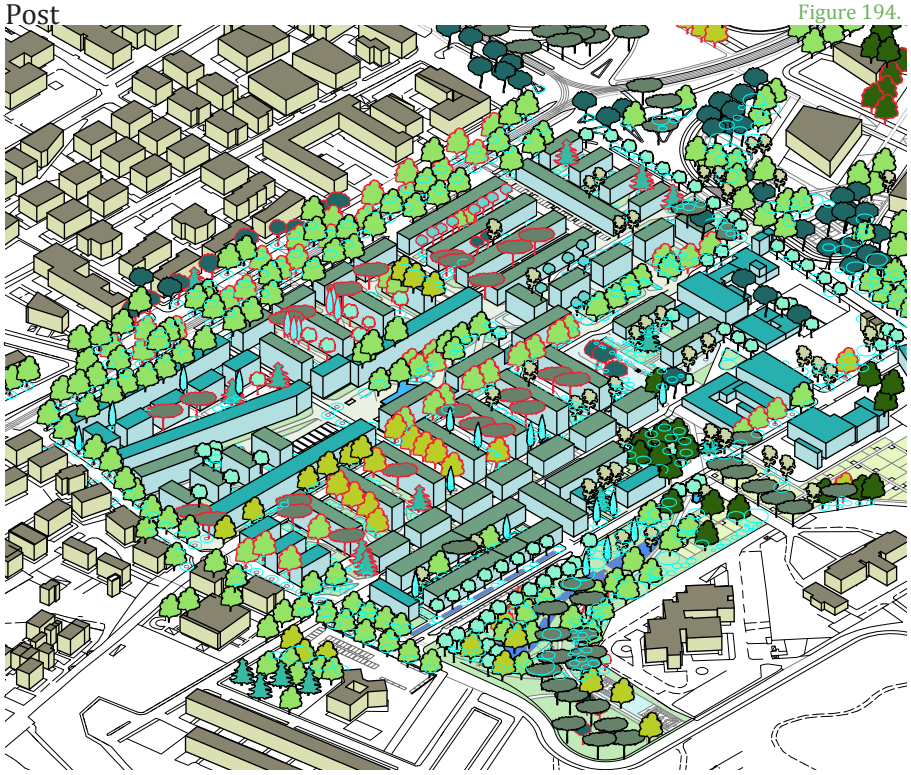
Figure 195. Indoor focus on the post intervention in a typical building. Author's elaboration, based on Lorenzo Mariani's dissertation

Figure 196. Air temperature at 2.00 om during the statistically hottest day of the year, pre and post intervention, indoor and outdoor

Figure 197. Post-intervention plan

Post

Figure 194.



Final masterplan

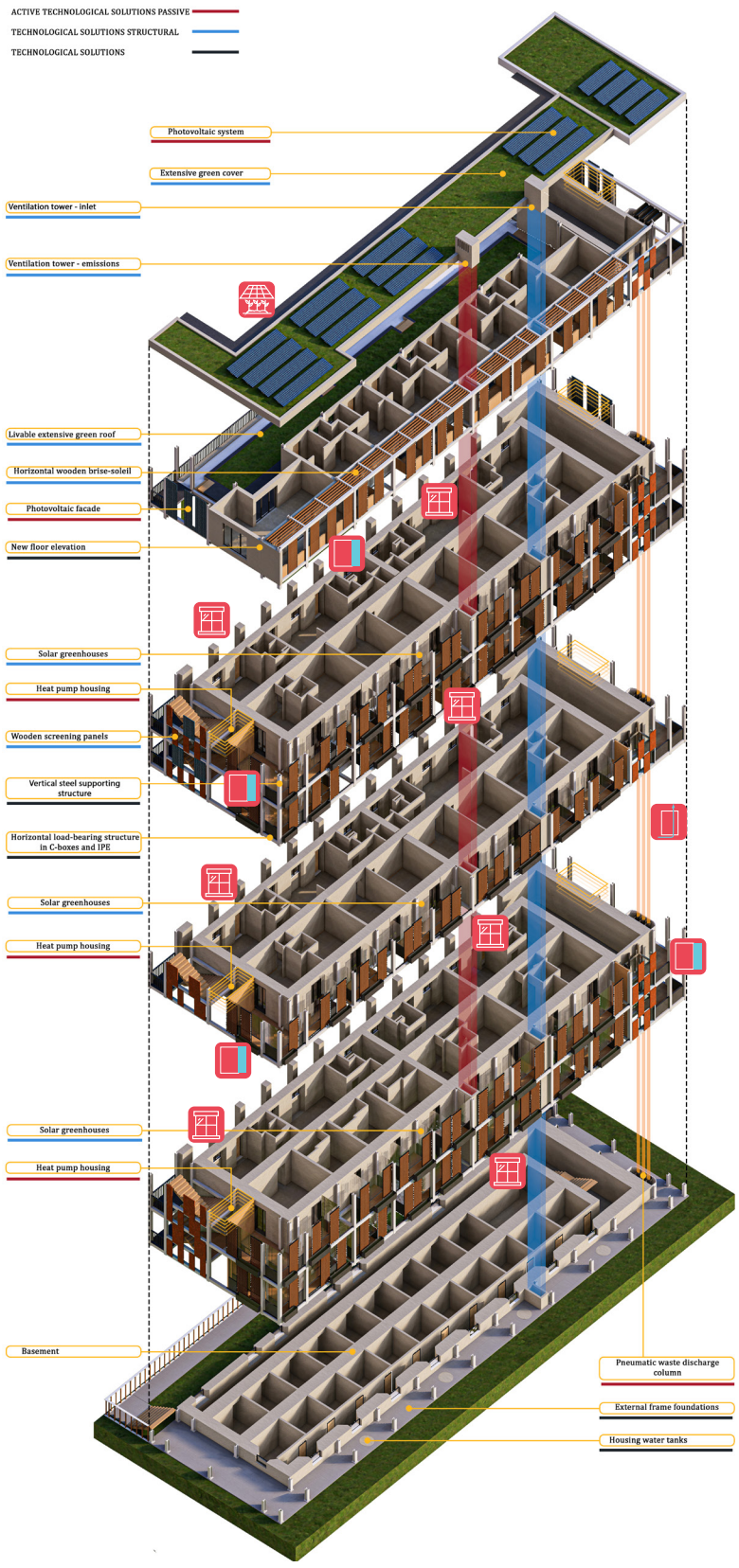


Figure 195.

Final Masterplan

Figure 150.

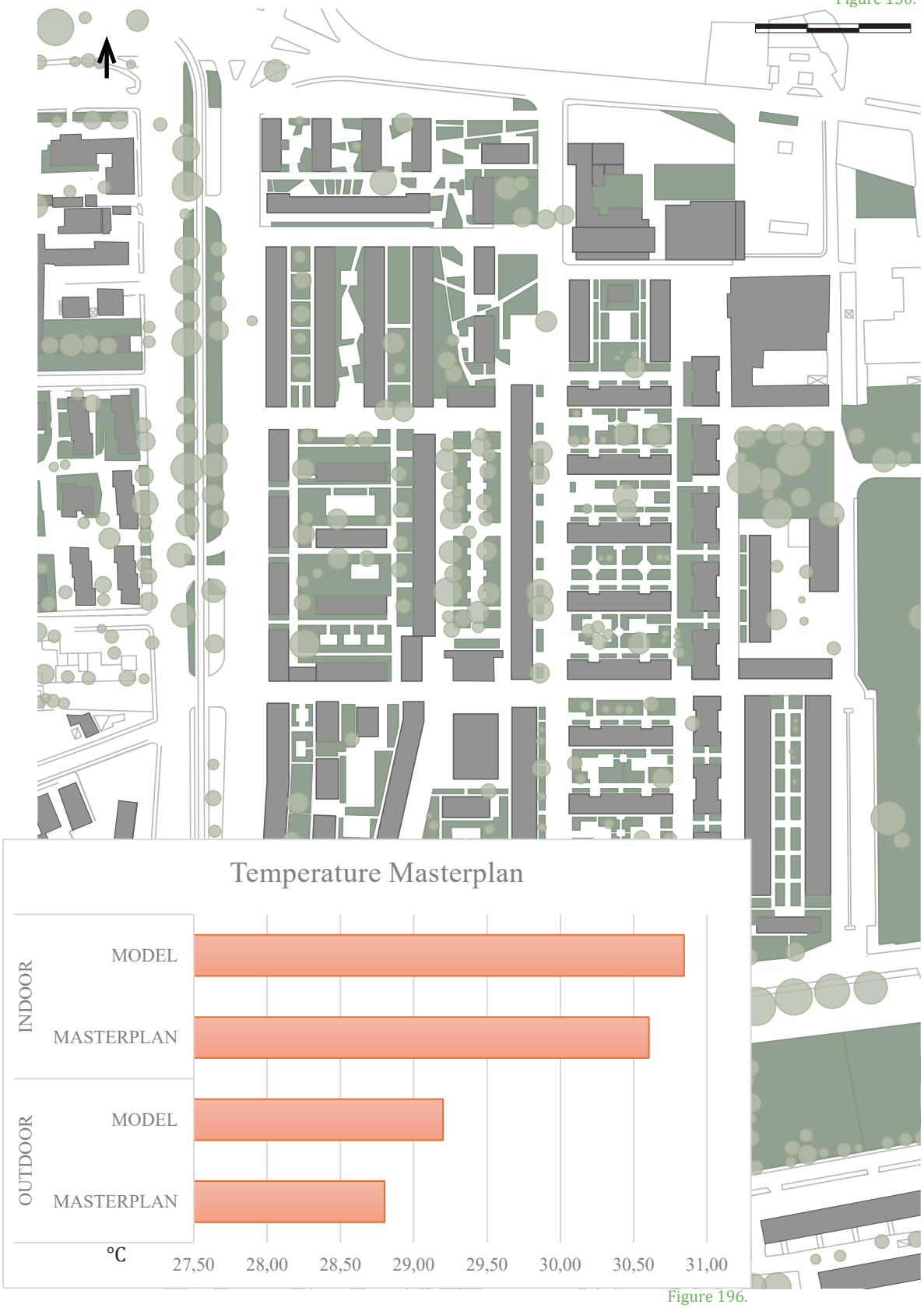


Figure 196.

Final masterplan

Figure 197.



Final Masterplan

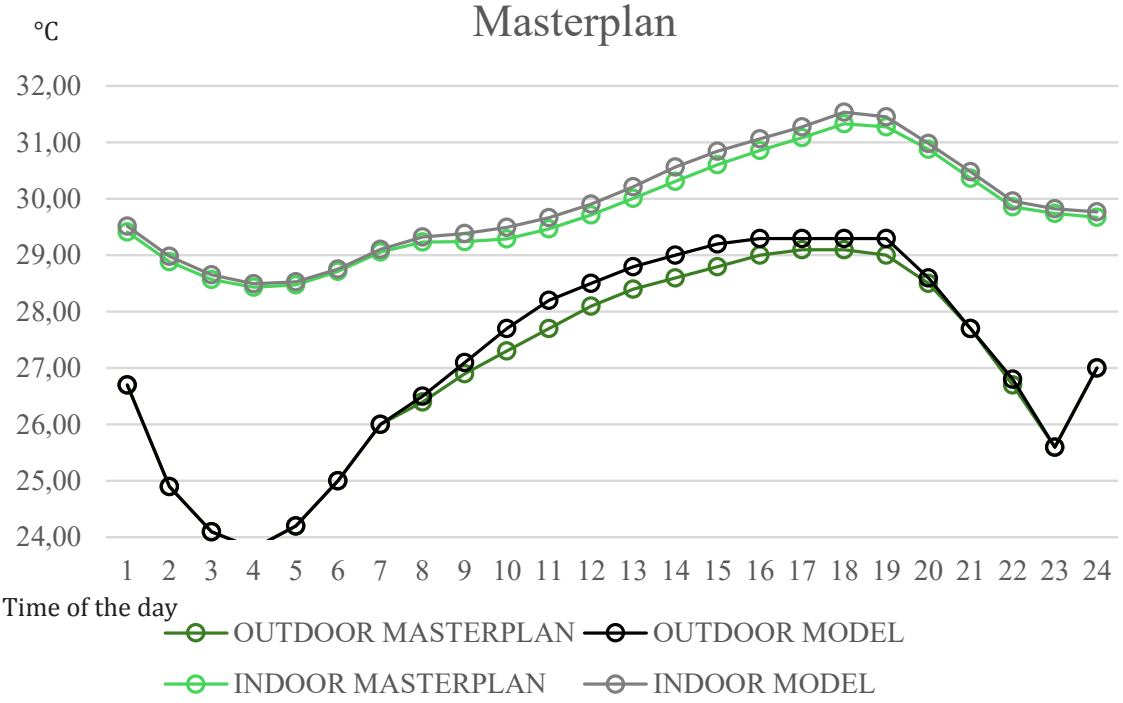


Figure 199.

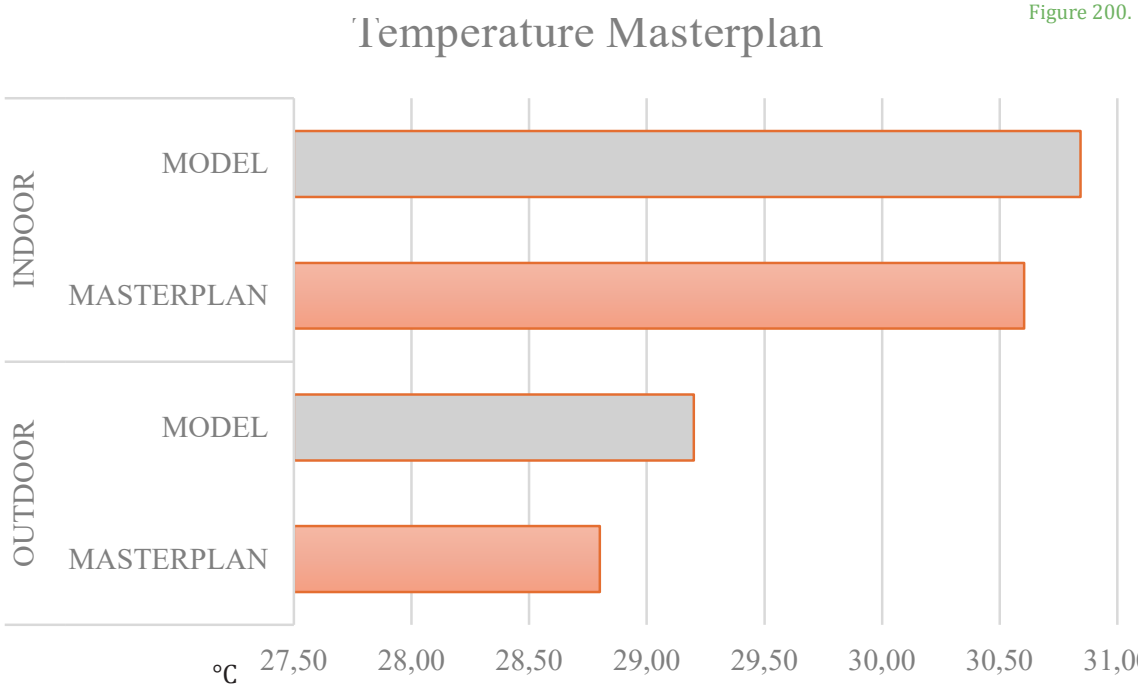


Figure 200.

Final masterplan

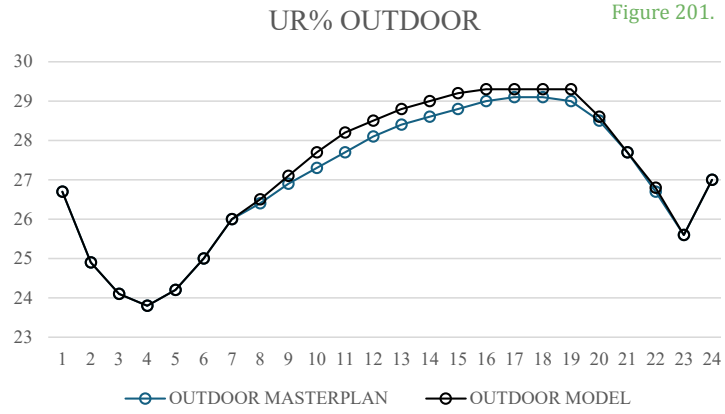


Figure 201.

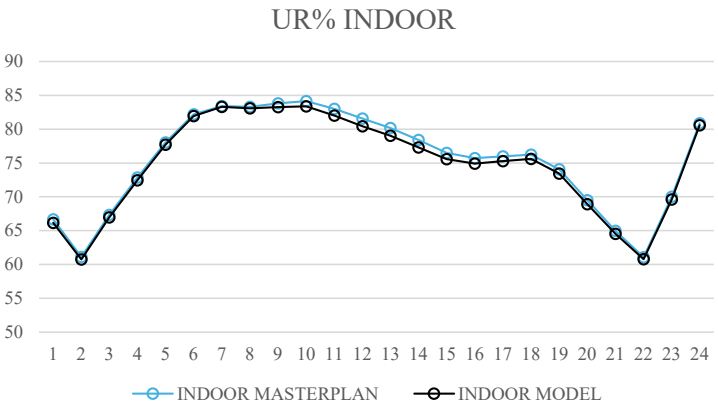


Figure 203.

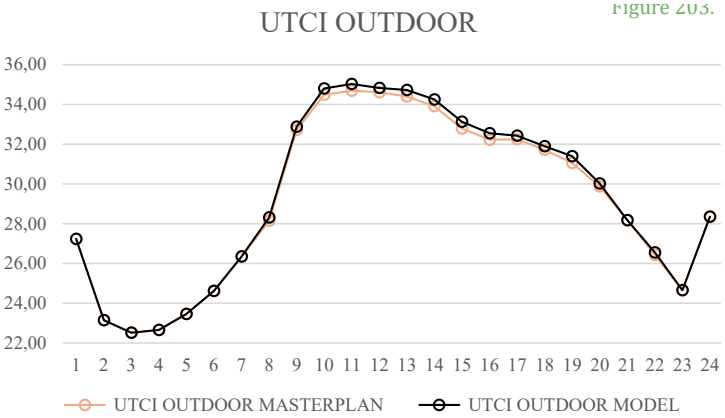


Figure 204.

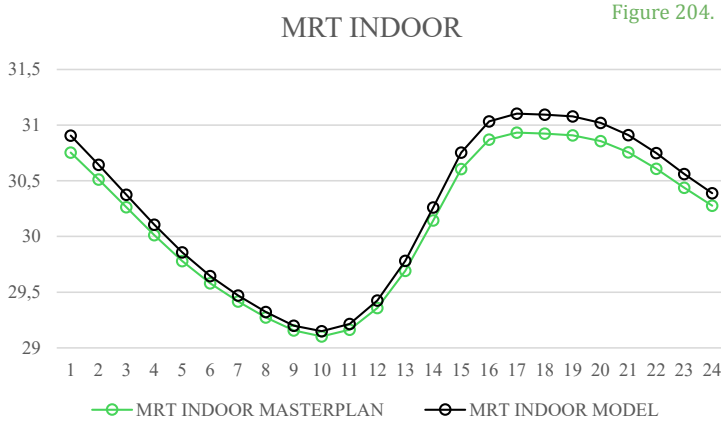


Figure 199. Air temperature trends during the statistically warmest day of the year, indoor and outdoor, pre- and post-intervention

Figure 200. Air temperature at 2.00 pm, during the statistically warmest day of the year, indoor and outdoor, pre- and post-intervention

Figure 201. Outdoor relative humidity trend, during the statistically hottest day of the year, pre- and post-intervention

Figure 202. Indoor relative humidity trend during the statistically hottest day of the year, pre- and post-intervention

Figure 203. Universal Thermal comfort outdoor trend during the statistically hottest day of the year, pre- and post-intervention

Figure 204. Trend of the average indoor radiant temperature during the statistically hottest day of the year, pre- and post-intervention

Figure 205. Analysis of the square metres of surface area post intervention

Figure 206. Analysis of the amount of square metres occupied by trees pre- and post-intervention

Figure 207. Analysis of the type of post intervention tree cover

Tab. IX. The table analyses the levels of effectiveness and efficiency for each action used, based on the scientific literature and simulations carried out

Figure 208. Analysis of post-intervention vertical surfaces

Innovative and integrated energetic and bioclimatic strategies for adapting existing contexts to climate change and extreme events, aiming to mitigate the environmental impact

p. 658

Final Masterplan

Objective:

MACRO OBJECTIVES

- Urban heat island adaptation and mitigation
- Extreme temperature adaptation and mitigation
- Heat wave adaptation and mitigation



- NATURAL SYSTEM
- Decreased rate of degradation of structures and infrastructure given by continued high temperatures
- Management and reduction of alien species
- Restoration and enhancement of natural habitats
- Redevelopment of existing consolidated buildings, environmental heritage
- Decrease in building consumption



ANTHROPOGENIC SYSTEM

- Adaptation to hydrogeological risk
- Fire risk adaptation and mitigation
- Adaptation to drought/aridity risk
- Reduction of climate-altering emissions
- Reforestation



WELL-BEING

- Increased indoor and outdoor comfort and well-being of residents,
- Including concerning reducing the risk of disasters and extreme events,
- Including raising prevention/response capabilities
- Increase in the level of livability of the area
- Encouragement of community development and growth



Figure 205.

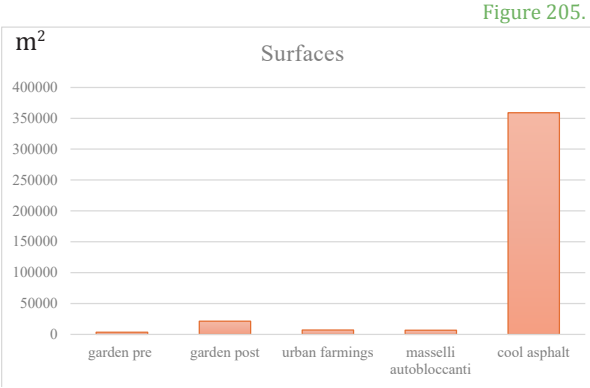


Figure 206.



Figure 207.

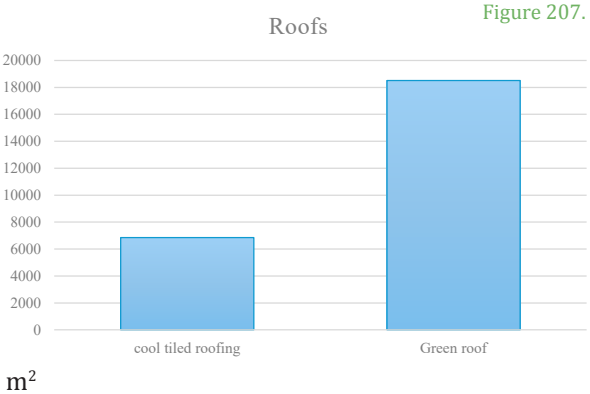
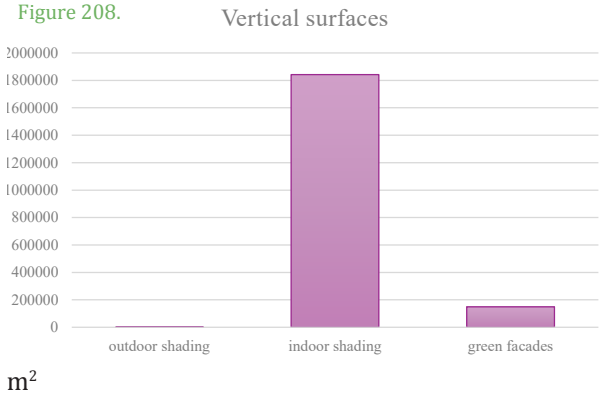


Figure 208.



Final masterplan

	EFFECTIVENESS:								RESPONSIVENESS			
	OUTDOOR				INDOOR				LIFE PERIOD			
	T	UR%	mrt	wind speed	T	UR%	mrt	wind speed	Period of installa-tion	Mainte-nace	Life span	Return en-vironemnta period
	●	●	●●	●	\	\	\	\	▭	!	▭	▭
	●	●●●	●●	●	\	\	\	\	▭	!!	▭	▭
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	●●●	●●●	●●	\	●●●	●●●	●●●	\	▭	!!!	▭	▭
	●	●●●	●●	\	●	●●	●	\	▭	!	▭	▭
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	●	●	●	\	\	\	\	\	▭	!!!	▭	▭

Tab IX.

Figure 209. Plan of the first, second, third, fourth and fifth floors of the post type building. Taken from Lorenzo Mariani's thesis paper.

Figure 210. Section A-A'. Taken from Lorenzo Mariani's thesis paper.

Figure 211. West elevation. Taken from Lorenzo Mariani's thesis paper.

Figure 212. South elevation. Taken from Lorenzo Mariani's thesis paper.



Figure 209.

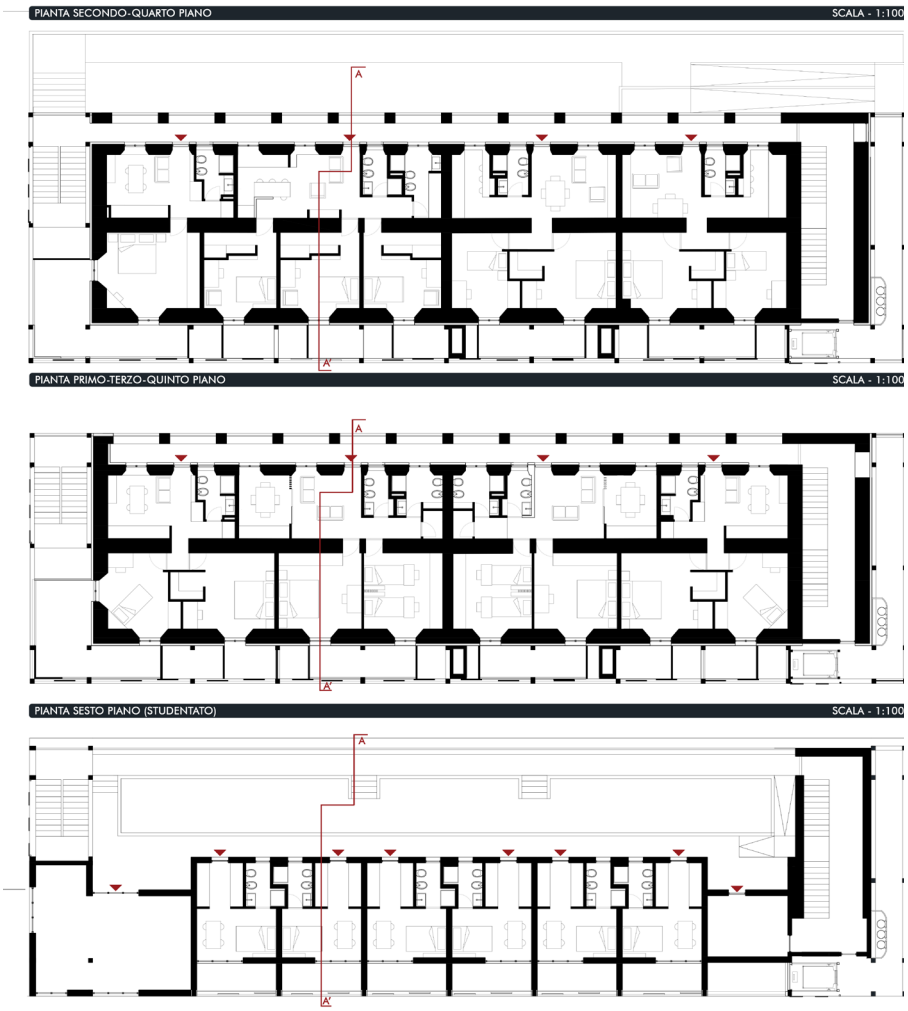


Figure 210.

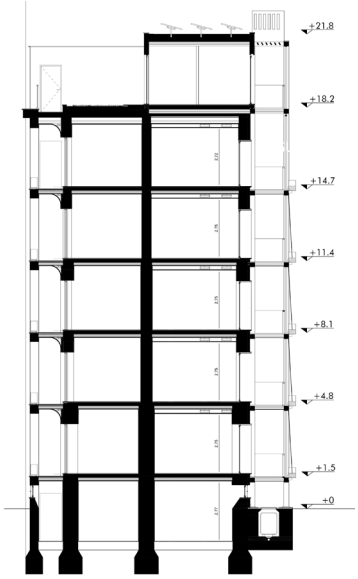


Figure 211.



Figure 212.



Solutions analysed and masterplan.

Before drawing up the final master plan, various simulations of individual technological solutions allowed a greater understanding of the response within the Quarticciolo district. Figures 147, 148, 156, 160, 166, 172, 178, 184, and 190 illustrate the composition of surfaces in relation to the total intervention area before and after mitigation and adaptation measures and systems were implemented. Table IX illustrates the actions and their simulated combinations. In particular, the use of shaded areas, cool materials, green infrastructure, green walls and roofs is modelled and simulated within the district. The combinations analysed are green infrastructure and cool materials, green infrastructure and shading systems, and green infrastructure combined with shading systems and cool materials. With this last combination, the highest levels of well-being are obtained, equal to the value obtained with the master plan and significant reductions in outdoor temperatures. Among the results of the simulations is that the use of green roofs shows significant decreases in indoor and outdoor air and surface temperatures. Using a mix of actions makes it possible to intervene on several fronts in an integrated manner, at a broader range and different scales: the different technological solutions interact with each other and together increase their level of effectiveness compared to a single use.

The master plan at the outdoor level presents a combination of technologies, including the installation of bioswales, grassed screeds, cool surfaces and roofs, increased green surfaces and trees, shade spots and water squares, which allowed for a decrease in temperature of 1.2 °C. Thus, outdoor comfort is increased by 1.13. At the level of active systems, agro-photovoltaic systems on the roofs and a mini-wind system decrease the area's energy requirements. At the indoor level, the interventions consist of installing wooden greenhouses, heat pumps and ventilation towers. Simulations show a decrease in temperature of 0.82 °C. In general, using this mix of actions results in high increases in relative humidity and a decrease of 0.73 °C for the average indoor radiant temperature.

Tab. IX.

	T_{out}	T_{in}	$UTCI_{out}$	mrt_{in}	$UR\%_{out}$	$UR\%_{in}$
Cool	6.50	1.55	1.50	6	6.50	61.65
Green	6.50	1.53	1.56	5	6.50	61.43
Cool + Green	6.50	7.70	6.30	6	6.50	70.53
Masterplan	6.50	5.11	4.69	6	6.50	58.99

Table IX. shows the simulation results with the UWG generator on the Quarticciolo. The result illustrates the difference between the model with no adaptation or mitigation actions and the lowest result model with them. Author's elaboration

4.3| Shuangta, Suzhou, CN

Figure 211. Suzhou localization - Autor's elaboration on QGIS

Figure 212. Suzhou area - Autor's elaboration on QGIS

Figure 213. Autor's elaboration on QGIS

Figure 214. Neighborhood area - Autor's elaboration on QGIS

Contextualisation in the urban fabric.

The site is located along Shiquan Street and corresponds to the historical district of Suzhou, a historical settlement on the Yangtze River in Jiangsu Province. The city is located west of Shanghai and is renowned for its canals, bridges, and classical gardens. On the site are buildings with different characteristics, such as former single-storey villas, later inhabited by several families and subject to remodelling and additions, built to house students and professors of the nearby Suzhou University.

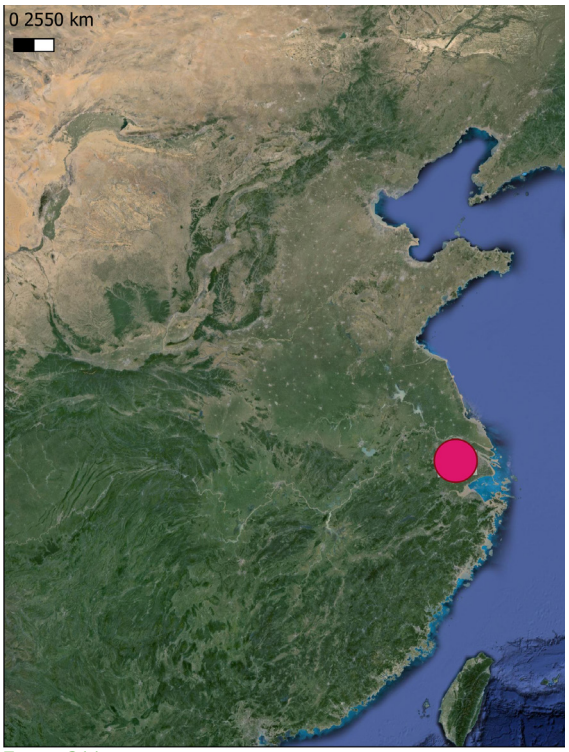


Figure 211.



Figure 212.

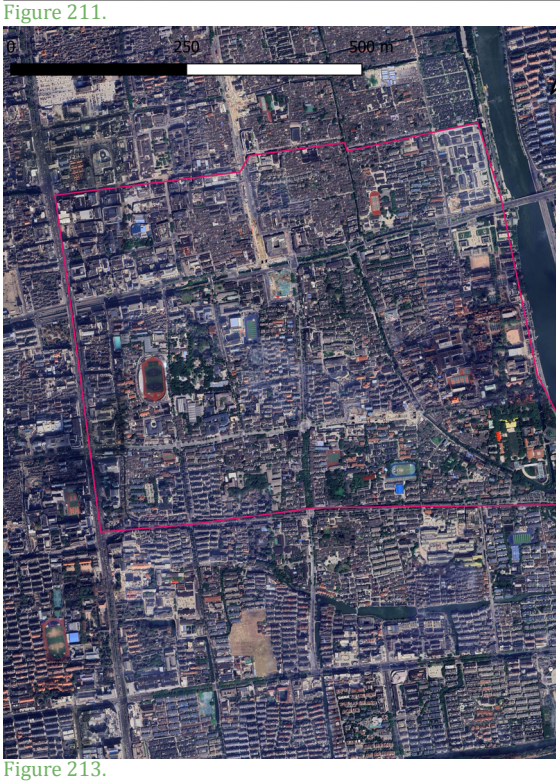


Figure 213.



Figure 214.



Figure 215.

Figure 215. Photographic reconstruction of a street in the Shuangta district.The data are extracted from the 2022 Annual Report, provided by Prof. Y. Dong from the Design School at Xi'an Jiaotong-Liverpool University, titled 'Safeguarding Heritage and Community of Shuangta Area'.

Figure 216. Pictures of Shangta neighborhhod (005005, 005007 section). Author's elaboration.

Figure 217. Pictures of Shangta neighborhhod (005005, 005007 section). Author's elaboration.



Figure 216.

Figure 218. Pictures of Shangta neighborhhod (005005, 005007 section). Author's elaboration.

FIgure 219. Pictures of Shangta neighborhhod (005005, 005007 section). Author's elaboration.



Figure 218.





Figure 217.



Figure 219.

Innovative and integrated energetic and bioclimatic strategies for adapting existing contexts to climate change and extreme events, aiming to mitigate the environmental impact
p. 668

Figure 220.

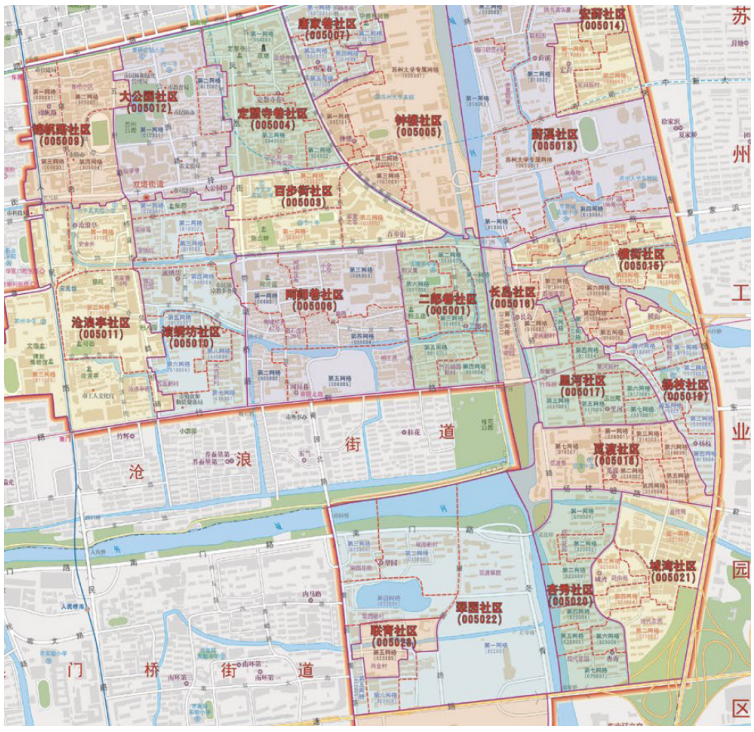


Figure 220. Different sections of the neighborhood. The data are extracted from the 2022 Annual Report, provided by Prof. Y. Dong from the Design School at Xi'an Jiaotong-Liverpool University, titled 'Safeguarding Heritage and Community of Shuangta Area'.

Figure 221. Sections under analisys. The data are extracted from the 2022 Annual Report, provided by Prof. Y. Dong from the Design School at Xi'an Jiaotong-Liverpool University, titled 'Safeguarding Heritage and Community of Shuangta Area'.

Figure 221.



Climate analysis.

During the year, on average, the sky is partly cloudy. As can be seen in the graphs, the rainy season is mainly concentrated in the summer period, with peaks of twenty rainy days per month. Temperatures fluctuate between 0 °C, with periods of frost concentrated in December, January and February, and 40 °C reached in June, July and August. The heavy rainfall brought by monsoon events also affects June, characterising the entire area. The strongest winds - 20/30 km/h - blow from the south-southeast. Humidity varies from a minimum of 26% during the dry months to a maximum of 100% during the wettest months. Compared to Rome, Suzhou has more frequent rainfall, with a peak intensity in June. Compared to San Antonio, the Chinese city has a more significant temperature fluctuation, with extended cold periods and frequent rainfall phenomena.

Climatic Framework

Figure 222.

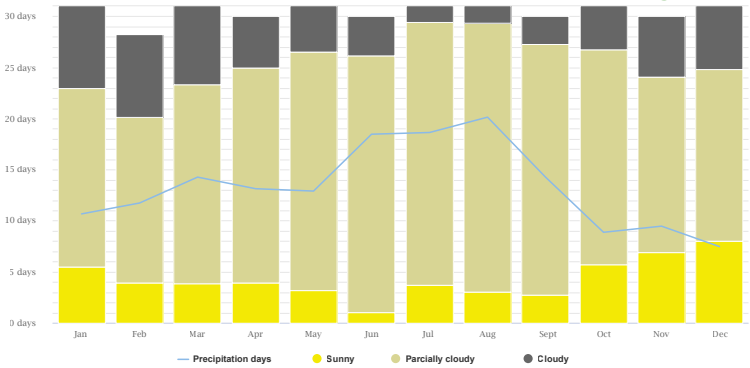


Figure 222. The diagram represents the sky conditions in Suzhou for different months of the year. www.meteoblue.com

Figure 223.

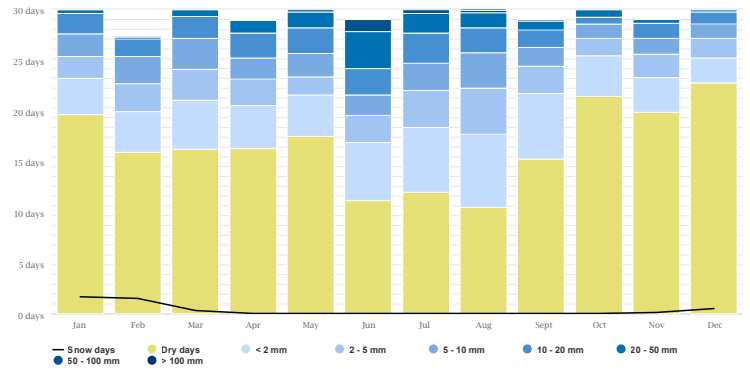


Figure 223. The diagram represents the average temperature in Suzhou in the various months of the year. www.meteoblue.com

Figure 224.

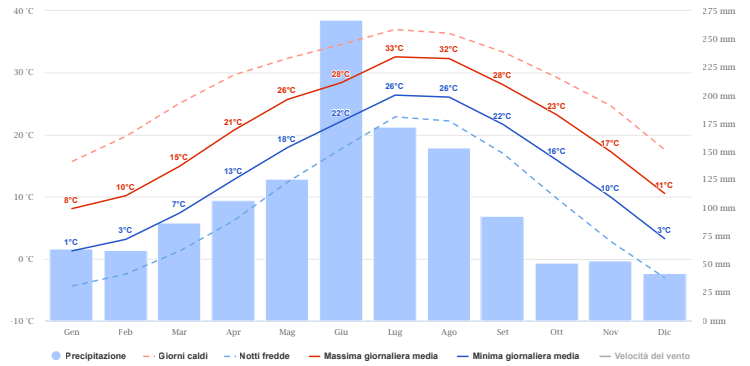


Figure 224. The diagram represents the wind characteristics (direction and speed) in Suzhou. www.meteoblue.com

Climatic Framework

Figure 225.

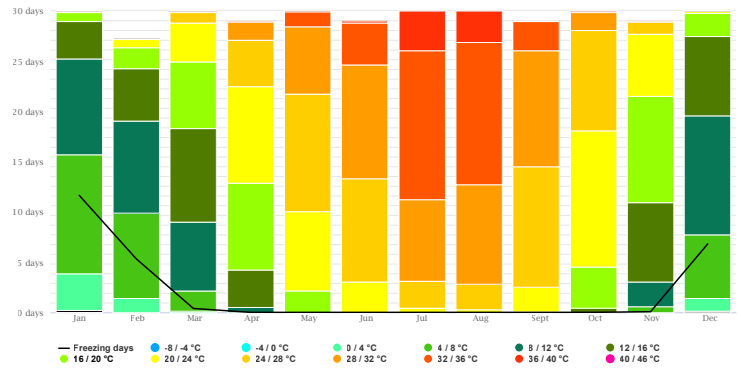


Figure 226.

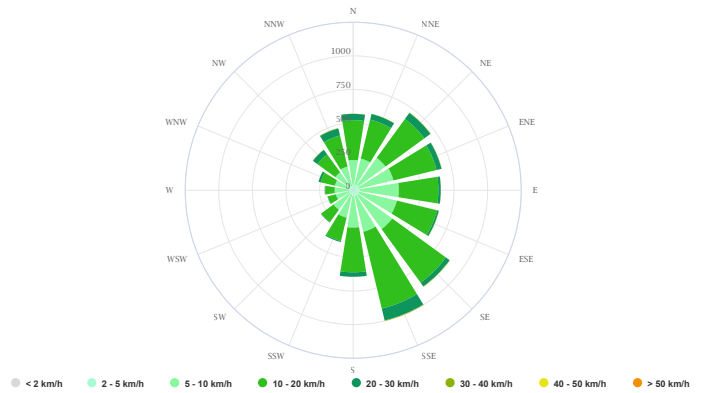


Figure 227.

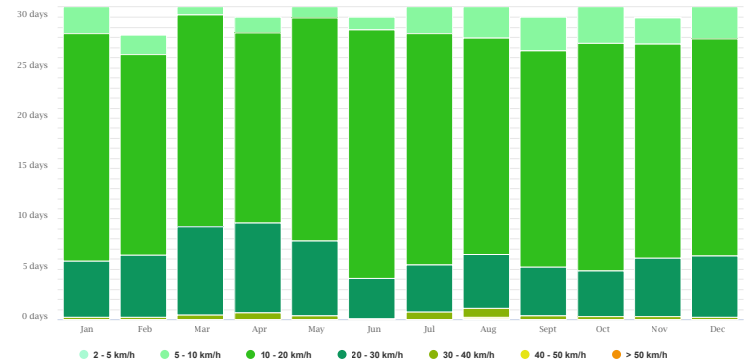


Figure 225. The graph represents the amount of rain that fell and the dry days during the various months of the year. www.meteoblue.com

Figure 226. The graph represents the average wind speed in different months of the year. www.meteoblue.com

Figure 227. The graph represents precipitation, average nighttime and daytime temperatures, maximums, and minimums for the various months of the year. www.meteoblue.com

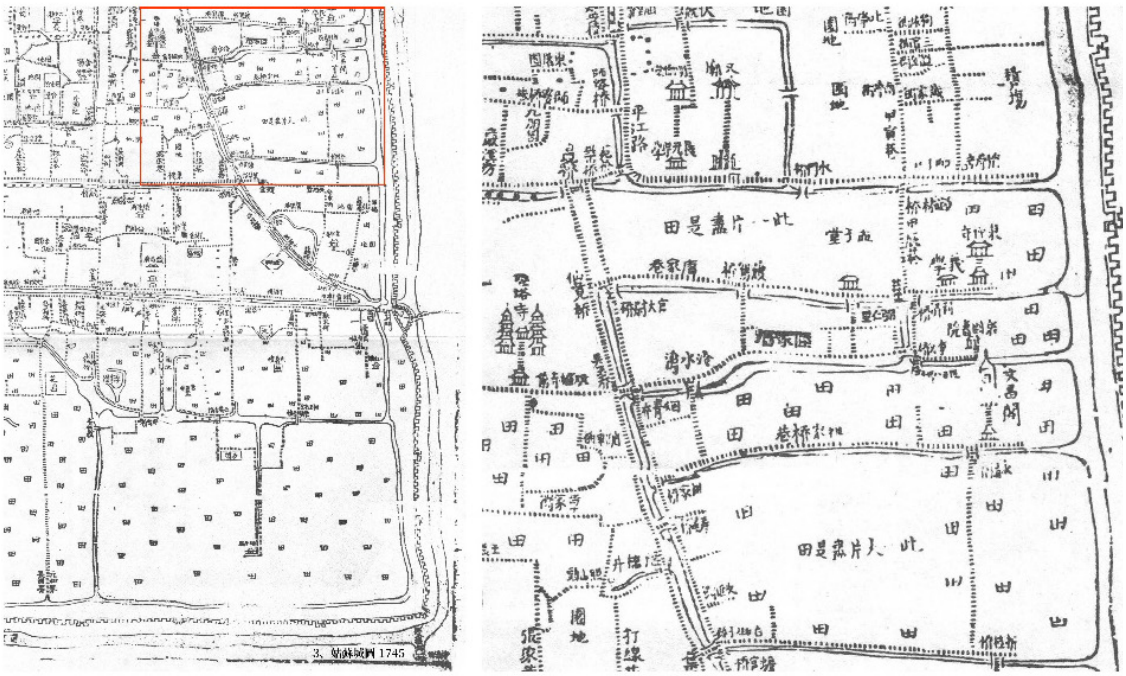
Figure 228. Timeline. The data are extracted from the 2022 Annual Report, provided by Prof. Y. Dong from the Design School at Xi'an Jiaotong-Liverpool University, titled 'Safeguarding Heritage and Community of Shuangta Area'.

Historical analysis.

The historical district of Shuangta in the Chinese city of Suzhou was built around 1930. The historical background on which the district is based dates back to 514 B.C. when King Helu of the Wu dynasty established the capital in Suzhou. In 473 BC, the Wu state was destroyed, and the city became the capital of the Yue state. The city of Suzhou was founded in 589 BC. On this occasion, the Grand Canal was opened, crossing the area from north to south. Suzhou's prosperity was second only to Chang'an during the Tang Dynasty. In 1130, the city was destroyed, and raids by Jin soldiers massacred the residents. During the Ming dynasty, the city was one of the significant cultural centres in the country, and numerous private gardens were built during this period. Other important events in the town include the attack in 1860 led by Li Xiucheng. The city became a trading port in 1895 following the signing of the Treaty of Shimonoseki. Finally, Suzhou was severely damaged during the clash between China and Japan in 1937. The district began to be marked on maps in 1745. Since this date, the area has developed through the construction of the oldest dwellings, which were on one floor and had an internal courtyard, which, with the passage of time and the housing crisis, were divided into other small dwellings and internal courtyards were built.

4 | Verification of pilot cases
p. 673

Hystorical analisys: evolution of the city

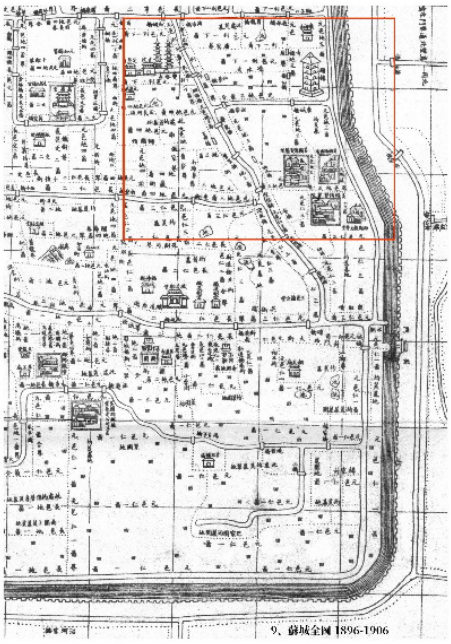


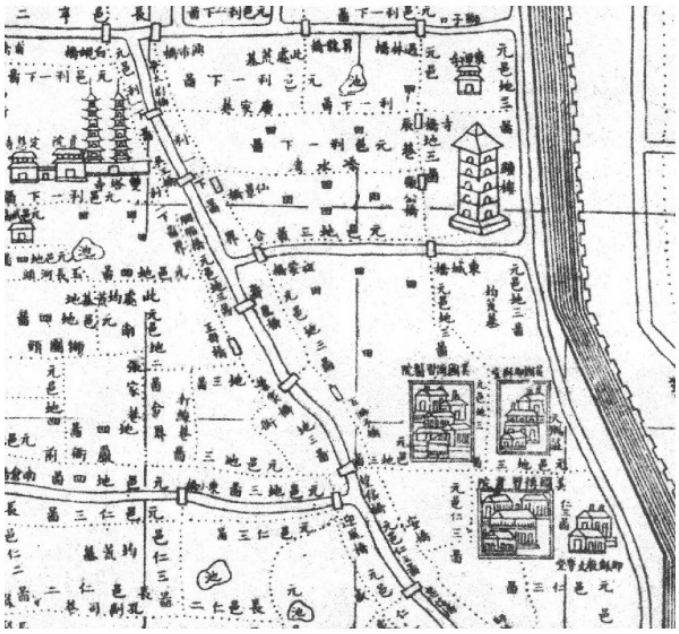
1745

1872 - 1881

Figure 228.

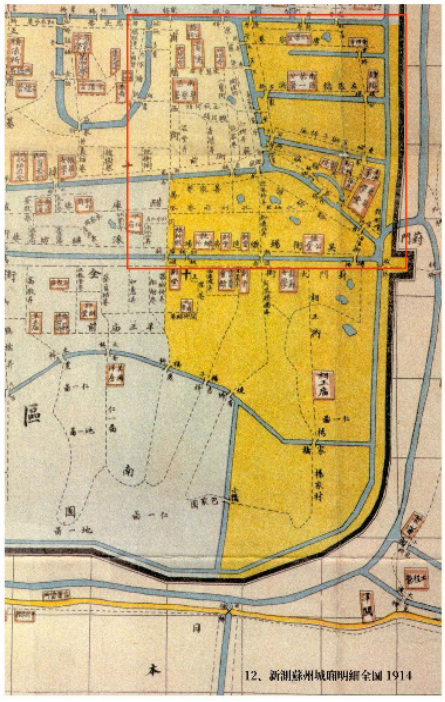
Hystorical analisys: evolution of the city

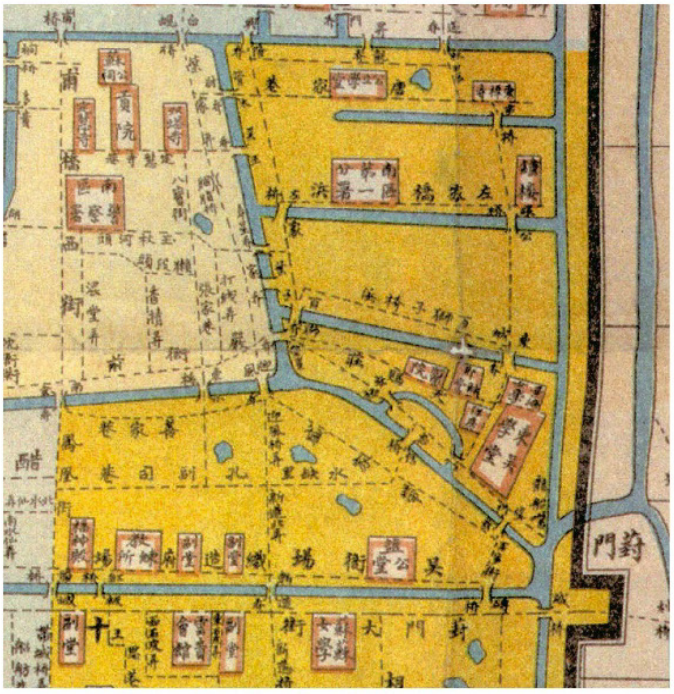




1896 - 1906

1914





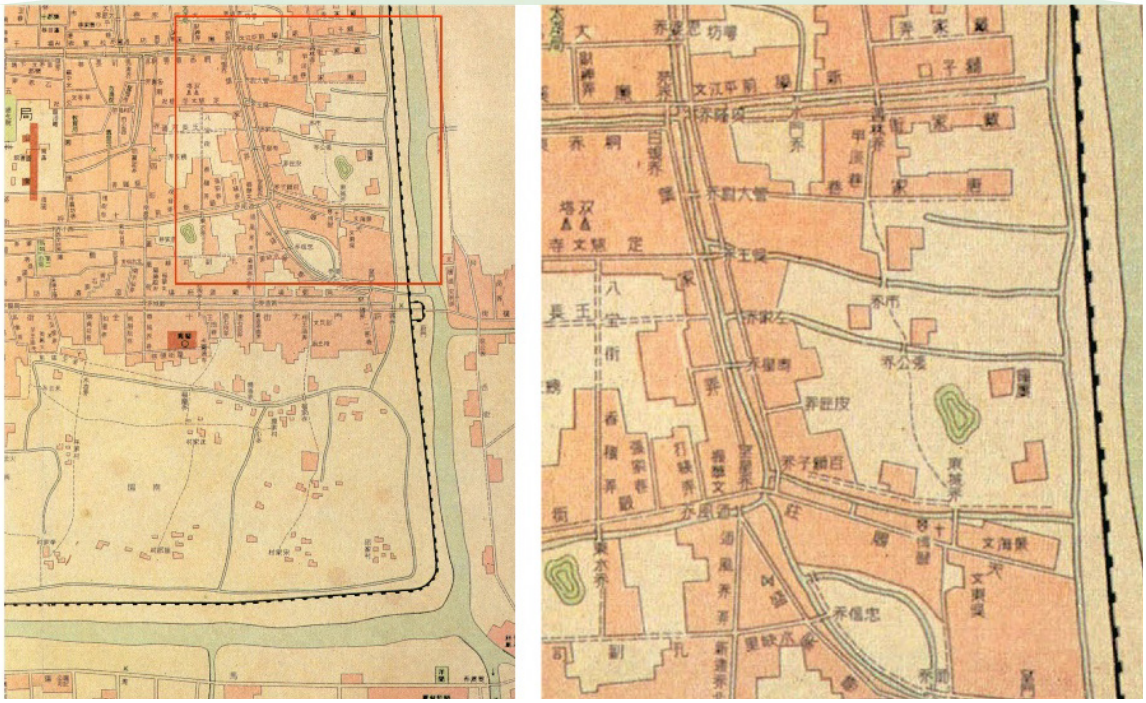
Hystorical analisys: evolution of the city



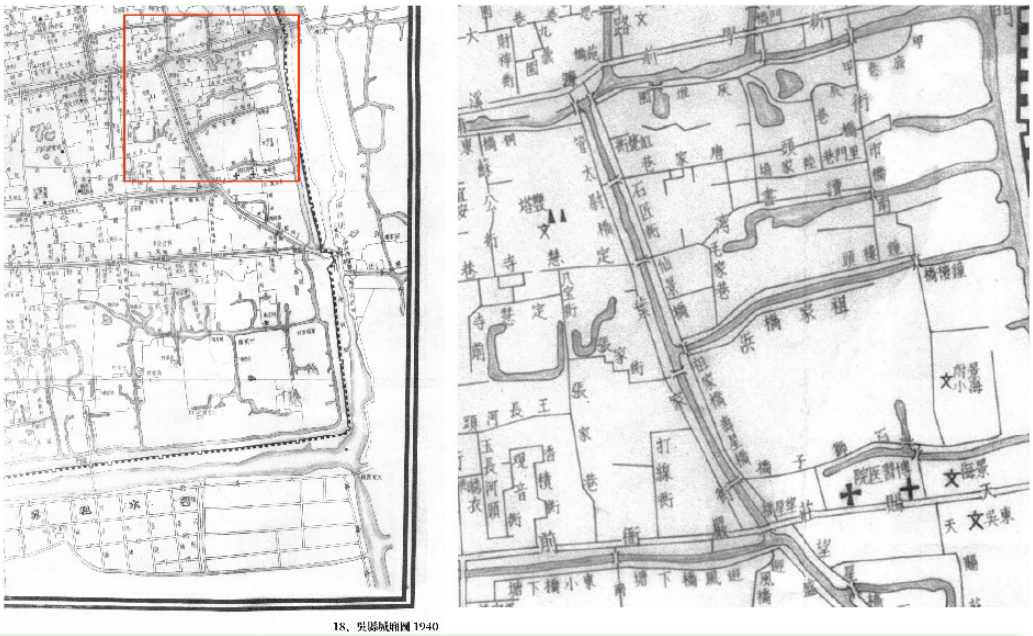
Figure 228.

1927

1938



Hystorical analisys: evolution of the city



Innovative and integrated energetic and bioclimatic strategies for adapting existing contexts to climate change and extreme events, aiming to mitigate the environmental impact

p. 678

Figure 229.

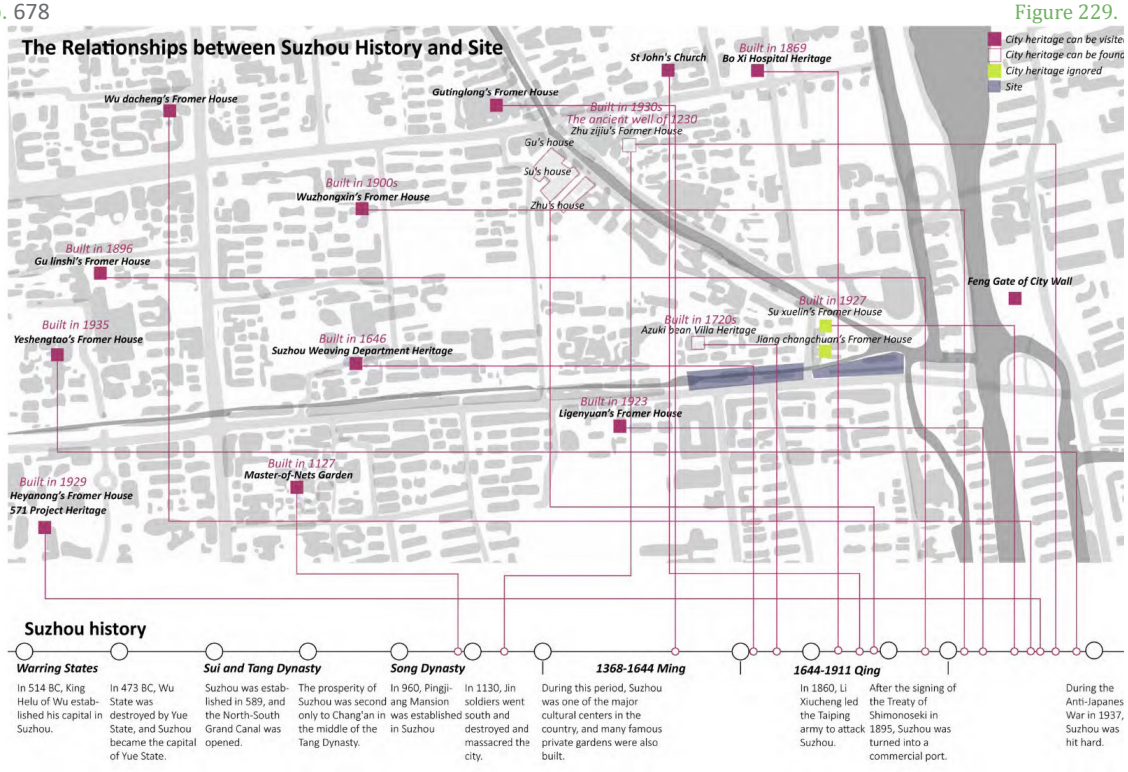


Figure 229. Evolution of the neighborhood. The data are extracted from the 2022 Annual Report, provided by Prof. Y. Dong from the Design School at Xi'an Jiaotong-Liverpool University, titled 'Safeguarding Heritage and Community of Shuangta Area'.

Figure 230 a, b, c. Cities evolution over time. The data are extracted from the 2022 Annual Report, provided by Prof. Y. Dong from the Design School at Xi'an Jiaotong-Liverpool University, titled 'Safeguarding Heritage and Community of Shuangta Area'.

Figure 231. Picture of Shuangta market, one of the main turistic site in Shuangta. Author's elaboration

Figure 232. Picture of Twins Pagodas, one of the main turistic site in Shuangta. Author's elaboration

Relation between Suzhou history and site

Figure 230 a.

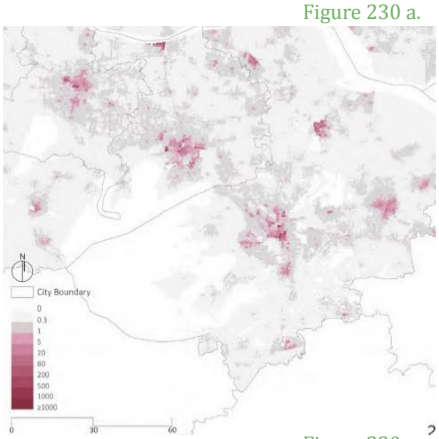


Figure 230 b.

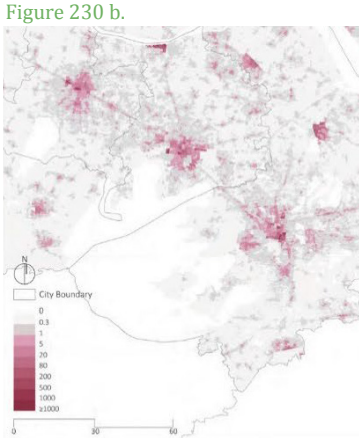
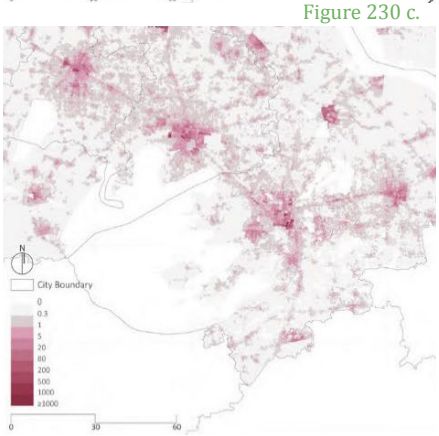


Figure 230 c.



Relation between Suzhou history and site

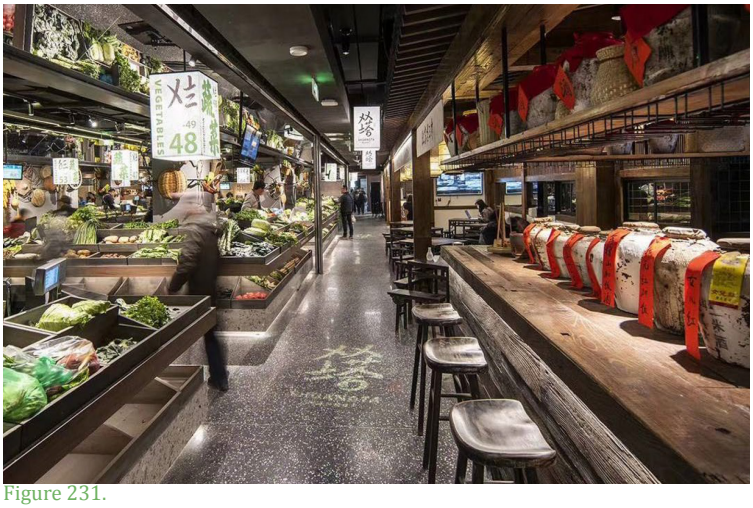


Figure 231.

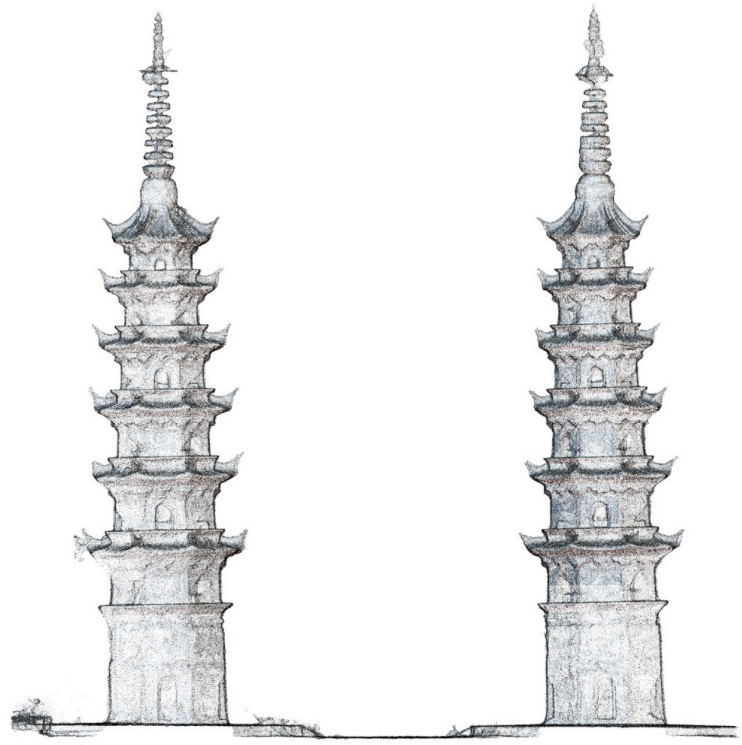


Figure 232.

Morpho-typological analysis

The neighbourhood comprises social housing with low single-storey buildings and blocks of up to four storeys. The average height of the buildings is 12 metres. The street width varies from a minimum of 10 metres to a maximum width of 19 metres: the ratios of building height to street width thus vary from 1.2 in the narrowest streets to 0.6 in the widest, while the average ratio of building height to street width most commonly is 0.9. The external envelope consists of a layer of perforated bricks. It is protected by a thin layer of internal and external plaster, while the roof consists of an uninsulated concrete slab[38].

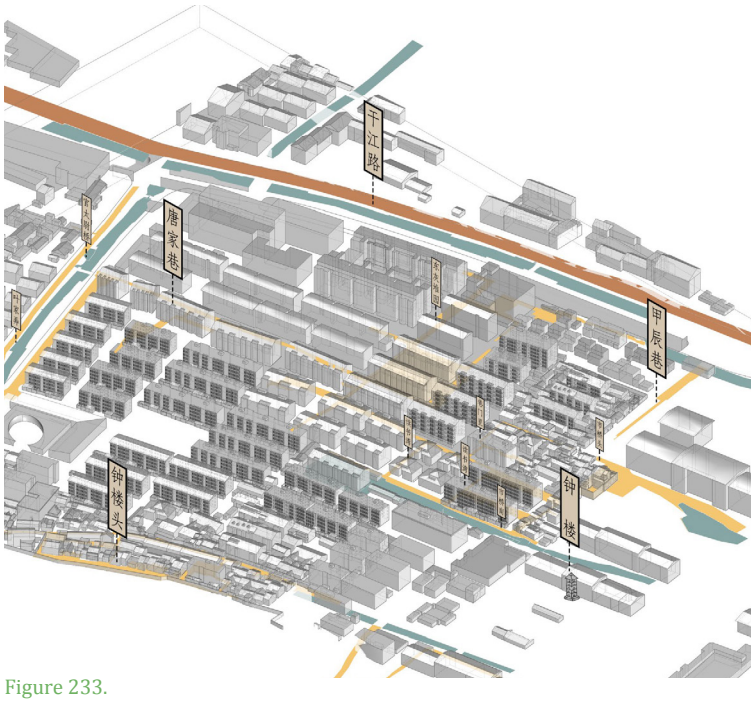


Figure 233.

38. The data are extracted from the 2022 Annual Report, provided by Prof. Y. Dong from the Design School at Xi'an Jiaotong-Liverpool University, titled 'Safeguarding Heritage and Community of Shuangta Area'.

Figure 233. Morphology analisys. The data are extracted from the 2022 Annual Report, provided by Prof. Y. Dong from the Design School at Xi'an Jiaotong-Liverpool University, titled 'Safeguarding Heritage and Community of Shuangta Area'.

Figure 234, 235. Example of a typical chinese home present in Shuangta neighborhood. The data are extracted from the 2022 Annual Report, provided by Prof. Y. Dong from the Design School at Xi'an Jiaotong-Liverpool University, titled 'Safeguarding Heritage and Community of Shuangta Area'.

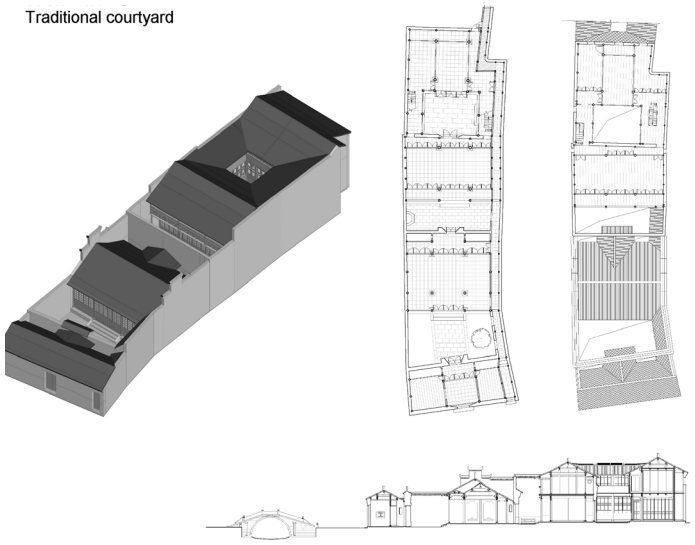


Figure 234.

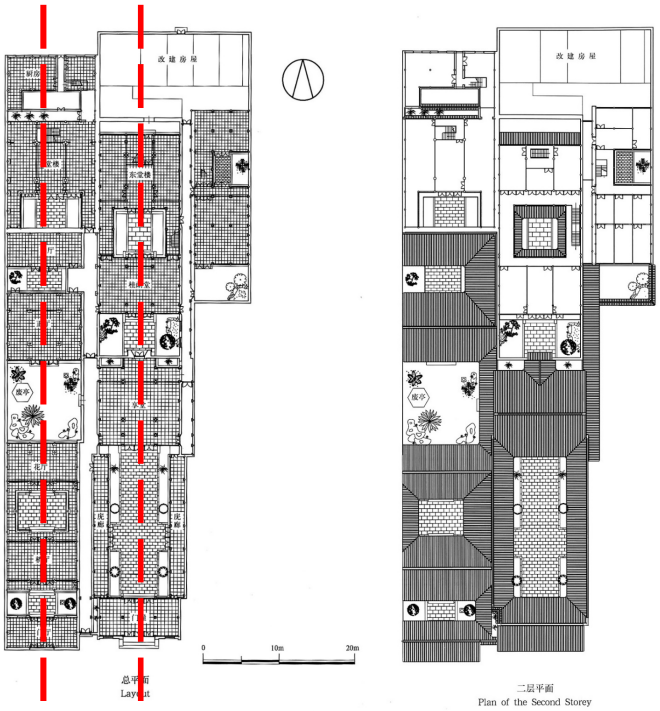


Figure 235.

ANALYSIS OF THE AREA

Figure 236. Analysis of services within the area. The data are extracted from the 2022 Annual Report, provided by Prof. Y. Dong from the Design School at Xi'an Jiaotong-Liverpool University, titled 'Safeguarding Heritage and Community of Shuangta Area'.

Figure 236.

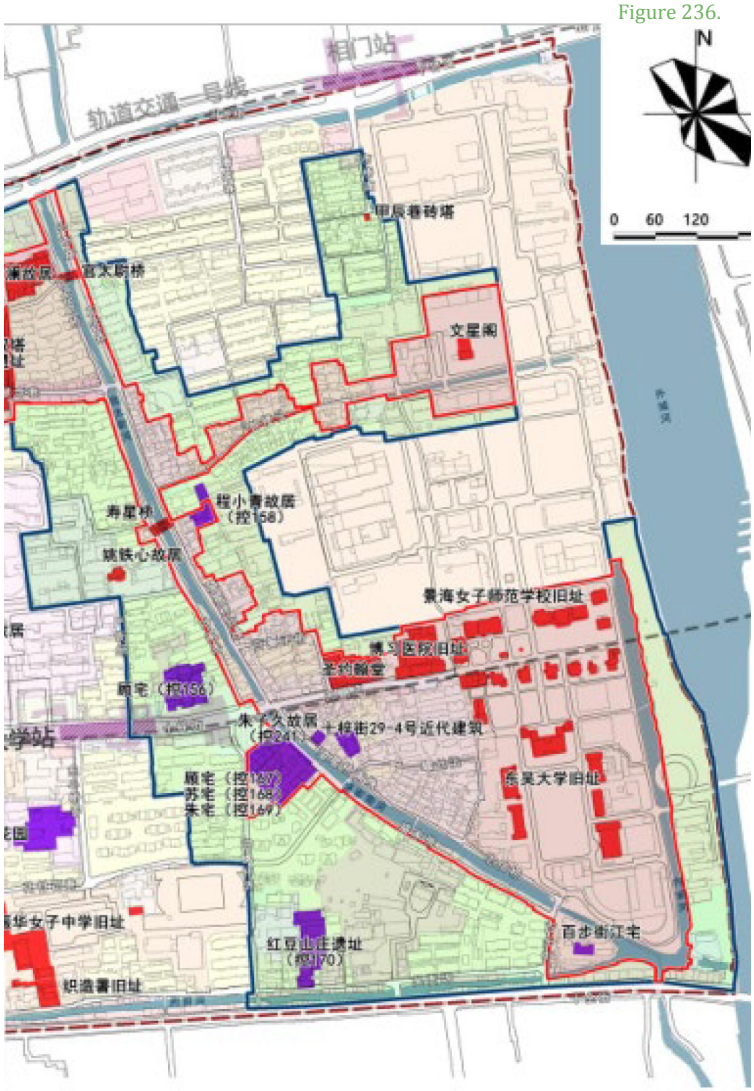


Figure 237.

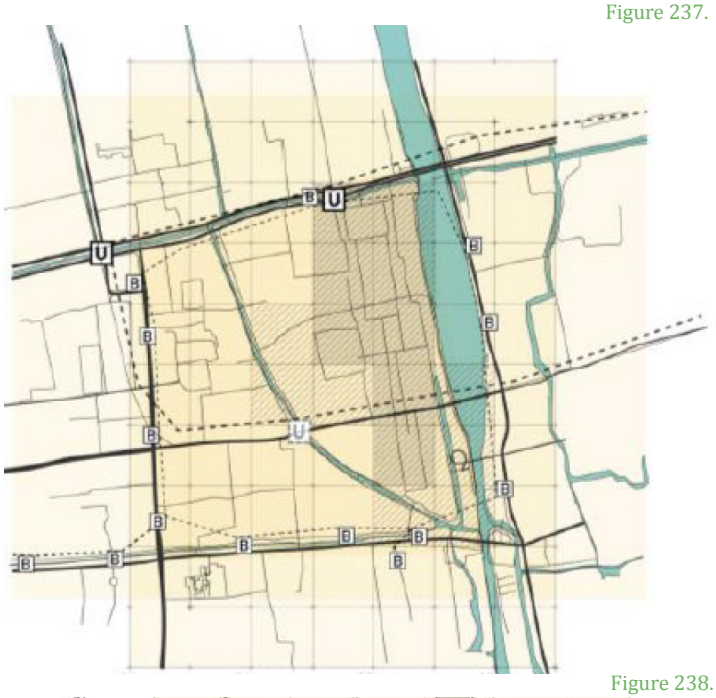


Figure 237. Traffic analysis. The data are extracted from the 2022 Annual Report, provided by Prof. Y. Dong from the Design School at Xi'an Jiaotong-Liverpool University, titled 'Safeguarding Heritage and Community of Shuangta Area'.

U UNDERGROUND: there are 2 subway stations. The distance between the two stations is within 1 km.

B BUS: bus stops are mainly distributed along the main roads. The distance between them is modest.

ROADS

Figure 238.



Figure 238. Analysis of important points in the neighbourhood. The data are extracted from the 2022 Annual Report, provided by Prof. Y. Dong from the Design School at Xi'an Jiaotong-Liverpool University, titled 'Safeguarding Heritage and Community of Shuangta Area'.

EDUCATION: a part from residencial use, educational institutes take up more than one tird of the total plot area of the district. Souzhou Universityoccupies much spots. Unfortunately it is not over to the public.

CULTURE /RECREATION

MEDICAL

MARKET

SUPERMARKET

CONVENIENT STORE



Figure 239 a.



Figure 239 b.



Figure 239 c.

Figure 239 a, b, c. Problem spots within the neighbourhood:
a: undeveloped waterfront
b: very fragmented leisure spaces
c: Unfriendly street system
The data are extracted from the 2022 Annual Report, provided by Prof. Y. Dong from the Design School at Xi'an Jiaotong-Liverpool University, titled 'Safeguarding Heritage and Community of Shuangta Area'.

Services analysis.

The area represents one of the city's most important sites from a historical and cultural point of view. It borders the adjacent Pin Jian Lou, a national and international tourist shopping destination inside the city's western gates. Adjacent to the area is also the historic Shuang-Ta market and the twin pagodas Shuang-Ta Ying Yuan. The district under consideration is purely residential and is divided into old courtyard dwellings on one floor and multi-storey dwellings once reserved for students and professors of the nearby Suzhou University. There are not many offices in the area, but instead, there are many restaurants, shops, supermarkets and convenience stores. The hospital and the University of Suzhou are east of the area. To the north, on Shizi Street, there are various services, including church food shops and restaurants. In particular, the area is subject to a historical protection restriction within which protected buildings are culturally important. To the west, the area is bordered by the Waicheng River, which, together with the presence of historical walls, historically, physically and functionally divides this part of the city from the rest.
From a transport point of view, the area is bounded by the major arteries of Shiquan St, Moye Rd, Fenghuang St, and Ganjiang E Rd. These four roads have bus and metro stops. In the centre of this area runs Shizi St. The area is also crisscrossed by small lanes no more than three metres wide, which run into the residential area.
The relationship with the waterfront along Wangxing Brg North Tu is always articulated in the delimitation of the banks by vegetated species, the presence of a pedestrian pavement and the presence of the roadway.

Figure 240. Waterfront analisys The data are extracted from the 2022 Annual Report, provided by Prof. Y. Dong from the Design School at Xi'an Jiaotong-Liverpool University, titled 'Safeguarding Heritage and Community of Shuangta Area'.

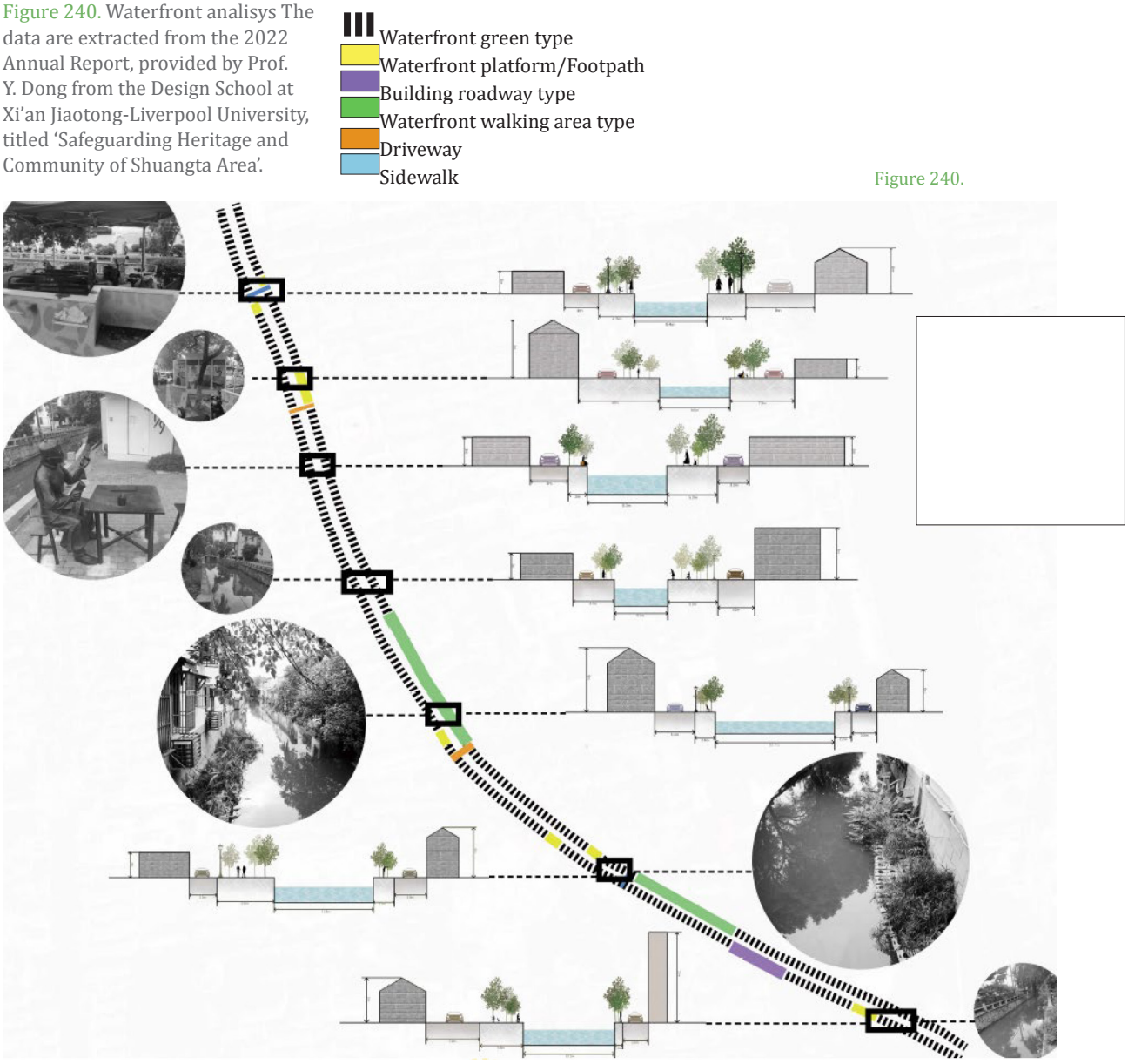


Figure 240.

Figure 241.

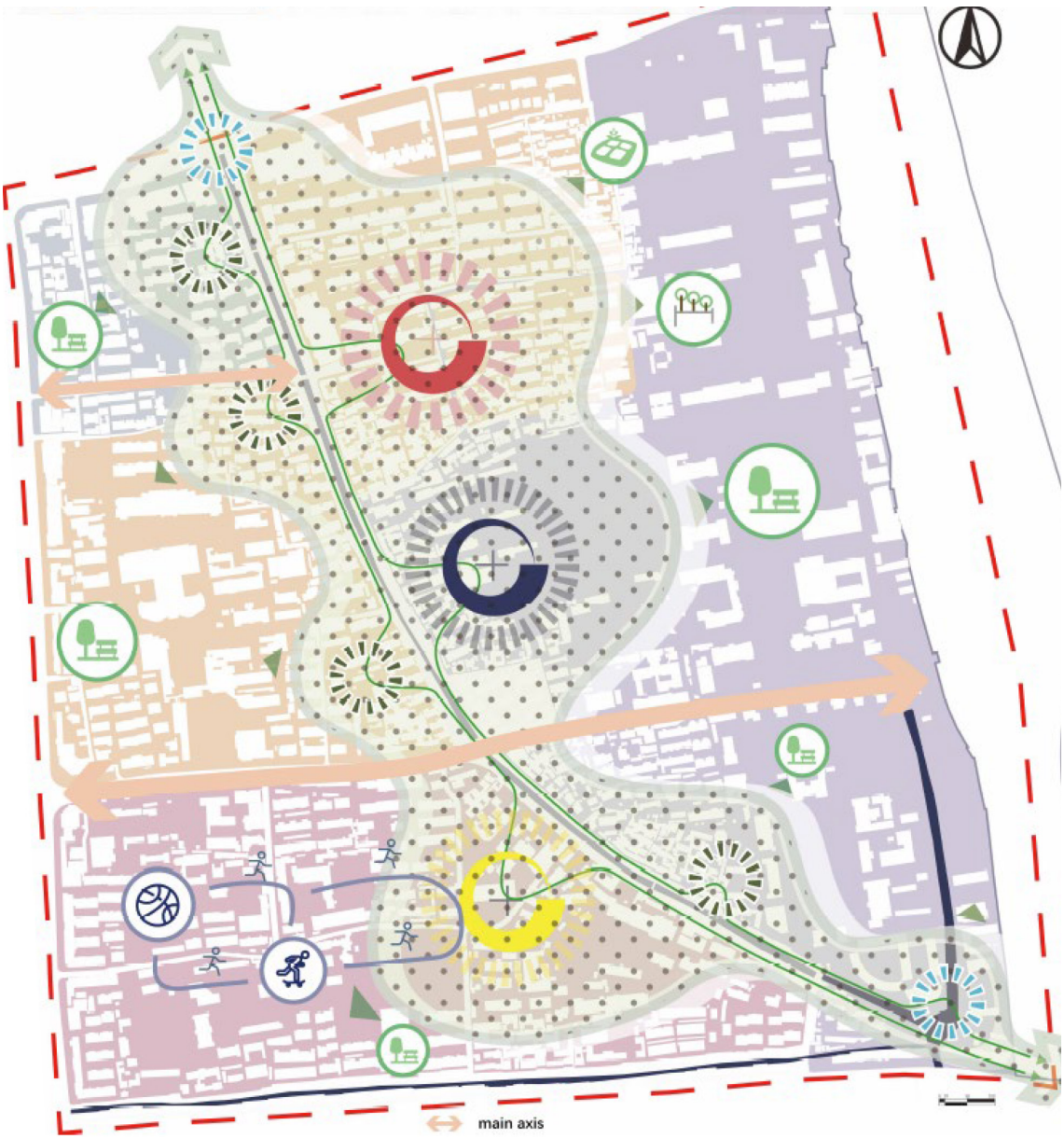


Figure 241. Service analisys near the waterfront. The data are extracted from the 2022 Annual Report, provided by Prof. Y. Dong from the Design School at Xi'an Jiaotong-Liverpool University, titled 'Safeguarding Heritage and Community of Shuangta Area'.

Figure 242.

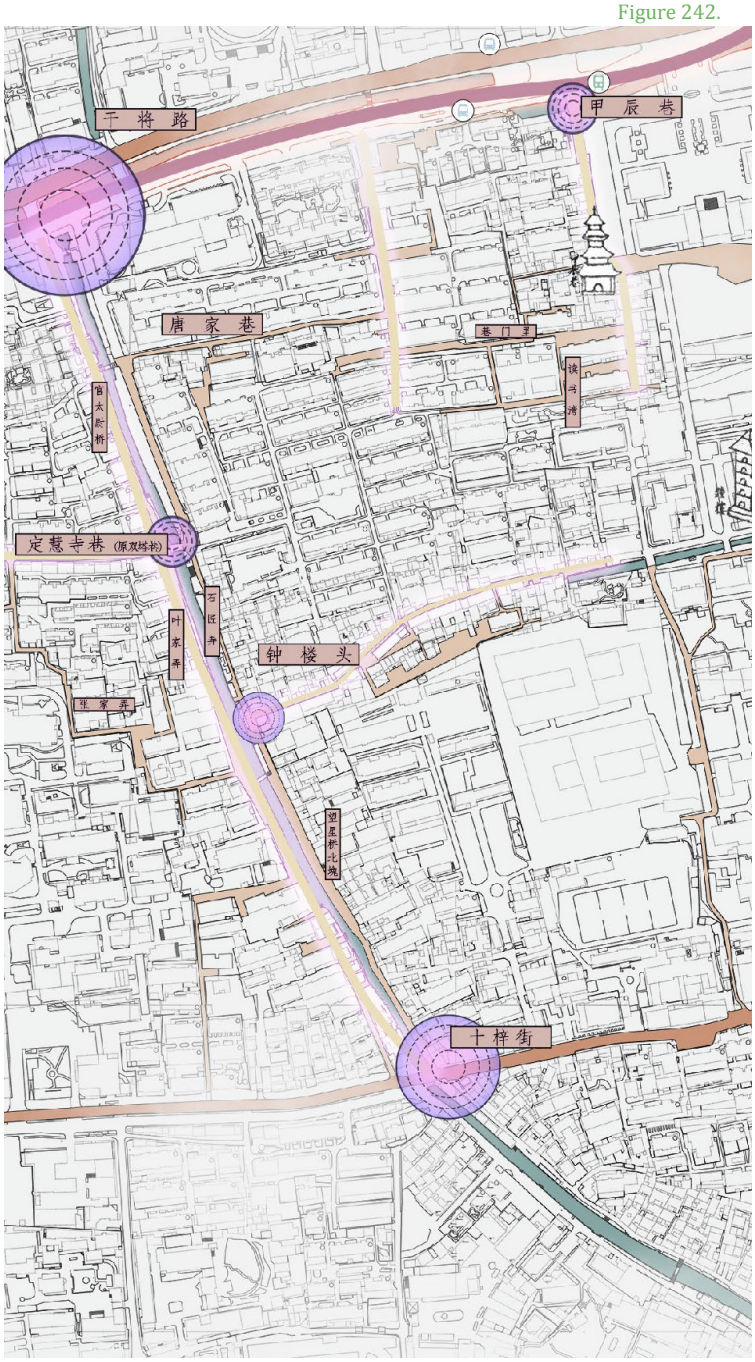


Figure 242. Transport and road system in the Shuangta district. The main road junctions are highlighted in purple and the main arterial roads in orange. The data are extracted from the 2022 Annual Report, provided by Prof. Y. Dong from the Design School at Xi'an Jiaotong-Liverpool University, titled 'Safeguarding Heritage and Community of Shuangta Area'.

Surface and vegetation analysis .

The area lies at the mouth of one of China's most important rivers, the Yangtze, before the metropolis of Shanghai. The whole area is crossed by canals and tributaries of the same size and by lake complexes of different sizes. Although the hydrogeological risk is high, the continuous maintenance and control of the embankments contain it.
The roofs of the buildings consist mainly of dark-coloured tiles, typical of the area, and concrete in the four-storey buildings constructed to house university students and teachers. To the north-east and south-west of the area are two green areas. Most surfaces generally consist of asphalt, dark tiled roofing and lawn. Within the area, it is possible to find autochthonous and non-native tree species of Populus alba, Acer pseudoplatanus, Cedrus deodara, Euonymus japonica, Ficus benjamina, Laurus nobilis, Magnolia grandiflora, Nerium oleander, and Salix babylonica. Root systems and foliage are of different sizes, depending on the available space: large specimens of Populus alba line the large avenue of Shizi Street, large magnolias shade the banks of the canal, and smaller specimens of Ficus are found in courtyards and private gardens. The runoff of the project area amounts to 240161.

Types of surfaces in the neighborhood

Figure 243.

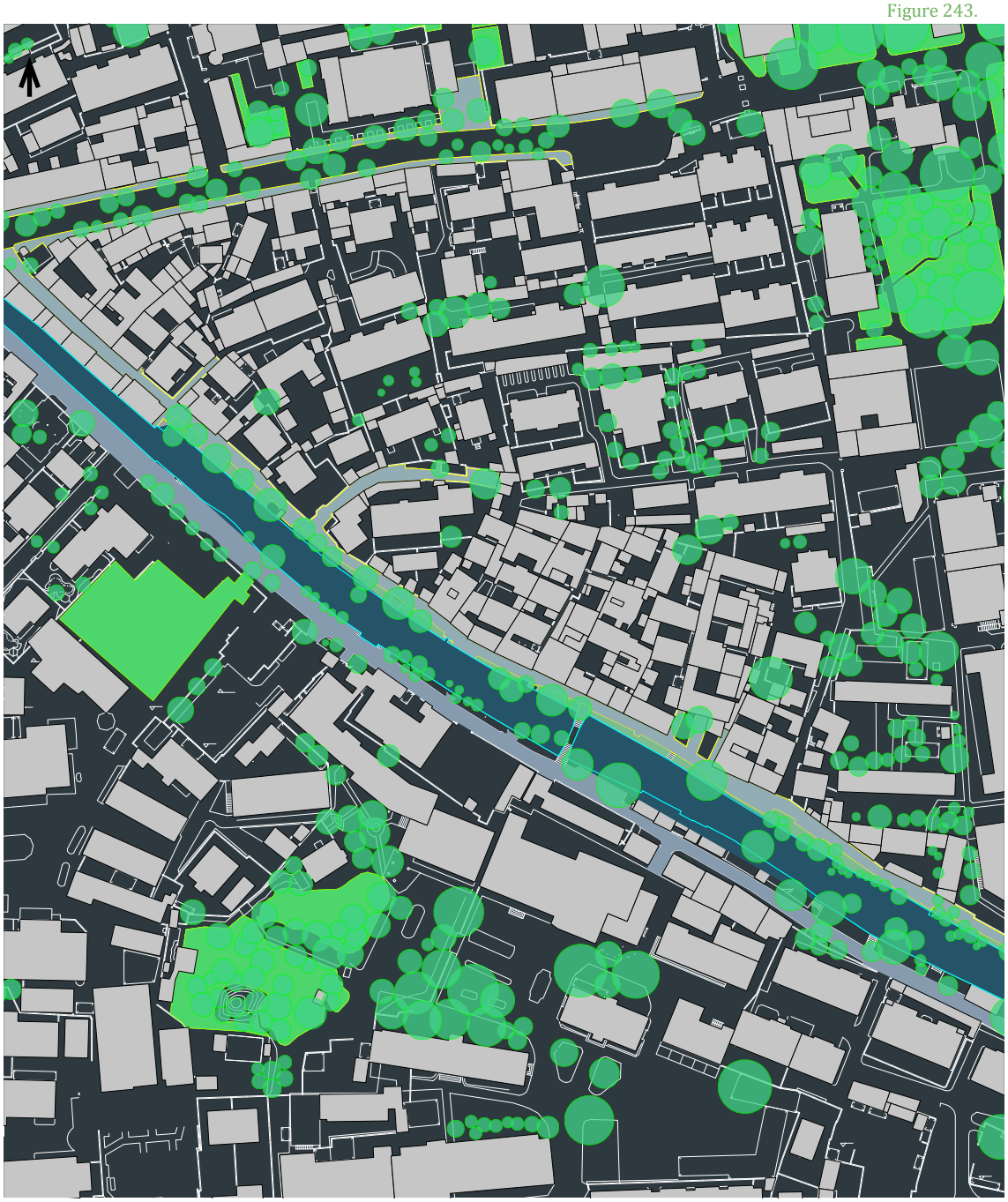


Figure 243. Surfaces analisys - Author's elaboration



Figure 244.

Figure 244. Green system's analisys. Author's elaboration

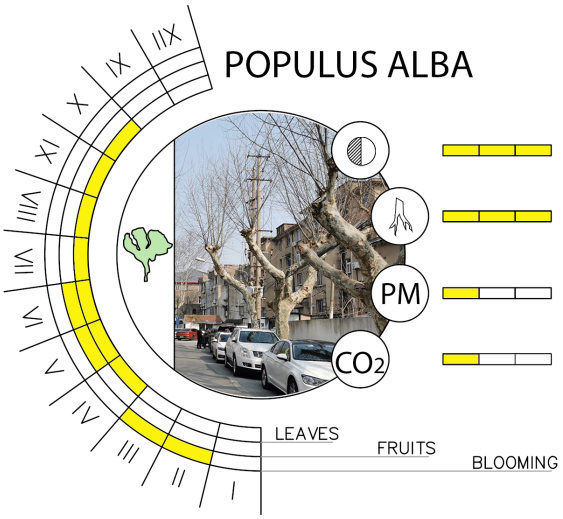
LEGEND:

Breadth of foliage and possibility of producing shade

Breadth of root system

PM absorption capacity

CO_2 absorption capacity



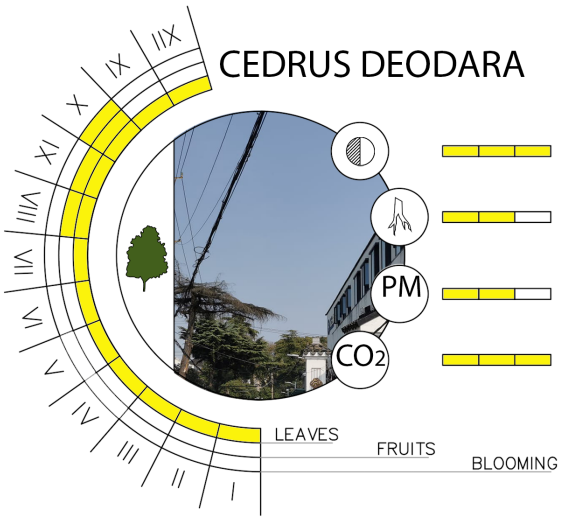
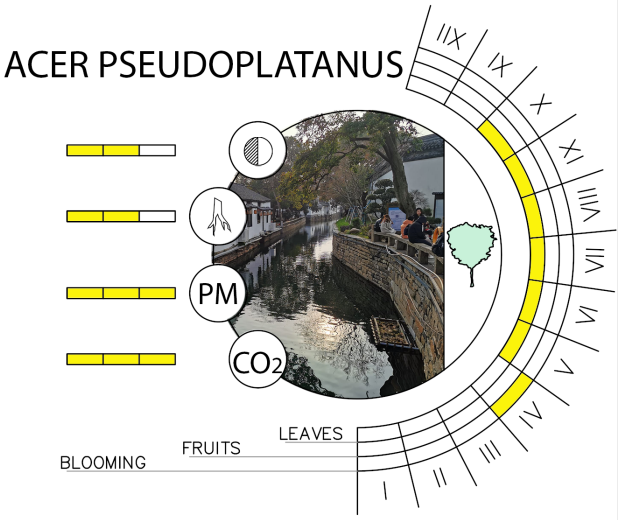


Figure 244.


ACER PSEUDOPLATANUS
PM
CO2
LEAVES
FRUITS
BLOOMING
I
II
III
IV
V
VI
VII
VIII
XI
X
IX
IIX

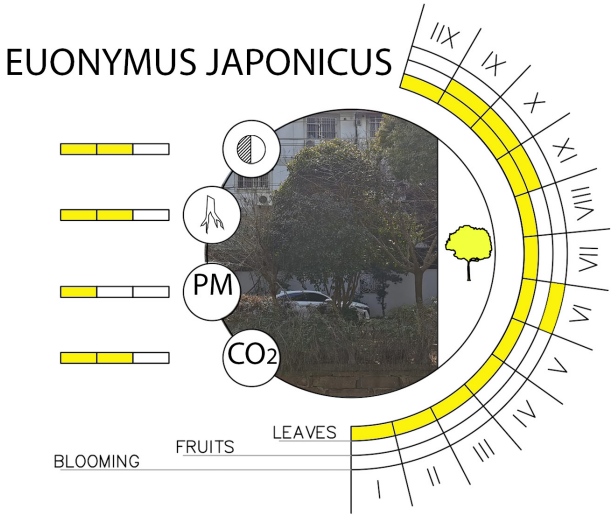
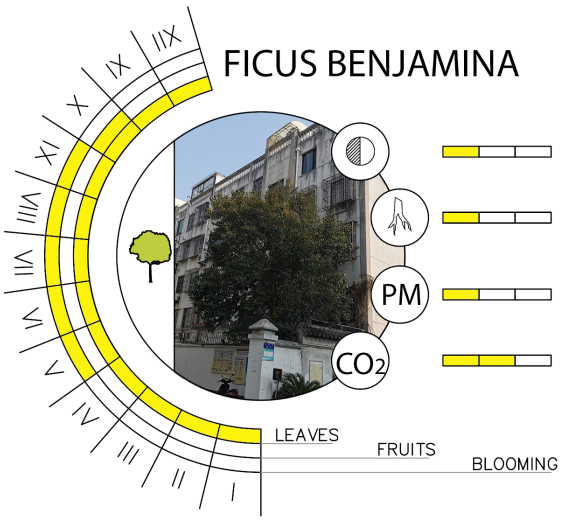

EUONYMUS JAPONICUS
PM
CO2
LEAVES
FRUITS
BLOOMING
I
II
III
IV
V
VI
VII
VIII
XI
X
IX
IIX

Figure 244.


FICUS BENJAMINA
PM
CO2
LEAVES
FRUITS
BLOOMING

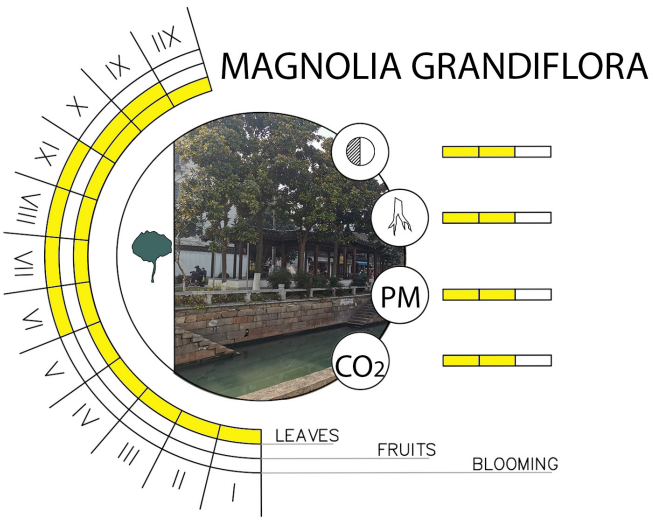
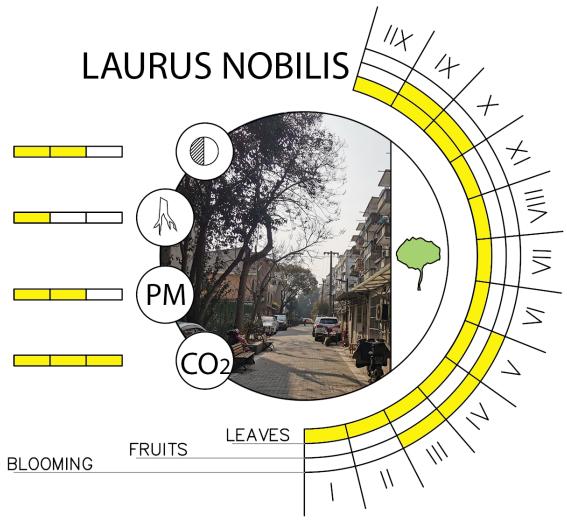

MAGNOLIA GRANDIFLORA
PM
CO2
LEAVES
FRUITS
BLOOMING

Figure 244.


LAURUS NOBILIS
XII
IX
X
XI
VIII
VII
VI
V
IV
III
II
I
PM
CO2
LEAVES
FRUITS
BLOOMING

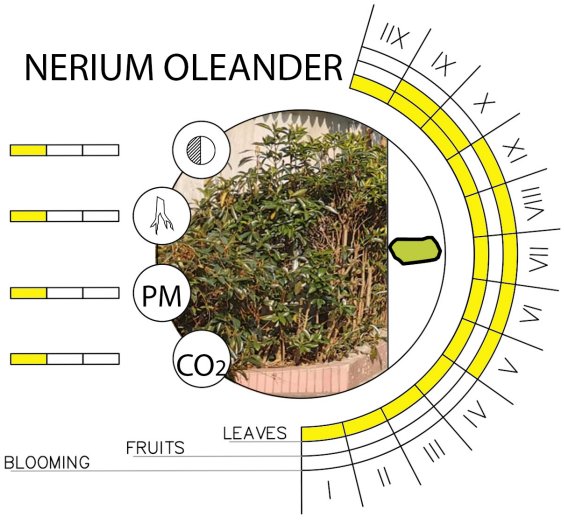
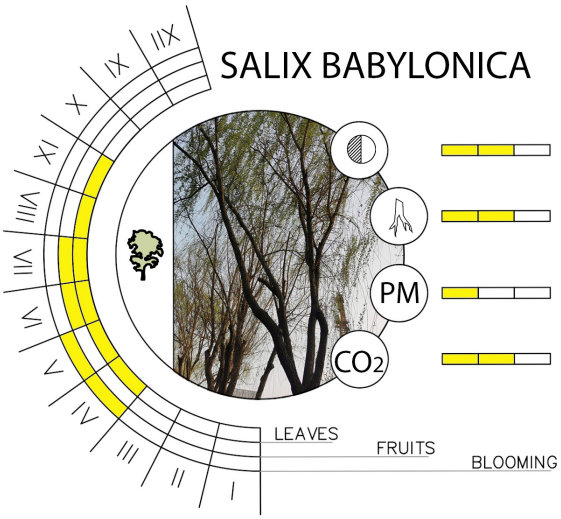

NERIUM OLEANDER
XII
IX
X
XI
VIII
VII
VI
V
IV
III
II
I
PM
CO2
LEAVES
FRUITS
BLOOMING

Figure 244.


SALIX BABYLONICA
PM
CO2
LEAVES
FRUITS
BLOOMING
I
II
III
IV
V
VI
VII
VIII
IX
X
XI
XII

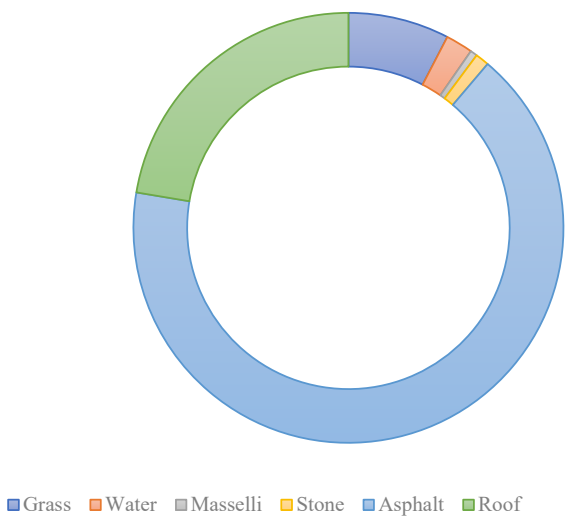
Type of surfaces: Coeff.

- Pavement:
- Asphalt: 180501 mq 1
- Stone: 2811 mq 1
- Massello autobloccante: 1427 mq 0.4
- Grass: 20672 mq 0.05
- Roofs: 60768 mq 0.9
- River: 5538 mq 0.1

RUN OFF = 240161

Figure 245. The graph represents the division according to the type of surfaces in Shuangta. Author's elaboration

Figure 245.



Exposition analysis.

Figure 246 shows the development of the heat island within the district. The figure shows that the phenomenon occurs mainly during the night and afternoon when the city's constituent materials dissipate the heat accumulated during the day. The heat island in Shuangta leads to temperature differences of up to 10 °C. Figures 247 and 248, on the other hand, are elaborations carried out through the Google Earth engine GEE - see section on exposure for the Westside pilot case. In particular, Figure 247 shows the ground temperature fluctuating between about 51.00 °C and 33.00 °C.
The ground temperature drops dramatically at watercourses: the more significant the watercourse, the greater the drop in temperature. Slight decreases are also recorded in green areas, while higher ground temperatures - between 46 and 51 °C - are recorded in the most densely populated areas. Figure 248 shows a concentration of vegetation around the banks of the main watercourse bordering the area to the east and in other punctual areas at gardens, schools, libraries or university buildings. The highest concentration of vegetation reaches 68% and is located in the southern part of the area under analysis. In general, the entire district is characterised by the presence of tree-lined avenues and green infrastructures such as squares, traffic islands, shaded areas and a network of canals that positively influence the temperature and comfort and the

Figure 246.

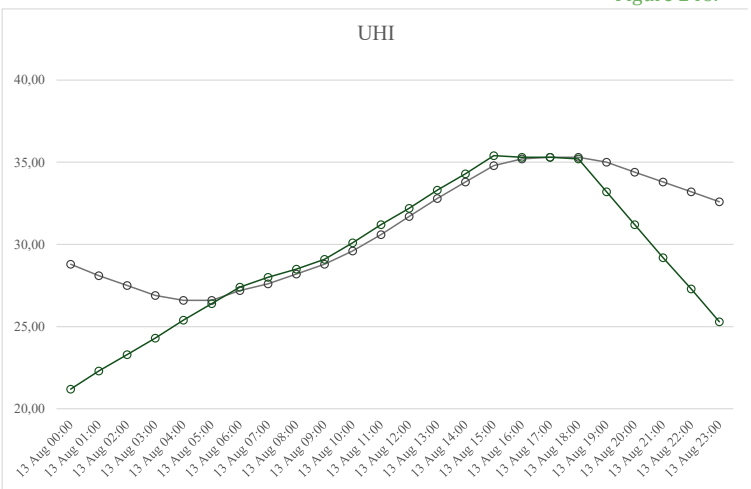


Figure 246. The graph illustrates the heat island in the area under investigation. The green break represents the temperatures of a typical day as measured by the nearest weather station. In contrast, the grey break represents the temperatures simulated through modelling on Ladybug, setting up and generating the city microclimate. Author's elaboration

heat island of the entire area.

Figure 247.

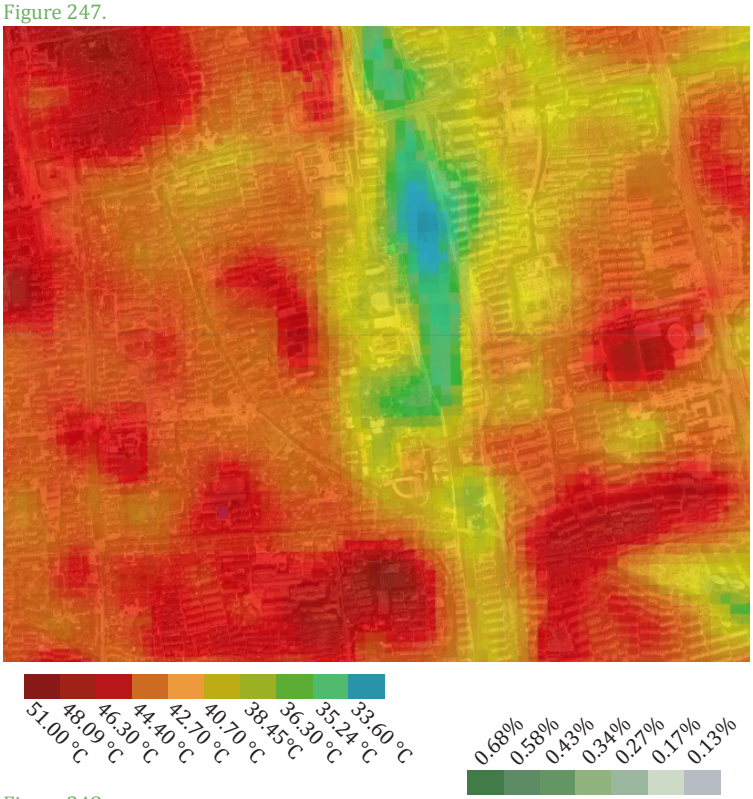


Figure 247. Graphical representation of the ground temperature in the analysed Shuangta area. Elaborated with the help of architect Stefano

Figure 248. Graphic representation of the percentage of green areas in the analysed Shuangta area. Elaborated with the help of architect Stefano Urbinati.

Figure 248.



Similar case studies, SWOT and objective individualization.

The district's streets are predominantly paved, consisting of self-locking paving slabs or stone blocks. The canal banks that run through the neighbourhood are treated by planting halophytic species.
The roofs of the buildings consist mainly of dark-coloured tiles, typical of the area, and concrete in the four-storey buildings constructed to house university students and teachers. To the north-east and south-west of the area are two green areas. Most surfaces generally consist of asphalt, dark tiled roofing and lawn. Within the area, it is possible to find autochthonous and non-native tree species of Populus alba, Acer pseudoplatanus, Cedrus deodara, Euonymus japonica, Ficus benjamina, Laurus nobilis, Magnolia grandiflora, Nerium oleander, and Salix babylonica.
Ultimately, the district's strengths lie in its great historical and architectural importance, proximity to important cultural sites, buildings and courtyards of historical and architectural interest, and canals around the area. On the contrary, the weaknesses consist of the degradation of some parts of the river banks, the fragmentation of some public spaces, and the difficulty for pedestrians to use the road network in some places. In particular, the Ganjiang E road divides the area into two distinct parts: touristy and poor and degraded. Despite being adjacent to highly touristy areas, the district's inhabitants live in a degraded state, without primary services such as toilets. From a planimetric point of view, the area has many superfetations and moving around in it is difficult. Areas of the park are forbidden to foreigners. These weaknesses, if not changed, may lead to the wasting of important parts of the area's historical and architectural heritage, to a further impoverishment of living conditions, to the degradation of structures and infrastructure, to a decrease in well-being, to an increase in the phenomena of abandonment of the neighbourhood, and an increase in the dangers of drought, floods and fires.
The opportunities connected to the district consist of regenerating an area that could acquire a tremendous historical identity and become an important junction between monuments and sites of interest connected to the area.
The objectives related to this pilot case are to increase the levels of adaptation and mitigation of impacts related to heat waves and heat islands. In particular, decreasing soil, air and surface tempe-

ratures during the hottest periods is necessary. The project aims to decrease hydrogeological, fire and drought risks. Therefore, the strategies adopted to achieve the objectives include increasing the green network and using vegetated cover, bioclimatic atria, and cool surfaces. Following the objectives and actions developed in the SWOT, the technologies suggested within the matrix developed in paragraph 2.1.3 consist of green infrastructures, wetlands and bioswales, green walls and roofs, cool materials, bioclimatic atria, buffer zones and cooling towers. Climate Consultant software – a free tool that can help provide an in-depth understanding of the climate context and choose technological solutions in line with this to increase user comfort - confirms the effectiveness of these actions. The proposed solutions align with the specific characteristics of the local vernacular architecture, an aspect that reinforces the choice of solutions, which are based on the same operating principles. For this pilot case, the principles underlying the redevelopment include increasing shaded areas, promoting cross ventilation, incorporating enclosed buffer spaces sheltered from bioclimatic conditions, and enhancing green infrastructure.

PILOT CASE - SHUANGTA - SUZHOU - CHINA

Similar Case study

Ecobarrio Trinitat Nova | Trinitat Nova | Spain

Cost: \

Designers:	Gail Vittori, Pliny Fisk III
Customers and stake holders:	City of Austin Office of sustainability
Design year:	2012
Construction year:	2014
Completion year:	2017

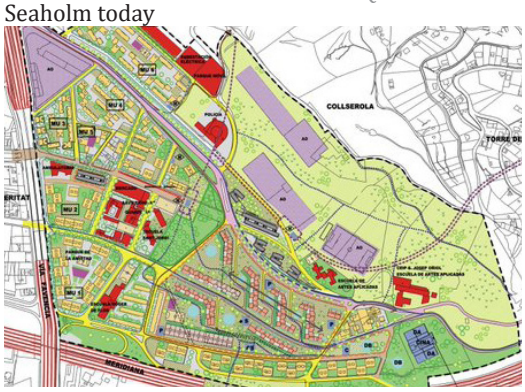


Geolocalization- Author elaboration on QGIS

Trinitat Nova in the 60's

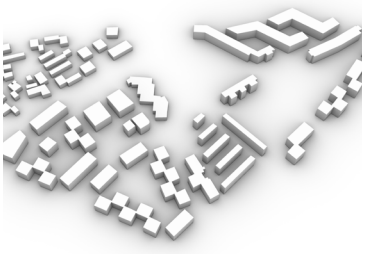


Seaholm today





Inhabitants: 2500
Dimension: 33 ha
Morphology: Centralized
H/L: 1.1



Similar issues to the case study:

- Lack of planning: most of the buildings were bilt without the presence of projects
- Poor neighbourhood built to solve the housing problem
- The area lacked of the minimun of euippement

Solutions adopted:

- water-saving plumbing systems for dual-flow faucets and toilet drains
- collection and reuse of water from showers, bathtubs, bidets, sinks and washing machines
- Trombe-walls
- Face change materials
- Solar accumulation systems
- Doubleglass windows
- Cross ventilation

PILOT CASE - SHUANGTA - SUZHOU - CHINA

Similar Case study
Amsterdam Centre zone | Amsterdam | Netherlands

Cost: 25.189.520 Euro dall'UE; total cost: 42.874.939

Designers:	Amsterdam Metropolitan Area, Innovative SME's and start-ups, Operators and providers of electricity, district heating, fiber, telco, gas
Customers and stake holders:	
Design year:	2014
Construction year:	2018
Completion year:	2020

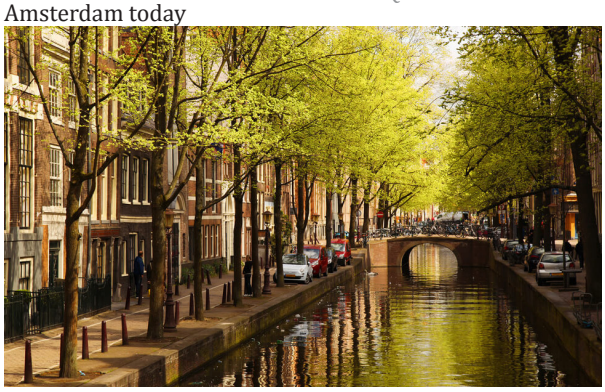


Geolocalization- Author elaboration on QGIS

Amsterdam in the 60's



Amsterdam today





Inhabitants: 850000
Dimension: 52000 mq
Morphology: Centralized
H/L: 3



Similar issues to the case study:

- Risk of flooding
- Risk of heat islands
- Energy-intensive building stock

Solutions adopted:

- Installation of double glazing
- Insulation of the roof and external envelope
- Application, where possible, of photovoltaic systems and adaptation of such systems to buildings of historical and cultural interest
- Connections to HT DHN (integrated in the duct). Heat comes from waste incineration, which will be partly replaced by deep geothermal wells in the future
- Establishment of shadow zones by planting plant species

Figure 249.

Figure 249. SWOT analisys. Author's elaboration

Strenghts:

- Historical context
- Presence of old fabric of courtyard type houses
- historical heritage area
- Good geographic position
- Presence of historic monuments, such as Shuang-Ta Market and Shuang-Ta Ying Yuan
- Presenza di canali
- Vicinanza a Pin Jian Lu: importante sito turistico

S

Opportunities:

O

- Regeneration of a part of the area envisioning a living space that aims to resume morphological continuity between old context and present ways of life.
- The site could gain cultural identity becoming an important node to connect the monuments in the area
- Possibilità di riqualificazione e di "salvataggio" dal degrado di molte abitazioni a corte tradizionali
- Possibilità di inserimento di servizi in vari locali dismessi

Weaknesses:

- Public recreational space fragmented
- Traffic and roads unfriendly
- Reacreational walks are quite difficult
- The site is a residencial area that has long been separated from modern life
- Loss of vitability of residents
- Poor condition of people
- Lack of comunication between streets and lanes
- Poor condition of urban facilities
- Messy plant design, difficult to change
- The infrastructure system hinder the access from one part of the neighborhood to another, cutting the neighborhood in two parts: one more turistic and another one very poor
- Difficoltà di accesso in alcune zone
- Quartiere molto chiuso e poco accessibile agli stranieri

W

T Threats:

- Waste of cultural resouces
- Ulteriore impoverimento delle condizioni di vita
- Incremento del degrado di strutture e infrastrutture
- Incremento dei costi di manutenzione e risanamento
- Aumento della mortalità e diminuzione del benessere
- Incremento del fenomeno di abbandono del quartiere
- Incremento delle temperature esterne
- Incremento siccità
- Incremento pericolo alluvioni
- Incremento pericolo incendi

Figure 250.

Figure 250. Elaboration of strategies and action scenario of Shiangta neighborhood- Author elaboration

Objective:

- Urban Heat Island Adaptation and Mitigation
- Adaptation to extreme temperatures
- Adaptation to heat waves

- Hydrogeological Risk Adaptation
- Adaptation to fire risk
- Drought/aridity risk adaptation
- Improve the quality of life of the inhabitants
- Reducing soil, air and surface temperatures

- Improve the relation betwe-en nature history and the site
- Restoration of the cutural sites
- Diminuzione della temperatura del suolo, dell'aria e delle superfici

- Create a liveable and durable neighborhood
- Requalification of the area

Strategies and actions:

- Build of green infrastructures
- Use plant materials expecially on the west to minimize heat gain
- Use of radiant barrier that can help reduce radiated heat gain trought the roofs
- Use light colored building materials and cool roof (with hight emissivity) to minimize conductive hat gain

Guidelines:

- Use of effective strategies that, in the short term, solve the greatest number of problems with the least expenditure of resources reducing emissions in buildings
- Increasing outdoor ventilation and indoor cross ventilation during peak periods
- Development of innovative territorial governance models that also involve the local community

Actions scenarios:

- Scenario 1: greening
- Scenario 2: cooling surfaces
- Scenario 3 Greening + cooling surfaces

Figure 251.

SELECTION OF ACTIONS

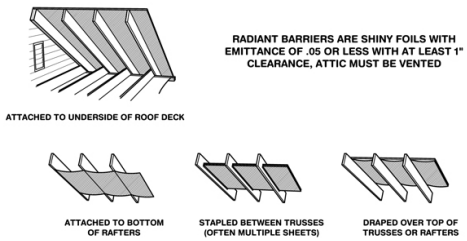
Wildfires	Parks, garden squares, pocket gardens, and urban farmings, trees and green corridors
Drought	Parks, garden squares, pocket gardens, and urban farmings, trees and green corridors
Stress of structures	Water surfaces, rain garden and phytodepuration, wetland ad bioswales, parks, garden squares, pocket gardens, and urban farmings, trees and green corridors, Cooling towers, green systems embedded in buildings, green houses and winter gardens, external coat, green roofs, green walls, ventilated roofs/floors, permeable surfaces, ponds on roof/ground floor, cool materials
Stress of infrastructures	Evaporative cooling, water surfaces, rain garden and phytodepuration, wetland ad bioswales, parks, garden squares, pocket gardens, and urban farmings, trees and green corridors, permeable surfaces, ponds on roof/ground floor, cool materials
Problems with finishing materials	External coat, Parks, garden squares, pocket gardens, and urban farmings, trees and green corridors, green roofs/walls, permeable surfaces, cool materials, cooling towers, green systems embedded in buildings, ventilated roofs/walls
Increasing indoor temperature	Artificial and natural urban devicesfor guide wind flows, parks, garden squares, pocket gardens, and urban farmings, trees and green corridors, bioclimatic atria, cooling towers, green houses and winter gardens
Increasing mortality	Parks, garden squares, pocket gardens, and urban farmings, trees and green corridors, bioclimatic atria, wind chimney, reen houses and winter gardens
Rainfall	Parks, garden squares, pocket gardens, and urban farmings, trees and green corridors
Decreasing of comfort conditions	Parks, garden squares, pocket gardens, and urban farmings, trees and green corridors, bioclimatic atria, wind chimney, reen houses and winter gardens
Energy transmission losses and facilities	Artificial and natural urban devicesfor guide wind flows, artificial shade systems, natural shade systems, Parks, garden squares, pocket gardens, and urban farmings, trees and green corridors, buffer zones, external coat, green roofs, permeable surfaces, ponds on roof/ground floor, phasechange and thermocromic materials, thermal mass

Figure 251. Matrix of hazards related to urban heat island and heat waves and technologies sets that can decrease all the KPI related to each hazard - Author elaboration

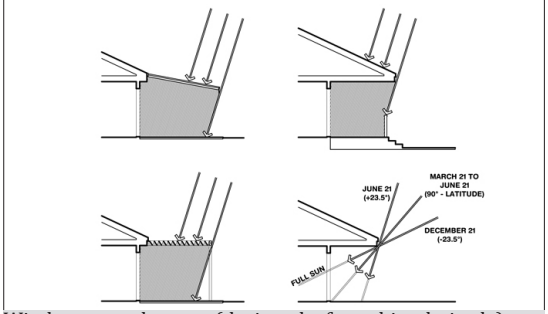
Negative impact for renewerable energies	Evaporative cooling, water surfaces, rain garden and phytodepuration, wetland ad bioswales, Parks, garden squares, pocket gardens, and urban farmings, trees and green corridors, green roofs/walls, permeable surfaces, ponds on roof/ground floor, cool materials, external coat, ventilated roofs/walls
Increasing costs for preventing measures	Water surfaces, raingardens and phytodepuration, wetlands and bioswales, parks, garden squares, pocket gardens, and urban farmings, trees and green corridors, cooling towers, green systems embedded in buildings, green houses and winter gardens, cool materials, green roofs/walls, permeable surfaces, ponds on roofs/ground floors, ventilated roofs/walls, green systems embedded in buildings
Neighborhoods abandonement	Parks, garden squares, pocket gardens, and urban farmings, trees and green corridors
Buildings abandonement	Parks, garden squares, pocket gardens, and urban farmings, trees and green corridors, bioclimatic atria, cooling towers
Increasing maintenace costs	Water surfaces, rain garden and phytodepuration, wetland ad bioswales, parks, garden squares, pocket gardens, and urban farmings, trees and green corridors, green systems embedded in buildings, green walls, green roofs, permeable surfaces, ponds on roof/ground floor, photocatalityc materials, cool materials, cooling towers, ventilated roofs/walls
Increasing recovery costs	Water surfaces, rain garden and phytodepuration, wetland ad bioswales, parks, garden squares, pocket gardens, and urban farmings, trees and green corridors, green systems embedded in buildings, green walls, green roofs, permeable surfaces, ponds on roof/ground floor, photocatalityc materials, cool materials, cooling towers, ventilated roofs/walls
Increasing deterioration rate of systems and materials	Water surfaces, rain garden and phytodepuration, wetland ad bioswales, parks, garden squares, pocket gardens, and urban farmings, trees and green corridors, green systems embedded in buildings, green walls, green roofs, permeable surfaces, ponds on roof/ground floor, photocatalityc materials, cool materials, cooling towers, ventilated roofs/walls
Increasing deterioration rate of infrastructures	Rain garden and phytodepuration, wetland ad bioswales, parks, garden squares, pocket gardens, and urban farmings, trees and green corridors, permeable surfaces, ponds on roof/ground floor, photocatalityc materials, cool materials, cooling towers, ventilated roofs/walls
Buildings may became unsuitable for use	Parks, garden squares, pocket gardens, and urban farmings, trees and green corridors, bioclimatic atria, cooling towers
Infrastructures may became unsutaible for use	Parks, garden squares, pocket gardens, and urban farmings, trees and green corridors
Decrease of air quality	Artificial and natural urban devicesfor guide wind flows, parks, garden squares, pocket gardens, and urban farmings, trees and green corridors

CLIMATE CONSULTANT

Shandings:

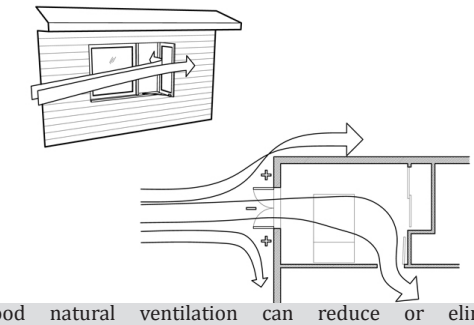


A radiant barrier (shiny foil) will help reduce radiated heat gain through the roof in hot climates

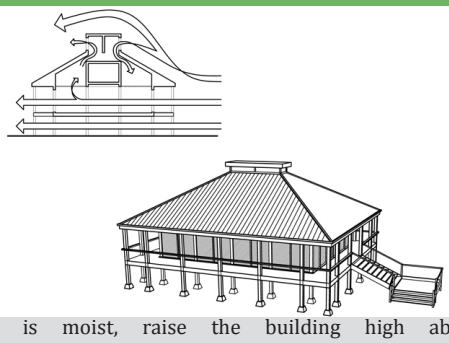


Window overhangs (designed for this latitude) or operable sunshades (awnings that extend in summer) can reduce or eliminate air conditioning

Cross ventilation:

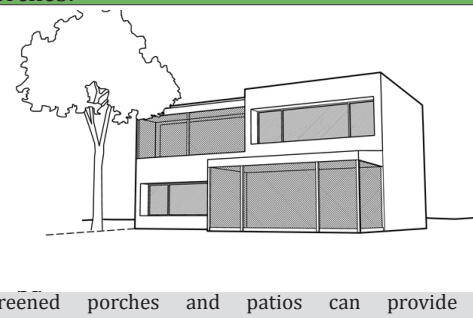


Good natural ventilation can reduce or eliminate air conditioning in warm weather, if windows are well shaded and oriented to prevailing breezes

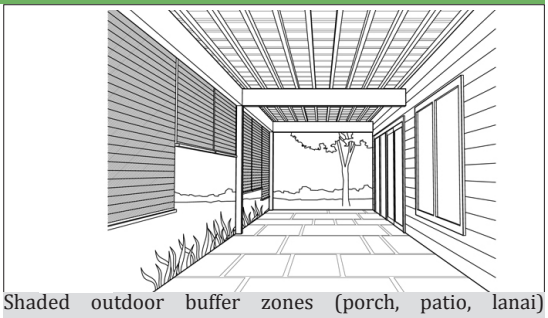


If soil is moist, raise the building high above ground to minimize dampness and maximize natural ventilation underneath the building

Porches:

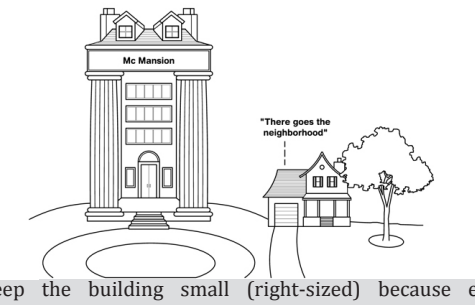


Screened porches and patios can provide passive comfort cooling by ventilation in warm weather and can prevent insect problems

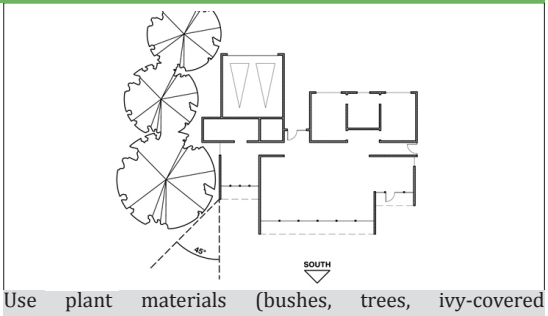


Shaded outdoor buffer zones (porch, patio, lanai) oriented to the prevailing breezes can extend living and working areas in warm or humid weather

Size of buildings, orientation and greenery:



Keep the building small (right-sized) because excessive floor area wastes heating and cooling energy



Use plant materials (bushes, trees, ivy-covered walls) especially on the west to minimize heat gain (if summer rains support native plant growth)

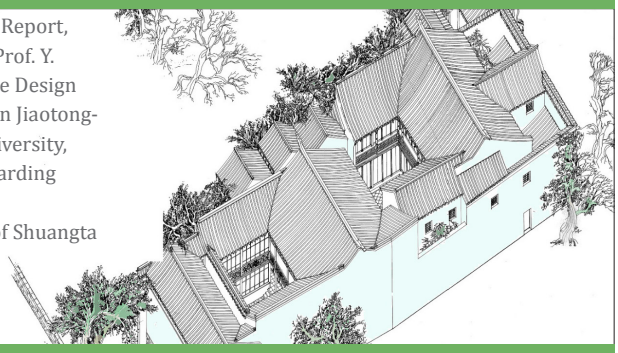
VERNACULAR ARCHITECTURE







2022 Annual Report, provided by Prof. Y. Dong from the Design School at Xi'an Jiaotong-Liverpool University, titled 'Safeguarding Heritage and Community of Shuangta Area'.







Pictures taken by the author.

ACTIONS USED IN REQUALIFICATION ACTIONS

The redevelopment project includes various shaded areas.

Cross ventilation is encouraged by the installation of green and grey screens.

The presence of buffer zones is encouraged through their maintenance and the conversion of some of them into bioclimatic atriums.

The presence of green infrastructure has increased.

Model setting .

The model setup is the same as in the other pilot cases: through the UWG generator, a city microclimate can be generated for the area under investigation. The information entered as input relates to the environmental climate context and the built environment, such as the reflectance of surfaces, the geometry of the model and the intended use. The model is processed on Rhinoceros 6.0 software and then connected to the algorithm on Ladybug, through which indoor and outdoor microclimatic information is obtained. The wall packages loaded on the model correspond to the layers found in the literature - see morpho-typological analysis. In particular, the buildings subjected to the intervention have a standard clay brick envelope without insulation and a plaster finish both outside and inside. The roof is reinforced concrete topped with cement mortar levelling, an asphaltic felt waterproofing and a loose fill gravel finishing layer. The KPIs investigated through the simulation are indoor and outdoor temperatures, indoor and outdoor relative humidity, indoor mean radiant temperature and indoor and outdoor UTCI.

Figure 252.

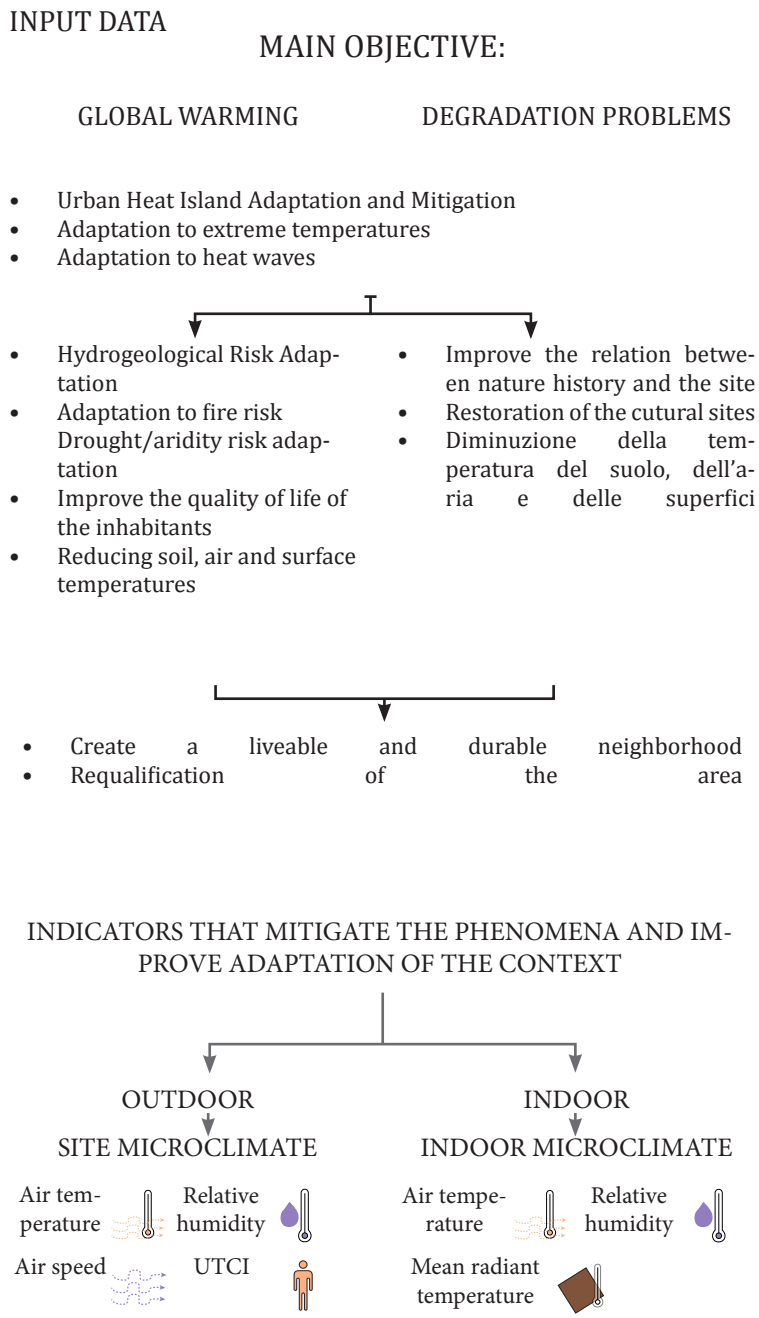


Figure 252. KPIs evaluated on Ladybug tools - Author elaboration

Figure 253.

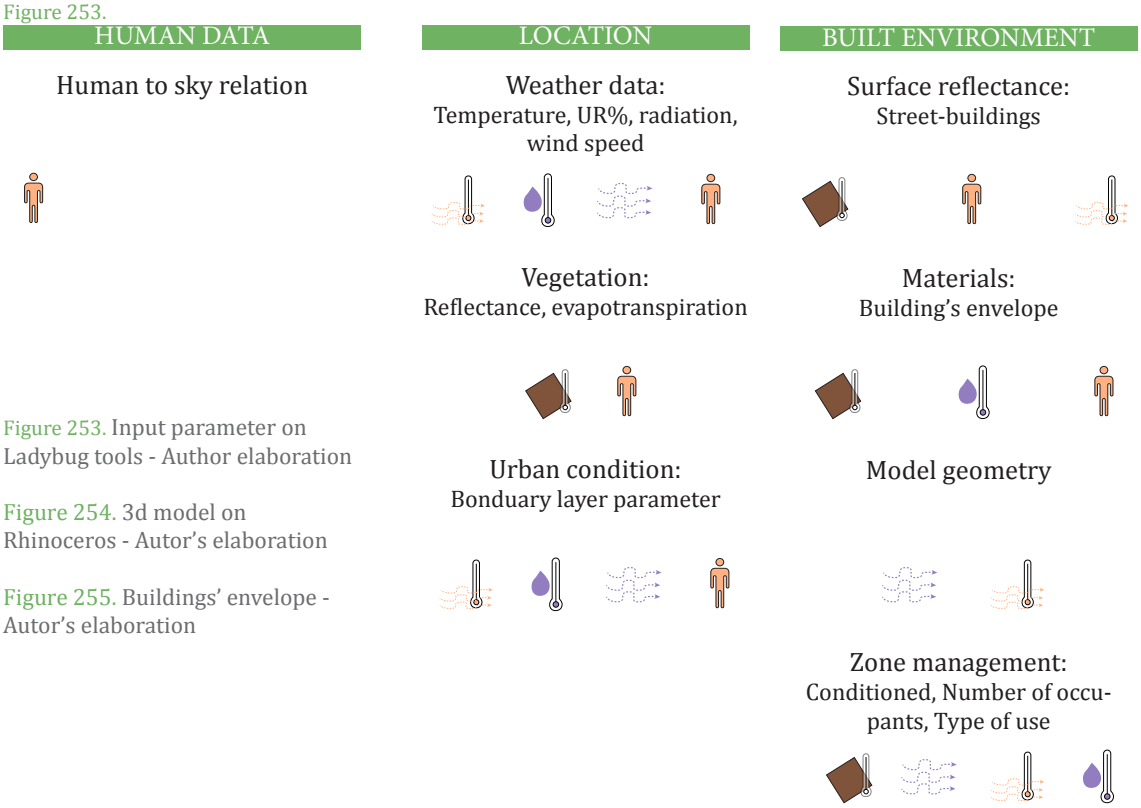


Figure 253. Input parameter on Ladybug tools - Author elaboration

Figure 254. 3d model on Rhinoceros - Autor's elaboration

Figure 255. Buildings' envelope - Autor's elaboration

TECHNOLOGIES INVOLVED:

- Trees and green corridors
- Buffer zones
- Bioclimatgic atria
- Cooling towers
- Wetlands and bioswales
- Greening: parcks, gardens, squares, pocket gardens, urban farming

INPUT DATA

Weather data:

It is usually represented by a .epw file where there are the main values of a region that concernes Temperature, UR%, radiation and wind speed. The-

Human to sky relation:

Calculate parameters for the relationship between human geometry and the sky given the position of a human subject and context geometry surrounding this position. It represent a Ldybig component and is used to calculate MRT of a certain person inside the model.

Figure 254.

Model Geometry and points of simulation:

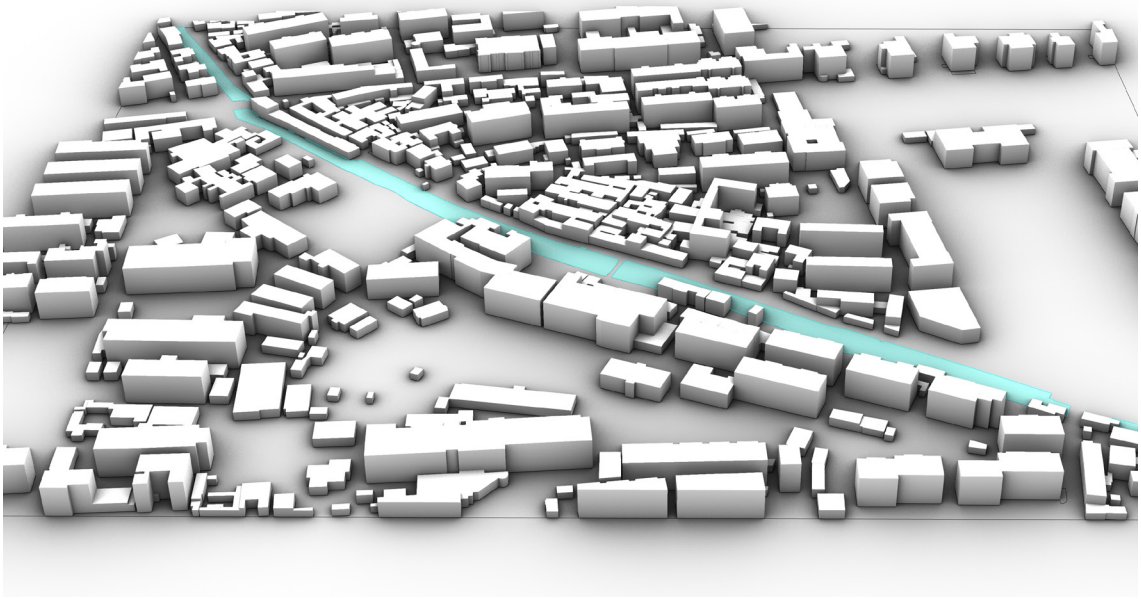
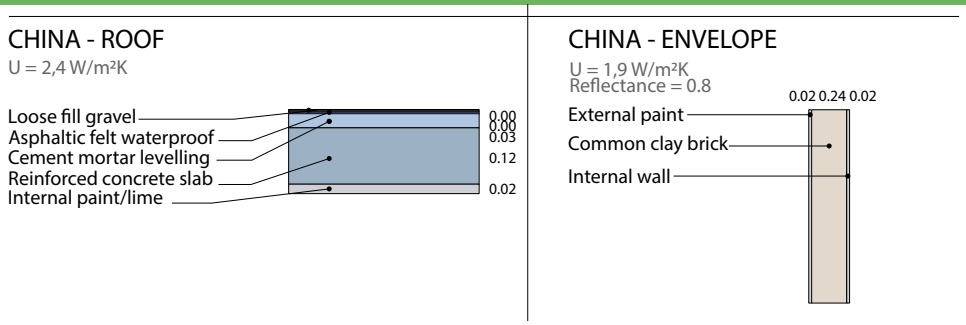


Figure 255.

Building envelope:



Solutions analysed and masterplan.

Figures 258, 259, 264, 270, and 276 illustrate the composition of different surfaces in relation to the total intervention area, before and after mitigation and adaptation measures and systems were implemented. The simulations conducted before developing the master plan included adding cold surfaces and green infrastructure and combining these two solutions. Combining the two solutions yields low KPI improvements; however, developing a master plan with a broader mix of solutions leads to significant KPI value changes, see tab. X. At the outdoor bioclimatic level, the technologies used within the master plan consist of increasing green surfaces and trees, installing water squares, using cool finishes for paving road surfaces and roofs and decreasing outdoor temperatures by 1.20 °C. At the indoor level, installing bioclimatic atria, buffer spaces, and cool and ventilated enclosures allows a maximum temperature decrease of 4.20 °C and an average radiant temperature of 6.22 °C. At the energy level, agro photovoltaic roofs are installed on the four-storey buildings that the university formerly used as accommodation for professors and students. With this technological combination, high levels of well-being and relative humidity increases are achieved indoors and outdoors.

Tab. X.

	T_{out}	T_{in}	$UTCI_{out}$	mrt_{in}	$UR\%_{out}$	$UR\%_{in}$
Cool	1.10	0.56	1.04	0.36	4	1.53
Green	0.70	0.34	0.65	0.21	3	0.99
Cool + Green	1.10	0.56	1.04	0.36	4	1.56
Masterplan	1.10	4.20	1.04	6.22	4	12.39

Table X. shows the simulation results with the UWG generator in Shuangta District. The result illustrates the difference between the model with no adaptation or mitigation actions and the lowest result model with them. Author's elaboration

Cool materials

Pre

Figure 256.



Post

Figure 257.

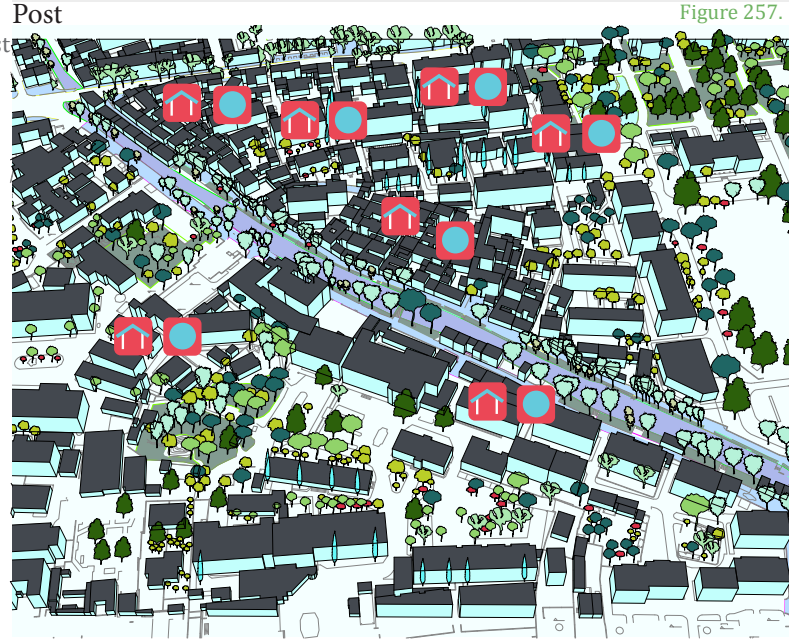


Figure 256. Pre-intervention schematic representation of the air under consideration for the Shuangta district

Figure 257. Post-intervention schematic representation of the area under investigation in the Shuangta district

Figure 258. The graph illustrates the different types of surfaces present before the intervention.

Figure 259. The graph illustrates the different types of surfaces present following the redevelopment work.

Figure 260. Trend of temperatures during the statistically hottest day indoors and outdoors, pre- and post-intervention

Figure 261. Plan of the pre and post intervention area.

Figure 262. Plan of the post area

Figure 263. Pre and post intervention indoor and outdoor air temperature at 2.00 pm on the statistically hottest day of the year.

Cool materials

PRE			COOL		
Surfaces	138473	mq	Cool surfaces	260709	mq
Streets	124062	mq	Cool streets	124062	mq
Roofs	23078	mq	Cool roofs	23078	mq
Garden pre	15144	mq	Garden pre	15144	mq
Tree pre	33840	mq	Tree pre	33840	mq
Pavements	1426	mq			

EFFECTIVENESS:

Outdoor:

Wind speed: \

UTCI: ●

Temperature: ●

UR%: ●●●

Indoor:

Wind speed: \

UTCI: ●

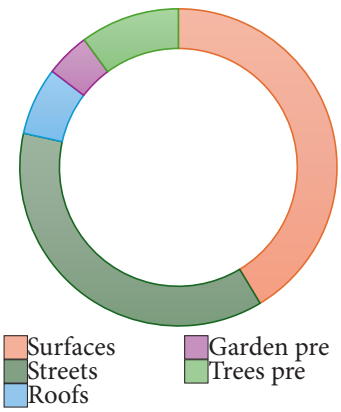
mrt indoor: ●●●

UR%: ●

Temperature: ●

Pre

Figure 258.



Cool materials

Figure 259.

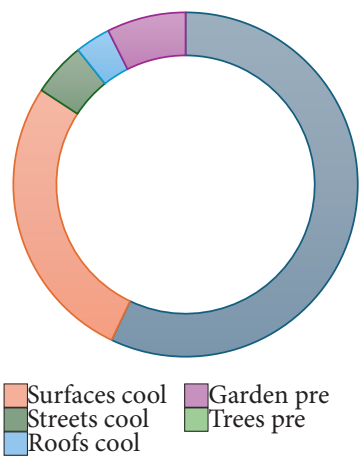
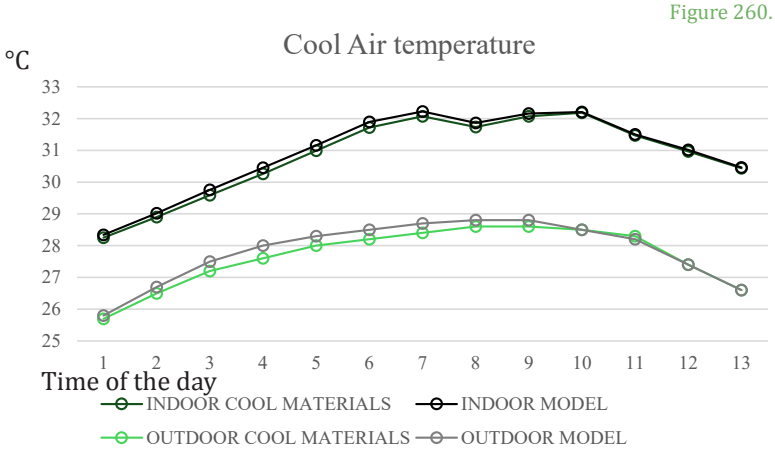


Figure 260.



Cool materials

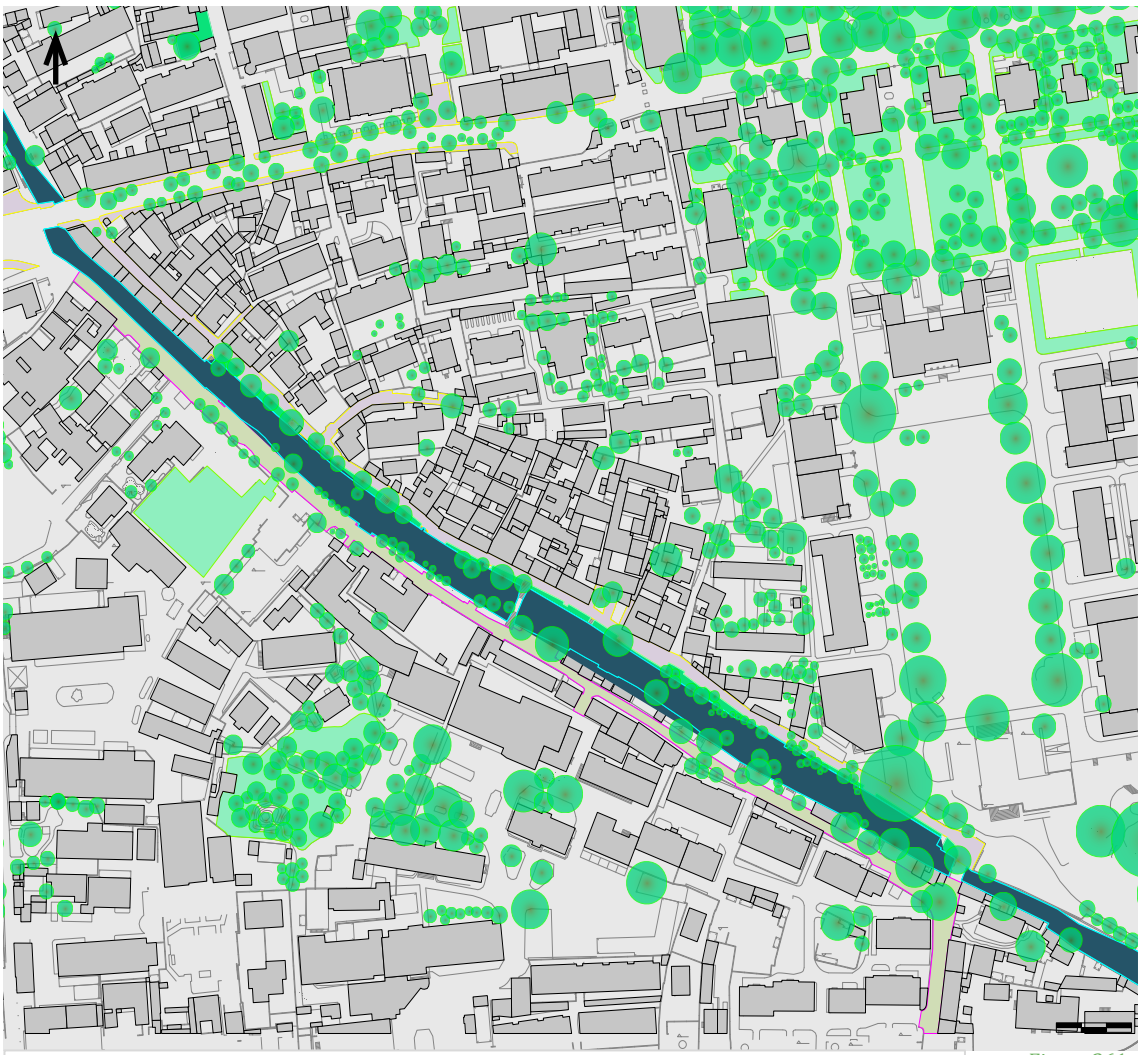


Figure 261.

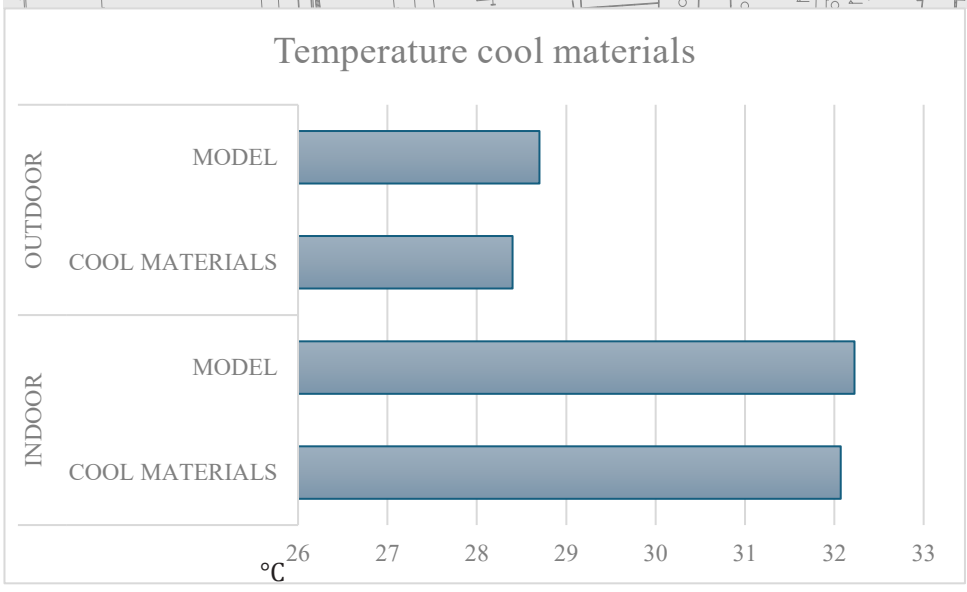


Figure 263.

Cool materials



Figure 262.

LEGEND:

- Grass
- Trees
- Cool roofs
- Cool Pavements
- Blocks
- Cool surfaces

Greening

Figure 264. The graph illustrates the different types of surfaces present following the redevelopment work.

Figure 265. Temperature trends during the statistically hottest day of the year, indoor and outdoor, pre- and post-intervention

Figure 266. Schematic representation of the area under investigation in the SHuangta district post intervention

Figure 267. Post planimetry

Figure 268. Air temperature during the statistically hottest day of the year at 2.00 pm, indoor and outdoor, pre and post intervention

Pre

Figure 256.



Post

Figure 266.



Greening

PRE			GREEN		
Surfaces	138473	mq	Garden pre	15134	mq
Streets	124062	mq	Trees pre	33840	mq
Roofs	23078	mq	Trees post	38883	mq
Garden pre	15144	mq	Garden post	17144	mq
Tree pre	33840	mq	Surfaces	260709	mq
Pavements	1426	mq	Streets	124062	mq
			Roofs	23078	mq

EFFECTIVENESS:

Outdoor:

Wind speed:

UTCI:

Temperature

UR%:

Indoor:

Wind speed:

UTCI:

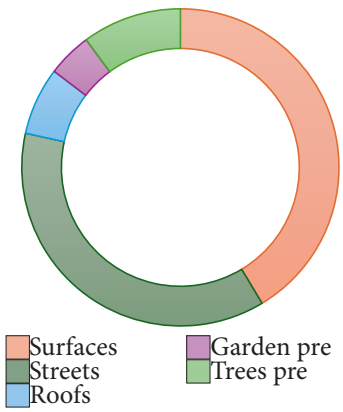
mrt indoor:

UR%:

Temperature:

Pre

Figure 258.



Greening

Figure 264.

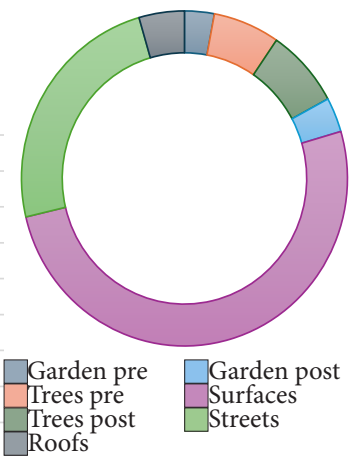
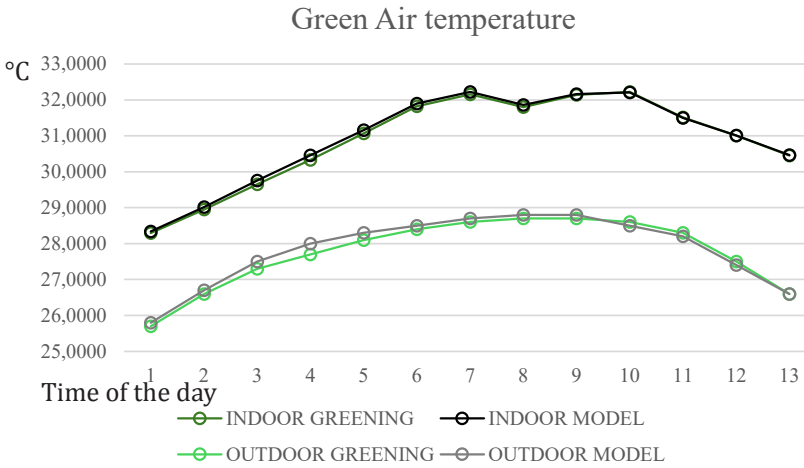


Figure 265.



Greening

Figure 261.



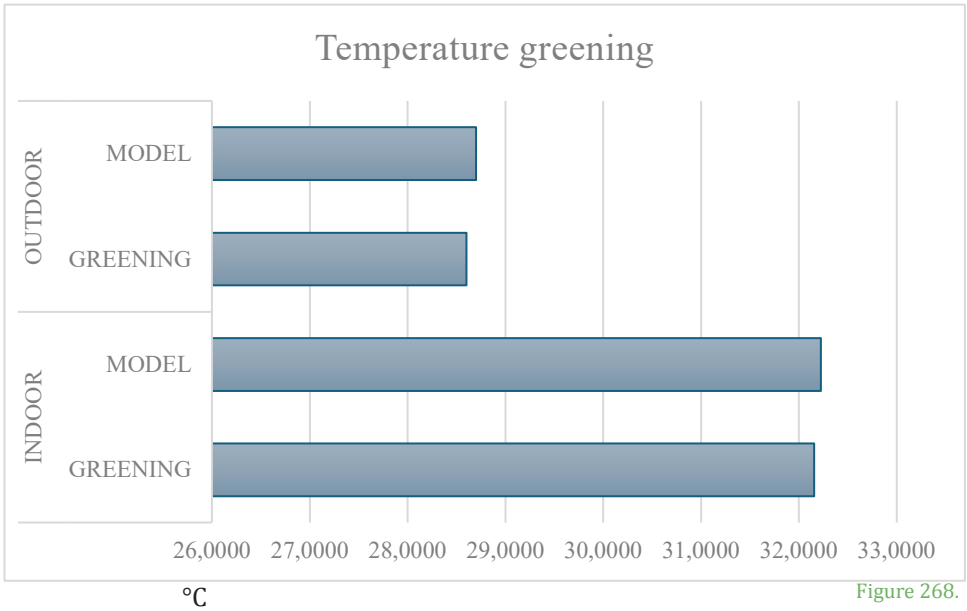
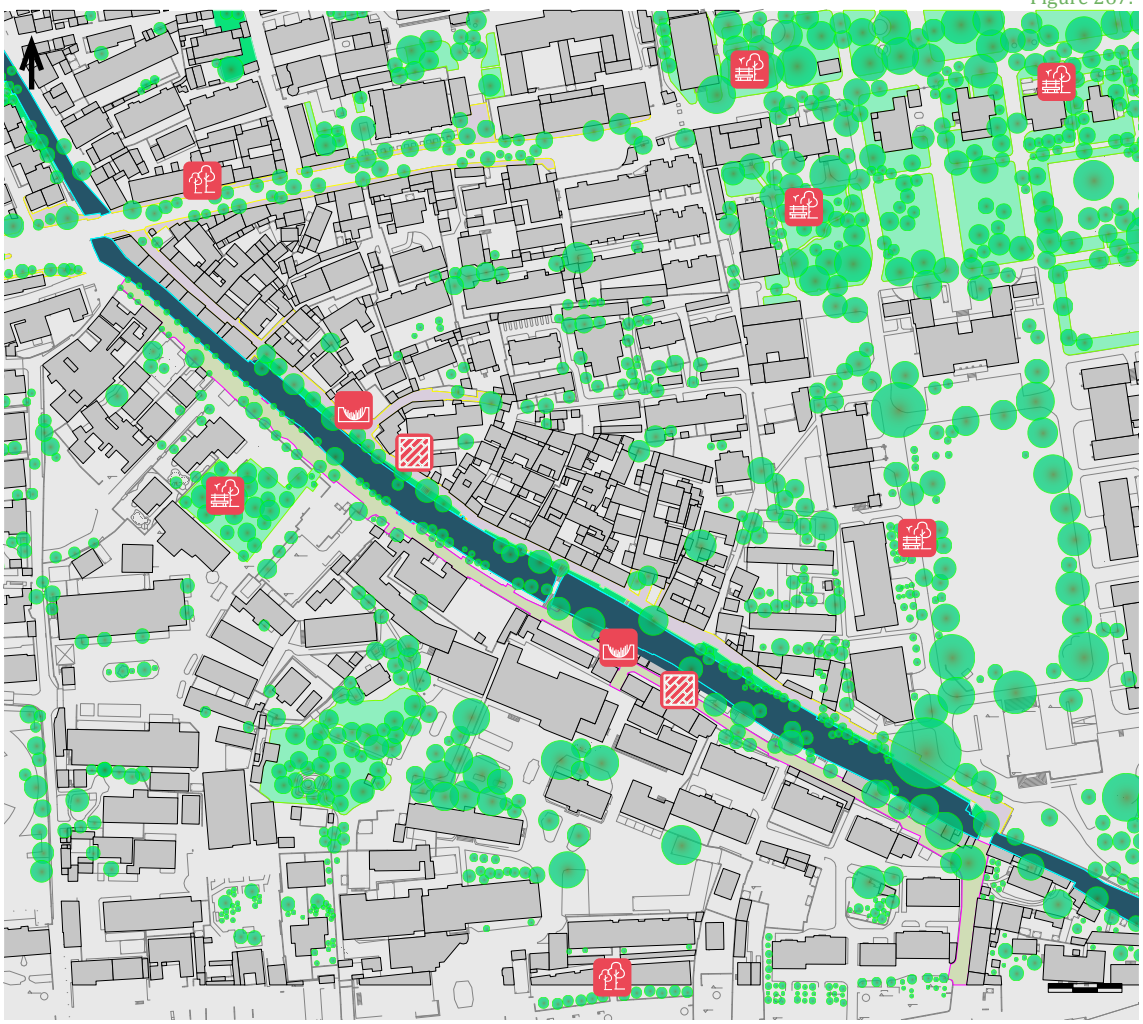


Figure 268.

Greening

Figure 267.



Cool materials and greening:

Pre

Figure 256.



Post

Figure 269.



Figure 269. Graphic representation of the area under investigation in the Shuangta district, post intervention

Figure 270. The graph illustrates the different types of surfaces present following the redevelopment work.

Figure 271. Temperature trends during the statistically hottest day, indoor and outdoor, pre- and post-intervention

Figure 272. Air temperature at 2.00 pm during the statistically hottest day of the year, indoor and outdoor, pre- and post-intervention

Figure 273. Post planimetry

Cool materials and greening:

PRE		
Surfaces	138473	mq
Streets	124062	mq
Roofs	23078	mq
Garden pre	15144	mq
Trees pre	33840	mq
Pavements	1426	mq

GREEN + COOL		
Garden pre	15134	mq
Trees pre	33840	mq
Trees post	38883	mq
Garden post	17144	mq
Cool surfaces	260709	mq
Cool streets	124062	mq
Cool roofs	23078	mq

EFFECTIVENESS:

Outdoor:

Wind speed: ●●●

UTCI: ●●

Temperature ●●

UR%: ●

Indoor:

Wind speed: ●

UTCI: ●●●

mrt indoor: ●●●

UR%: ●●●

Temperature:

Figure 258.

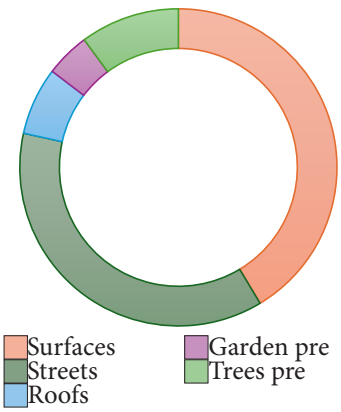


Figure 270.

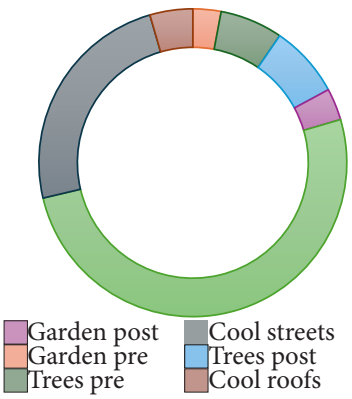


Figure 271.

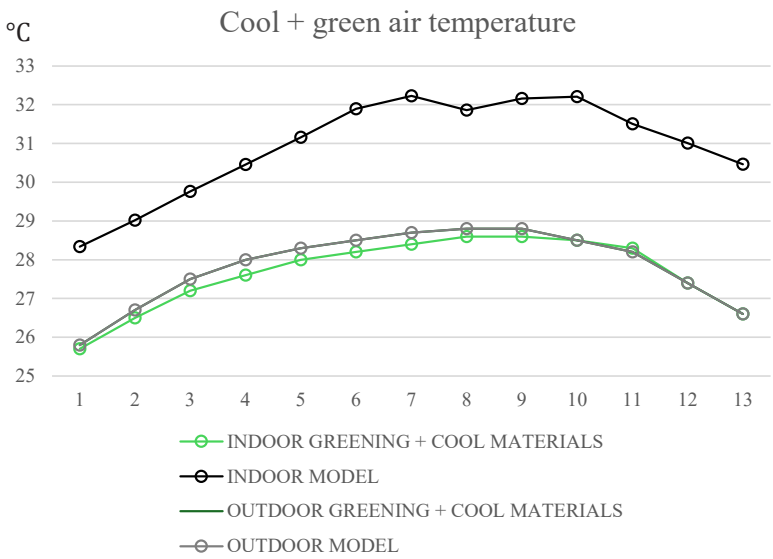
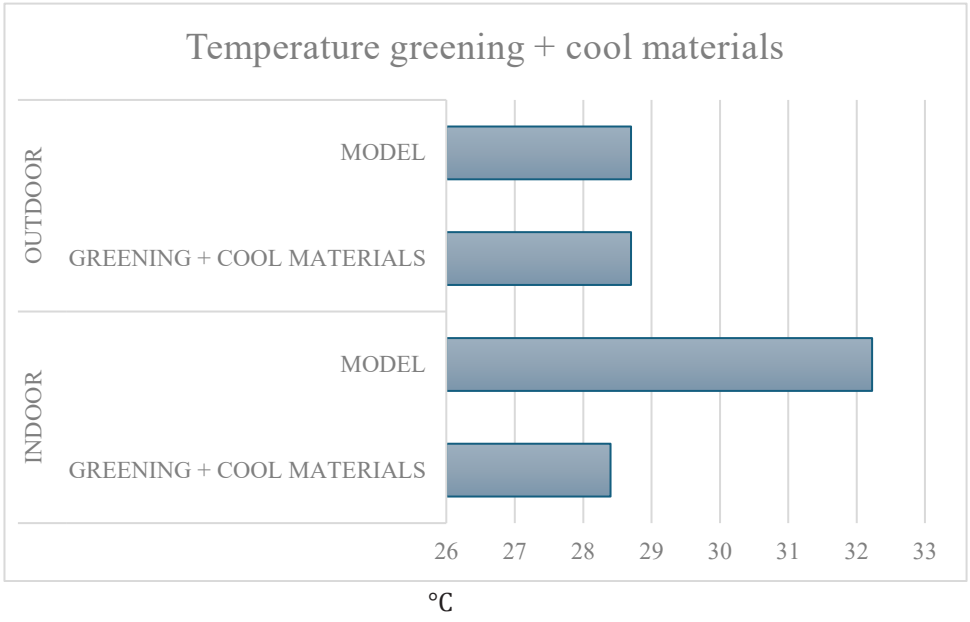


Figure 261.



Figure 272.



Cool materials and greening

Figure 273.



Masterplan

Objective:

MACRO OBJECTIVES

- Urban heat island adaptation and mitigation
- Extreme temperature adaptation and mitigation
- Heat wave adaptation and mitigation



ANTHROPIC SYSTEM

- Improve the relationship between nature history and the site
- Decrease in soil, air and surface temperature
- Increase in the liveability of the area
- Encouragement of community development and growth



NATURAL SYSTEM

- Hydrogeological risk adaptation
- Adaptation to fire risk
- Drought/aridity risk adaptation

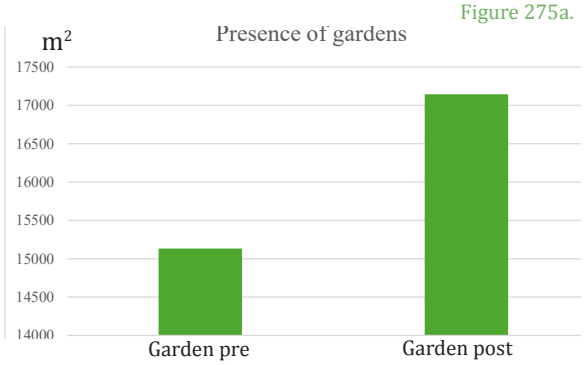


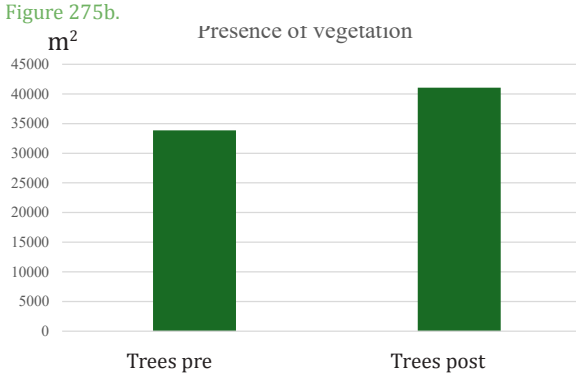
WELLNESS

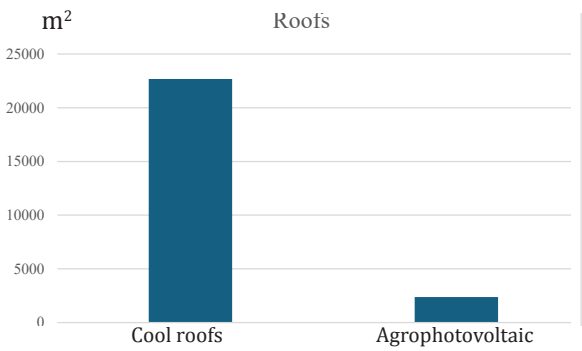
- Create a liveable and durable neighborhood
- improve the quality of the life of the inhabitants



Figure 275a. Figure 275b.







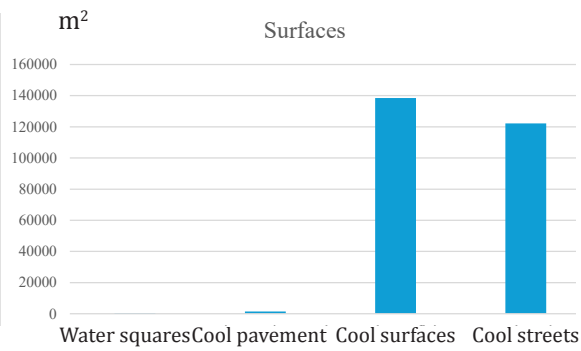


Figure 275c. Figure 275d.

Masterplan:

Tab XI.

	EFFECTIVENESS:								RESPONSIVENESS			
	OUTDOOR				INDOOR				LIFE PERIOD			
	T	UR%	mrt	wind speed	T	UR%	mrt	wind speed	Period of installation	Maintenace	Life span	Return environemntal period
	●	●	●●	●	\	\	\	\	▭	!	▭	▭
	●	●●●	●●	●	\	\	\	\	▭	!!	▭	▭
	●	●●●	●●	●	\	\	\	\	▭	!!	▭	▭
	●●●	●●●	●●	●●●	●●	●●	●●	●	▭	!!!	▭	▭
	●●	●●●	●●	●●	●	●	●	\	▭	!!!	▭	▭
	●	●●	●●	\	●●●	●●●	●●	\	▭	!!!	▭	▭
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Figure 258.

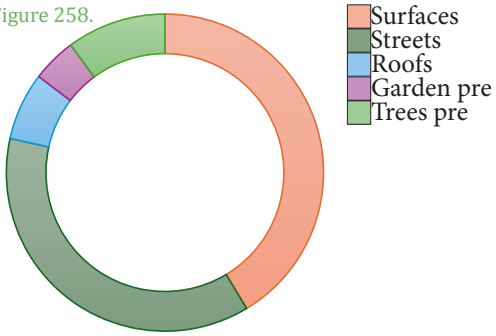
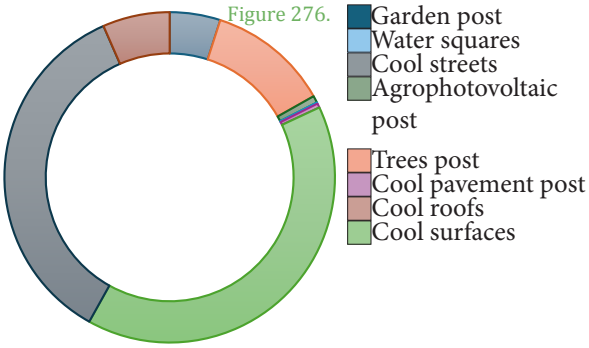


Figure 276.



p. 732 Masterplan



Figure 261.

Masterplan:

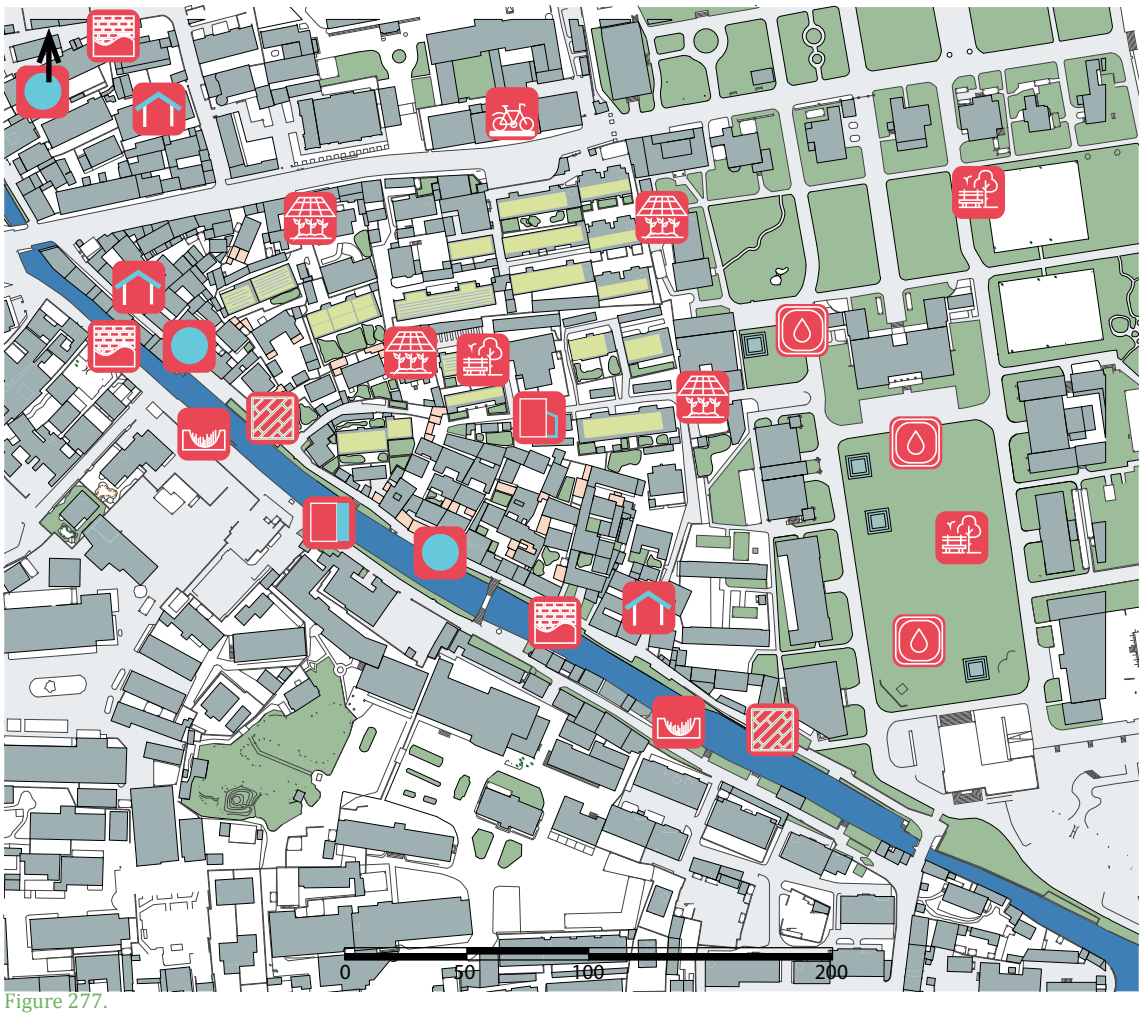


Figure 277.

Legend:

- Self-blocking permeable blocks
- Bioswales
- Watersquares
- Green areas
- Agrophotovoltaics systems
- Bioclimatic atria
- Cool surfaces
- Cool roofs
- Insulation systems improvement
- Green roofs
- Trees
- Greening

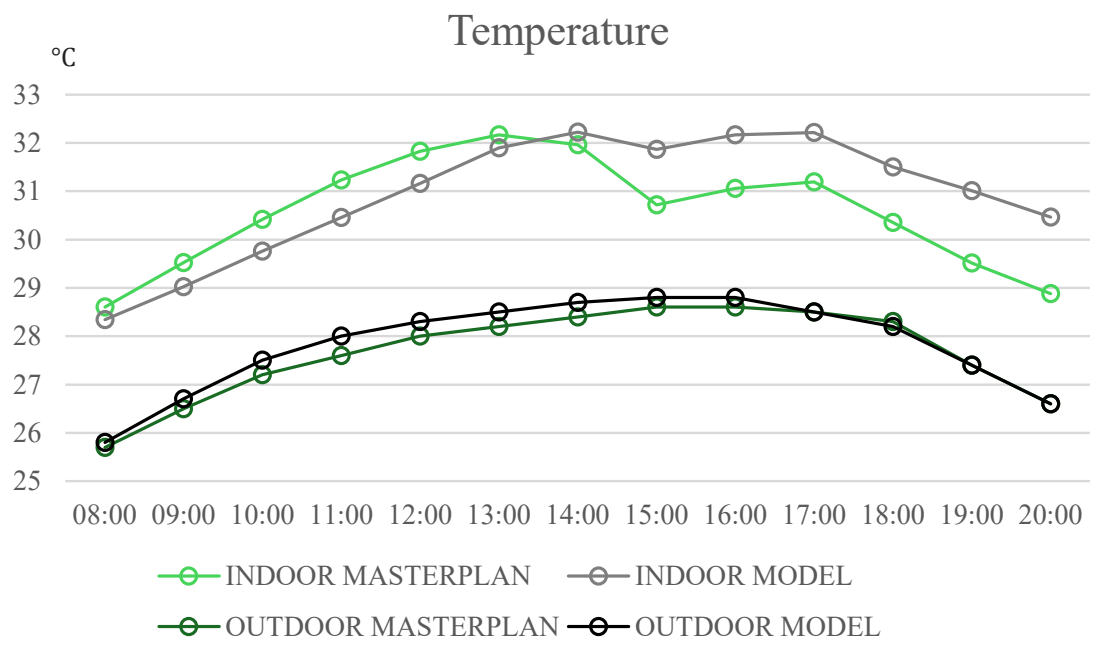


Figure 278.

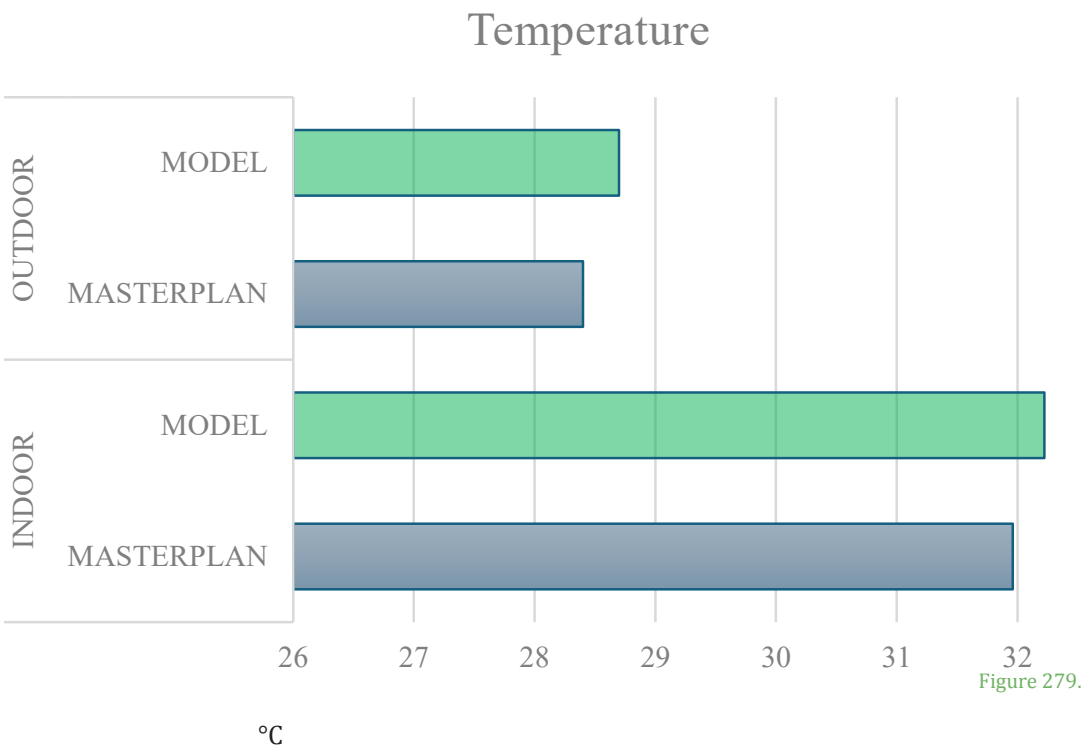


Figure 279.

Masterplan:

Figure 280 a.

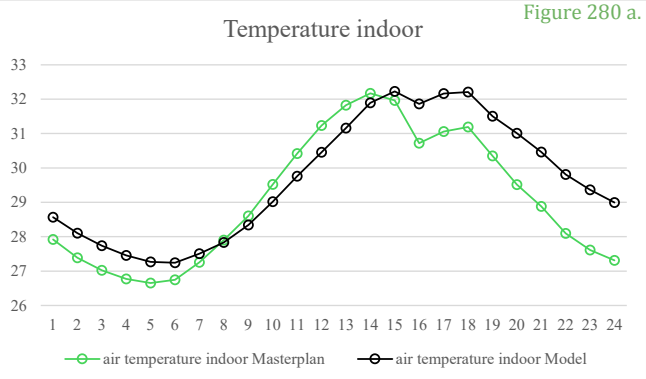


Figure 280 b.

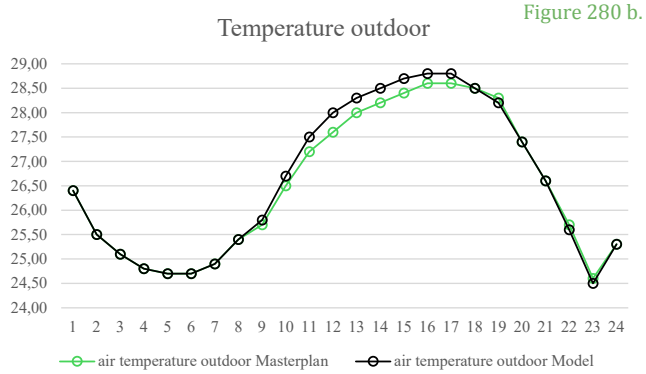


Figure 280 c.

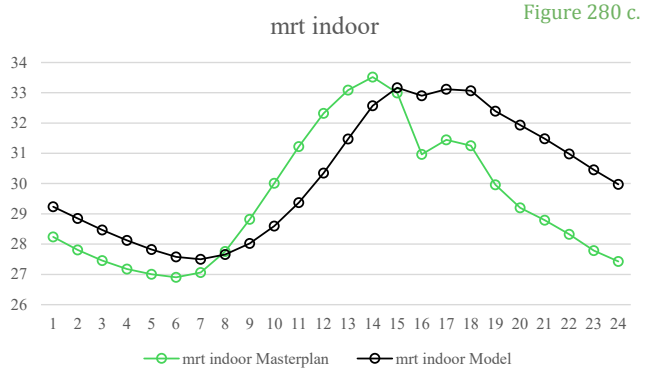


Figure 280 d.

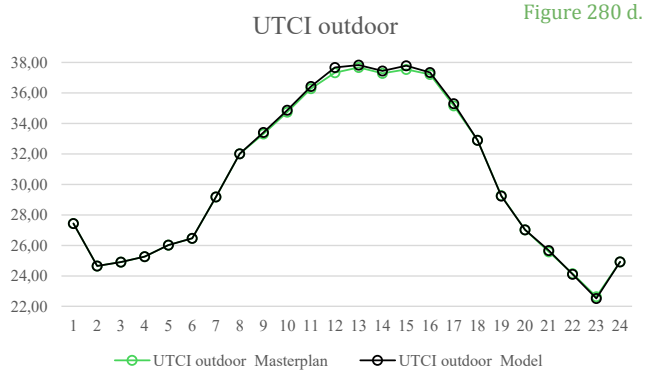


Figure 275 a. The graph represents the amount of green space pre- and post-intervention

Figure 275 b. The graph represents the amount of pre- and post-intervention trees

Figure 275 c. The graph represents the types of post intervention roofing

Figure 275 d. The graph represents the post types of surfaces

Figure 276. The graph illustrates the different types of surfaces present following the redevelopment work.

Figure 277. Master plan

Figure 278. Temperature trends during the hottest statistical day of the year, indoor and outdoor, pre- and post-intervention

Figure 279. Indoor and outdoor air temperature pre and post intervention

Figure 280 a, b, c, d. Trends in indoor and outdoor T, indoor mrt and outdoor UTCI, during the statistically hottest day of the year

Tab XI. The table summarises the effectiveness and effciency levels of each action used on the basis of the simulations carried out and the relevant literature

Masterplan

Pre

Figure 256.



Figure 282. Schematic representation of the marterplan

Figure 283. Post section. The data are extracted from the Annual Report 2022, provided by Prof. Y. Dong of the School of Design, Xi'an Jiaotong-Liverpool University, entitled "Safeguarding Heritage and Community of Shuangta Area".

Figure 284. Graphical representation of the interventions on the building. The data are extracted from the Annual Report 2022, provided by Prof. Y. Dong from the Design School of Xi'an Jiaotong-Liverpool University, entitled "Safeguarding Heritage and Community of Shuangta Area".

Legend figures 282, 283, 284:

- Self-blocking permeable blocks
- Bioswales
- Watersquares
- Green areas
- Agrophotovoltaics systems
- Bioclimatic atria
- Cool surfaces
- Cool roofs
- Insulation systems improvement
- Green roofs
- Greening

Post

Figure 282.

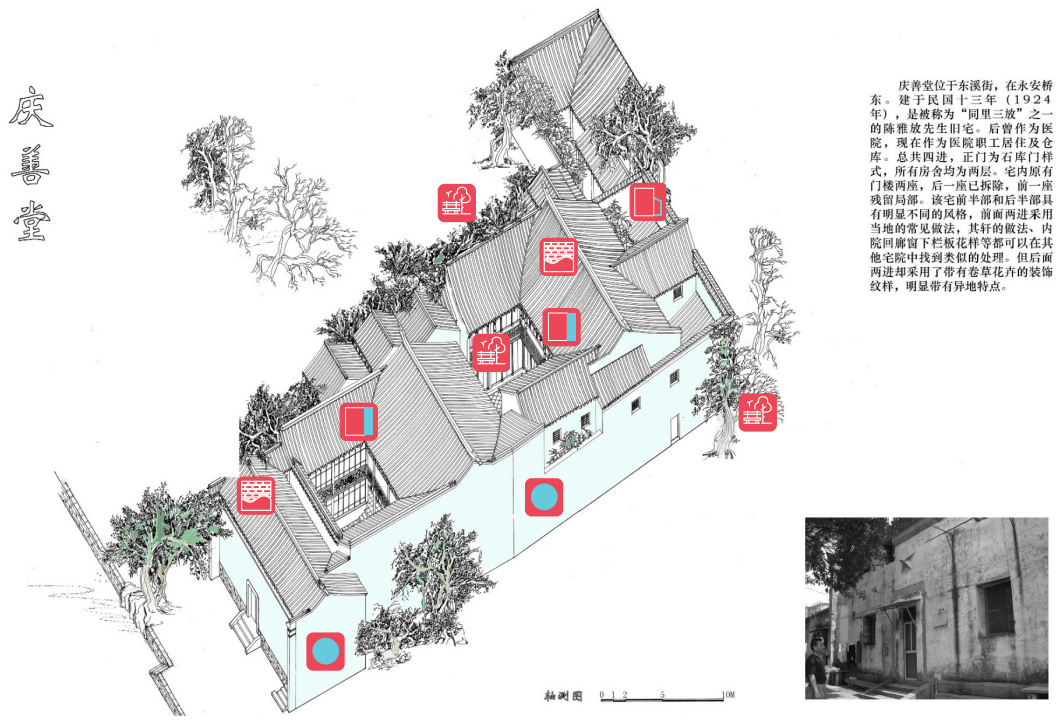


Masterplan:



Figure 283.

Figure 284.



4.4| Results and discussion:

Figure 285. Heat island in the three different pilot cases. The green line represents the outdoor temperature in the cities, while the blue line represents the temperature measured by the weather station.

Figure 285.

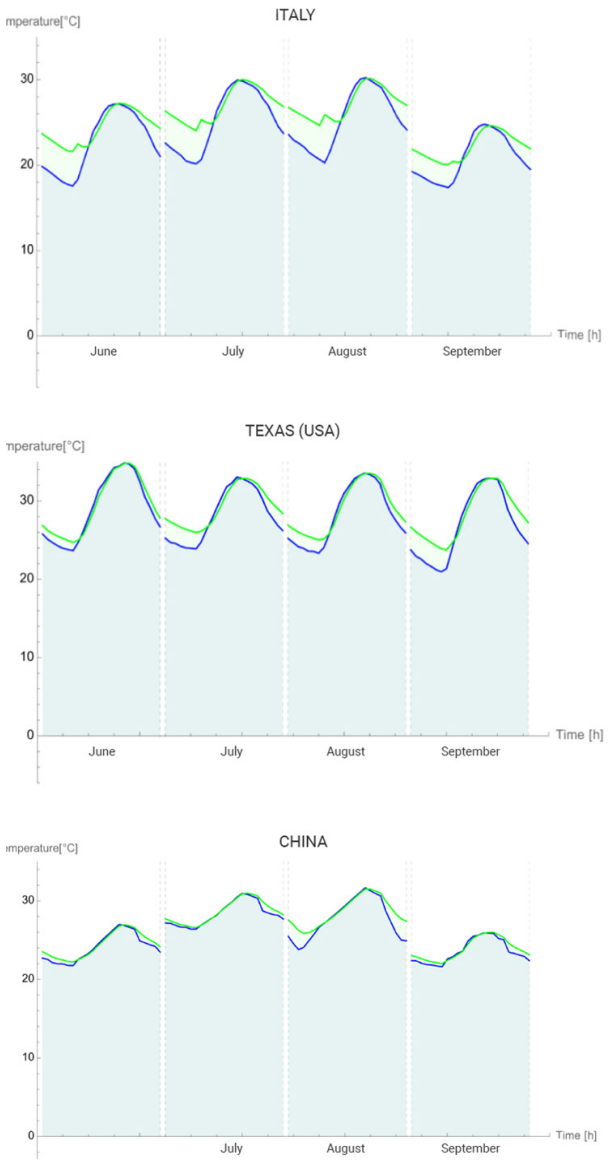


Figure 285 illustrates the impact of density, urban morphology, and enclosure type on defining the urban microclimate. The artificialisation of the soil and the presence of materials and surfaces that inhibit heat loss through thermal radiation promote more significant heat accumulation and increased temperatures in urban areas. Considering that heat islands occur when the temperature of the urban surface and atmosphere is at least three degrees higher than that of a rural area (L.-W. Lai & Cheng, 2009), it is interesting to note that, in the Italian case, the heat island phenomenon turns out to be more relevant than in the other two case studies (with a gap of 5 °C in Italy, 1.5 °C in Texas and 3 °C in China): this is due to several constructional and morphological factors, which favour the increase in temperatures, including the width of roads, which in some places reaches up to 40 meters, with the consequent presence of dark-coloured asphalt surfaces (reflectance equal to 0.1).
On this basis, comparing the pilot cases, it is interesting to analyse the starting conditions of the three districts. The common strengths that emerge in all three cases underscore the historical and cultural significance of the sites. In particular, the Shuangta neighbourhood features historic buildings and important cultural sites such as the twin pagodas and the Shuangta Market. The Westside features the 19th-century shotgun houses, and the shape of Quarticciolo takes its cue from the village/small town model designed by Roberto Nicolini. In addition, all three neighbourhoods feature a wide variety of native plant species. Thus, all three neighbourhoods have comparable historical and environmental bases. It is interesting to note the differing treatment of the riverbanks in the Far East and Westside: while in Shuangta, the banks are lined with vegetation, featuring enhanced embankments and attention to the aesthetic effect of the landscape, the Westside has embankments in a state of disrepair. This heightened sensitivity is due to various reasons, including cultural motivations, the area's proximity to important tourist sites, and previous redevelopment efforts. The Chinese state in Suzhou regularly maintains and monitors these areas, ensuring the condition of the plant species.
In contrast, the Westside does not reside near tourist points of interest; this is also why it receives little attention. Analysing the weaknesses affecting the Suzhou district reveals a lack of primary services within the historic dwellings that have undergone superfetation, as multiple families now reside in dwellings previously arranged for only one household. This area, which is served by va-

rious tertiary activities and well-connected to the subway, suffers from a cut-off with the adjacent, more touristy area of Pin Jian Lou due to a high-speed road that divides the district into two separate compartments, distinct in function and type of visitors. Similarly, the railroad's presence in the Westside divides the neighbourhood from downtown San Antonio. Finally, it appears that in both the Westside and Quarticciolo, the significant points of weakness reside in the degraded condition of the public green space, which in both cases has inferior maintenance, the absence of equipped areas that make the areas poorly usable, and which is instead present in Suzhou. The opportunities for all three neighbourhoods include the better use of abandoned buildings and areas: both Shuangta, the Westside, and Quarticciolo have disused premises or entire buildings that could represent an important redevelopment opportunity for all three areas. The street network in Shuangta and the Westside creates a caesura in the built-up area, dividing it into two distinct neighbourhoods from the rest of the city. This caesura causes a significant shift in scenery in both cases, from a central and highly visited area to a deprived one. Considering the common opportunities across all three areas, increased green infrastructure would enhance liveability levels and have a favourable impact on islands and heatwaves. However, while Suzhou pays considerable attention to surface treatment, this is not the case in the other two areas with highly impermeable surfaces. The Chinese city's attention to surface treatment also derives from climatic causes. Hefty and persistent rainfall affects this part of China during the monsoon period (June to August).

In contrast, Rome and San Antonio do not experience rainfall phenomena that occur regularly throughout the year, and the amount of rain expected is less than in Suzhou. However, weighty rainfall events have been recorded in both cities, causing flooding and damage. Increasing permeable surfaces would enhance drainage, thereby decreasing soil dryness and the risk of flooding. For all three pilot cases, the primary threats lie in rising temperatures, which could increase the risk of droughts, floods, fires, or worsen air quality. In general, there is a decrease in well-being and an increased risk of heat-related illnesses that would affect the weaker sections of the population. Finally, a possible depopulation of the areas considered, with a consequent increase in physical and social degradation, is a threat that affects all three areas.

A comparison of the use of different technologies reveals that gre-

en infrastructure, including tree rows, parks, and pocket gardens, significantly impacts temperature, ventilation, and relative humidity. In Westside and Quarticciolo, significant increases of around 6% relative humidity are due to evapotranspiration. In Suzhou, humidity variations are minor. However, the latter district has a much higher building density than the other two. In addition, the Suzhou district already focuses on green infrastructure, as evidenced by creating a park within the area, embankment treatment, and tree rows. So, in the project, the green infrastructure is only increased. The cool materials are highly effective considering all the KPIs for the Westside neighbourhood, which has fewer shaded areas than others and consists mainly of asphalt or poorly draining surfaces. In the Quarticciolo area, using cool surfaces is also very effective, although it is not a solution that directly affects ventilation. On the contrary, cool materials are less effective in the Suzhou area. This effect is due to the morphological conformation, which presents a very compact building and the typically dark colour of the roofs. As these are traditionally protected buildings, they cannot be changed. Interestingly, combining several solutions has significant advantages in Suzhou, resulting in decreases in outdoor temperature of approximately 1.1 °C and indoor temperature of 4.20 °C.
In contrast, there are no significant improvements over the use of systems of technologies in the other two districts: in Italy, for example, the average indoor radiant temperature with the use of cool materials undergoes more significant temperature changes than with the use of an integrated package of solutions - 1.03 °C and 0.73 °C respectively. This result depends on various external factors, the own characteristics and the morphology of the area in which one operates, which does not always correspond to an increase in actions a greater effectiveness about the difference between the pre and post-intervention regarding air and surface temperature, comfort and ventilation indoors and outdoors: technologies, geometry materials, climatic conditions, influence each other preventing a linear increase in effectiveness. The KPIS are distinct parameters, and having high variations for all the parameters is challenging. Furthermore, the different technologies work in different ways and at different times: for example, passive radiative cooling techniques conventionally reveal their potential to dissipate terrestrial heat during the night; however, during the day, materials absorb much more energy than they can emit through the atmospheric window (Lim, 2020; Morales-Inzunza et

al., 2023).
Cool materials exhibit a medium to high effectiveness in regulating temperature, as observed in simulations between 1.1 °C and 6.5 °C. These data confirm the (European Environment Agency., 2020b). According to the aforementioned document, shading has low effectiveness in temperature and outdoor comfort, as confirmed by the simulations. Green infrastructure demonstrates the highest levels of effectiveness, as evidenced by the simulations of pilot cases, where the air temperature, for example, varies between 0.7 °C and 6.50 °C[39]. The literature confirms this. In particular, vegetated covers, as seen in various case studies (see Section 2.3), enhance efficiency when combined with green areas and trees. In simulations and literature, parks and trees significantly contribute to decreased outdoor temperature and improved comfort conditions. The presence of green walls, which, according to the literature, presents average effectiveness, shows low levels of effectiveness in the simulations compared to the other solutions analysed. Interestingly, the model of the green walls is the same as that of the ventilated façades, except for the finishing layer, which is composed of vegetation for the green walls; the programme does not foresee the use of this technology. The software does not perform fluid-dynamic calculations. Therefore, the ventilation behaviour following the installation of the different technological solutions is evaluated based on the state of the art, which, considering a certain tolerance, is compatible with the results obtained from the simulations.
Comparing the results of the simulations in the three different areas, it emerges that the difference in outdoor air temperature before and after the various interventions yields very similar or equal results, as the technologies used (or systems of technologies) vary in the Shuangta and Quarticciolo districts, ranging between 0.60 °C and 1.20 °C. On the contrary, in the Westside, the outdoor temperature difference presents much higher values than in the Chinese and Italian neighbourhoods, with 6.50 °C for all simulated solutions. This result is unsurprising, as the Westside is characterised by low-density construction, with low, one-storey, wooden buildings and surfaces consisting mainly of concrete or topsoil. The simulations indicate that the change in indoor air temperature before and after the intervention is less than 1 °C in both Italian and Chinese areas when simulating cool and urban greening solutions separately and in combination. Values greater than one de-

39. (European Environment Agency., 2020b; Malcevschi & Bisogni, 2016; Tucci, 2018)

gree Celsius are recorded in the American neighbourhood with the simulation of cool materials and increased urban greening. These results depend heavily on the composition of the wall envelope, which, depending on the transmittance values, is affected differently by external conditions. Precisely due to the composition of the external envelope, it is not surprising that low indoor temperature variations are achieved, both through the combined simulation of increased urban greenery and cool materials and through the integrated development of various technological solutions, ultimately resulting in the definition of the master plan. Similarly, it is not surprising that the indoor temperature in the Westside decreases significantly - 7.70 °C - a symptom that the building envelopes, consisting of wooden frames, thick insulation and the often wooden or sheet metal finishing layer, are strongly influenced by external conditions. The lowest indoor temperature variation is observed in Shuangta, where the increase in green infrastructure results in the highest variation value of 0.34. This result is not surprising, as urban greenery primarily influences the outdoors.
Additionally, the Chinese district, characterised by a higher building density than the other two districts, allows for a minor increase in greenery compared to the other pilot cases. The temperature of the indoor surfaces in the Westside case shows more significant variations than in the other two areas, whose variations range between 0.21 °C and 1.03 °C (Quarticciolo, cool materials). The only variation is represented by a difference of 6.22 °C in Shuangta, resulting from the combination of various technologies that led to the final master plan. The outdoor relative humidity values increase by 5% to 6% due to the expansion of green infrastructure and the use of cool materials in the American area. In the Italian area, the relative humidity increases are lower, ranging from 2% (through the increase of green infrastructure) to 5% (through the increase of green spaces and the use of cool surfaces). In contrast, they increased by 4% and 3% in the Chinese area. In the indoor environment, the relative humidity increases significantly on the Westside due to the increased urban greenery and cool materials. This behaviour is caused by the large availability of space, which has led to an intensification of green infrastructure and a low density of housing, allowing the use of cool and/or draining materials and thereby increasing humidity. In China and Italy, the values are lower, ranging between 0.62% and 6.08%.
In conclusion, it emerges that in the evaluation of efficiency, va-

Tab XI a, b. The graphs represent the differences between the pre and post indoor and outdoor KPIs in the analysed pilot cases. Author's elaboration

rious aspects of the territory play a fundamental role: first of all, the morphological aspect: suffice it to see how the use of the same technology - for example, cool materials - in one case causes the outside air temperature to vary by 6.50 °C in the Westside, by 1.10 °C in Shuangta and by 1.20 °C in Quarticciolo. Similarly, green infrastructure allows for a decrease of 6.50 °C in the Westside, 0.70 °C in Shuangta, and 0.6 °C in Quarticciolo. The ample space available in American cities and the low, wooden, single-family buildings allow for a more homogeneous increase in greenery and, consequently, a more significant decrease in temperature than in the other two cases, where there is a denser, taller built-up area.

Tab. XI a.

	T_{out}			T_{in}			$UTCI_{out}$		
	CH	**IT**	**US**	**CH**	**IT**	**US**	**CH**	**IT**	**US**
Cool	1.10	1.20	6.50	0.56	0.91	1.55	1.04	1.13	1.50
Green	0.70	0.60	6.50	0.34	0.62	1.53	0.65	0.56	1.56
Cool + Green	1.10	1.20	6.50	0.56	0.75	7.70	1.04	1.13	1.50
Masterplan	1.10	1.20	6.50	4.20	0.82	5.11	1.04	1.13	1.54

Tab. XI b.

	mrt_{in}			$UR\%_{out}$			$UR\%_{in}$		
	CH	**IT**	**US**	**CH**	**IT**	**US**	**CH**	**IT**	**US**
Cool	0.36	1.03	1.43	4	5	6	1.53	2.76	61.65
Green	0.21	0.83	1.39	3	2	6	0.62	2.05	61.43
Cool + Green	0.36	0.39	6.30	4	5	5	1.56	2.01	70.53
Masterplan	6.22	0.73	4.69	4	5	6	6.08	2.17	58.99

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PART 5

Results, Conclusions and Discussion

CHAPTER 5

5.1| RESULTS, CONCLUSIONS AND DISCUSSION

5.1| Results, Conclusions and Discussion

5.1.1| Results.

In the light of ever-accelerating climate change, heat islands and heat waves are highlighted as two of the most dangerous phenomena that can lead to disruption at both urban and natural levels. According to the literature analysis, heat islands can be mitigated by configuring the urban fabric and using specific strategies and technological solutions. At the same time, the morphology of the urban fabric and specific strategies can decrease the incidence of heat waves to a much lesser extent on a monthly scale.
The ways of action to mitigate and adapt to the existing extreme phenomena due to temperature increase are ascribable to bioclimatic architecture and energy efficiency: topics in symbiotic coexistence and not divisible. A bioclimatic design can lead to a decrease in energy consumption. Also, from an economic point of view, research in renewable energy and new bioclimatic strategies involves initial but short-term costs, future growth and gains. This research is structured through a multidisciplinary approach, taking as a keyword '*resource*' in its broadest meaning (i.e. any limited asset that is a source of wealth), each of the elements constituting a system: in this sense, buildings infrastructures, neighbourhoods in a state of degradation or abandonment which are highly energy-consuming but which potentially, if combined with specific strategic actions, can contribute to mitigating and adapting to extreme phenomena caused by rising temperatures, can be considered resources.
As seen in paragraph 1.1.5, the Ladybug software, particularly the UWG generator, is identified as a tool for evaluating the effectiveness of different actions on the existing fabric indoors and outdoors. The convenience of using this type of modelling lies in the possibility of parameterisation, the speed of calculation, the possibility of indoor and outdoor analysis, an accurate characterisation of the model, high interoperability with other simulation tools and the possibility of free use as a plug-in within Grasshopper.

This tool is important because it allows quick, precise evaluations despite the model's limitations.
This thesis proposes a system for analysing these phenomena and identifies the dangers in associated built-up areas — Section 2.1. In particular, the greatest dangers that can occur suddenly lie in the collapse of buildings and damage to physical and material infrastructure, such as transmission and distribution lines, transformers, and substations. Due to rising temperatures, sudden dangers include buildings and infrastructure that could become unfit to perform their functions.
The analysis of the phenomena shows that the KPIs that have the most significant impact are air temperature, wind speed, average radiant temperature and relative humidity - section 2.3.2. The hazards that are influenced by a smaller number of KPIs are not less dangerous than those influenced by all. On the contrary, it is true that on the former, it is necessary to focus on just a few factors, while on the latter, it is necessary to consider the whole range of KPIs and choose actions that integrate all the indicators involved. In addition to these indicators, there is also the UTCI for the evaluation of comfort, which is not the subject of this research but which is nevertheless interesting to evaluate to understand how humans are affected by rising temperatures and how some of the dangers on the city are related to the human perception of heat.
From the analysis of case studies, literature and possible actions for mitigation and adaptation to urban heat islands and heat waves, it is found that the installation of cool materials, green infrastructures, roofs and green walls, are the most effective and efficient as they have instantaneous response times, and influence most of the KPIs both indoors and outdoors. In particular, the presence of trees and green corridors proves to be the most effective action as it influences the air temperature, the surface temperature, the humidity, and the wind speed with instantaneous response times. The matrix developed in the paragraph. 2.3.2 can be used in research or as a decision support framework for professionals and public administrations.
Using the UWG generator, it is possible to develop analysis sheets on the effectiveness of specific actions within existing fabrics. The proposed tool, at the outdoor level, with the same climatic conditions, when the morphology varies, the effectiveness of the technologies varies while maintaining the same order of magnitude. In contrast, at the indoor level, there are significant variations. The

tool can provide quick decision support for professionals, public administration, and researchers. Finally, in part 4, the framework is further used and tested on pilot cases, which, despite having different construction techniques from each other, have similarities in terms of climate and, to some extent, also of context: historical and architectural cultural importance, general degradation and physical and social discomfort.
From the analysis of the pilot cases, the results differ from the elaborations in section 3.1. In this case, both at the outdoor and indoor levels, morphology plays a fundamental role in evaluating the effectiveness of strategies and actions: the simulations show significant variations of several degrees at both the outdoor and indoor levels. Variations also appear when using the exact technological solutions or combinations in different case studies. These variations suggest that even small climatic changes in areas that belong to the same climatic zone, but have their peculiarities, cause effectiveness to vary significantly.
The proposed combination of technologies allows temperature decreases of up to six degrees. These results are part of a context that requires integrated action on multiple fronts to act at different scales on climate change. Politics is the pillar of change: initiatives such as *Next Generation EU*, the *Green Economy* and the *Green Deal* are the foundations on which strategies and actions must grow. Consolidated relations between the territories, scientific knowledge, and the participation of citizens, who must approve the adoption of specific strategies as their own, are indispensable tools for change. This research proposes a method in this sense, identifying actions contributing to mitigation and adaptation and a framework for evaluating combinations of qualitative, quantitative strategies and actions on the existing fabric.

5.1.2. Conclusion and discussion

The tools to evaluate effectiveness can be various - see section 1.1.5 - and Ladybug tools are the most appropriate for evaluating the identified KPIs, as it has short response times, evaluate the most significant number of indicators indoors and outdoors, and are freeware. Notwithstanding this, considering the uniqueness of each case, it is important to analyse territorial, climatic, morphological, historical, environmental and cultural aspects as the base of

the design work. The approach to bioclimatic design must always be accepted and shared by the community living in the area. Otherwise, even the most effective combination of strategies may lead to undesirable effects because the users do not recognise it.
The analysis of the case studies shows that the choice of strategies and actions is highly dependent on compatibility with the place's materials, structures, morphology, availability, and cultural characteristics. In this sense, high-performance actions that may affect the place's aesthetic and constructive character on various levels are used less or considered less.
The analysis of technology response shows that to achieve significant levels of mitigation and adaptation, active and passive systems must act together: the former can work alongside the latter but not completely replace them, as it acts simultaneously on all the significant factors that cause islands and heat waves. Ultimately, passive technological systems have much higher levels of effectiveness than active technological systems, as, on average, they have an integrated impact on more KPIs than active ones without energy consumption. On the other hand, passive technologies alone, despite bringing environmental improvements on various factors, often fail to achieve acceptable comfort levels. Active technology systems that compensate for this gap can achieve these comfort levels. Interventions for deep retrofitting buildings are essential in achieving climate targets.
Using the UWG Generator on typical geometries with the same technology and climate resulted in variations of the same order of magnitude outdoors and greater variations indoors.
From the simulations carried out with cool materials, greening, green roofs and walls, it is possible to state in general terms that in an Italian climate, as the morphology varies, green infrastructures are the most effective outdoors in terms of both the air temperature parameter and Universal Thermal Comfort, while indoors the effectiveness of the various actions varies as the shape varies (see chapter 3.1).
The UWG generator, when applied to the pilot cases, resulted in variations of different orders of magnitude outdoors and indoors. These differences suggest that even minor climatic variations significantly impact the effectiveness of technologies and their combinations, although the areas considered belong to the same climate zone. In particular, the mix of actions that proved to be most effective on the Westside consisted of the presence of gre-

en infrastructure, permeable surfaces, agro photovoltaics, shaded spots, use of cool materials, installation of thermal break windows, bioswales and water squares, and bioclimatic atriums. The mix of actions that turns out to be most effective in Quarticciolo, Rome turns out to be the presence of points in the shade, permeable surfaces, green infrastructure, bioswales and water squares, agro photovoltaic roofing, the installation of external insulation and thermal break systems, green walls and roofs, shading systems on buildings of ventilation chimneys. Finally, the mix of actions found to be most effective in Shuangta is the presence of shading systems, green infrastructure, permeable surfaces, bioswales and water squares, agro photovoltaic roofing, cool materials, external insulation systems, thermal break window frames, screened greenhouse spaces, and bioclimatic atriums.

The simulations conducted on the three pilot cases show a close correlation between urban density, materials used in construction and air temperature, surface temperature, humidity, wind speed and human comfort. In this context, the complex links between climate, urban form and the indicators considered are analysed by studying morphological and construction models in the different pilot cases. Microclimatic conditions are simulated by developing a model for the different cases, envelope types and characteristics of the existing built environment. The assessment tool shows that, as the morphology varies, the outdoor effectiveness is similar. At the same time, the variations are much greater indoors and of several orders of magnitude. Climatic specificities may lead to such significant variations. When the location varies, the results of outdoor simulations using the same actions also respond very differently. A case-by-case assessment is necessary, considering specific climatic data, materials and morphology: climatic specificities cause macro variations in the behaviour of technologies outdoors, materials mainly affect indoor behaviour, and morphology affects both indoor and outdoor behaviour, although with variations of the same order of magnitude.

The results of this research are in line with the literature. For example, the effectiveness of the actions highlighted in the RESIN research corresponds to the results obtained in the present research despite the different evaluation tools used. However, the report evaluates the effectiveness of newly constructed case studies, which sometimes lead to different results. Despite the broad methodological similarities, Cooling Singapore makes a broad classi-

fication of usable tools and actions, specifically focused on the city under consideration and in a slightly different climate.

The specificity of this research makes it possible to understand how technologies and design strategies influence the phenomena of heat islands and heat waves in a warm temperate climate and existing and established contexts, giving preference to short return times. This specificity makes it possible to outline an innovative methodology that links the various problems brought about by the phenomena studied to solutions through the association of physical evaluation parameters.
Today, the building sector is one of the key players in an energy and socio-economic transition aimed at mitigating the rise in temperatures and reducing emissions expressed in the transition from "design of things" to "design of cities". Achieving these objectives implies an in-depth knowledge of the relationships and interrelationships between people, buildings and the environment to develop regeneration interventions.
In the end, as in the past, the key to an architecture that avoids incurring climatic changes that are disastrous for man himself and the environment is always the observation of climatic and natural characteristics by incentivising or disincentivising specific physical behaviours that anthropic structures can cause on urban and natural fabrics. In the end, even if by different means, like the Indians of Mesa Verde, we continue to work on the thermal inertia of structures, we continue to channel the wind and work on shading as the Arabs did many years ago, building complex carvings in the wood that, in addition to a not inconsiderable aesthetic value, increased the ventilation inside the rooms and protected from the sun. Studying the climatic phenomena to be mitigated allows us to understand how to transform the interactions between artificial and natural into tools supporting sustainable development, conserving energy resources and preserving natural and artificial environments.
The careful study of the morphology of the territory, even if in a state of decay, makes it possible to transform the various elements that make up the urban, natural and climatic fabric into *resources*. In this way, it is possible to convert the built environment from a "wound" in the ecosystem into a system of symbiotic coexistence, with positive implications regarding safeguarding natural systems, increasing comfort levels, decreasing emissions, and incre-

asing economic viability.
Apart from the results obtained specifically for this project, the results for the more general field of study consist of the definition of a methodological approach through which many other issues can be addressed. The innovative approach consists of the decomposition of the factors that make up the problem, of KPIs, the search for solutions that influence them, and the evaluation of the best solution through the definition of simplified models and verification. The study of effectiveness alongside response times represents an element of innovativeness, providing the research landscape with another tool for achieving the goals set by the UN. Cutting research only to warm temperate climates and existing contexts makes it possible to reduce the assessment of the effectiveness of actions to a few targeted KPIs, resulting in an innovative methodology for selecting strategies and actions according to the instances it has to address.

Limitations and future developments.

Based on the definition of R=HxVxE - see ch.1.0.4, this research simplifies the various factors to make KPIs quantifiable and assessable. This approach in the subject area of Architectural Technology is very suitable, especially in comparison to natural phenomena that are difficult to describe otherwise and could also be used to study the adaptation and mitigation of other phenomena related to climate change. Furthermore, in this way, the development of systems that act on various factors related to climate change in an integrated manner is of primary importance since the efficiency level of the entire system changes as the actions are taken to change.
From the point of view of conducting the research, the most important difficulties encountered consist in managing very different instances in the search for characteristics to find standard assessable parameters. Once found, another difficult factor is understanding how to manage them, as they present different units of measurement, act at different scales, affect climate phenomena differently and have different effects on the natural and human environment. The actions also affect the parameters considered in different ways simultaneously. This difference means that the results obtained are qualitative-quantitative and not quantitative. Another difficulty encountered is the differentiation and reordering of the data, KPIs and information obtained from the literature

review. Their checking, sorting, and reordering took much time.
From an instrumental point of view, acting on the existing is impossible to carry out unambiguous standardisation due to the uniqueness of each project and the effectiveness of the identified actions. The model simplifies reality and overlooks some of the interconnections. In particular, the model used to evaluate effectiveness does not make fluid-dynamic calculations and thus does not consider wind behaviour within the different urban geometries. The model does not account for cross-ventilation, natural ventilation through blue/green corridors, or ventilation chimneys. On the other hand, such a calculation, if considered, would be very long. Another limitation is the difficulty of simulating some of the actions involving water through the Ladybug software[40]. The evapotranspiration parameters entered into the model are fixed, whereas, in reality, these vary depending on the season and the plant species.
Including actions such as blue infrastructure, ventilation chimneys, and natural ventilation through blue-green corridors would result in a more comprehensive quantitative evaluation. Including plugins such as Butterfly would increase the accuracy of simulations by assessing wind behaviour inside buildings and settlements. In addition, a greater characterisation of greenery, particularly of plant species' absorption and evapotranspiration levels, would lead to increased accuracy in evaluating microclimates. Managing a model that can operate at different scales presents another challenge: initially, the simulation was divided into outdoor and indoor models. However, the same input data was necessary for the two models, and the possibility of accidental errors was higher. Subsequently, merging the two models and having a single algorithm was possible, which was more expeditious and easier to control.
This research clearly shows that studying natural phenomena, behaviours, physical interactions with the environment and the anthropic system is essential for gaining a deep understanding of how to tackle related, but not identical, issues such as climate change. In particular, it could be extremely interesting to explore not only the effect of a single action but also the combined effects for mitigating and adapting to the studied phenomena: whether certain combinations of technologies lead to better performance or whether they compromise each other, resulting in worse outcomes. In this sense, further developments of the thesis could lead to the definition of effectiveness assessment analysis for a given climate zone, not only for individual technological solutions but also for systems of solutions. It would also be helpful to conduct a

40. Water's behaviour is difficult to control in Grasshopper. Usually, if there is a need to model water, interpolations are made with other tools, such as ENVImet. This software provides a water and heat exchange simulation within the soil system. Three-dimensional heat transfer simulation as a function of soil material and water content. Advanced calculation of hydraulic water exchange in the soil, including root water uptake and plant water supply. (ENVI_MET, 2025)

verification and comparison through tests on the actual situation, using direct on-site measurements, despite the proven verification and calibration of the instrument used.
In the future, it would be interesting to use the same research methods to study phenomena other than those studied. It could be interesting to carry out simulations as morphology changes, even in climates other than the Italian one, such as the Chinese or American ones, to understand how minor climatic differences influence the effectiveness of technological solutions. Further research prospects may lie in the experimentation of new combinations, materials and innovative green, blue and grey technologies that, in an integrated manner, can bring greater results than other technologies or their combinations in terms of efficiency, effectiveness and cost for mitigation and adaptation to islands and heat waves. New combinations integrating common materials and technologies could find new uses combined with innovative ones. Research is not concerned with the economics of using specific solutions and combinations. A further step could involve an evaluation on an economic basis as well as effectiveness and efficiency.
The ecological transition represents one of our time's revolutions involving the building sector and all sectors, including the economy. As Rifkin says, '*The great economic turning points in history have a common denominator. They all require three elements, each interacting with the others to enable the system to function: a means of communication, an energy source and a transport mechanism... We are now in the midst of a third industrial revolution. The Internet of Communications is converging with the Internet of Renewable Energy, solar- and wind-powered electricity, and an Internet of Mobility, logistics consisting of autonomous electric and hydrogen-powered, green-powered vehicles, on top of an Internet of Things (ICD) platform that, embedded in commercial, residential and industrial buildings, will transform society and the economy of the 21st century*'.(Rifkin, 2019).

5| References:

Rifkin, J. (2019). Un Green New Deal globale: Il crollo della civiltà dei combustibili fossili entro il 2028 e l'audace piano economico per salvare la terra. Milano: Mondadori.

PART 6

Appendix

APPENDIX

A1| Hazard analysis on the existing residential stock

Table IV

N.	Link	Year	Title	Authors	Type
1	https://wmo.int/media/2019-concludes-decade-of-exceptional-global-heat-and-high-impact-weather	2019	2019 concludes a decade of exceptional global heat and high-impact weather	WMO	Paper on web
2	https://wmo.int/media/news/wmo-aerosols-bulletin-focuses-fires	2021	WMO Aerosols Bulletin focuses on fires	WMO	Paper on web
3	https://www.ipcc.ch/report/ar6/s+H23+B16:B23	2023	IPCC, 2023: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland.	IPCC	Report
4	https://wmo.int/media/2019-concludes-decade-of-exceptional-global-heat-and-high-impact-weather	2019	WMO Provisional Statement on the State of the Global Climate in 2019	WMO	Report
5	http://ehponline.org/static/pdf/hhcc_report.pdf	2010	A Human Health Perspective on Climate Change: A Report Outlining Research Needs on the Human Health Effects of Climate Change	The Interagency Working Group on Climate Change and Health	Report
6	https://www.ipcc.ch/report/ar6/wg2/downloads/faqs/IPCC_AR6_WGII_FAQ-Brochure.pdf	2022	Climate Change 2022: Impacts, Adaptation and Vulnerability	IPCC	Report

Table IV. The present table analyses the most important documents reviewed for this part of the research. For each document, there is a link, the title, the authors, the year of publication, the type of document, and a brief summary of the topic.

Topic
2019 ends the decade where the most climate change-driven extreme events occurred: peak climate-altering gas concentration, floods, droughts, cyclone fires
Many studies have verified increased fires with peaks in aerosol gas concentrations and pollution.
Short-term risks to the existing due to increased temperatures consist of increased mortality and decreased comfort levels, increased flooding and extreme rainfall, increased dryness of land and drought, increased frequency and strength of tropical cyclones, increased fire risk due to water scarcity, danger to coastal infrastructure, danger to buildings and infrastructure, the danger of abandonment of buildings and neighbourhoods, faster degradation of materials.
In addition to conflicts, insecurity and economic slowdowns and downturns, climate variability and extreme weather events are among the key drivers of the recent rise in global hunger and one of the leading causes of severe food crises.
With climate change, there has been an increase in asthma, respiratory allergies and airway diseases. Increased cancer phenomena, disorders concerning stress, decreased speed of development, increased malnutrition, increased neurological disorders
Increased temperature and heat waves cause degradation of structures and infrastructure, increased mortality, decreased welfare, possible collapse, drought, increased pollutants

N.	Link	Year	Title	Authors	Type
7	https://linkinghub.elsevier.com/retrieve/pii/	2017	The urban heat island effect, its causes, and mitigation, with reference to the thermal properties of asphalt concrete	Abbas Mohajerani, Jason Bakaric, Tristan Jeffrey-Bailey	Paper
8	https://data.europa.eu/doi/10.2800/534806	2017	Climate change, impacts and vulnerability in Europe 2016: an indicator based report.	EEA	Report
9		2004	Heat waves: risks and responses	WHO	Report
10	https://linkinghub.elsevier.com/retrieve/pii/S2212095517300263	2017	Current trends in urban heat island mitigation research: Observations based on a comprehensive research repository	Or Aleksandrowicz, Milena Vuckovic, Kristina Kiesel, Ardeshir Mahdavi	Paper
11	https://linkinghub.elsevier.com/retrieve/pii/S0921344911001303	2012	How to make a city climate-proof, addressing the urban heat island effect	Laura Kleerekoper, Marjolein van Esch, Tadeo Baldiri Salcedo	Paper
12	https://www.nature.com/articles/nature04188S0301479717303201s+H23+B16:B23	2005	Impact of regional climate change on human health	Jonathan A. Patz, Diarmid Campbell-Lendrum, Tracey Holloway & Jonathan A. Foley	Paper

Topic
Effect of UHI on the existing fabric: increased energy demand, smog and decreased air quality, increased thermal stress on public and residential buildings, impact on the urban ecosystem, increased disease, mortality, and general decrease in well-being
Increased temperature, heat islands and waves bring indoor thermal discomfort, decreased comfort levels, increased energy consumption for cooling, and increased probability of flooding
Heat waves increase the occurrence of issues concerning physiological and epidemiological aspects, increasing indoor temperatures
This paper indicates that an increase in UHI could impair people's thermal comfort at street level, exacerbate discomfort caused by overheating indoor spaces, and increase energy consumption from building cooling energy demand. The paper concentrates on four UHI mitigation measures: shade trees, cool building envelopes, ground vegetation, and green roofs. The research is conducted in warm, temperate climates.
Extreme temperatures can stress the thermoregulatory system, resulting in discomfort or even health hazards. Heat stress can cause illnesses such as heat syncope, which means the inability of the circulation to maintain blood pressure and supply oxygen to the brain, cardiovascular stress, heat exhaustion, or even heat stroke. Heat stroke can lead to respiratory distress syndrome, renal failure, liver failure, and disseminated intravascular coagulation (blood clots). These complications can, in turn, lead to death.
Many prevalent human diseases are related to climate fluctuations, from cardiovascular mortality and respiratory diseases caused by heat waves to altered transmission of infectious diseases and malnutrition caused by crop failure.

N.	Link	Year	Title	Authors	Type
13	https://linkinghub.elsevier.com/retrieve/pii/S0301479717303201S0301479717303201s+H23+B16:B23	2017	The urban heat island effect, its causes, and mitigation, with reference to the thermal properties of asphalt concret	Abbas Mohajerani, Jason Bakaric, Tristan Jeffrey-Bailey	Paper
14	https://linkinghub.elsevier.com/retrieve/pii/S2210670715000657	2015	Urban Heat Island (UHI) mitigating strategies: A case-based comparative analysis	Christopher O'Malley, Poorang Piroozfar, Eric R.P. Farr, Francesco Pomponi	Paper
15		2018	Visual Analytics of Spatio-Temporal Event Predictions: Investigating Causes for Urban Heat Islands	Miller, Matthias	Master thesis
16		2008	Climate Change and Extreme Heat Events	George Luber and Michael McGeehin	Paper
17	http://ehponline.org/static/pdf/hhcc_report.pdf	2010	A Human Health Perspective on Climate Change: A Report Outlining Research Needs on the Human Health Effects of Climate Change	The Interagency Working Group on Climate Change and Health	Report
18	https://journals.ametsoc.org/doi/10.1175/BAMS-89-1-75	2008	Analog European Heat Waves for U.S. Cities to Analyze Impacts on Heat-Related Mortality	LAURENCE S. KALKSTEIN, J. SCOTT GREENE, DAVID M. MILLS, ALAN D. PERRIN, JASON P. SAMENOW, AND JEAN-CLAUDE COHEN	Paper
19		2019	Piano Nazionale di Prevenzione degli effetti del caldo sulla salute	Centro Nazionale di prevenzione e controllo malattie	International plan
20	https://linkinghub.elsevier.com/retrieve/pii/S0048969723031182	2023	Evolution of the local climate in Montreal and Ottawa before, during and after a heatwave and the effects on urban heat islands	Chang Shu, Abhishek Gaur, Liangzhu Wang ("Leon"), Michael A. Lacasse	Paper

Topic
Effect of UHI on the existing fabric: increased energy demand, smog and decreased air quality, increased thermal stress on public and residential buildings, impact on the urban ecosystem, increased disease, mortality, and general decrease in well-being
Increased temperature and UHI can bring heat stress-induced damage to the thermoregulatory system in the form of heat syncope, cardiovascular stress, heat exhaustion, heat stroke, and cardiorespiratory diseases; on the other hand, the increased t produced by UHI can stimulate the formation of ground-level ozone
Part of the thesis focuses on the effects of UHI on existing. In particular, adverse effects on human health, increased mortality, degradation of air quality, increased energy consumption
With climate change, there has been an increase in asthma, respiratory allergies and airway diseases. Increased cancer phenomena, disorders concerning stress, decreased speed of development, increased malnutrition, increased neurological disorders
Demonstration of increased mortality concerning rising temperatures
Meteorological changes, are causing an increase in extreme phenomena, causing increased risks to human health and increased mortality
The heat wave that the Ontario-Quebec area experienced in 2018 resulted in significant morbidity and mortality. This study investigated how this heat wave affected Montreal and Ottawa's respective urban heat islands (UHIs).

N.	Link	Year	Title	Authors	Type
21	https://wmo.int/media/news/summer-of-extremes-floods-heat-and-fire	2021	Summer of extremes: floods, heat and fire	WMO	Site
22		2021	Impacts of 1.5°C of Global Warming on Natural and Human Systems	IPCC	Report
23	https://link.springer.com/10.1007/978-3-030-34196-1	2020	Quantifying Effects of Urban Heat Islands: State of the Art	Ragaa Abd El-Hakim and Sherif El-Badawy	Paper
24	https://linkinghub.elsevier.com/retrieve/pii/S037877881500033X	2015	Regulating the damaged thermostat of the cities—Status, impacts and mitigation challenges	Santamouris	Paper
25		2013	Field studies on human thermal comfort An overview	Asit Kumar Mishra, Maddali Ramgopal	Paper
26		2000	The effect of the Athens heat island on air conditioning load	S. Hassid et al.	Paper
27	http://link.springer.com/10.1007/s00484-012-0608-9	2014	Climate change and thermal comfort in Hong Kong	Chi Shing Calvin Cheung & Melissa Anne Hart	Paper
28	http://www.sciencepublishinggroup.com/journal/paperinfo.aspx?journalid=162&doi=10.11648/j.ijema.20150302.15	2015	Urban Heat Island: Causes, Effects and Mitigation Measures - A Review	Md. Nuruzzaman	Paper

Topic
Increased peaks caused by heat waves and climate-changing gas streams from Siberia
The report analyses the physical basis of climate change; in particular, it focuses on the risks posed by individual drivers
Heat islands cause increased daytime temperatures, reduced nighttime cooling, and increased levels of air pollution linked to the UHI, which affect human health by causing general malaise, breathing difficulties, heat cramps, and exhaustion.
The study classifies and summarises the energy, health, environmental and economic impacts of district heating.
Literature review on adaptive comfort and ways of influencing the environment
Study on the energy consumption of buildings
The UTCI index helps assess thermal comfort in Hong Kong in the past and future through the IPCC climate scenarios
The article reviews all measures to mitigate the heat island. Inside is an interesting graph analysing the processes set in motion by UHI, including the increase of pollutants in the atmosphere

N.	Link	Year	Title	Authors	Type
29		1995	Mitigation of urban heat islands: materials, utility programs, updates	Arthur H. Rosenfeld, Hashem Akbari, Sarah Bretz, Beth L. Fishman, Dan M. Kurn, David Sailor, Haider TahaDan M. Kurn, David Sailor, Haider Taha	Paper
30	https://linkinghub.elsevier.com/retrieve/pii/S037877881500033X	2015	Regulating the damaged thermostat of the cities—Status, impacts and mitigation challenges	Santamouris	Paper
31	https://linkinghub.elsevier.com/retrieve/pii/S0301479717303201	2017	The urban heat island effect, its causes, and mitigation, with reference to the thermal properties of asphalt concrete	Abbas Mohajerani, Jason Bakaric, Tristan Jeffrey-Bailey	Paper
32	https://linkinghub.elsevier.com/retrieve/pii/S1352231005010885	2006	Impact of urban heat island on regional atmospheric pollution	C. Sarrat, A. Lemonsu, V. Masso, D. Guedalia	Paper
33	https://linkinghub.elsevier.com/retrieve/pii/S2210670715000657	2015	Urban Heat Island (UHI) mitigating strategies: A case-based comparative analysis	Christopher O'Malley, Poorang Piroozfar, Eric R.P. Farr, Francesco Pomponi	Paper
34	https://journals.ametsoc.org/view/journals/clim/20/20/jcli4288.1.xml	2007	Soil Moisture – Atmosphere Interactions during the 2003 European Summer Heat Wave	Erich M. Fischer et al.	Paper
35	https://www.jstor.org/stable/pdf/45009459.pdf?refreqid=fastly-default%3A29e1fab2f112a89d153fbafabeb3204d&ab_	2009	Temperature Extremes and Health: Impacts of Climate Variability and Change in the United States	Marie S. O'Neill and Kristie L. Ebi	Paper

Topic
High temperatures in urban 'heat islands' increase cooling energy consumption and accelerate the formation of urban smog.
The study classifies and summarises the energy, health, environmental and economic impacts of district heating
Effect of UHI on the existing fabric: increased energy demand, smog and decreased air quality, increased thermal stress on public and residential buildings, impact on the urban ecosystem, increased disease, mortality and general decrease in well-being
This study shows that urban effects, both at night and during the day, have an important impact on regional primary and secondary pollutants, in particular ozone and nitrogen oxides (NOx)
Rising temperatures and UHI can lead to heat stress-induced damage to the thermoregulatory system in the form of heat syncope, cardiovascular stress, heat exhaustion, heat stroke and cardiorespiratory diseases; on the other hand, the increase in t produced by ohi can stimulate the formation of ground-level ozone
Heat islands cause soil dryness and worsen air quality
Rising temperatures and heat islands strongly affect human health and air quality

N.	Link	Year	Title	Authors	Type
36	https://pdf.sciencedirectassets.com/271833/1-s2.0-	2011	Urban and rural mortality rates during heat waves in Berlin and Brandenburg, Germany	Katharina M.A. Gabriel and Wilfried R. Endlicher	Paper
37	https://www.die-erde.org/index.php/die-erde/article/view/49/pdf_3	2014	Quantification of heat-stress related mortality hazard, vulnerability and risk in Berlin, Germany	Dieter Scherer et al.	Paper
38	https://pdf.sciencedirectassets.com/271089/1-s2.0-	2000	The effect of the Athens heat island on air conditioning load	S. Hassid et al.	Paper
39		2024	Air quality in Europe: 2020 report.	European Environment Agency.	Report
40	https://www.salute.gov.it/imgs/C_17_pubblicazioni_2867_allegato.pdf	2019	Piano Nazionale di Prevenzione degli effetti del caldo sulla salute	Centro Nazionale di prevenzione e controllo malattie	National plan
41	https://wmo.int/media/2019-concludes-decade-of-exceptional-global-heat-and-high-impact-weather	2019	2019 concludes a decade of exceptional global heat and high-impact weather	WMO	Report
42	https://www.sciencedirect.com/science/article/pii/	2009	Air quality influenced by urban heat island coupled with synoptic weather patterns	Li-Wei Lai, Wan-Li Cheng	Paper
43	https://iris.uniroma1.it/retrieve/1b4370e6-bdaf-4365-999e-cc5f799c74bd/D%27Olimpio_L%27adattamento_2022.PDF	2022	L'ADATTAMENTO CLIMATICO DEI CONTESTI URBANI: PRINCIPALI STRATEGIE DI MITIGAZIONE DELL'ISOLA DI CALORE URBANA	Domenico D'Olimpio	Paper

Topic
Heat island is closely linked to increased mortality and respiratory diseases.
Study on the energy consumption of buildings. Statistical analysis of the relationship between increased heat and increased mortality, risk and vulnerability for the city of Berlin
Study on the energy consumption of buildings.
96% of the European population is exposed to pollutants with high health risks.
Meteorological changes are causing an increase in extreme phenomena, which are posing increased risks to human health and increasing mortality.
2019 ends the decade with the most extreme events: peak concentration of climate-changing gases, floods, droughts, fires, and cyclones.
Through synoptic weather patterns, specific synoptic weather patterns worsen air quality and induce the UHI phenomenon.
The study of the factors that determine the microclimatic conditions, with particular reference to the thermal factor, in the urban environment, allows to control the quality of the urban microclimate in terms of mitigation of the environmental discomfort conditions, induced by the interaction of the environmental components of climatic level with the built assets. In order to make our cities more liveable and healthier, it is now essential to know the parameters and factors on which to intervene to control the urban microclimate and its characterizing phenomena, such as the urban heat island, as well as to define the strategies and methods of intervention capable of implementing effective microclimatic improvement and mitigation actions. From this perspective, the quality control of the urban microclimate becomes a new and possible strategy for the definition of sustainable urban environments.

N.	Link	Year	Title	Authors	Type
44		2013	LEED: reference guide for buildings operations and maintenance	LEED	Certification
45		2019	UNI/PdR13.1:2019 Environmental sustainability of construction works - Operational tools for sustainability assessment Residential buildings	UNI-ITACA	Regulation
46		2018	Costruire e abitare green; green buildings and dwellings	F. Tucci	Book
47		2024	Mitigazione del clima e comfort umano; uno strumento per la modellazione e dimulazione di supporto alle decisioni	R. Zarcone, F. Nava, F. Tucci	Paper
48		2024	Heat waves response strategies through technological approach for adaptation and mitigation in urban areas	F. Tucci, D. D'Olimpio, M. Giampaoletti, V. Cecafosso, F. Nava	Paper
49		2025	Carbon neutral urban districts: case studies, energy and bioclimate solutions	Lidia Maria Giannini, Kristina Mitrik, Federica Nava, Maria Michaela Pani	Paper
50		2023	Verso la neutralità climatica di architetture e città green; sperimentazioni e casi studio nel sud Europa e in area Mediterranea	Fabrizio Tucci, Marco Gianpaoletti, Federica Nava, Violetta Tulelli	Book

Topic
LEED developed a standard for existing buildings to increase the efficiency, bioclimatic behaviour and life
The document specifies the criteria on which the multi-criteria analysis system for assessing the environmental sustainability of residential buildings is based, with a view to their classification using performance scoring. The subject of the assessment is an individual building and its external appurtenance area.
The book reviews various factors that influence the 'green' and sustainable aspects of construction and design processes
This study proposes a methodological approach for numerical simulation of the interactions between climate phenomena, the built environment, and the individual, based on the assumption that thoroughly understanding these connections will enable the development of more effective intervention strategies for climate mitigation and human comfort.
The paper analyses the importance of a design that considers the issue of increasingly recurring and impactful heat waves under a climate change re-gime with predictably higher occurrence of extreme events. Cities show higher temperatures than surrounding areas and these prospects amplify negative effects on infrastructure, human health, the environment and the economy. Of extreme interest are the logics followed by the most virtuous cities that deal with the prob-lem and, in relation to their own context, try to defend themselves by organizing mitigation and adaptation strategies, able to tackle the situation and improving their resilience. The research analyses and reviews data and information on heat waves and implements a decision-making framework for bioclimatic retrofit. Technological strategies to mitigate heat waves are outlined, focusing on green, blue and grey solutions with the help of state-of-the-art instrumentation and ad-vanced technologies to increase the capacity to respond to excess heat also in perspective. Mitigation strategies consider the multifactorial aspects of the phe-nomenon and the scales of analysis and response with which the project must challenge itself.
Energy transition
Guidelines for achieving climate neutrality in cities

N.	Link	Year	Title	Authors	Type
51		2021	Verso la neutralità climatica delle Green city Approcci, indirizzi, strategie, azioni	F. Tucci, P. Altamura, V. Cecafosso, G. Turchetti, M. Gianpaoletti, F. Nava, M.M. Pani, G. Romano, V. TulelliC. Dalsasso, L. Giannini, I. Fabiani, G. Trifoglio, M. Vadalà	Report
52		2019	UNI/PdR13.0:2019 Environmental sustainability of construction works - Operational tools for sustainability assessment Residential buildings	UNI-ITACA	Regulation
53		2015	Effects of climate extremes on the terrestrial carbon cycle: concepts, processes and potential future impacts	Dorothea Frank, Markus Reichstein, Michael Bahn, Kirsten Thonicke, David Frank, Miguel D. Mahecha, Pete Smith, Marijn Velde, Sara Vicca, Flurin Babst, Christian Beer, Nina Buchmann, Josep G. Canadell, Philippe Ciais, Wolfgang Cramer, Andreas Ibrom, Franco Miglietta, Ben Poulter, Anja Rammig, Sonia I. Seneviratne, Ariane Walz, Martin Wattenbach, Miguel A. Zavala, Jakob Zscheischler	Paper
54		2024	Multidisciplinary parameters for characterizing the 3D urban morphology: An overview based on the relational perspective	Kaixin Li , Hui Zeng	Paper

Topic
Guidelines for achieving climate neutrality in cities and case studies
Criteria on which the multi-criteria analysis system for assessing the environmental sustainability of residential buildings is based
A review of the literature on carbon cycle relevant responses of ecosystems to extreme climatic events. Given that impacts of climate extremes are considered disturbances, the authors assume the respective general disturbance-induced mechanisms and processes to also operate in an extreme context.
Studies on the most important morphological indicators that characterise the city three-dimensionally, how they interact with each other, hierarchy and effects

N.	Link	Year	Title	Authors	Type
55		2025	Optimizing pedestrian thermal comfort in urban street canyons for summer and winter: Tree planting or low-albedo pavements?		Paper
56		2023	A systematic review on role of humidity as an indoor thermal comfort parameter in humid climates	D. Amaripadath, R. Rahif, M. Velickovic, S. Attia	Paper
57		2025	Urban and rural mortality rates during heat waves in Berlin and Brandenburg, Germany	Katharina M.A. Gabriel a,b, Wilfried R. Endlicher	Paper
58		2024	Analysis of Rivers' Hidden Cooling Potential on a River Front City- a Case Study on Vijayawada City, Andhra Pradesh, India	Haripavan Nekkanti, Nisha Radhakrishnan, Kannamma D	Paper
59		2024	Effects of Retrofit Strategies on Thermal Comfort and Energy Performance in Social Housing for Current and Future Weather Scenarios	Lucienne G. Basaly, Arman Hashemi, Heba Elsharkawy, Darryl Newport, Nancy Mahmoud Badawy	Paper
60			Evaluation of Air Quality and Thermal Comfort in University Dormitories in China	Yanpeng Wu, Xiaoyu Li, Sheng Zhao, Qianglong Wang, Shanxin Wang , Liyang Yu and Faming Wang	Paper
61		2015	THE PASSIVEHAUS DESIGNER'S MANUAL	Christina J. Hopfe, Robert S. McLeod	Manual

Topic
The study systematically investigated the effect of different albedo floors on thermal comfort in street canyons, using albedo measurements, experimental data, and simulations. The results show that a low albedo index positively influences comfort (PET)
This paper analyses how humidity was incorporated into spatial and personalized thermal comfort assessments and models. In addition, the paper studied different indoor thermal comfort indices in terms of index type and time temporality
Heatwaves and mortality rates
The importance of the presence of the river for cooling built environment
This study investigates the impacts of different retrofitting scenarios on overheating risk and energy performance in social housing for current and future climate conditions.
The CO2 concentration was used as an indoor air quality evaluation index to characterise the freshness of the air. Different window opening conditions in the dormitory were simulated, and corresponding improvement plans were proposed.
Passivehaus manual for an implementation of zero energy building.

N.	Link	Year	Title	Authors	Type
62		2023	Il retrofitting energetico e bioclimatico nella riqualificazione edilizia	Domenico d'Olimpio	Book
63		2024	Climate change and the built environment - a systematic review	Ibrahim Tajuddeen, Seyed Masoud Sajjadian	Paper
64		2013	Quantification of heat-stress related mortality hazard, vulnerability and risk in Berlin, Germany	Dieter Scherer, Ute Fehrenbach, Tobia Lakes, Steffen Lauf, Fred Meier and Christian Schuster	Paper
65		2024	A Systematic Review of Climate Change Implications on Building Energy Consumption: Impacts and Adaptation Measures in Hot Urban Desert Climates	Najeeba Abdulla Kutty, Dua Barakat, Abeer Othman Darsaleh and Young Ki Kim	Paper
66		2020	Linking green infrastructure to urban heat and human health risk mitigation in Oslo, Norway	Zander S. Venter, Norun Hjertager Krog, David N. Barton	Paper
67		2023	Evolution of the local climate in Montreal and Ottawa before, during and after a heatwave and the effects on urban heat islands	Chang Shu, Abhishek Gaur, Liangzhu Wang ("Leon"), Michael A. Lacasse	Paper
68		2021	Causes, Modeling and Mitigation of Urban Heat Island: A Review	H. M. Imran, Mahaad Issa Shammas, Ataur Rahman, Stephanie J. Jacobs, A. W. M. Ng, Shobha Muthukumaran	Paper
69		2023	Urban heat islands: a review of contributing factors, effects and data	Hajer Khaled Jabbar, Mustafa N Hamoodi and Amjed N Al-Hameedawi	Paper
70		2015	Impacts of heat waves and corresponding measures: a review	Jian Zuo a, Stephen Pullen, Jasmine Palmer, Helen Bennetts, Nicholas Chileshe, Tony Ma	Paper

Topic
Retrofitting content and technical solutions
A comprehensive state-of-the-art review of such studies within the last 10 years (2013–2023) to understand the effectiveness of active and passive solution impact, their tangible applications, and their empirical evidence.
The objective of this study is to test the applicability of a risk concept and associated event-based risk-analysis method for quantifying heat-stress related mortality
This study aims to systematically review the existing literature to document building energy performances in and the associated adaptation measures of the Middle East Gulf states, regarding the implications of climate change. It is accomplished by answering the following questions: 'How well do we understand the effects of climate change on building energy use in hot urban deserts?' and 'What are the most appropriate adaptation strategies to reduce energy use in hot urban deserts?'
This study investigates the impacts of different retrofitting scenarios on overheating risk and energy performance in social housing for current and future climate conditions.
The heatwave event to which the Ontario-Quebec area was subjected in 2018 resulted in significant morbidity and mortality. In this study, an investigation was conducted on how this heatwave affected the respective urban heat islands (UHIs) in Montreal and Ottawa.
The study summarizes the important features and limitations of different modelling techniques and mitigation measures of the UHI.
This paper explained a comprehensive review of the phenomenon of UHI from its first appearance with regard to causing factors, its influences on people's lives and the urban environments, and widely used data for measuring and evaluating the intensity of UHIs. The finding of most studies mentioned that UHI values are different from city to city based on land-use changes.
This review provides useful inputs to policy-making and industry practice on improving the resilience of urban and regional areas to future extreme weather conditions such as heat waves.

N.	Link	Year	Title	Authors	Type
71		2020	Development of Future Heatwaves for Different Hazard Thresholds	Martha M. Vogel, Jakob Zscheischler, Erich M. Fischer, S. I. Seneviratne	Paper

Topic

The paper analyzes the largest spatiotemporal moderate heatwaves—three-dimensional (space-time) clusters of hot days—in simulations of global climate models. The paper uses three different hazard thresholds to define a hot day: fixed thresholds (time-invariant climatological thresholds), seasonally moving thresholds based on changes in the summer means, and fully moving thresholds (hot days defined relative to the future climatology). The paper finds a substantial increase of spatiotemporally contiguous moderate heatwaves with global warming using fixed thresholds, whereas changes for the other two hazard thresholds are much less pronounced.

A2| Analysis of documentation for the identification of short-term objectives and hazard KPIs

Table VI

N. Document	Key word	KPI
1	Greenhouse gases	T
	Floods	UR%
	Drought	UR%, T
	Wildfires	UR%, T
	Cyclones	Wind speed, UR%
2	Wildfires Greenhouse gases Pollution	T, UR%
3	Mortality	T, UR%, wind speed, mrt
	Comfort decreasing	T, UR%, wind speed, mrt
	Floods	
	Pollution	T, UR%
	Cyclones	
	Buildings abandonment	
	Neighborhood abandonment	
	Danger for infrastructures	
	Wildfires	T, UR%, wind speed
	Drought	
	Danger for buildings	
	Faster degradation of materials	
4	Air quality degradation	T, UR%, wind speed
	Urban heat island	T
	Floods	UR%
	Drought	
	Wildfires	
5	Air quality degradation	
	Mortality	T, UR%, wind speed, mrt
	Comfort	T, UR%, wind speed, mrt
6	Stress of structure	T, mrt
	Stress of infrastructure	T, mrt
	Comfort	T, UR%, wind speed, mrt
	Flooding	UR%
	Collapses	T, UR%, wind speed, mrt
	Drought	UR%
	Pollution	T, UR%, wind speed, mrt

Near term objective
Mitigation and adaptation actions to ensure a sustainable development, according with 2030 agenda
Use of adaptation and mitigation strategies
Promoting civic engagement adaptation actions Without frameworks for collaboration, and coupled with commercial and security sensitivities, this remains a barrier to routine sharing and cooperation between operators.
Nature-based solutions e.g., urban greenery at multiple spatial scales; vegetation; shading; lower energy costs; green roofs; community gardens; enhanced space conditioning in buildings; and der access to public health systems for most vulnerable populations. Less economic stress on residents through utilities, especially electricity. Tree planting in communities that lack urban greening.
Stormwater management, green infrastructure, sustainable urban drainage systems Early warning systems, Adaptive Social Protection (ASP) to reduce vulnerable populations, nature-based solutions e.g., in sponge cities to enhance flood protection and regulate storm- and floodwaters; this can be improved through reduced risk unto vulnerable urban systems such as stormwater management, sustainable urban drainage system, etc. Green infrastructure can be more flexible and cost effective for providing flood risk reduction.
Demand and supply side management strategies that include incorporation of indigenous/local knowledge and practices, equitable access to water. Better water resource management will increase quality of water available. More beneficial physical and social teleconnections to bring mutual benefit of water resources between regions.
Enhanced air quality monitoring in rapidly developing cities, investment in air pollution controls, e.g., stricter emissions. regulations, and increased GHG emissions controls resulting in co-benefits with air quality improvements. Increase trees or vegetated barriers with low VOC emissions, low allergen emissions, and high pollutant deposition potential to reduce particulate matter and maximise adaptation benefits.

N. Document	Key word	KPI
7	Increasing energy demand Pollution Comfort Increasing indoor temperature Mortality	
8	Comfort Mortality Increasing indoor temperature Increasing energy demand Rainfall	T, UR%, wind speed, mrt T, UR%, wind speed, mrt T, UR%, wind speed, mrt mrt UR%, T
9	Comfort Mortality Increasing indoor temperature	T, wind speed, UR%
10	Comfort Urban heat island Mortality	
11	Comfort Mortality Pollution Obstruction of the sky Evapotranspiration reduction Wind speed	T, wind speed, UR%
12	Comfort Mortality	T, UR%, wind speed
13	Increasing energy demand Pollution Thermic stress of buildings Thermic stress of infrastructures Comfort Mortality	T, mrt T, UR% T, UR%, mrt T, UR%, mrt T, UR%, mrt, wind speed T, UR%, mrt, wind speed
14	Comfort Mortality	T
15	Comfort Mortality Pollution Increasing energy demand	
16	Comfort, pollution, mortality	
17	Comfort Mortality Pollution	T, UR%, wind speed, mrt
18	Mortality	Temperature, dew point temperature, mean daily cover, mean daily sea level pressure
19	Comfort, mortality	
20	Mortality	Temperature, dew point temperature, mean daily cover, mean daily sea level pressure
21	Floods, Pollution	
22	Pollution, greenhouse gases, drought	

Near term objective
Reflective pavements, thermocromic materials, hernessing the heat, photovoltaics pavements, green roofs, phasechange mateials, recyclued water
Decrease anthropogenic emissions, land use, changes in tourism flows, developins systems for monitoring
1. minimize solar heating of the building during the hot season; 2. minimize the rate of indoor temperature elevation in summer during daytime; 3. maximize the rate of cooling of the indoor temperature in summer during the evening and ensure indoor comfort at night; 4. utilize natural energy for passive cooling in summer; 5. minimize the heat loss of the building in winter, and 6. utilize passive solar energy systems for heating in winter.
Cool buildings envelope, green roofs, green facades, shade trees, ground vegetation, water bodies, cool pavements, water retentive pavements, built environment typical section built environment orientation to prevailing winds, built environment orientation to the sun
Fountains, green infrastructure, cool materials, shade of cities, permeable materials
Sun shading, rooftop vegetation, solar and wind power, indoor ventilation, process and building heat recovery, light surfaces/high albedo, minimizing heat loss, energy efficiency, air corridors, easy public transport access, water surface, surface with water retention capacity, open green space, process and building heat recovery
Vegetation, presence of water, use of material with hight albedo rating

N. Document	Key word	KPI
23	Pollution, comfort, mortality	
24	Increasing energy and economic demand, comfort, mortality	
25	Comfort, mortality	
26	Comfort, energy demand	
27	Comfort	T, ur%, wind speed, mrt
28	Pollution, increasing of energy demand, comfort, mortality, increase od fuel building	mrt mrt Evapotranpiration, absorption of CO_2 mrt Cooling by infiltrated water Evapotraspiration, wind speed Wind speed Evapotransipiartion, run off
29	Increasing temperature and energy demand	T, mrt
30	Increasing energy demand Mortality Increasing economic demand Comfort	T, UR%, wind speed, mrt
31	Increasing energy demand, increasing indoor temperature, comfort, mortality, stress of buildings, stress of infrastructures, pollution	UR% Wind speed, mrt UR%, Wind speed, mrt mrt T, UR%, UTCI indoor mrt T, UR%, UTCI indoor mrt, T, UR% mrt mrt mrt, T, UR% UR%, mrt UR%, mrt UR%, mrt
32	Pollution	Wind speed
33	Comfort, pollution, mortality	T, ur%, wind speed, mrt
34	Pollution, drought	UR%, Wind speed
35	Comfort, pollution	T
36	Mortality, comfort	Thermal stress
37	Mortality, comfort	Thermal stress
38	Increasing energy demand	Hot season, T, mrt
39	pollution, comfort, extreme drought, vegetation reduction, eutrophication, acidification	
40	Comfort, mortality	
41	Pollution, floods, drought, wildfires, cyclones	T, pollens, UV radiations

Near term objective
High albedo roofing materials High albedo pavements Greening Shade trees Pervious pavements Water bodies Urban planning Green roofs Greening, hight albedo materials
Urban green spaces use green roofs, use of reflective roofs, cool pavements, increase the albedo of cities, use low-temperature natural sinks for heat dissipation, decrease anthropogenic heat
Water retaining pavements Urban canyon Greening Thermocromic materilas Photovoltaic pavements Phase-change materials Harnessing the heat with small thermoucoples Recycled water Cool pavements Reflective pavements Evaporative and water reflective pavements Porous pavers Permeable pavements Pervious pavements
Certification such as LEED, BREEAM, CASBEE, BEAM, inclusion of porous and water retentive materials, high albedo materials, presence of urban water bodies, harnessing natural wind
Keep the soil wet
Technologies, including urban design, energy policy, water use, and transportation plan
-shading of south- and west-facing windows and glazing with adjustable external blinds and/or shades - enhance natural ventilation by opening windows during the dayconsents the renewal of indoor air with cooler outdoor air - spend a few hours in air-conditioned rooms - mechanical fans only accelerate air movement but do not lower the room temperature. Thus, the perceived temperature decreases, and while providing relief, fans stimulate sweating and increase the risk of dehydration if the exposed person does not simultaneously take in large amounts of fluids

N. Document	Key word	KPI
42	Pollution	Wind speed
43	UHI	- increased absorption of solar radiation by the built environment; - decrease in dissipated thermal radiation - increase in thermal accumulation in the environment affected by the urban layout - decrease in soil evapotranspiration - decrease in convective heat loss present in the urban ambient due to the reduction of wind speed compared to non-urbanized areas
44	Heat island reduction, energy efficiency, bioclimatic behaviour	
45	Primary energy reduction Encouraging the production of energy from renewable sources Maintenance of a satisfactory level of thermal comfort Ensure ventilation to maintain a high degree of air healthiness	kW kW kW/m^2K - number of hours
46	- energy transition - bioclimate responsiveness	
47		
48	Climate mitigation, heat waves, climate adaptation	
49		

Near term objective
- Increased vegetation within urban areas (green areas, green infrastructure, green roofs, etc.); - Increase albedo relative to artificial surfaces (roads, vertical building surfaces and roofs).
Use the following strategies for at least 50% of the site paving. Use the existing plant material or install plants that provide shade over paving areas (including playgrounds) on the site within 10 years of planting. Plants must be in place at the time of certification application. · Install vegetated planters. Plants must be in place at the time of occupancy permit and cannot include artificial turf. · Provide shade with structures covered by energy generation systems, such as solar thermal collectors, photovoltaics, and wind turbines. · Provide shade with architectural devices or structures with a three-year aged solar reflectance (SR) value of at least 0.28. If three-year-old value information is unavailable, use materials with an initial SR of at least 0.33 at installation. · Provide shade with vegetated structures. · Use paving materials with a three-year aged solar reflectance (SR) value of at least 0.28. If three-year aged value information is not available, use materials with an initial SR of at least 0.33 at installation. · Use an open-grid pavement system (at least 50% unbound).
Use of natural native species
Percentage ratio between the periodic thermal transmittance value of the building walls to be assessed and the corresponding legal limit and number of hours the room is occupied, where the absolute difference between the operating temperature and the reference temperature is less than 4°C, is greater than 85% of the hours the room is occupied - No. of spare parts - Type of windows and doors - Presence of controlled ventilation system

N. Document	Key word	KPI
50	Drought, Stress of structures, stress of infrastructures, problems with finishing materials, increasing indoor temperature increasing mortality, rainfall, decreasing comfort conditions, energy transition losses and facilities, negative impact of renewerable energies, increasing costs for preventing measures, neighborhoods abandonement, buildings abandonements, increasing operation energy and costs, increasing recovery costs, increasing deterioration rate of systems and materials, increasing deterioration rate of infrastructures, buildings may became unsutable for use, infrastructures may became unsutable for use, decrease of air quality	
51	Stress of structures, stress of infrastrucutres, problems with finishing materials, Increasing indoor temperatures, increasing mortality, rainfall, decreasing of comfort conditions, energy transmission losses and facilities, negative impact for renewerable energies, increasing costs for preventing measures, neighborhood abandonement, buildings abandonements, increasing operational rate of systems and materilas, increasing deterioration rate of infrastructures, buildings may became unsutable for use, infrastructures may became unsutable for use, decrease of air quality	
53	Wildfires, drought	Climate change, impacts
54		Urban morphology

Near term objective

N. Document	Key word	KPI
55	Decreasing of comfort conditions, increasing mortality	Temperature, mrt, PET, albedo, tree cover
56	Indoor comfort	UR%
57	Increasing mortality	Thermal stress
58	Urban heat islands Increasing temperature Polluted air Global warming	mrt River cooling effect
59	Indoor rising temperature Natural ventilation	Comfort Air temperature, wind speed
60		Carbon dioxide concentration Ventilation
61	Mortality, comfort, stress of structure, indoor temeprature, buildings abandonement, energy transmission losses and facilities, decrease air quality	T, ur%, wind speed, mrt

Near term objective
Although low-albedo pavements increase air and surface temperatures and long-wave radiation, they enhance thermal comfort by reducing reflected shortwave radiation, lowering the Physiological Equivalent Temperature (PET) by up to 3.9 °C in summer. Tree planting was more effective, reducing PET by up to 27.9 °C. Under trees or building shade, albedo changes had minimal impact on thermal comfort.
1. The existing indoor comfort indices with humidity use a point-in-time approach where the measured parameter is evaluated at a single point in time or an instantaneous moment. There is a need to develop indices that can measure the thermal comfort parameters over a while and predict the underlying phenomena like overheating. 2. There is a need for the development of an indoor hygrothermal discomfort indicator, which assesses comfort in terms of both operative temperature and relative humidity. The IOD index considers the characteristics of this suggested indicator like time-integration and multizonal analysis. However, this index is based on operative temperature and ignores relative humidity. Another disadvantage of the existing IOD index is that there are no recommended threshold values for limiting short-term and long-term overheating. 3. The study findings indicated that thermal comfort is not influenced just by temperature. At very low humidity levels, the occupants could feel warm and still feel comfortable or slightly uncomfortable. However, at very higher humidity levels, they would feel very uncomfortable. This level of comfort or discomfort will influence their actions, such as turning on the fan or air conditioner, etc. Therefore, humidity should be considered while addressing thermal comfort and overheating issues.
The urban neighbourhoods near the river experience a reduction in temperature due to its cooling effect. The distance between the river and various urban form factors significantly determines their relationship with land surface temperature. The observed thermal dynamics along the river stretch underscore the complex interplay between hydrological features and surface temperatures within riverine environments.
Increase insulation, pay attention to construction materials
Use of a package of specific solutions for each building to reduce energy consumption, based on the principles of: • Thermal transmittance • Relationship between natural and artificial light and energy consumption • Hygrothermal insulation • Hot water energy management • Good ventilation • Use of renewable energy sources

N. Document	Key word	KPI
62	Stress of structures, problems with finishing materials, increasign indoor temperature, increasing mortality, decreasing comfort conditions, energy trasmission losses and facilities, negative impact of renewerable energy, increasing costs for preventing measures, increasing operational energy costs, increasing recovery costs, increasing deterioration rate os sytems and materials, buildings may became unsutable for use, decrease of air quality	
63		
64	Comfort Increasing mortality	Indoor thermal stress Summer air temperature
65	Energy consumption, global warming, adaptation strategies	Temperature, humidity, global sea level, seawater temperature, precipitation intensity, wave climate, storm frequency, atmospheric CO_2
66		
67	Urban heat island, Weather research and forecast, Heatwave Regional climate, Extreme weather Anticyclone	Wind speed, morphology, sensible heat flux, latent heat flux, heat storage flux
68		Loss of vegetation and permeability, urban morphology and size of the cities, properties of construction materials (thermal emissivity, albedo, heat capacity), anthropogenic heat, synoptic conditions, wind flow and cloud cover
69	Comfort, mortality, an increase in temperature, energy consumption, a decrease in air quality	Air temperature, surface temperature
70	Extra power consumption, community health, water consumption and quality, and additional costs within the natural and built environments	Temperature
71		Temperature

Near term objective
Ventilation and related measures, phase change materials (PCM) related measures, fenestration, roof and other related measures, insulation, active solution
Passive design considerations are considered highly effective in mitigating and adapting to climate change implications. Thermal insulation and efficient window glazing are identified as the best-performing strategies, while the use of solar Photovoltaic (PV) is considered efficient in meeting the primary energy demands
Trees, green roofs, green walls, use of specific construction materials, cool roofs, cool pavement, permeable pavement, thermal inertia, urban design and solar radiation, urban design and airflow, windows of buildings, reduction of air conditioner heat, reduction of urban vehicles
Increase green infrastructures, pay attention to land use (adopting permeable surfaces, cool materials, green), decrease anthropogenic activities (including industrial processes, buildings, automobiles, all energy consumption
institutional policies, design/technological solutions, cultural and behavioural variables

A3| Symulation setting

42. The data are kept from the Grasshopper database.

43. A number between 50 and 300 for resistance of the plants to moisture transport (s/M). Plants with low values of stomatal resistance will result in higher evapotranspiration rates than plants with hight resistance.

Setting part 2.

- Materials:

- **Green systems:**
  - **Walls:**
    - **HB Vegetation material:** Create a vegetation material representing plants and soil that can be plugged into the "HB Opaque Construction" component. This component was developed using horizontal roofs, so caution is needed when applying it to vertical walls – see par. 3.1.
    - **HB Opaque material:** VENTILATION: thickness: 0.04; conductivity: 0.11; density: 1.2815; spec. heat: 1004.832; roughness: Smooth(42)
    - **HB Opaque material:** ROMAN-STYLE TUFF PIECES WITH SPARSE SOLID BRICK RECURSIONS: thickness: 0.6; conductivity: 0.81; density: 1500; spec. heat: 795.492; roughness: Rought
    - **HB Opaque material:** INTERNAL PLASTER: thickness: 0.02; conductivity: 1; density: 1858.1417; spec. heat: 837.36; roughness: Smooth
  - **Roofs:**
    - **HB Vegetation material:** _plant_ height: 1; _leaf_area_index: 4.9; _stomat_resist_ (43)51
    - **HB Opaque material:** DRENAGE: thickness: 0.1; conductivity: 0.1; density: 2558.7893; spec. heat: 794; roughness: Very Rought
    - **HB Opaque material:** SHEATH: thickness: 0.02; conductivity: 0.26; density: 1858.1417; spec. heat: 837.36; roughness: Smooth
    - **HB Opaque material:** SLOPE SCREED: thickness: 0.07; conductivity: 1.4; density: 1121.2924; spec. heat: 1507.248; roughness: VeryRought
    - **HB Opaque material:** BRICK FLOOR SLAB: thickness: 0.05; conductivity: 0.6; density: 2240.0014; spec. heat: 795.492; roughness: Rought

- **HB Opaque material:** AIR: thickness: 0.28; conductivity: 0.11; density: 12.8147; spec. heat: 1004.832; roughness: Smooth

- **HB Opaque material:** CEILING TILE: thickness: 0.02; conductivity: 0.6; density: 2240.0014; spec. heat: 837.36; roughness: Smooth

- Walls:

- **HB Opaque material:** EXTERNAL PLASTER: thickness: 0.04; conductivity: 1; density: 1858.1417; spec. heat: 795.492; roughness: Rough

- **HB Opaque material:** ROMAN-STYLE TUFF PIECES WITH SPARSE SOLID BRICK RECURSIONS: thickness: 0.6; conductivity: 0.81; density: 1500; spec. heat: 795.492; roughness: Rought

- **HB Opaque material:** INTERNAL PLASTER: thickness: 0.02; conductivity: 1; density: 1858.1417; spec. heat: 837.36; roughness: Smooth

- **HB Opaque material:** EXPANDED POLYSTRYRENE – EPS – 12 IN: thickness: 0.12; conductivity: 0.0346; density: 192.22; spec. heat: 1130.43; roughness: Medium Smooth

- **Roof:**

- **HB Opaque material:** PAVING IN CONCRETE COVERED WITH BITUMINOUS SHEATING/RESIN: 0.05; conductivity: 3; density: 1600; spec. heat: 1256.04; roughness: Very rough

- **HB Opaque material:** SAND AND CONCRETE SUB-BASE SCREED: thickness 0.04; conductivity: 1.4; density: 1600; spec. heat: 879.228; roughness: Medium rough

- **HB Opaque material:** SHEATH: thickness: 0.02; conductivity: 0.26; density: 1858.1417; spec. heat: 837.36; roughness: Smooth

- **HB Opaque material:** SLOPE SCREED: thickness: 0.07; conductivity: 1.4; density: 1121.2924; spec. heat: 1507.248; roughness: VeryRought

- **HB Opaque material:** BRICK FLOOR SLAB: thickness: 0.05; conductivity: 0.6; density: 2240.0014; spec. heat: 795.492; roughness: Rought

- **HB Opaque material:** AIR: thickness: 0.28; conductivity: 0.11; density: 12.8147; spec. heat: 1004.832; roughness: Smooth

- HB Opaque material: CEILING TILE: thickness: 0.02; conductivity: 0.6; density: 2240.0014; spec. heat: 837.36; roughness: Smooth

- Windows:

- HB Window material:

- _u_factor: 5.9
- _shgc: 0.61

- HB Window frame:

- _width: 0.058
- _conductance: 56.4

- Indoor rooms:

- HB Construction Set by Climate: Get a construction set from the standards library using a climate zona, building vintage and construction type

- Climate zone: An integer between 1 and 8 for the ASHRAE climate zone in which the building is located. ASHRAE climate zone exists for all locations on Earth and can typically be looked up online or within the .stat file that downloads next to the .epw file. The climate zone determines the code-recommended insulation and solar heat gain protection for the construction set. 3 - Warm

- _vintage_: text for the building vintage to search. Pre - 1980

- _constr_type: text for the construction type of the set. Mass

- HB Room from solid:

- _program_: text for the program of the rooms. Midrise Apartment

- Conditioned_: it indicates whether the rooms considered are conditioned. false

- Outdoor buildings:

- DF Context Shade: creates a Dragonfly Context shade

- Uwg_is_veg_: boolean to note whether the shade represents a tree canopy within simulations with the Urban Weather Generator (UWG), which will be incorporated into the simulation as tree cover.

- DF Building from solid: It creates Dragonfly Buildings from solid geometry (closed Rhino polysurfaces)

- _bldg_geo as list: a list of closed Rhino polysurfaces to be covered into buildings

- _floor_to_floor: an array of floor-to-floor height instructions that describes how a building mass should be divided

into floors. The array should run from the bottom floor to the top floor. Each item in the array can be either a single number for the floor-to-floor height or a text string that codes for how many floors of each height should be generated.

- _program_: text for the program of the buildings: Midrise Apartment

- _constr_set_: a construction set object that can be assigned to HB rooms to specify all default construction on the rooms

- Conditioned: false

- DF Apply Facade Parameters: it is used for apply windows parameters and/or shading parameters to any Dragonfly object

- _df_obj as list: the Dragonfly building, Story, or Room2D which will have the input Window Parameter and/or Shading Parameters assigned to it

- _win_par_as list: a window parameter object that dictates how the window geometries will be generated for each of the walls. 0.18

- DF Assign Building UWG Properties: edit the properties of a Dragonfly Building that affect simulation with the urban weather generator

- _building: the dragonfly building which is to have its urban weather generator (UWG) properties assigned.

- Program_: text for the name of the building program: midrise Apartment

- Vintage_: text for the vintage of the building. This will be used to set default constructions. Pre 1980

- Shgc_: A number from 0 to 1 that represents the SHGC of the building's windows. This is used to evaluate the amount of solar heat reflected into the street canyon. 0.18

- Wall_alb_: a number between 0 and 1 that represents the exterior wall albedo of the building. When I simulate cool material I set it as 0.9.

- Roof_alb_ a number between 0 and 1 that represents the exterior roof albedo of the building. When I simulate cool roofs I set it as 0.9.

- Roof_veg_ a number between 0 and 1 that represents the fraction of the building's roofs covered in vegetation.

- **LB Generate Point Grid:** generate a mesh with

- _geometry: Brep or mesh from which to generate the points and grid

- _grid_size: number for the size of the test grid. 2

- _offset_dist_: number for the distance to move points from the surfaces of the input_geometry. Typicall, this should be a small positive number to ensure points are not blocked by mesh.

- Quad_only_: True

- DF Terrain:

- _terrain_geo: an array of Breps or meshes that together represent the terrain. This should include the entire area of the site, including that beneath the footprints

- _albedo_: a number between 0 and 1 that represents the albedo of the pavements. When I use cool materials it is set at 0.9

- _thickness. A number that represents the thickness of the pavement material in meters. 0.5

Setting part 3.

- Microclimate:

- DF Model: It creates a dragonfly model, which can be translated into a Honeybee model and sent for simulation

- _buildings: a list of Dragonfly Building objects to be added to the Model.

- Context_: optional Dragonfly ContextShdae objects to be added to the model

- DF Traffic Parameters: It creates traffic parameters representing the traffic within an urban area

- _watts_per_area: a number representing the maximum sensible anthropogenic heat flux of the urban area in watts per square meter. This is specifically the heat that DOES NOT originate from buildings and mainly includes heat from automobiles, street lighting, and human metabolism. If auto-calculate, it will be estimated from the average building story count of the model hosting the traffic parameters (Default: auto-calculate). Values for different cities can be found in (Sailor, 2011). I put 8 W/m2, as a typical mixed-use part of Toulouse, France

- DF Assign Model UWG properties: it edits the proper-

ties of a Dragonfly Model that affect simulation with the Urban Weather Generator (UWG)

- _model: A Dragonfly Model with assigned Urban Weather Generator (UWG) properties.

- _terrain: A Terrain object that dictates the properties of the street and ground beneath the buildings.

- _traffic_: A TrafficPararameter object that defines the activity and intensity of traffic within the urban street canyons.

- Tree_cover: A number from 0 to 1 that defines the fraction of the exposed terrain covered by trees. If None, it will be determined by evaluating the horizontal area of all ContextShade geometry with a true is_vegetation property. I put 0 for the model without any actions and 0.9 for the model with green infrastructures.

- Grass_cover: A number from 0 to 1 defines the fraction of the exposed terrain covered by grass or shrubs. If None, no grass will be assumed for the urban area. I put 0 for the model without any actions and 0.9 for the model with green infrastructures.

- DF UWG Simulation Parameter: Create a simulation parameter object with a complete set of Urban Weather Generator (UWG) simulation settings that can be plugged into the "DF Run Urban Weather Generator" component.

- __run_period_: A Ladybug Analysis Period object to describe the period to run the simulation. If None, the simulation will be run for the whole year.

- _veg_par_: An integer for the number of timesteps per hour at which the calculation will be run.

- _epw_site_: A ReferenceEPWSite object to specify the properties of the reference site where the input rural EPW was recorded. If None, generic airport properties will be generated

- _bnd_layer_: A BoundaryLayerParameter to specify the properties of the urban boundary layer. If None, generic boundary layer parameters will be generated.

- DF Vegetation Parameters

- _albedo_: A number between 0 and 1 representing the ratio of reflected radiation from vegetated surfaces to incident radiation upon them.

- _tree_latent_: A number between 0 and 1

representing the fraction of absorbed solar energy by grass given off as latent heat (evapotranspiration). Currently, this does not affect the moisture balance in the uwg but will affect the temperature.

- DF Reference EPW Parameters: Create Reference EPW Site parameters representing the site's properties where rural EPW data was recorded for an Urban Weather Generator (UWG) simulation.

- DF Boundary Layer Parameters: It creates boundary layer parameters representing the properties of the urban boundary layer in an urban weather generator simulation

- DF Run Urban Weather Generator: It morphs a rural or airport EPW to reflect the conditions within an urban street canyon.

- _model: A Dragonfly Model to morph the EPW for the urban area.

- _epw_file: Full path to a .epw file. This rural or airport file will be morphed to reflect the climate conditions within an urban canyon. I use the EPW file of Rome.

- _sim_par_: A dragonfly UWG SimulationParameter object that describes all the simulation settings. If None, some default simulation parameters will be used.

Setting part 4.

- Sim Indoor:

- HB Simulation output: It creates a simulation output object by selecting sets of commonly requested output variables. The resulting object can be used to request output variables from EnergyPlus

- HB Shadow Calculation: it creates settings for the EnergyPlus Shadow calculation

- LB EPW to DDY: It produces a DDY file from the data in an EPW or STAT file. If None is found, the heating and cooling design days will be derived from analysis of the annual data within the EPW. Analyzing the annual TMY data is less representative of the climate since only one year of data is used to derive the DDY (instead of the usual multi-year analysis). However, suppose the EPW is the best available representation of the climate for a given site. In that case, it can often be preferable to use a DDY con-

more years of data but from further away. Information on the uncertainty introduced using only one year of data to create design days can be found in AHSRAE HOF 2013, Chapter 14.14. The DDY file will only be produced for STAT files if the design day information is found within the file. If no information on the relevant design days is found, an error will be raised, and the component will fail to run.

- Ehwather_file: The path to a .epw file or .stat file on your system, from which a .ddy will be generated. In my case, I used an EPW file.

- HB Sizing Parameter: It creates parameters with criteria for sizing the heating and cooling system

- HB Shade: It creates a Honey Bee shade

- HB Aperture: It creates a Honey Bee aperture

- HB Door: il creates a Honey Bee door.

- HB Simulation Parameter: It creates a simulation parameter object that carries a complete set of Energy Plus simulation settings and can be plugged into the "HB ModelTo OSM" component.

- HB Model: HB Model creates a Honey Bee Model, which can be sent for simulation

- HB Model to OSM: We need this command to execute an Open Studio workflow (.ows) and run the resulting IDF file through EnergyPlus

- LB Analysis Period: An analysis period is created to describe a time slice during the year. In my case, I checked the statistically hottest moment of the year: on the 25th of August at 2.00 pm.

- Outdoor mrt calcalculation

- LB Import EPW imports climate data from the standard .epw file. In order to calculate the UTCI in the microclimate built in the existing environment, I linked this command with the urban epw file generated by the UWG generator.

- LB Human to Sky Relation: It calculates parameters for the relationship between human geometry and the sky given the position of a human subject and context geometry surrounding this position

- LB Outdoor Solar MRT: This command calculates the mean radiant temperature as a result of outdoor shortwave solar shining directly onto people and longwave radiant exchange with the sky. This component uses the SolarCal model of ASHRAE-55 to

methods to determine longwave radiant exchange.

Setting part 5.

- Indoor output

- HB Read Room Comfort Result: It parses all the common room-level comfort-related results from an SQL result file that has been generated from an energy simulation

- _squl: the file path of the SQL result file that has been generated from an energy simulation

- Indoor visualization

- HB Read Face Result: It parses all of the common Room-level comfort-related results from an SQL result file that has been generated from an energy simulation

- HB Sensor Grid from Rooms: It generates SensorGrid objects from the floors of honeybee rooms.

- HB Assign Grids and View: Add radiance Sensors Grids and/or views to a honey bee model. This assignment is necessary for any radiance study, though whether a grid or a view is required for a particular type of study is dependent upon the recipe used

- HB Recipe Settings: Specify settings for the run of a recipe, including the number of workers/CPUs, the project folder, and other settings

- HB Color Faces: It visualizes face and sub-face level energy simulation results as coloured geometry

- HB UTCI Comfort Map: Compute spatially-resolved Universal Thermal Climate Index (UTCI) and heat/cold stress conditions in an EPW and Honeybee model. This recipe uses EnergyPlus to obtain surface temperatures, indoor air temperatures, and humidities. Outdoor air temperatures, relative humidities, and air speeds are taken directly from the EPW. The energy properties of the model geometry determine the outcome of the simulation, though the model's Radiance sensor grids determine where the comfort mapping occurs. Longwave radiant temperatures are obtained by computing spherical view factors from each sensor to the room surfaces of the model using radiation. These view factors are then multiplied by the surface temperatures output by EnergyPlus to yield longwave MRT at each sensor. For outdoor sensors, each sensor's sky view is multiplied by the EPW sky temperature to account for longwave radiant exchange with the sky. All outdo-

or context shades and the ground are assumed to be at the EPW air temperature unless they have been modelled as Honeybee rooms. A Radiance-based enhanced 2-phase method is used for all shortwave MRT calculations, which precisely represents direct sun by tracing a ray from each sensor to the solar position. To determine Thermal Comfort Percent (TCP), the occupancy schedules of the energy model are used for indoor sensors if no schedule_ is input. Any hour of the energy model occupancy schedule that is 0.1 or greater will be considered occupied. If no schedule_ is input, all hours of the outdoors are considered occupied.

- HB Read Thermal Matrix: It reads the detailed results of a thermal mapping analysis from a folder of CSV files output by a thermal mapping component

- HB Visualize Thermal Map. Spatially visualize the detailed results of a thermal mapping analysis from a comfort matrix

- Outdoor output + visualization:

- LB UTCI Comfort (UTCI): Compute spatially-resolved Universal Thermal Climate Index (UTCI) and heat/cold stress conditions in an EPW and Honeybee model. This recipe uses EnergyPlus to obtain surface temperatures, indoor air temperatures, and humidities. Outdoor air temperatures, relative humidities, and air speeds are taken directly from the EPW. The model geometry's energy properties determine the simulation's outcome, though the model's radiation sensor grids determine where the comfort mapping occurs. Longwave radiant temperatures are obtained by computing spherical view factors from each sensor to the room surfaces of the model using radiation. These view factors are then multiplied by the surface temperatures output by EnergyPlus to yield longwave MRT at each sensor. For outdoor sensors, each sensor's sky view is multiplied by the EPW sky temperature to account for longwave radiant exchange with the sky. All outdoor context shades and the ground are assumed to be at the EPW air temperature unless they have been modelled as Honeybee rooms. A Radiance-based enhanced 2-phase method is used for all shortwave MRT calculations, which precisely represents direct sun by tracing a ray from each sensor to the solar position. To determine Thermal Comfort Percent (TCP), the occupancy schedules of the energy model are used for indoor sensors if no schedule_ is input. Any hour of the energy model occupancy schedule that is 0.1 or greater will be considered occupied. If no schedule_ is input, all hours of the outdoors are considered occupied.

- LB Adaptive Comfort (Adaptive): Calculate Adaptive thermal comfort. The Adaptive thermal comfort model is for use on the interior of buildings where a heating or cooling system is not operational, and occupants can open windows for natural ventilation. The PMV thermal comfort model should be used for fully conditioned buildings.

- LB PMV Comfort (PMV): Calculate Predicted Mean Vote (PMV). PMV is a thermal comfort model for use on the interior of buildings where a heating or cooling system is operational. The Adaptive thermal comfort model is recommended for naturally ventilated buildings and outdoor conditions; models such as Universal Thermal Climate Index (UTCI) or Physiological Equivalent Temperature (PET) are recommended.

- LB Hourly Plot: Create a coloured plot of hourly data collection.

A4| Data that Ladybug presets

Data that the program pre-sets:

- Materials (mat):

- _therm_absp_: number between 0 and 1 of long wavelength that is absorbed by the material (default: 0.9)

- _sol_absp_: number between 0 and 1 of the fraction of incident solar radiation that is absorbed by the material (default: 0.7)

- _vis_absp_: number between 0 and 1 of the fraction of visible wavelength absorbed by the material (default: 0.7)

- _t_vis_: number between 0 and 1 of transmittance of glass (default: 0.6)

- Window frame (frame)

- _edge_to_cent_: number between 0 and 4 of the ratio of the conductive part of the glass next to the frame to the centre glass. This command is used only for constructions with multiple panes of glass. This ratio usually needs to be greater than 1 as long as the space separating the glass panels is usually more conductive than the space between the panels. A value of 1 indicates no space. Values are usually obtained from the LBNL WINDOW program, so the unique characteristics of the building fixtures can be taken into account (default: 1)

- Outside_proj_: number for the distance that the outside of the frame from the outside surface of the glass (m). this is used for the chalking of frame shading on the glass, IR emitted and absorbed by the frame, and convection from the frame (default: 0)

- Inside_proj_: number of the distance that the inside of the frame from the inside surface of the glass. This is used to calculate the IR emitted and absorbed by the frame and convection from the cornice (default: 0)

- _therm_absp_: number between 0 and 1 of the fraction of incident long wave absorbed by the material. (default: 0)

- _sol_absp_: number between ' and 1 of the fraction of incoming solar radiation from the material (default: 0.7)

- _vis_absp_: number between 0 and 1 of the fraction of

visible long wave absorbed by the material (default: 0.7)

- HB Window material

- _t_vis_ a number between 0 and 1 for the visible transmittance of the glazing system (default: 0.6)

- HB window frame: Create a window frame material that can be assigned to a window construction company by plugging it into the frame. It represents an input for the "HB window construction" component

- _edge_to_cent_: number between 0 and 4 for the ratio of the glass conductance near the frame (excluding air films) divided by the glass conductance and the centre of the glazing (excluding air films). This is used only for multi-plane glazing constructions. This ratio should usually be more significant than 1.0 since the spacer material that separates the glass panes is usually more conductive than the gap between panes. A value of 1 effectively indicates no spacer (default: 1).

- Inside_proj_: number for the distance that the frame projects inward from the inside face of the glazing (m). this is used to calculate solar absorbed by the frame, IR emitted and absorbed by the frame, and convection from the frame (default: 0)

- _therm_absp_: a number between 0 and 1 for the fraction of incident long wavelength radiation that is absorbed by the materials (default: 0.9)

- _sol_absp_: a number between 0 and 1 for the fraction of incident solar radiation absorbed by the material (default: 0.7)

- _vis_absp_: a number between 0 and 1 for the fraction of incident visible wavelength radiation absorbed by the material (default value is the same as the _sol_absp_

- HB Room from solid: creates Honeybee Rooms from solid closed Rhino polysurfaces)

- _mod_set_as list: Text for the modifier set of the Rooms, which assigns all default radiance modifiers needed to create a radiance model. The text should refer to a Modifier set "within the library or can also be a Modifier St object. Without input, the room will have a generic construction set that is not sensitive to the room's climate or building energy code.

- DF Assign Building UW properties: This command edits the properties of a Dragonfly Building that affect simulation with the Urban Weather Generator (UWG)

- Fr_canyon_: a number from 0 to 1 representing the fraction of the building's waste heat from air conditioning that gets

rejected into the urban canyon. (default: 0.5)

- DF terrain: il creates a terrain object representing the land on which an urban area sits. This includes both the geometry and the properties of the pavement within the urban area.

- _conductivity_: a number representing the conductivity of the pavement material in W/MK (default: 1W/MK, typical of asphalt).

- _vol_heat_cap_: a number representing the volumetric heat capacity of the pavement material in J/M3k. this is the number of joules needed to raise one cubic meter of the materials by 1 degree Kelvin (default: 1.6e6 J/M3k, typical of asphalt).

- DF Traffic Parameters: Create traffic Parameters representing the traffic within an urban area

- DF Vegetation Parameters: It creates vegetation parameters representing the behaviour of vegetation within an urban area

- _start_month_: an integer from 1 to 12 representing the month vegetation evapotranspiration begins (leaves come out). By default, the month will be automatically determined by analyzing the epw to see which months have an average monthly temperature above 10 °C.

- _end_month_: an integer from 1 to 12 representing the month vegetation evapotranspiration ends (leaves fall off). By default, the month will be automatically determined by analyzing the epw to see which months have an average monthly temperature above 10 °C.

- DF Reference EPW Parameters: The command creates reference EPW Site parameters that represent the properties of the site where rural EPW data was recorded for an Urban Weather Generator (UWG) simulation

- _obstacle_hght_: a number that represents the height in meters of objects that obstruct the view of the sky at the weather station site. This includes both trees and buildings (default: 0.1 m)

- _veg_cover_: a number between 0 and 1 representing the fraction of the reference EPW site covered in grass. (default: 0.9)

- _temp_hght: a number that represents the height in meters at which temperature is measured in the weather station. (default: 10m, the standard measurement height for US DoE EPW files)

- _wind_hght_:a number that represents the height in meters at which wind speed is measured on the weather station.

(default: 10m, the standard measurement height for US DoE EPW files)

- DF Boundary Layer Parameters create boundary layer parameters representing the proprieties of the urban boundary layer in an urban weather generator (UWG) simulation.

- _day_hght: a number representing the height in meters of the urban boundary layer during the daytime. This is the height to which the urban meteorological conditions are stable and represent the overall urban area. Typically, this boundary layer height increases with the height of the buildings. (default: 1000 meters)

- _night_hght: a number that represents the height in meters

- _inversion_hght: A number that represents the height in meters at which the vertical profile of potential temperature becomes stable. (Default: 150 meters)

- _circ_coeff_: a number representing the circulation coefficient. (Default: 1.2, per Bueno (2012))

- _exch_coeff_: A number representing the exchange coefficient (Default: 1.0 per Bueno (2014)).

- Sim_par:

- _timestep_: An integer for the number of timesteps per hour at which the calculation will be run (Default: 12)

- LB Human to Sky Relation:

- North_: A number between -360 and 360 for the counterclockwise difference between the North and the positive Y-axis in degrees. 90 is West and 270 is East (default: 0)

- _pt_count_: A positive integer for the number of points used to represent the human subject geometry. Points are evenly distributed over the _height_and are used to compute fracitonal values for the fract_body_exp in the case that only some of the points can see the sun. (Default: 1)

- _height_A number for the height of the human human subject in the current Rhino Model units. (Default: 1.8 m in the equivalent Rhino Model units; roughly the average height of a standing adult).

- _cpu_count_: An integer to set the number of CPUs used in the execution of the intersection calculation. If unspecified, Ladybug will automatically default to one less than the number of CPUs currently avaiable on the machine or 1 if only one processor is avaiable

- LB Outdoor Solar MRT: Calculate Mean Radiant Temperature (NRT) from outdoor shortwave solar shining directly onto people and longwave radiation exchange with the sky.

- _ground_ref_: a single number between 0 and 1 or a data collection that represents the reflectance of the floor. The default is 0.25, characteristic of outdoor grass or dry, bare soil.

- Shadow_calc:

- _calc_method_: text nothing whether CPU-based polygon clipping or GPU-based pixel counting method should be used. For low numbers of shading surfaces (less than 200), PolygonClipping requires less runtime than PixelCounting. However, PixelCounting runtime scales significantly better at more shading surfaces. pixelCounting also has no limitations related to room concavity when used with any "Fullinterior" solar distribution options. (default: PolygonClipping)

- _update_method_: text describing how often the solar and shading calculations are updated concerning the flow of time in simulation (default: periodic)

- _frequency_: integer for the number of days in each period for a unique shadow calculation. This field is only used if the AverageOverDaysInFrequency method is used in the previous field. (default: -30)

- _max_figures_: integer for the number of figures used in shadows overlaps. (default – 15000)

- Ddy_file

- _percentile__ a number between 0 and 50 for the percentile difference from the most extreme conditions within the EPW or STAT to be used for the design day. Typical values are 0.4 and 1.0. (default: 0.4)

- Monthly_cool_: a Boolean to note whether the resulting .ddy file should contain twelve cooling design days for each of the months of the year.

- Sizing:

- _filter_ddays_: Boolean will note whether the design days in the ddy_file_ should be filtered only to include 99.6% and 0.4% design days. If None or False, all design days in the ddy_file_ will be incorporated into the sizing parameters

- _heating_fac_: a number that will be multiplied by the peak heating load for each zone in the model to size the heating system for the model. It must be greater than 0 (default: 1.25)

- _cooling_fac_: a number multiplied by the peak cooling load for each zone in the model. It must be greater than 0. (default 1.15)

- HB Shade: Create Honeybee shade

- Attached_as list: Boolean to note whether the Shade is attached to other geometry. This is automatically set to True if the shade is assigned to a parent room, face, aperture or door but will otherwise default to false. If the shade is not readily assignable to a parent object but is attached to the building, then this should be set to True. (default: False)

- HB door:

- Glass_: Boolean to note whether the door is transparent. (default: false)

- Sim_par:

- _north_: a number between -360 and 360 for the counterclockwise difference between the north and the positive Y-axis in degrees. 90 is west, and 270 is east. (default: 0)

- Holidays_: a list of ladybug date objects for the holidays within the simulation. If None, no holidays are applied. Default: none

- _start_dow_: text for the day of the week on which the simulation stars. (default: Sunday)

- _terrain_:text for the terrain type in which the model sits, used to determine the wind profile. (default: city)

- _sim_control_: a simulationControl object that describes which calculation types to run. This can be generated from the "HB Simulation Control" component. Default: Perform a sizing calculation but only the simulation for the RunPeriod

Glossary

- **Atmospheric circulation:** Atmospheric circulation consists of the large-scale movement of air. Together with ocean circulation, it is how thermal energy is redistributed on the surface of the Earth.
- **Rossby's waves:** They are due to the increase of the Coriolis parameter with latitude, together with the condition of conservation of angular momentum, presenting themselves as inertial oscillations around the 'equilibrium point' given by the perfect geostrophic balance, a situation in which the Coriolis force exactly balances the pressure forces. They owe their name to Swedish physicist Carl-Gustav Arvid Rossby, who first identified them in the atmosphere and gave the explanation in 1939. From a meteorological point of view, the Rossby wave is associated, through divergence and convergence of air, with anticyclonic or high-pressure zones and cyclonic or low-pressure zones, respectively (e.g., sacs up to the eventual cut-off in the form of cold drops), resulting in advection of air masses with different physical characteristics. These waves and the atmospheric phenomena associated with them, thus, represent one of the fundamental means by which the Earth's atmospheric circulation exchanges heat from the equator to the poles.
- **Remote feedback:** In addition to atmospheric processes, local and remote drivers and feedbacks associated with ocean and land surfaces can influence the frequency of heat waves. In particular, feedbacks between the land surface and cloud cover are important. The latter can decrease due to the presence of drier air when latent heat flux is limited (as in the case of heat waves), increasing shortwave solar radiation. In addition, reduced cloud cover can decrease precipitation, decrease soil moisture, and amplify the heat wave. An abnormal sea surface temperature is also important. In particular, these anomalies can give rise to persistent atmospheric circulation patterns that lead to heat waves on adjacent continents.

- **Greenhouse gases:** The atmospheric emissions of carbon dioxide (CO_2) and other gases that contribute to the so-called "greenhouse effect" have reached a critical threshold, so much so that they have become the subject of international policies and measures for mitigating and adapting to climate change. The so-called greenhouse gas (GHG) emissions are recognized as impacting global warming (GWP - Global Warming Potential). The assessment of emissions compared to GWP requires a comparison of environmentally diverse situations. The "carbon footprint" (CF) is the tool typically used to define the amount of GHG deriving from an anthropic product or service. (Mussinelli, Bolici, Fanzini, Castaldo, & Tartaglia, 2020)
- **Aerosol:** Suspended solid or liquid particles are emitted directly into the atmosphere or produced in the atmosphere by precursor gases such as nitrates and sulphates. Due to their relatively short lifetimes, aerosol concentrations show substantial spatial variations and have regional effects on climate. Aerosols interfere with climate through radiative effects and cloud microphysical interactions that alter their properties, producing near and remote impacts on regional temperature, hydrological cycle and atmospheric circulation (Kasoar et al., 2018; Samset et al., 2018; Westervelt et al., 2018). Overall, most anthropogenic aerosols are associated with increased scattering, absorption and reflection (cloud brightening) of solar radiation, which causes net darkening and cooling, mitigating long-term warming due to increased greenhouse gases (Calvin et al., 2023)
- **Ventilative blockage:** It consists of long-lived quasistationary anticyclonic flow anomalies, including high-amplitude upper tropospheric ridges (Domeisen et al., 2022)
- **Sky view factor:** The Sky View Factor (SVF) is a dimensionless parameter that gives, with values between 0 and 1, the degree of exposure of a surface to the sky, i.e. the portion of sky visible from a given point at ground level (Oke, 1981). The components of the urban fabric influence this factor, the elements of street furniture and the presence or absence of trees: values close to 1 correspond to a large visible portion, and values close to 0 indicate a limited view of the sky. as the ratio between the radiation received (or emitted) by a planar surface and the radiation emitted (or received) by the celestial vault (Zhang et al., 2012)

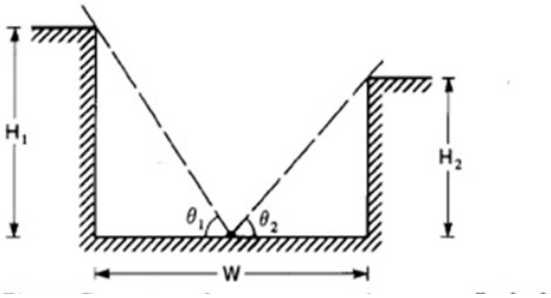
- **Medium building height:** The average height of the buildings, or Mean Height, is the average of the heights of the n buildings present in area A under analysis. Knowing both the volume V and the covered area Sc of all the n buildings present in area A, MH can also be calculated as the ratio between them:

$$MH = \frac{\sum_{i=1}^{n} V_i}{\sum_{i=1}^{n} Sc_i} [m]$$

- **Biotope area factor:** The Biotope Area Factor BAF is a dimensionless parameter that evaluates the ecosystem functionality of the built environment, primarily referring to the overall permeability of a specific urban area (block, district or city), valid for evaluating and planning multiple environmental and urban aspects. The definition of the BAF is based on an abacus of type-technological solutions that associate the various types (nine in all) of paving and roofing (grass, self-locking paving, asphalt, green roof) with a coefficient between 1 (total permeability) and 0 (absolute impermeability)1. In order to determine the BAF value on a plot, it must be divided into homogeneous polygons concerning the coefficients of the surfaces identified by the BAF. (Bianco, 2020)
- **Building Impact Reduction Index:** The RIE, Building Impact Reduction, describes the environmental quality of an urban area and helps certify building interventions that improve the permeability of soils and green areas. The City of Bolzano has adopted it as an operative urban planning tool. (Bassolino, Riduzione Impatto Edilizio (RIE), 2020)
- **Urban aspect ratio:** The Urban Aspect Ratio, also known as the Height Width Ratio (H/W), is a dimensionless parameter that indicates the morphology of so-called 'street canyons', i.e. urban spaces defined by continuous building curtains. It is defined by the ratio between the height of a building façade (H) and its distance from the opposite façade (W), within a range of values usually between 0 and 3+. However, which may also reach higher values concerning specific characteristics of urban fabrics (Musco, 2016): low values of H/W correspond to low-density building fabrics, high values to dense fabrics, in which the height of the buildings is greater than the width of the streets they face (as is typically the case within historicised fabrics) (Alberti & Guerri, 2020)

- **Albedo:** The albedo is an index that measures, in a dimensionless way, the quantity and quality of incident solar energy reflected by a surface. The albedo goes from 0 to 1, where 1 is the highest reflectance value and indicates a body capable of reflecting all the incident energy (white surface). At the same time, 0 represents the highest absorption value of solar radiation (black surface). (Bassolino, 2020)
- **Permeability Index:** The permeability coefficient (α) represents the ratio between the volume of stormwater capable of reaching the subsoil through the specific pavement and the total volume of rainwater on it. (Swart et al., 2012, p. 153) (Timmerman et al., 2017). (Bosco, Cozzolino, & Donadio, 2020)
- **Normalized index Vegetation Index:** Among the most used vegetation indices there is the Normalized Difference Vegetation Index (NDVI) (Xue & Su, 2017), which assumes theoretical (mathematical) values between -1 and +1, but whose fundamental values usually range between -0.1 and +0.8. Values <0 correspond to the presence of water bodies (lakes, rivers, etc.), values slightly higher than 0 refer to soils bare or very scarcely covered by plants, and values between 0.4 and 0.8 express vegetation's presence. In particular moderate values of NDVI (0.2–0.3) identify bushes and scrubs, whereas higher NDVI values (0.3–0.7) testify the occurrence of forest communities (very dense and highly stratified forests score NDVI values up to 0.8) (eg, Gomarasca 2004; Xue & Su, 2017; Earth Observing System 2019) (Di Pietro, Iamonico, & Strumia, 2020)
- **Building density (BD),** or building index, represents the ratio between the volume V of the n buildings in the area under analysis (Gerundo, 2018)
- **Urban street canyon:** Many urban climatologists see the urban street canyon as the basic urban unit and the space above the street and between the buildings. By studying the climate in these canyons, they aim to extrapolate to the city and find general properties of urban climate applicable to various cities. Oke was one of the first to study this subject during his career, followed by other researchers who improved his first definition. Many focus primarily on canyon shape, which they find has a more significant impact on microclimate than the materials of buildings and streets. Two important metrics for measuring street

canyon climate include the aspect ratio and sky view factor. (Massachusetts Institute of Technology, 2025)



- **Frontal area density:** Frontal area density (FAD) measures frontal area per unit of horizontal area and per unit of height increment. (Gerundo, 2018).
- **Urban morphology:** Urban morphology includes various indicators and indices. Referring to theoretical and methodological sources, the study carried out by (Li & Zeng, 2024) divides the various indicators into five categories: landscape metrics, area metrics, urban coverage metrics, building metrics and other metrics. The indicators currently used have the following characteristics. Firstly, many indicators have a strong hierarchy and interconnected heterogeneity in the network. Some leading indicators (e.g. average building height and green percentage) occupy central positions in the network, and the nodes' strength follows a power-law distribution. Secondly, the different types of indicators have distinct preferences for describing objectives and terminology and applying themes. Few indicators have focused on vegetation, and their application is prevalent in environmental research. Thirdly, the indicator network has a hybrid mesoscale structure combining core-periphery and community structures, corresponding to mainstream indicators governed by core and nascent indicators. Finally, the aforementioned research concludes that the multidisciplinary indicators form an overlapping, developing an integrated framework to quantify the three-dimensional morphology of cities, which should provide a systematic synthesis and reference for indicators for the analysis of urban morphology. Following the literature study conducted by the undersigned, the most important morpho-

logical indicators for this thesis are divided into Topographic indicators and Urban green descriptive parameters. The first group includes the elevation and the average height of buildings. Land cover ratio, building density, non-permeable surface rate, biotope area factor, reduction of building impact, urban aspect ratio, sky view factor, frontal area density, form ratio, and albedo. The second group comprises the green area ratio, normalised difference vegetation index, and leaf area index - par 1.1.4.

- **Nature:** The natural world, emphasising the diversity of living organisms, including people, and their interactions with each other and their environment. (Secretariat of the Convention on Biological Diversity, 2006)
- **Realms of nature:** Land, ocean, freshwater and atmosphere. These are significant components of the natural world that differ fundamentally in their organisation and function (Secretariat of the Convention on Biological Diversity, 2006)
- **Biodiversity:** The variability among living organisms from all sources including terrestrial, marine and other aquatic ecosystems and their ecological complexes. This includes diversity within species, between species, and in ecosystems. (Secretariat of the Convention on Biological Diversity, 2006)
- **Ecosystem:** A dynamic complex of plant, animal and micro-organism communities and the non-living environment, interacting as a functional unit. (Secretariat of the Convention on Biological Diversity, 2006)
- **Environmental assets:** The naturally occurring living and non-living components of the Earth constituting the biophysical environment, which may benefit humanity. (Secretariat of the Convention on Biological Diversity, 2006)
- **Ecosystem assets:** A sub-set of environmental assets related to diverse ecosystems. (Secretariat of the Convention on Biological Diversity, 2006)
- **Natural capital:** The stock of renewable and non-renewable natural resources such as plants, animals, air, water, soils and minerals that combine to benefit people. (Secretariat of the Convention on Biological Diversity, 2006)
- **Impact:** Impacts refer to a change in the state of nature (quality or quantity), which may result in changes to the capacity of nature to provide social and economic functions. Impacts can be positive or negative.

- **Anthropogenic heat:** Anthropogenic heat refers to the heat released to the environment as a result of human activities, such as high-grade heat generated and low-grade heat lost by power plants, heat generated by industrial activities, heat generated within commercial, residential, and service-related buildings, and human metabolism.
- **Ecosystem services:** The expression ecosystem services refers to natural actions and processes that directly or indirectly affect the quality of human life and all the species. The Millennium Ecosystem Assessment (MEA) is today the most extensive systematization in ecosystems. It is developed by about a thousand scientists on behalf of the United Nations, and it defines ecosystem services as «the multiple benefits provided by ecosystems to humankind» (MEA, 2005) (Mussinelli, Gambaro, Riva, Cerati, & Tartaglia, 2020)

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