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Performance based Design: Bouça Residents' Association Housing

Dissertação de Mestrado
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Trabalho efetuado sob a orientação de
Professor Doutor Paulo Jorge Figueira de Almeida Urbano de Mendonça
Professor Doutor Bruno Acácio Ferreira Figueiredo

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ANEXO 3

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ANEXO 4

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Resumo

A arquitectura performativa é a arquitectura baseada no desempenho do edifício, uma arquitectura em que tanto as decisões funcionais como as formais e ou estéticas estão ao mesmo nível uma da outra. Ver estes dois aspectos como independentes um do outro leva a uma arquitectura em que os aspectos funcionais são deixados para trás até à fase final de tomada de decisões de concepção, a fim de confirmar algumas normas e padrões energéticos. O objectivo desta investigação é trazer de volta a discussão em torno do desempenho do edifício para as mãos dos projectistas ou arquitectos, utilizando como ferramenta, métodos analíticos e softwares de simulação como, por exemplo, o *Climate Studio*. Esta investigação destina-se a compreender as vantagens da utilização da tecnologia durante o processo de concepção, mais especificamente a utilização do software de modelação e simulação *Climate Studio* em Rhinoceros 3D, para analisar e simular a luz natural e o desempenho térmico nos edifícios.
Considerando a evolução e disseminação de novas tecnologias aliadas à arquitectura, estamos actualmente a experimentar uma mudança de paradigma no processo de concepção arquitectónica. Desde 1970, são utilizados softwares de modelação e simulação para estudar o desempenho dos edifícios. Agora que a tecnologia está facilmente disponível para todos, o software de simulação que antes tinha um fluxo de trabalho difícil de compreender agora é mais fácil de aprender e utilizar e pode mesmo ser aplicado em diferentes fases de concepção.
A habitação, no seu conceito mais básico e primário, destinam-se a proteger e proporcionar conforto. O Conjunto Habitacional da Associação de Moradores da Bouça, utilizado como caso de estudo, foi projectado para realocar pessoas que vivem nas ilhas do Porto e proporcionar-lhes um espaço confortável para viver. Este projecto marca um ponto de viragem significativo nas experiências de habitação social em Portugal no século XX e por isso é relevante na história arquitectónica portuguesa.
Nesta investigação é analisado e comparado o desempenho de diferentes variações projetuais com o caso de estudo, com o objetivo de se compreender as vantagens associadas à utilização do software de modelação e simulação para a melhoria da performance de um edifício.

Palavras-chave: Arquitectura performativa, Luz natural, Conforto térmico,Conjunto Habitacional da Bouça, *Climate Studio*

Abstract

Thinking about performance in architecture is thinking about the synergy between both technical and architectural aspects of a design. Seeing these two aspects as independent of each other can lead to an architecture where the technical aspects are left in the final decision-making phase, in order to conform the building to a certain norms and standards. A more holistic way of designing would be to think about performance in the different design phases so that the technical aspects are on par with the form-making.

The aim of this research is to bring the discussion around the performance of the building back in the hand of the designers or architects by using simulation software like *Climate Studio* as a design tool. This investigation is intended to understand the advantages of using technology during the design process, more specifically the use of the computer modelling and simulation software, *Climate Studio*, in Rhinoceros 3D, for analysing and simulating natural light and thermal performance in buildings.

Considering the evolution and dissemination of new technologies related to architecture, we are currently experiencing a paradigm shift in the way technology is being implemented during the architectural design process. From the 1970s onwards, digital modelling and simulation software are being used to study the performance of buildings. Nowadays, due to the advancement in the hardware and software, the simulation technology is available for wide use and can be applied during several design phases.

Dwellings, in their most basic and primary concept, are meant to protect and provide comfort. The case study Bouça Residents' Association Housing was a project to reallocate and provide affordable and comfortable housing for the people living in the "ilhas" of Porto. This project marks a significant turning point in Portugal's social housing experiments in the 20th century, and also marks a period in Portuguese architectural history.

In this research, the performance of different design variations are analyzed and compared with the existent case study, in order to understand the advantages associated with the use of modelling and simulation software to improve the performance of a building.

Keywords: Performative architecture, Natural light, Thermal Comfort, Bouça Residents' Association Housing, *Climate Studio*

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List of acronyms

EAAD. Escola de Arquitetura, Arte e Design da Universidade do Minho
Rhino. Rhinoceros 3D
GH. *Grasshopper*
EPBD. Energy Performance of Buildings Directive
RCCTE. Regulation of thermal performance characteristics of buildings
SCE. Energy certification system for buildings
REH. Regulation on Energy Performance of Residential Buildings
RECS. Regulation on the energy performance of commercial and services buildings
EPW. *EnergyPlus* Weather (Weather data file saved in the standard *EnergyPlus* format)
HVAC. Heating, ventilation, and air conditioning
SAAL. Local Ambulatory Support Service (Serviço de Apoio Ambulatório Local)
FFH. Housing Promotion Fund (Fundo de Fomento da Habitação)
ID. Identification
DLF. Daylight Factor
Tr. Thermal resistance
Msi. Effective surface mass
DBT (Cº). Operative Temperature
RH %. Relative humidity
Bdg. Building
Sml. Simulation

1. Introduction

Figure 1.1. Natural light, Thermal comfort, Housing

1.1. Theme

Architectural work is often multilayered and performed on different scales. Despite the multi-scale of architectural work, the human scale remains one of the most crucial factors in architecture. The human scale is essential because architectural works are often meant for human beings to experience.

Thinking about the human scale also means thinking about comfort because it plays a significant role in how humans experience and appropriate the built environment. Sometimes, the aesthetic aspect of architecture overrides the building's functional performance requirements. The lack of balance between these two aspects makes architects think of them as independent and sequential instead of simultaneous, resulting in buildings with their aesthetic aspects being more developed. In contrast, the functional aspect falls short of expectations. Comfort is achieved when both of these aspects are in harmony with each other. [1,2]

Comfort is an abstract concept that can be confusing because of its inherent duality of being part of both a subjective and objective reality. Comfort can be measured based on measurable data sets, but it has the human as an inherent and impossible-to-predict factor. The human metabolism constantly adapts according to the changes of its surroundings and human behaviour, and although this is a factor that is difficult to predict with 100% accuracy, because its different parameters vary constantly, it cannot be forgotten. These needs vary according to the time of day, seasons, geographical location, ambient temperature, and individual's characteristics. Due to the diversity of assumptions, it becomes almost impossible to define common environmental criteria for any practical purpose.

Therefore, the current information regarding comfort in architecture is mostly focused on observation through empirical analysis. It is based primarily on temperature, light, acoustics, and air quality, which satisfy the biological and sensory conditions of an average human being in his material reality.

Although comfort is one of the concepts inherent to architectural education, its performance aspect is sometimes neglected. [3] Comfort analysis is seen by some architects as an obligation to prove adherence to specific standards, rather than a design tool.

Thinking about comfort in architecture is thinking about the idea of the domestic space, a space where the individual finds his plenitude, where he spends most of his day and where comfort is a given necessity. [3] My personal experience about the importance of comfort in a dwelling comes from the house where

I grew up which, in my opinion, is a pleasant dwelling to look at. In terms of architectural design, the spaces are well-designed and organized, which makes my daily life convenient. Although the spaces are practical for use, it is a different story when describing their comfort. The description is opposite to that of the aesthetic aspect. The spaces are uncomfortable and unpleasant because they are too cold during winter and too warm during summer. During the winter and summer seasons, the inner air temperature is almost equal to the outdoor temperature, making it almost impossible to stay comfortable without turning on the air-conditioning in the summer and the fireplace in the winter. That is why it is essential that equal attention is given to aesthetics and functional use in terms of comfort.

The project Bouça Residents' Association Housing by Álvaro Siza Vieira, in collaboration with António Madureira, will be used as a case study for this research. The project was selected because it marks a significant turning point in Portugal's social housing experiments in the 20th century and its relevance in Portuguese architecture history.

Not only its historical relevance, but also its design allowed to develop the research theme through the analysis of elements like the composition of the buildings of the neighbourhood, the organization of the interior and exterior spaces, the elements that compose the façade like the openings and their dimensions, the sunroom on the third floor, among others.

1.2. Problematic

According to Branko Kolarevic, there are two common ways of missing the reality of architectural work. The first is by seeing it from a purely rational technical viewpoint as an integrated system composed of different components that, when built, fulfil their function. The second is to see it only from the subjective aesthetic view, relating to its composition, precise placement, shape, colour, ornamentation, symmetry, proportions, layout and among others. Both approach buildings as freestanding objects in space that either result from rational thinking about technical specifications or as a confirmation of aesthetic expectations. In an ideal situation, architectural work is a synergy of these two approaches that go hand in hand from the initial design phase. [1]

In most cases, the comfort conditions, such as the thermal, lighting and acoustics, are studied and simulated in the last design phase to prove that the building fulfils the minimum requirements demanded by law, instead of seeing it as a design tool to ensure a certain level of comfort.

Dwellings, in their most basic and primary concept, are meant to protect and provide more comfortable conditions than outdoors. Therefore, both architectural design and comfort conditions need to be considered in dwellings. A change in mindset about how designers perceive performance and comfort is needed. These concepts can also be part of the design strategy, instead of being seen as an obligation put forward by standards and norms. These standards and norms are in flux and usually get stricter in time due to societal and climate change. Adding thicker insulation or changing the window's class at the end of a design phase to meet given minimum standards and norms is a temporary fix. It is not a sustainable answer to what comfort means for the inhabitants because how comfort is perceived does not depend on norms and standards.

This school of thought of seeing the buildings' performance as a part of the design strategy from the initial design phase is not often applied. So the question becomes: How can new technologies like digital modelling and simulation tools intervene in the initial design phase of an architectural project to make design decisions based on different parameters and variables that influence not only architectural quality but also comfort?

1.3. Objectives

This dissertation aims to understand the use of digital simulation tools as a design tool rather than just a means to justify compliance with thermal and natural lighting norms and regulations. The following are the four main objectives of this dissertation.

The first is to identify and understand the evolution of the different methods of natural light and thermal analysis in buildings. This is necessary to get a grasp of the evolution of the simulation techniques from an analogical to a more digital process and the advantages that came with the evolution.

The second objective is to analyse and identify the thermal and natural lighting characteristics of the chosen case study buildings, SAAL Bouça in Porto by Álvaro Siza, by using digital simulation. In order to confirm the simulation data of the thermal and natural light conditions, additional data in situ will be needed to confirm the accuracy of the data obtained from the simulation.

The third objective is to explore heat fluxes and daylight quality as a design strategy and optimize the case study building. By assessing the thermal and natural lighting performance of different design variations, architects can better understand how the design of a building can affect its use and, in turn, the user's comfort.

The fourth objective is to explore alternative design solutions based on thermal and natural light conditions with the gained knowledge through comparison of the variations. This possible design variation can be seen not as a criticism but as a potential design variation, which focuses lies on comfort as defined in the dissertation.

1.4. Structure

This Dissertation is organized into eight parts.

(1) The **first chapter** (1. Introduction) is an introductory chapter and is divided into five subchapters. The first chapter (1.1. Theme) frames and presents the theme under study. The second (1.2. Problematic) presents the importance of the research. The third (1.3. Objectives) addresses the main goals of the research. The fourth (1.4. Structure) presents the structure and organization of this document. The fifth (1.5. Methodology) addresses the methodology and the working process that guided this dissertation.

(2) The **second chapter** (2. Literature Review) is divided into four subchapters. The first subchapter, (2.1. Context) introduces the concepts and ideas that will be explored throughout the dissertation. The second subchapter (2.2 Evolution of thermal comfort regulation of buildings) presents the evolution of thermal comfort regulation in Portugal and in Europe. The third subchapter (2.3. Daylight in the context of the National System of Certification and Indoor Air Quality of Buildings) sets out the role of natural light in architecture. Lastly,the fourth subchapter (2.4. Advantages of design computational tools for building comfort analysis and simulation) presents the advantages of using simulation software to design, having to account for performance in architecture.

(3) The **third chapter** (3. Case study- Bouça Residents' Association Housing) relies on the historical and territorial analysis of the case study and is divided into five subchapters. The first, (3.1. Context) introduces the origin of the case study building, Bouça, with the Portuguese social and political past. The second subchapter (3.2 Photo Essay) presents a group of presents a group of photographs taken in the Bouça neibourhood. The third subchapter (3.3. The different phases) is further divided into five parts subchapters, each one describing the different phases and evolution of the Bouça neighbourhood, (3.3.1 First Design Phase), (3.3.2 First Construction Phase), (3.3.3 Living ruin), (3.3.4 Second Design Phase), (3.3.5 Second Construction Phase). The fourth subchapter (3.4. Analysis of the existent territory) describes an analysis made of the existent territory and the fifth subchapter (3.5. Housing unit analysis.),

looks at the different typologies of housing units in the case study Bouça neighbourhood.

(4) The **fourth chapter** (4. Analysis and Simulation on the prevailing performance condition of the neighbourhood.) explains the methodology used to explore one of the case study house units, in order to compare and assess the accuracy of the simulation data with in situ collected data. The chapter is further divided into six subchapters. The first subchapter (4.1 Metodology) explained the metodology used durin this research part presented in the following sub-chapters. The second subchapter (4.2. Use of the *Climate Studio* Software.) presents the steps taken in the software learning process and presents results of the workshop held. The ford subchapter (4.3. Building modelling and characterization.) explains the first step of the methodology, where the existing building is digitally modelled and characterized. The fourth subchapter (4.4. Data collected on site.) explains the process of data collection on-site for the two different studied simulations, which are light (4.4.1. Point in time iluminance analysis) an thermal analysis (4.4.2. Thermal analysis). The third subchapter (4.5. Data insertion in software + simulation.) explains the process of inserting the collected data into the software and performance of the simulation, and is also divided into two subchapters (4.5.1. Point in time simulation.) and (4.5.2. Thermal simulation.). Lastly, the sixth subchapter (4.6 Result comparison.) presents the comparison and conclusions of the two analysis results (4.6.1.Daylight factor-monitoring vs simulation) and (4.6.2.Thermal- monitoring vs simulation).

(5)The **fifth chapter** (5. Third Design Phase: Design Variations.) presents the results of a design strategy used to analyse the neighbourhood performance, considering different design variations. The chapter is divided into tree subchapters. The first subchpter (5.1 Context) presents the context. The second subchapter (Design in Dialogue) presents the results of an interaction with the inhabitants of the neibourhood. Lastly the third chapter present different design variation and their analysis (5.3.1. Variation1: Rotation of the north from 129° to 90°, 5.3.2. Variation 2: Rotation of the north from 129° to174°, 5.3.3. Variation 3: Rotation of the north from 129° to 219°, 5.3.4. Variation 4: Removing the outdoor stairs of the unit, 5.3.5. Variation 5: Changing the oppenings, 5.3.6. Variation 6: Sunroom on the third floor, 5.3.7. Variation 7: Removing trees. 5.3.8. Variation 8: Changing the circulation paths.

(6) The **sixth chapter** (Final Considerations) presents the results and conclusions of the whole work, as well as possible design alterations that this research may enable.

(7) The **seventh chapter** (Bibliography) presents all the bibliographies used throughout this dissertation.

(8) The **Annex** presents all the data used in this work and which was not previously presented

1.5. Methodology

Figure 1.5.1. Representative scheme of the various study phases with the aim of demonstrating the work methodology. [4]

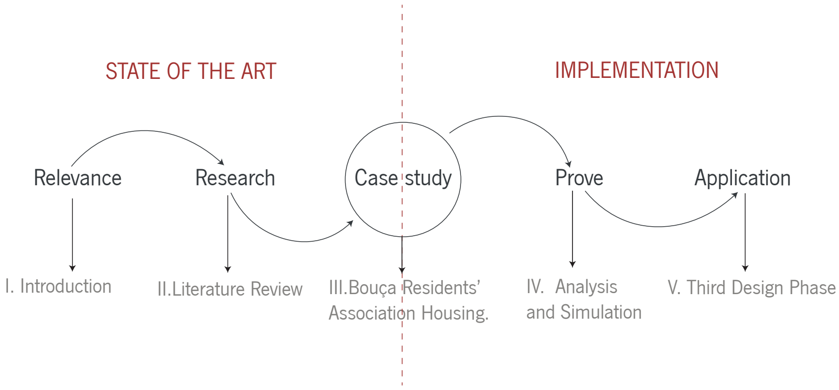


Figure 1.5.1.

The methodology of this dissertation is divided into five main phases which can be divided into two main themes, which are 'state of the art' and 'implementation'.

Under the theme 'state of the art', the first chapter (I. Introduction) starts by presenting the relevance of the investigation themes. In the second chapter (II. Literature Review) the research developed around the main themes are investigated. The third chapter (III. Bouça Residents' Association Housing) unites the two different themes. This chapter ends the first theme by introducing the case study together with its historic and cultural relevance.

The third chapter (III. Bouça Residents' Association Housing) starts with the theme, 'implementation', and continues with the focus on the analysis of the neighbourhood and certain housing units that are needed for further work. The fourth chapter (IV. Analysis and Simulation) presents the methodology used to perform light and thermal analysis to the case study building and proves the veracity of the simulation results obtained using the digital modelling and simulation tools. The fifth chapter (V. Third Design Phase) applies the knowledge accumulated through the investigation to develop different possible design variations for understanding their effects on the thermal and lighting conditions in the Bouça housing units.

2. Literature Review

Figure 2.1. Performance, Comfort, Technology

2.1. Context

Figure 2.1.1. "Comfort for Two" image made by Mike Webb and presented in Archigram 8 (Available online: http://4.bp.blogspot.com/-S-mbcJjZrq4/UMRKx9d9mvI/AAAAAAAAAQw/t0uEgCl1aqc/s1600/546_medium.jpg)

The figure 2.1.1 produced by Archigram architect, Michael Webb in 1963, reflects on the main theme of this dissertation, surrounding comfort. This edition by Archigram 8 revolved around eight terms: metamorphosis, nomad, indeterminacy, hard/soft, emancipation, exchange, response, and comfort, which promoted the debate in architecture about the role of technology, comfort, and adaption. It is also criticism against modernism for its false notion of comfort and 'aesthetic fetish'. [5]

The Cushicle and Suitaloon (1967) was a radical and utopian proposal by architect Michael Webb, who was a member of Archigram. Unlike the rest of the members of Archigram who were interested in infrastructures that could adapt to cities in constant transformation, Michael Webb was interested in scale interventions that would adapt and provide comfort to the needs of human beings.

Michael Webb's notion of comfort challenges the traditional meaning of what comfort means. In his radical utopian design of the Cushicle and Suitaloon comfort is provided by the means of technology which is able to adapt to the needs of humans. This definition of comfort puts the human as the main protagonist, supported by technology. Even though this utopian idea was never realized, it had a great impact and these topics are still relevant today, and the seed of this idea is still present in architecture as performative architecture. [6]

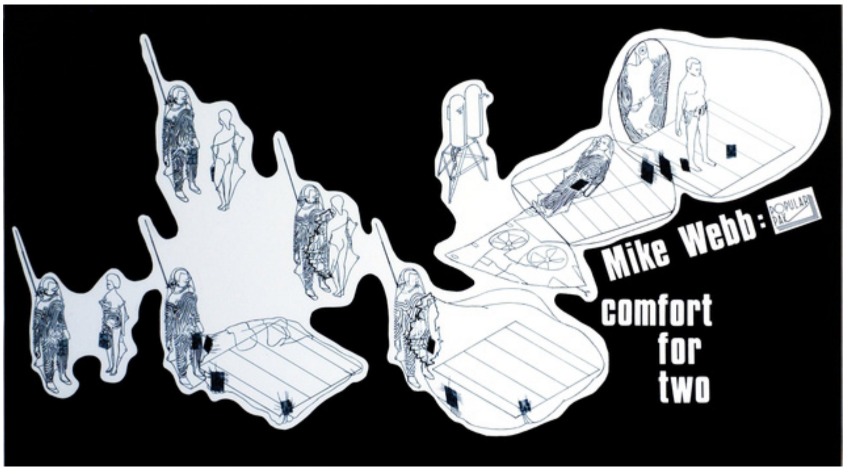


Figure 2.1.1.

Performative Architecture

Performative architecture is an approach to architecture in which the performance of the building is the guiding design principle. The book Performative Architecture beyond instrumentality by Branko Kolarevic (2005) was one of the primary references because performative architecture is one of the primary themes understudies. Different from the traditional interpretation of performance as an evaluative given, Kolarevic brings a more holistic approach to performance.

According to Kolarevic, the performance or behaviour of buildings is as relevant as the quality of their architectural design. A holistic approach to both of these aspects is needed because, according to Kolarevic, pure "technical interpretation of performance will lead to nothing more than an uncritical reaffirmation of old-style functionalist thinking—a kind of thinking that is both reductive and inadequate because it recognises only what it can predict".[1]

The author's perspective on the relationship between performance and the design process also raises and answers some relevant questions during the research process. The author emphasizes the current disconnection between the formal definition of buildings and the thought of their performance. This disconnection raises relevant questions such as: to which level does performance influence the design, and what does performance mean in architecture? Furthermore, the author also challenges the definition of the used parameters by raising the question of which are the most pertinent and whether they can be predicted or not.[1]

Comfort

Regarding the topic of comfort, Joana Amorim (2017), in the academic thesis "Reflections on the concept of comfort in housing," explains the concept of comfort as an abstract concept that is both measurable and unpredictable at the same time. The author discerns in her research that comfort in architecture is based on observation and empirical analysis of measurable concepts such as heat, sound, light, air quality and among others.

In his book 'Sein und Zeit' or Being and Time (1927), philosopher Martin Heidegger points out that existence is spatial with the german term Dasein (being there), which puts human beings inseparable from space because they do not exist as separate entities but coexist.

According to the Joana Amorim, characterizing a space as comfortable is an experience that is intuitive, spontaneous, and subjective. Comfortable spaces make an individual feel secure and good, which is of utmost importance for housing. Therefore, Comfort depends not only on observation and empirical analysis of measurable concepts but also on the subjective experience of human beings. [3]

Algorithm and parameters

In the publication “Methods of graphic object-oriented algorithmic design-On the example of *Ladybug*-App for *Grasshopper* with an energetically efficient design” by Julio Obregón Zepeda (2012), the author emphasizes on the importance of algorithms and parameters in architecture design and the potential of their use in the analysis of building’s performance. He further states, “many possible solutions for the problem could be presented, and the selection among them is part of the design process. Having a structure like an algorithm, which describes how the problem is presented and how it can be solved, is a crucial factor for finding the best possible solution.” [7] His approach to algorithms and parameters, in terms of their definition and integration in the architectural design process, is a point considered essential and a reference for this work.

Climate

Regarding the topic of climate discussed Duma Stouth (2019) in the publication “How to Design for Optimal Thermal Comfort (And Why it Matters)”, it emphasizes the fact that climate is changing. Moreover, it is increasingly essential to analyse the comfort in buildings to ensure comfort for the inhabitant due to global climate change. The author also clarifies the difference between comfort and thermal sensitivity, concepts of great importance for this research. The author brings an additional layer to what comfort means in dwellings by incorporating technology as a medium that makes daily life convenient and thus comfortable.

2.2. Evolution of buildings' thermal comfort regulation

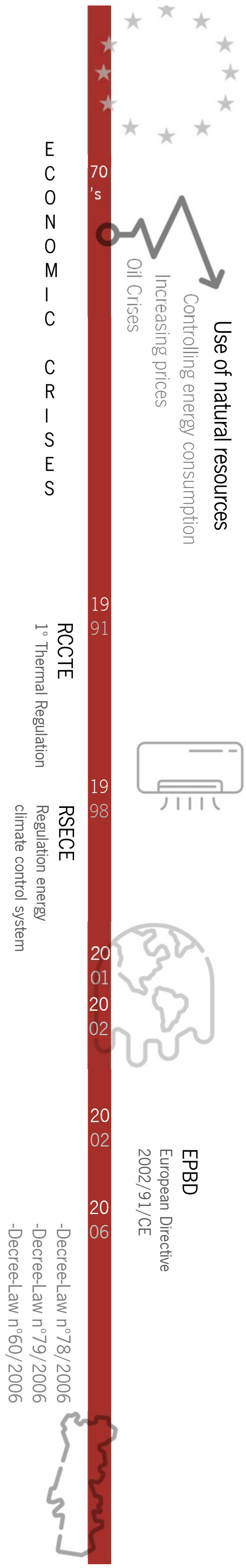


Figure 2.2.1.

People spend about 90% of their lives indoors, such as in their homes, workplaces, transport, or even in commercial spaces, so it is crucial to understand how to provide comfort in these indoor spaces to have a better quality of life. The need for better life quality has led to an exponential increase in the consumption of finite energy resources. The debate around the increasing use of natural resources is getting significant concerns due to the forecast of depletion of these finite natural resources and the worsening of global warming.[8] Europe has a building stock of around 25 billion m2 of functional floor area, of which around 25% is for non-residential use. The construction sector in Europe accounts for around 40% of total energy needs, of which 27% are from residential buildings and 13% are from services buildings. This leads to the construction sector being the most significant energy-consuming of all other sectors. [9]
In comparison to other European Countries, in Portugal, the transport sector contributes to the most extensive use of energy resources, with about 32% of the total energy resources. Followed closely by the construction sector with 30% of the total energy resource, of which 16.7% by domestic sectors and 13.3% by service buildings. Buildings also account for 36% of the total carbon dioxide (CO2) emissions. That is why energy-efficient buildings are vital to the EU's energy efficiency policy. [10]
During the 1970s, Europe consecutively experienced an economic and oil crisis that raised the cost of energy resources. However, the energy crisis led to a moderation of energy consumption. Furthermore, it motivated the population, which was looking for better comfort conditions, to use natural resources adequately by improving the building's energy performance.

In 1991 the first regulation around thermal performance, The RCCTE (Regulation of thermal performance characteristics of buildings), was issued in Portugal. The objective of the regulation was to introduce thermal and energetic aspects to improve comfort conditions without increasing energy consumption. In addition, it introduced specific requirements in the thermal quality of the insulation in the building's envelope. RCCTE was also the first regulation to consider thermal conditions in summer.

In 1998, the regulation of energy systems for air conditioning in buildings

(RSECE) was created. It established limits and restrictions on installing air conditioning systems and using equipment and systems, to control the amount of energy spent for cooling and warming the buildings. However, since most buildings were not adequately isolated, the oscillation in indoor temperature was too big to be comfortable inside, which meant it was too warm in the summer or too cold in the winter.

In 2001/2002, concerns over global warming led to a proposal for a directive on the energy performance of buildings.

Which led to the establishment of the European Directive 2002/91/CE in 2002 to promote the construction of more sustainable buildings. They deal with the growing environmental concerns and increasing regulatory demands, which demand more thermal quality and less energy consumption. This directive establishes a calculation methodology based upon minimum requirements to be met and imposes the issuing of energy certificates to prove the efficiency of energy systems and for effective diagnosis for improvement.

On the 4th of April 2006, by transposition of the European directive 2002/91/CE, three legislative documents were published:

– Decree-Law No.78/2006 (National System of Certification and Indoor Air Quality of Buildings)

Decree-Law No. 79/2006 (Revision of the Regulation of Buildings' Energy Systems for Air-Conditioning)

– Decree-Law No.80/2006 (Revision of the Regulation of Thermal Behavior Characteristics of Buildings)

Implementing these decree-laws sought to cause changes in the construction habits, seeking to contain costs and improve the quality of the indoor environment.

On the 1st of July 2008, the issuing of the Energy certificate became mandatory.

On the 19th of May 2010, the European Directive 2002/94/CE was updated to enhance the energy performance of buildings, taking into account the challenges and targets agreed by the member states for 2020 – 2010/31/UE.

On the 20th of August, Decree-Law No.118/2013 was published, offering improvements in the systematization and application of its standards. It unites the SCE (Energy certification system for buildings), the REH (Regulation on Energy Performance of Residential Buildings) and the RECS (Regulation on the energy performance of commercial and services buildings), harmonizing their terminology and making them easier to interpret.

The European Directive 2010/31/UE published in 2010 was reformed, creating the European Directive 2018/844/UE, which has set the targets

Figure 2.2.1. Timeline representing the Evolution of buildings' thermal comfort regulation. Part 1

Figure 2.2.2. Timeline representing the Evolution of buildings' thermal comfort regulation. Part 2

for 2030 to further reduce greenhouse gas emissions by 40% compared to 1990 and to increase the percentage of renewable energy consumption.

In 2020, Decree-Law No. 101-D/2020 established the requirements for improving the building's energy performance by regulating the energy certification system for buildings.

In 2021, Decree-Law No. 102/2021 established the requirements for access and exercise of the activity of the technicians of the system of energy certification of buildings. [11]

Europe and several other countries continue to make an effort to promote energy-efficient buildings, not only to provide a better indoor environment but also to use finite energy resources more resourcefully. This is because the building construction sector is one of the biggest consumers of energy resources. The sector accounts for 40% of total energy consumption in Europe.[9] The European Directive and the Decree-Law are the direct results of this energy problem, which has a direct effect on global warming and climate change.

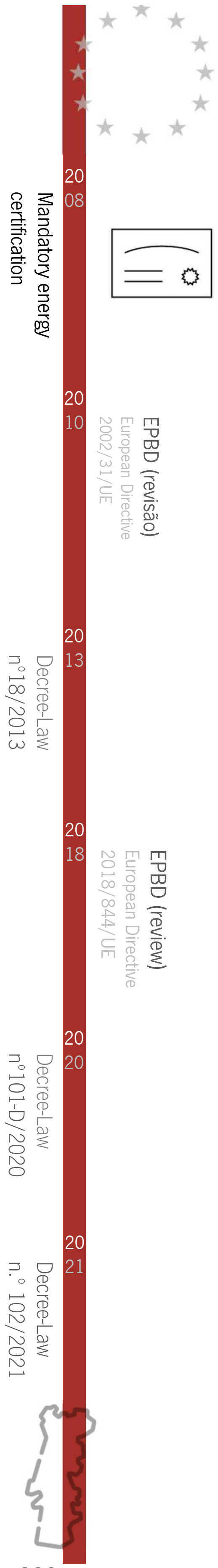


Figure 2.2.2.

2.3. Daylight in the context of the National System of Certification and Indoor Air Quality of Buildings

Lighting is a basic human need which determines the quality of the interior environment in the buildings. Therefore, optimal lighting can contribute to the well-being and efficiency of daily tasks.

In Portugal, the need to rationalize energy consumption in buildings has led to regulations that have imposed limits on nominal consumption, thus contributing to an increase in energy efficiency in buildings.

As previously mentioned, in 2006, the National System for Energy and Indoor Air Quality Certification of Buildings in Portugal was approved through Decree-Law no. 78/2006.

The requirements imposed by this decree-law aim to reduce energy consumption, both related to heating and cooling of buildings.

There are two forms of lighting in buildings: natural and artificial. Both of them provide ambient lighting, and specific lighting focused on visual tasks. The articulation between artificial and natural light is essential to achieve energy efficiency. In recent years, the use of daylight has been increasing as a direct response to energy crises, growing concern about the environmental impacts and increasing awareness of the physical and psychological benefits in human health. These trends have led to the need for a reduction in energy consumption in buildings and an increase in the quality of the indoor environment.

The key to reducing the amount of energy consumption by lighting is by taking greater advantage of natural lighting and introducing measurements to control artificial lighting. Simple measurements like reducing the amount of artificial light or even turning it off depending on the amount of natural light coming inside the building can help reduce the total amount of energy consumption in buildings. The light analysis will be an important part of this research, because of its importance for the building's comfort and functional performance.

Several techniques have been used in the past to study light during the design process of a project, including making maquettes and predicting the light in sections. Over time and with the evolution of technology, simulation software allowed architects and engineers to simulate different performance concepts like lighting.

2.4. Advantages of computational design tools for building comfort analysis and simulation

Designing a building is a multidisciplinary process which unites different fields of expertise. In this process, the various areas involved try to bring the best of their knowledge to create a coherent and functional project. That means not only taking into account architectural design but also structure, urban planning, lighting, thermal and acoustic comfort, and others.

Sometimes, the aesthetic aspect of architecture is overvalued compared to its functional behaviour. The lack of balance between these two aspects makes architects think of these two aspects as dependent and sequential, instead of simultaneously. As a result, it can lead to buildings that fall short in their technical aspects and are only aesthetically well-developed. Even if an architect does not have complete knowledge of the different fields mentioned above, they must have a basic understanding of the different expertise that are involved in building processes. This broad understanding of different fields ensures that technical aspects of behaviour and comfort are also considered during the preliminary design phases. However, if this is not the case, the developed projects might need later more interventions by specialists. The use of digital models for evaluating thermal, lighting, energy consumption, and other functional behaviour of the project, are valuable tools to guarantee the comfort and efficiency of the buildings.

When talking about comfort simulation models, we refer to different algorithms that simulate energy balances and heat transfers between spaces through surfaces. Using this type of quantitative and qualitative performance-based simulation model allows architects to quickly understand the expected behaviour of the designed rooms and the built environment without having to build the element first to be analysed later. They also blur the classical distinction between architects and engineers and promote digital collaboration between the two by blurring the distinction between geometry and analysis, appearance and performance. [1]

This type of software enables quick analysis of a building using a computer-generated 3D model to modify its elements and improve the results quickly. The first step of the simulation is creating a computer-generated 3D model and inserting the building data into the software like the composition of the different building elements, hot water schedules, and ventilation rate, among others. The next step is to relate an EPW file in the software, which gives the climate data of the location where the project is situated. The simulation uses the climate data from the EPW file to simulate the building's behaviour in that particular location. After the simulation, the given results are used for analysis and drawing conclusions to make a set of design decisions. The architects and the engineers can thus work together and iteratively to develop the optimal design solutions.

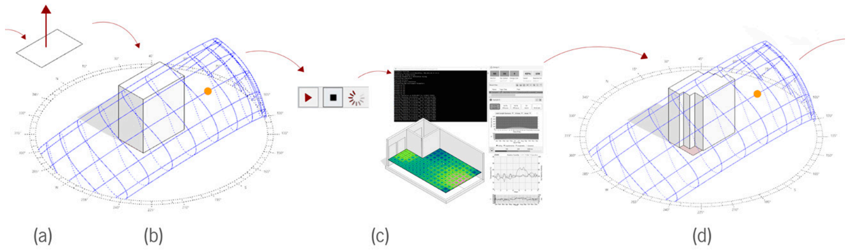


Figure 2.4.1.

Figure 2.4.1 Scheme representing the design and simulation process; (a) creation of a 3D computer model and insertion of the building data; (b) Running the simulation considering an EPW file; (c) analyses of the results and take conclusions; (d) improve the model and repeat.

Figure 2.4.2 Timeline representing the evolution of comfort simulation software-Part1.

The timeline presented on Figure 2.4.2 and Figure 2.4.3 represents the emergence of different simulation tools of simulation software over the years. Using the timeline as a reference, the different software, their objectives, and the difficulties and benefits encountered in their use will be described.

DOE-2

DOE-2 simulation software was introduced in the late 1970s and is still being used today. It is a free software and contains several features. It uses building layout, construction methods, operating hours, lighting data and schedules, HVAC systems, weather data, and utility tariffs to predict energy use and costs for any building.

This software is custom-made for its use in the United States. It uses a computer-generated 3D model for analysis similar to other simulation software. However, there is a long learning curve due to its rigid interface and data analysis using only graphs and numbers. The results get presented in numbers, and the user must manually name them to create graphs and interpret them for better results. In general, the basic concepts of this software are difficult to understand and use. [12]

ESP-r

The *ESP-r* software was developed in 1974 to simulate the natural conditions in buildings, such as their performance in energy consumption, the comfort of the inhabitants and air quality and control systems.

If compared to *DOE-2*, it has a more dynamic interface. However, prior knowledge of code language is necessary to use the software because of its extensive code base to, for example, add additional material to the database.

The software provides a list of relevant data related to the simulations and

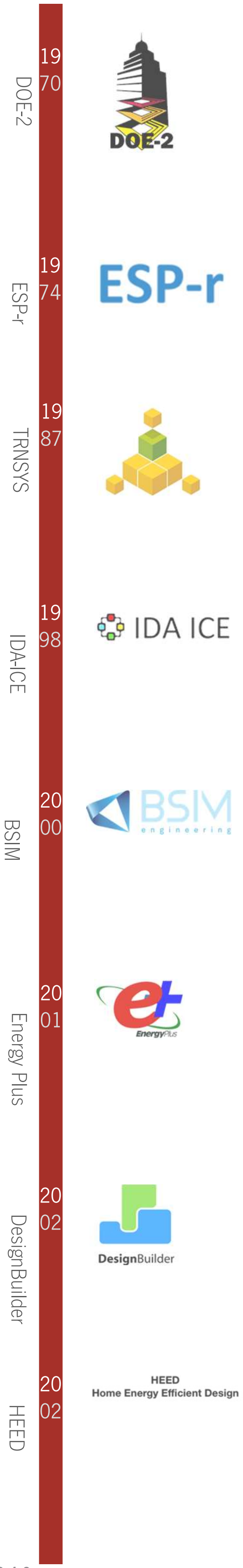


Figure 2.4.2.

graphs after doing the simulation. However, for those who do not have prior knowledge of code language, this data is hard to comprehend.[12]

TRNSYS

TRNSYS was created in 1987 and is used to simulate the behaviour of transient systems. While the vast majority of simulations are focused on assessing the performance of thermal and electrical energy systems, *TRNSYS* can also be used to model other dynamic systems such as traffic flow or biological processes.

"*TRNSYS* is made up of two parts. The first is an engine (called the kernel) that reads and processes the input file, iteratively solves the system, determines convergence, and plots system variables. The kernel also provides utilities that (among other things) determine thermophysical properties, invert matrices, perform linear regressions, and interpolate external data files. The second part of *TRNSYS* is an extensive library of components, each of which models the performance of one part of the system. The standard library includes approximately 150 models. Including pumps, multizone buildings, wind turbines to electrolysers, weather data processors and basic HVAC equipment. Models are constructed so that users can modify existing components or write their own, extending the environment's capabilities." [13]

The software has a graphic interface that allows users to create a complex system more efficiently by connecting different components. However, users require prior knowledge of Frontranto to be able to add new elements to the library.[12]

IDA-ICE

IDA-ICE was released for the first time in 1998, enabling building analysis as simulation and calculations of energy consumption, light conditions, humidity transfer, natural ventilation calculation and electrical reduction from integrated photovoltaic systems. To use this *IDA-ICE*, it is necessary to know the buildings' thermal behaviour and their constructive method.

Although the software can realize multiple types of analysis, it is limited to one simulation at a time. [12,13]

Bsim

Bsim was created in 2000 and is a tool for simulation and calculating energy consumption, daylight conditions, humidity transport, natural ventilation calculation, and electrical production of integrated photovoltaic systems. Before using the software, it is necessary to know in detail about the design of the building and how the building behaves thermally.

The user can define the parameters to be calculated to output on an hourly basis, in tabular or graphical form. The variables are presented in graphs or tables, and the results are exported to Excel. However, unlike other software, BSIM does not allow multiple simultaneous simulations at a time. [11,14]

Figure 2.4.3 Timeline representing the evolution of comfort simulation software-Part2.

Energy Plus

EnergyPlus was developed as software that provided integrated solutions that included not only the calculation of thermal loads but also a more detailed study of the impact of HVAC systems on the total energy consumption of the building.

The software was released in 2001 and allowed for performance analyses with intervals of less than half an hour.

It simulates in modules air conditioning based on multizone airflow and photovoltaic systems. Using it requires basic knowledge of physics and building material properties. It does not yet have a graphical user interface, and the results are in text form. Therefore, it is used combined with other software like Design-Builder, Open Studio, *Ladybug*, *Climate Studio* and others for importing and exporting data.[11,15]

Design Builder

The software was released in 2002 and assists in integrating mechanical systems into architectural design.

It works as an Energy plus interface, facilitating geometries and enabling the insertion of cad files. It is also possible to alter the cad model and simultaneously perform multiple simulations of several models.

The software allows for quick evaluation and various design scenarios for components like HVAC systems and controls, facades, lighting and renewable technologies.

One of the advantages of this open-source software is that the data is obtained directly in graphs and coloured grids, making it easy for users to read. Additionally, modifying the inputs and outputs is possible in Python and C#. [11,16]

HEED

HEED is an interactive and easy-to-use energy design tool that lets users simulate different design options for their houses to make them more energy-efficient and save money. Heed starts by creating a standard house that meets California's Energy Code. After that, Heed can make up to nine design variations that are at least 30% more energy efficient than the traditional house. *HEED* can thus suggest users different options to make a building more energy-efficient.

The user interface of Heed is very intuitive to understand. Users can draw the floor plan in the software and drag and drop different elements like trees, doors, windows, photovoltaic panels, solar hot water collectors, and others. There is a very high level of flexibility because users can input custom construction detail or standard wall and roof construction details. Heed lets users add passive heating and cooling solutions like ventilation, evaporative cooling, and passive solar heating. Users also have the option to download climate data for their location. *HEED* simulation can let users know how close their building is to Zero Net Energy and display other

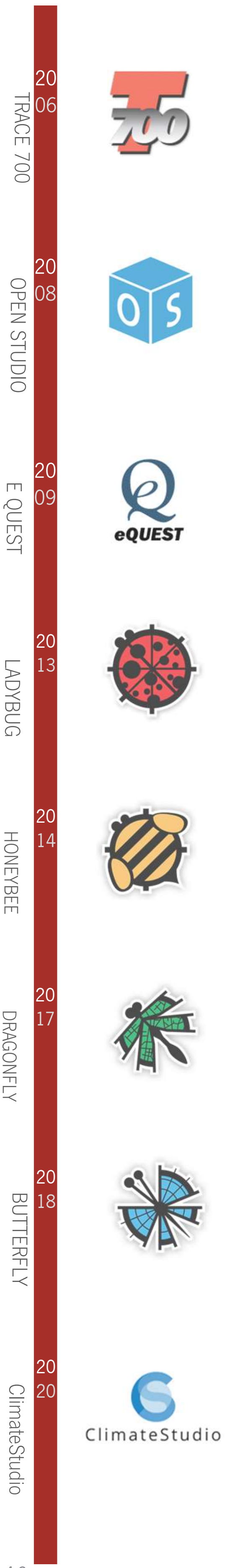


Figure 2.4.3.

building energy performance data. Heed offers users more detailed data input options and output display graphics from the original Solar-5. [11,17]

TRACE 700

TRACE 700 —Trane air conditioning economics— is a thermal load calculation program that was created in 2006 for HVAC designers. The software allows the HVAC designers to estimate the maximum loads of a building and the zones where these loads occur within the building to optimize and reduce costs during the design stages. [11,18]

EQuest

The software was released in 2009 with interactive graphics, patterns, parametric analysis and other features that let users perform analysis at various project stages.
The results are in graphs, and a summary of results is generated either from a single simulation or multiple simultaneous simulations and parametric tabular reports. Unfortunately, the simulation results are obtained hourly, and it is impossible to customize some simulation parameters. [11,19]

Ladybug

Ladybug was created in 2013 and is built on several validated simulation engines: Radiance, *EnergyPlus*/ *OpenStudio*, Therm/ Window and *OpenFOAM*.
"*Ladybug* runs within 3D modelling software and allows data transfer between its simulation engines. So all geometry creation, simulation, and visualisation happen within one interface and parametric visual." [20]
The parametric visual interface of *Ladybug* allows it to be used in different stages of design, producing results in interactive 3D graphics, animations, and data visualizations, making it easy to understand and compare.
The software is written in Python, meaning it can run on virtually any operating system and be plugged into any geometry engine. It can also perform a detailed analysis of climate data to produce customized, interactive visualizations for environmentally-informed design. Importing standard *EnergyPlus* Weather files (.EPW) into *Grasshopper* provides a variety of 2D and 3D interactive climate graphics that support decision-making during the preliminary design phase. It also supports the evaluation of initial design options through solar radiation studies, view analyses, sunlight-hours modelling, and more.
Using *Ladybug*, the users can: "produce (...) solar diagrams; understand where the sun is shining; make real-time animations (...) at different times of the day; find buildable volumes to maintain solar access; quickly quantify solar energy falling on (...) geometry; measure the visual connection to the outdoors; customize (...) thermal comfort graphics; evaluate the thermal comfort of passive designs; account for sky heat exchange (...); model radiant asymmetry, down draft discomfort; visualize

the regions of a shade that are most are helpful and harmful to thermal comfort and see the portions of the sky blocked by shades and context." [21]

Honeybee

Honeybee was released in 2014 and creates, runs, and visualizes daylight simulations using Radiance and energy models using *OpenStudio* and *EnergyPlus*. *Honeybee* runs by linking the *Grasshopper*/Rhino CAD.

Honeybee allows for analyses such as "Illuminance Studies, Annual Daylight Studies, Annual Sun Exposure, Glare Analysis, Advanced Solar Radiation, Electric Light Controls, Heating and Cooling Energy Use, HVAC Sizing, HVAC systems, Color Zones with Energy Model Results, Energy Balance Visualizations, Indoor Thermal Comfort, Microclimate Mapping, Passive Strategy Modeling and HVAC Strategy Modeling".[5] This type of analysis (HAVAC and Energy Zones and Balances) tends to be most relevant at the mid and later stages of design because the projects need to be more refined for proper data input to ensure more accurate results. [22]

Dragonfly

Dragonfly is a grasshopper plugin created in 2017 that enables the creation of district-scale models for energy simulation with URBANopt, electrical infrastructure simulation with OpenDSS, renewables optimization with REopt, and urban heat island modelling with the Urban Weather Generator (UWG).

"*Dragonfly* models can be translated directly into detailed 3D *Honeybee* models but can also be simulated directly in various engines. "[23] Energy simulations of *Dragonfly* models can be run with the URBANopt SDK, which leverages *OpenStudio* and *EnergyPlus*. Energy simulation results can be used to simulate loads on electrical infrastructure with OpenDSS and "can be incorporated into the cost-optimisation of renewables with REopt. Lastly, any dragonfly model can be used to morph rural EPW files to account for the urban heat island effect using the Urban Weather Generator (UWG)." [23]

Using *Dragonfly* enables the user to: "simulate annual energy usage across entire urban districts and color geometry with heating and cooling intensity; understand opportunities for new district thermal systems that capitalise on the simultaneous need for heating and cooling across a district; model peak loads across an entire district to understand the factors driving the need for heating and equipment; model demand-response strategies over districts to understand their efficacy in reducing peak loads; model the loading of transformers and power lines to understand impacts of electrification scenarios; model the impact of building retrofits on the need for electrical infrastructure to appropriately set up incentives; perform cost-optimisations for investment in photovoltaics and battery storage across a district using the Multiple Creation Pathways and construct district models from several source geometries (including detailed floor plans, solid building massing and building footprints)". [23]

Butterfly

Butterfly is a *Grasshopper*/Dynamo plugin that uses a python library to create and run advanced computational fluid dynamic (CFD) simulations using *OpenFOAM*. "At the present time, *OpenFOAM* is (...) an open-source CFD engine in existence and is capable of running several advanced simulations and turbulence models (from simple RAS to intensive LES)." [24]

Butterfly was released in 2018 to build and quickly export geometry to *OpenFOAM* and run numerous common types of airflow simulations applicable to building design. It includes outdoor simulations to model urban wind patterns and indoor buoyancy-driven simulations to model thermal comfort and ventilation effectiveness. It also: "simulates indoor wind-driven airflow to assess ventilation effectiveness; models outdoor wind patterns in urban settings and buoyancy-driven airflows from chimneys; atria and other common stack phenomena; and uses *Butterfly* with *Ladybug* and *Honeybee* to perform high-resolution indoor thermal comfort analysis that accounts for local air temperature and speed." If *Butterfly* is used" together with *Ladybug* and *Honeybee*, it generates a spatial map of outdoor thermal comfort". [24]

Climate Studio

Climate Studio is an environmental performance analysis software presented to the public in 2020 for Architecture, Engineering, and Construction (AEC) sector. It is a plugin for Rhinoceros 3D that also works with *Grasshopper*. *Grasshopper* extends the functionality of *Climate Studio* by adding more commands and capabilities.

"Its simulation workflows help designers and consultants optimize buildings for energy efficiency, daylight access, electric lighting performance, visual and thermal comfort, and other measures of occupant health." [25]

Architects can use the software to create buildings where comfort is as important as the design. It allows architects to obtain better results in terms of comfort and to adapt the shape of the building to an optimal architectural and comfort/functional solution.

This plugin allows a quick and precise evaluation of the environmental performance of both buildings and urban areas through various features such as sun path analysis and shadow studies, radiation maps, photorealistic renderings, climate-based daylighting metrics, annual and individual time step glare analysis, LEED and CHPS daylighting compliance, single thermal zone energy and load calculations, spatial thermal comfort study, advanced natural ventilation, renewable energy study, carbon calculator, parametric evaluation linking with geometries created in *Grasshopper*. [25]

Table 2.4.1. Comparation of the performance of the software in different project stages and analysis objectives. [11]

The table 2.4.1 compares the application and analysis objectives of the different software mentioned above. The table is divided into two main parts. The first one compares the application of the software in different design phases: conceptual, preliminary, detailed and management. The second part of the table presents the software and its applications for different analyses like energy, thermal, daylight, HVAC systems and airflow. Finally, it also presents whether the software is open source or not and if it is available online.

From this research, a conclusion can be drawn that the performance simulations were introduced when the concerns with the environmental impacts started emerging in the world. Together with regulations, they are meant to improve the performance of the building, but the hard interface of this software, and the hard-to-read results data, require specialists to work with it.

As the technology was developed further, the software was improved, making them easier to use and understand the results.

Simulation software has come a long way since the first simulation software was introduced. The advances in technology and the different scientific research in optimizing the building design have led to simulation software like the *Climate Studio*. The current simulation software is based upon the research that was done using algorithms to determine optimum building shape, orientation, wall and roof constructions, window type, window area, foundation, infiltration rate, insulation thickness, and shading of residential buildings.[26]

As a result, simulation software like *Climate Studio* is now more intuitive and easy to use for all the different design stages. Unlike past software, *Climate Studio* can be used even in the conceptual design phase and the further stages of a project.

	PROJECT STAGES				ANALYSIS OBJECTIVES						
Software	Conceptual	Preliminary	Detailed	Management	Energy	Thermal	Natural Light	HVAC System	Alrflow	Open Source	Available Online
DOE-2		○			○						○
ESP-r		○		○	○			○		○	○
TRNSYS			○		○	○				○	
IDA-ICE		○	○		○	○	○	○		○	
Bsim		○	○		○		○	○			
Energy Plus		○		○		○		○		○	○
DesignBuilder		○	○		○	○	○	○			○
HEED		○	○		○	○		○			○
Trace 700			○		○	○		○			
Open Studio		○	○	○	○	○	○	○		○	○
EQuest		○			○					○	○
Ladybug	○	○		○	○		○			○	○
Honeybee	○	○		○	○		○	○	○	○	○
Dragonfly				○		○				○	○
Butterfly		○	○					○	○	○	○
DIVA		○									
ClimateStudio	○	○		○	○		○		○		○

Table 2.4.1.

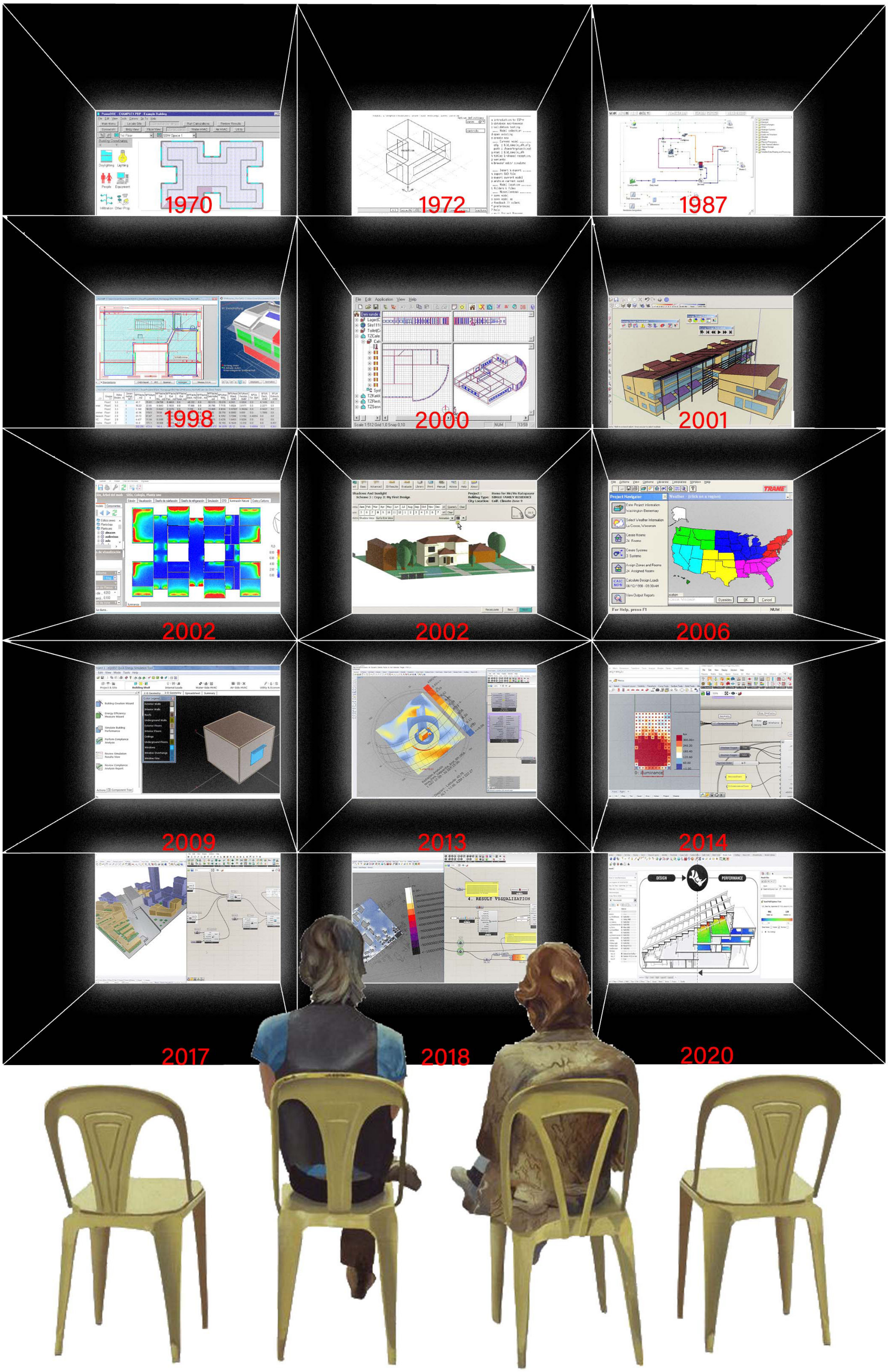


Figure 2.4.4. Representation of the emergence of different simulation tools.

3. Case study- Bouça Residents' Association Housing

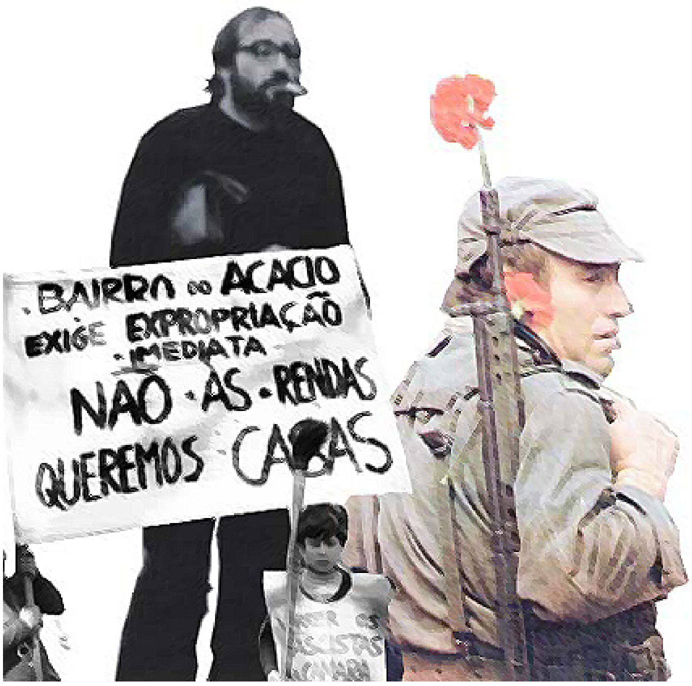


Figure 3.1.Carnation Revolution, SAAL Project, Bouça Residents' Association Housing

3.1 Context

Figure 3.1.1. Schemes of 'Ilhas' Composition

The case study presented in this investigation project departs from the Bouça Residents' Association Housing, a paradigmatic result of the SAAL – Serviço de Apoio Ambulatório Local–, established in August 1974 after the revolution that ended the dictatorship in Portugal on the 25th of April 1974. SAAL was an experimental housing project proposed by the architect Nuno Portas, at that time a member of the government, to provide better housing conditions to poor urban communities and neighbourhoods with insalubrious housing conditions. In Porto an 'Ilha' is a type of low-income housing development built inside city blocks from the mid-nineteenth century onwards and which still exists today. As an island is surrounded by the sea, an 'Ilha' is surrounded by other constructions using the backyards of middle-class houses. The contact to the street is usually granted through a small passage, sometimes tunnel shaped. Before the revolution, about 25% of the population in continental Portugal lived below living standards, and there was a shortfall of about 600,000 dwellings in the county. [27]

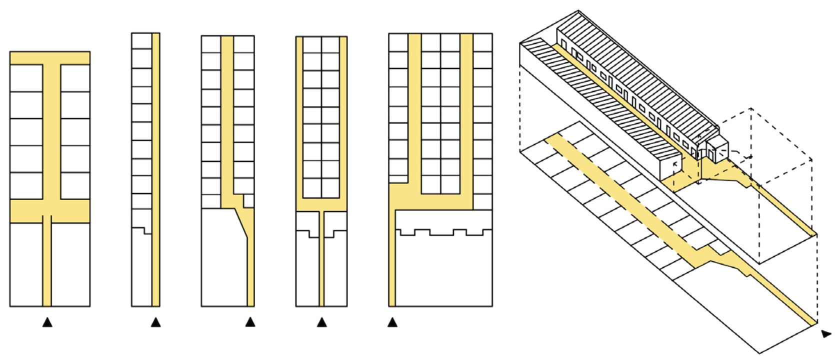


Figure 3.1.1.

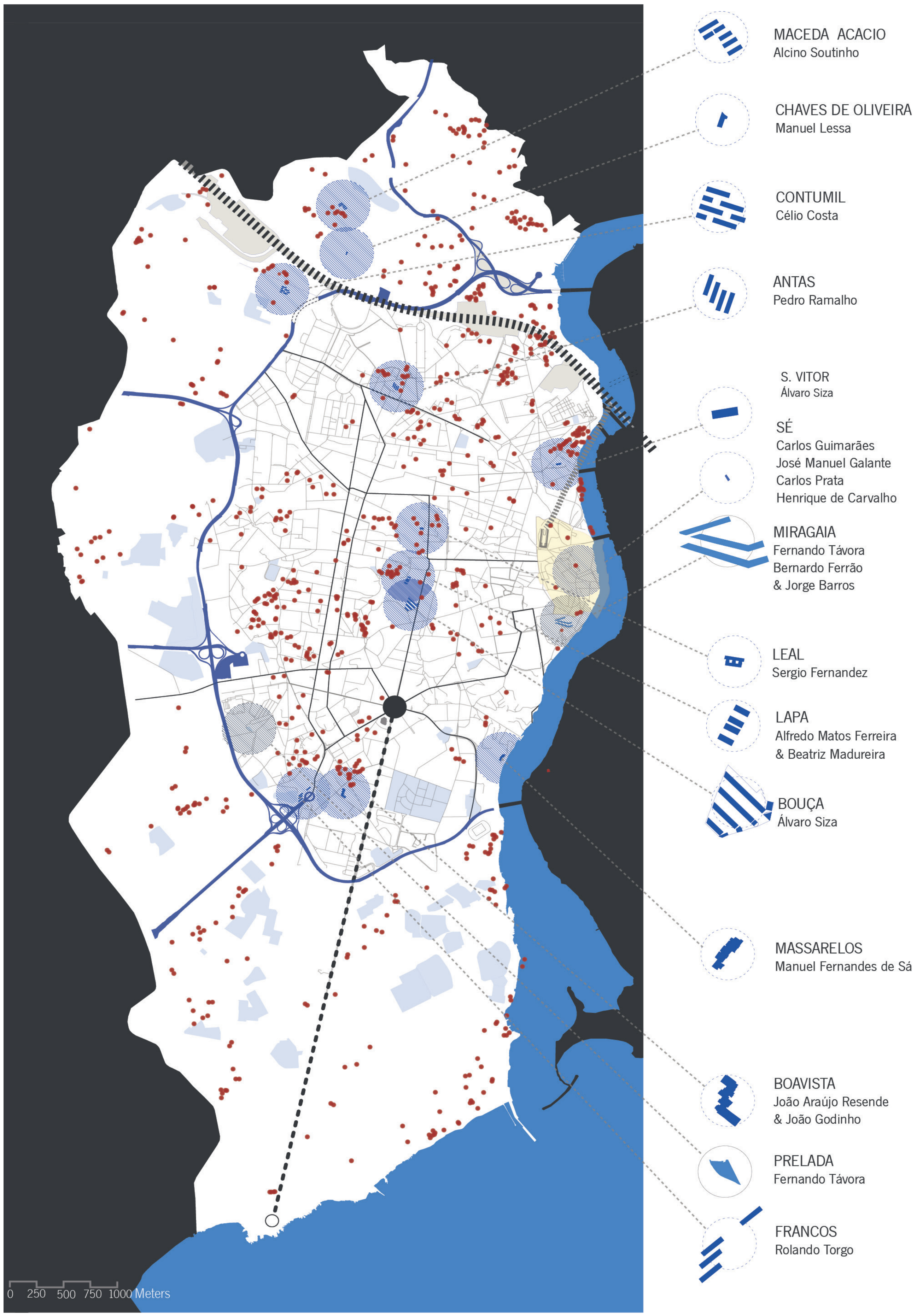
SAAL was initially created to respond to the high need for affordable housing for the low-income population. SAAL, together with the FFH —Fundo de Fomento da Habitação- Housing Promotion Fund—, was intended as a support organisation helping the poorly housed population to collaborate in the transformation of their neighbourhoods by investing their resources and even their monetary resources. There was a strong sense of collaboration between the SAAL and the residents regarding the neighbourhood's transformation because the initiative was partly given to the people organized in the association of the residents. [28]

"Their attitude was sometimes authoritarian, they denied all awareness of the architect's problems, they imposed their way of seeing and conceiving things. The dialogue was very contentious.(...) To enter the real process of participation meant to accept the conflicts and not to hide them, but on contrary to elaborate them. These exchanges then become very rich, although hard and often difficult. (Siza, cited by Frampton, 2016)" [29]

The Bouça project by Álvaro Siza marks a crucial turning point in the social housing experiment after the revolution. The FFH appointed Siza in 1973 as the head architect for a group of social houses, Bouça was one of them. Located on a plot between Rua da Boavista, Rua das Águas Férreas and Rua do Melo. The project was realized under SAAL operation and the supervision of architect Álvaro Siza and the brigades. The SAAL brigades were a group of architects who were responsible for the different neighbourhoods operations . Bouça SAAL brigades were composed by the architects Anni Gunther Nonell, Sérgio Gamelas and Maria José Abrunhosa de Castro.They were also in direct contact with the people that the Bouça social housing project would serve. This close collaboration with the future inhabitants and also with the funding partners separates Bouça from other SAAL operations. SAAL was also different from the previous government housing initiative for the low-income population, like the 1969 intervention in the historic centre of Ribeira Barredo, where the population was removed from the city centre to a neighbourhood on the outskirts of the city. [28]

The map shown in Figure 3.1.2 represents the existent 'ilhas' and the neighbourhoods created to relocate the inhabitants of the 'ilhas'. The other social housing neighbourhoods, except SAAL, were reallocated from the centre of Porto to the peripheries of the city. The neighbourhood project by SAAL was the only social housing project that remained near to the original location of where the ilha's were situated.

Figure 3.1.2. Map comparing Porto's 'Ilhas' and social neighbourhoods, emphasising the social neighbourhoods created by the SAAL Project



MACEDA ACACIO
Alcino Soutinho
CHAVES DE OLIVEIRA
Manuel Lessa
CONTUMIL
Célio Costa
ANTAS
Pedro Ramalho
S. VITOR
Álvaro Siza
SÉ
Carlos Guimarães
José Manuel Galante
Carlos Prata
Henrique de Carvalho
MIRAGAIA
Fernando Távora
Bernardo Ferrão
& Jorge Barros
LEAL
Sergio Fernandez
LAPA
Alfredo Matos Ferreira
& Beatriz Madureira
BOUÇA
Álvaro Siza
MASSARELOS
Manuel Fernandes de Sá
BOAVISTA
João Araújo Resende
& João Godinho
PRELADA
Fernando Távora
FRANCOS
Rolando Torgo
0 250 500 750 1000 Meters

Figure 3.1.2.

3.2. Photo Essay


Figure 3.2.1. Photograph taken in Bouça neighbourhood. Focus on the outer stairs.


Figure 3.2.2. Photograph taken in Bouça neighbourhood. Focused on the ground floor passage.


Figure 3.2.3. Photograph taken in Bouça neighbourhood. Facade 1.


Figure 3.2.4. Photograph taken in Bouça neighbourhood. Middle outdoor area, focus on the circulation path.

Figure 3.2.5. Photograph taken in Bouça neighbourhood. Facade 2.

Figure 3.2.6. Photograph taken in Bouça neighbourhood. Focus in the exterior circulation stairs.

Figure 3.2.7. Photograph taken in Bouça neighbourhood. Circulation concrete wall.


Figure 3.2.8.Photograph taken in Bouça neighbourhood. Passage though the concrete wall on the ground floor.


Figure 3.2.9.Photograph taken in Bouça neighbourhood. Passage though the concrete wall on the third floor.

Figure 3.2.10. Photograph taken in Bouça neighbourhood. Focus in the exterior circulation passage and stairs.


Figure 3.2.11. Photograph taken in Bouça neighbourhood. Focus in the exterior circulation stairs-2.

Figure 3.2.12. Photograph taken in Bouça neighbourhood. Outdoor area.

3.3. The different phases

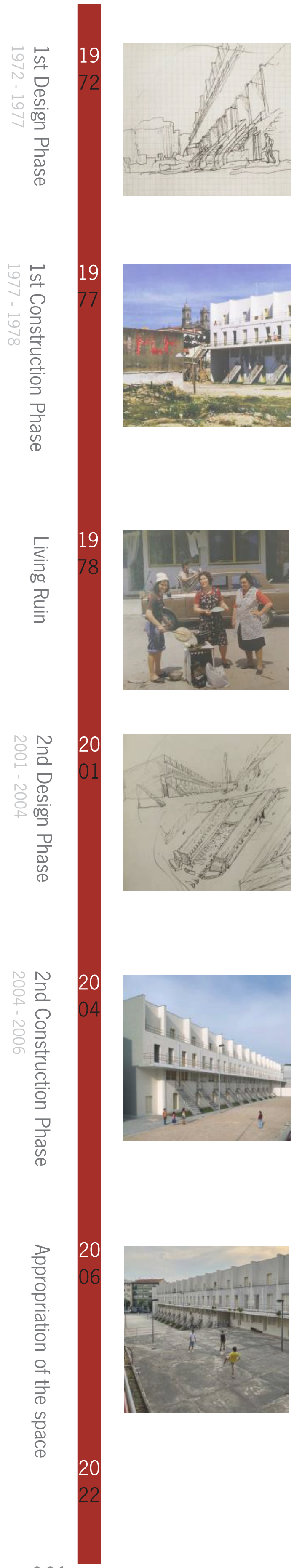


Figure 3.3.1.

Bouça Residents' Association Housing project process can be roughly divided into 5 different phases, presented in Figure 3.1.1 two related to design, another two related to construction and one in the middle related to the appropriation of space. [33]

3.2.1 First Design Phase

The first design phase occurred between 1972 and 1977 when there was still no regulation in Portugal regarding thermal comfort in the buildings. During this period of time, Álvaro Siza Vieira designed almost all the time in collaboration with the Bouça Association of Inhabitants. Together, they redefined and adjusted the design that Siza already had created for the more affluent population on that given site.

The building is located in the city centre of Porto, near an old railway line. To separate the dwellings from the railway, a wall was erected in the design. The wall, in combination with the socio-economic context of the future inhabitants, provided the basis for the design of the project. The project consists of row houses that are arranged in four strips. The open spaces between the strips connect, on one side, to the street and are confined by the concrete wall blocking the train noise on the other side. The layout of the open spaces can be related to the layout of the "ilhas" corridor. [28, 34, 35]

3.2.2 First Construction Phase

The first construction phase lasted from 1977 until 1978. During that construction period, two parts of C and D strips were built. In total, 56 housing units out of 128 units were built.

The construction was interrupted due to the political shift to the right within the military, which had hitherto supported the SAAL operation. This change abruptly ended the dream of town planning in collaboration with the affected population. The projects were deliberately left incomplete to demonstrate the incompetence of the left wind brigades. In October 1976 the control of the SAAL operations was entrusted to the municipalities, leading to a stop to all the projects that were under construction. [28, 34, 35]

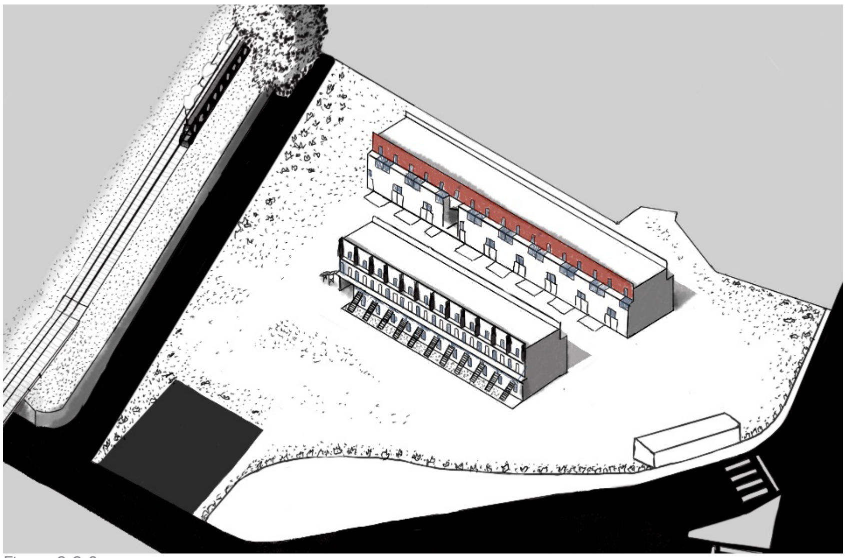


Figure 3.3.2.

Figure 3.3.1. Timeline representing the different phases of Bouça Residents' Association Housign.

Figure 3.3.2. Representation of the site after the first construction phase.

Figure 3.3.3. Representation of the site after the secound construction phase.

3.2.3 Living ruin

For 30 years, the project stayed the same just the two parts of strips C and D were built, surrounded by empty land. The unfinished buildings were appropriated to the needs of the inhabitants. A wood stair to reach the third floor to enter the top apartments and as time passed, the inhabitants changed the inner and outer parts of the buildings to fulfil their needs. The inhabitants made changes like adding doors, windows, and shading and fenced the front gardens to grow trees and vegetables.
In the interior, furnitures were added and also removed from the interior spaces and some spaces were even fully renovated.
During these thirty years, the society rapidly changed, and climate change got more concerns from both the public and government in Europe specially. Which meant that the dwellings didn't comply with the contemporary norms and standards regarding energy consumption in buildings and the quality of the indoor environment. Although, when the second design phase started, exceptions were made to preserve and to celebrate the original design concept. [28, 34, 35]

3.2.4 Second Design Phase

The second design phase started around 2001 and lasted until 2004. During this time, the decision was made to complete the whole project. Siza remained the head architect, and the project was further developed with the change in the context and also the inhabitants living. He redesigned the project with the Bouça Association of Inhabitants for the second phase. In his original design from the 1970s. Siza did not foresee the advent of cars and the population change because it was not asked for and necessary at that time.
Small changes were made in the design of the new and old building blocks according to the needs of the inhabitants, which had changed over the years. The design followed the original design scheme from the

1970s. New in the second design phase was the addition of underground parking and a storage level. The structure of the parking is organized in an eight meters grid which was different to that of the housing units, with a four meters structural grid.
There were some minor changes in the housing plans and to the exterior, made by the inhabitants in the 30 years period between the two construction phases. The changes like front garden fences, alternative window frames, planting in the front gardens, the wooden stairs, among others, were removed in the second construction phase in order to maintain a uniform image of the neighbourhood and to be coherent to the initial design.
Regarding thermal comfort, the exterior of the façade was finished with an outer coating of ETICS – External Thermal Insulation Composite System – composed by plastic plaster, with the respective (fibreglass) reinforcing mesh, and thermal insulation of expanded polystyrene. An exception was made when it comes to complying with the standards because of the notoriety of Bouça and Álvaro Siza in the national and international architectural scene. "The newly designed buildings maintain an identical solution consisting of prefabricated slabs with pre-stressed beams resting on mixed masonry brick walls and solid reinforced concrete pillars." [28]
One of the components of the building that Siza decided to keep but could be changed was the concrete wall because the train railway that was there before had become a metro station, a lot more silent than the train. [28, 34, 35]

3.2.5 Second Construction Phase

From 2004 to 2006, the second construction phase took place, and the neighbourhood was finally finished. The stripes A and B were constructed from scratch together with the car parking, and the four pavilions, adding 72 housing units to the neighbourhood with outdoor semipublic space with trees and gardens.

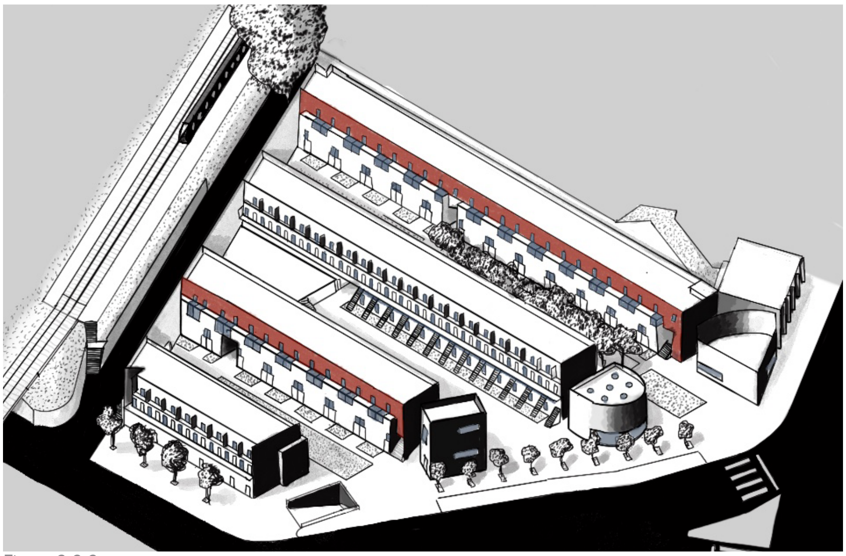


Figure 3.3.3.

3.4. Prevail territory analysis

In order to understand the climate condition of the existing territory, a sun and wind analysis was made.

In the Figure 3.4.1., the sun path represents the Summer Solstice. The solstice is the moment when the Sun, during its apparent movement on the celestial sphere, reaches its greatest declination in latitude, measured from the equator. Twice a year, the solstices occur: in June and in December. The exact day and time vary each year. When it occurs in summer, it means that the day length is the longest of the year. Similarly, when it occurs in winter, it means that the length of the night is the longest of the year.

When the sun is at its highest point of the day, the southwest corner of the Bouça neighbourhood receives the highest amount of sun rays. This means that in the morning the eastern façades receive more solar radiation and in the afternoon the western façades receive more solar radiation. The image also demonstrates the prevailing annual wind directions, which is Northwest, East and South.

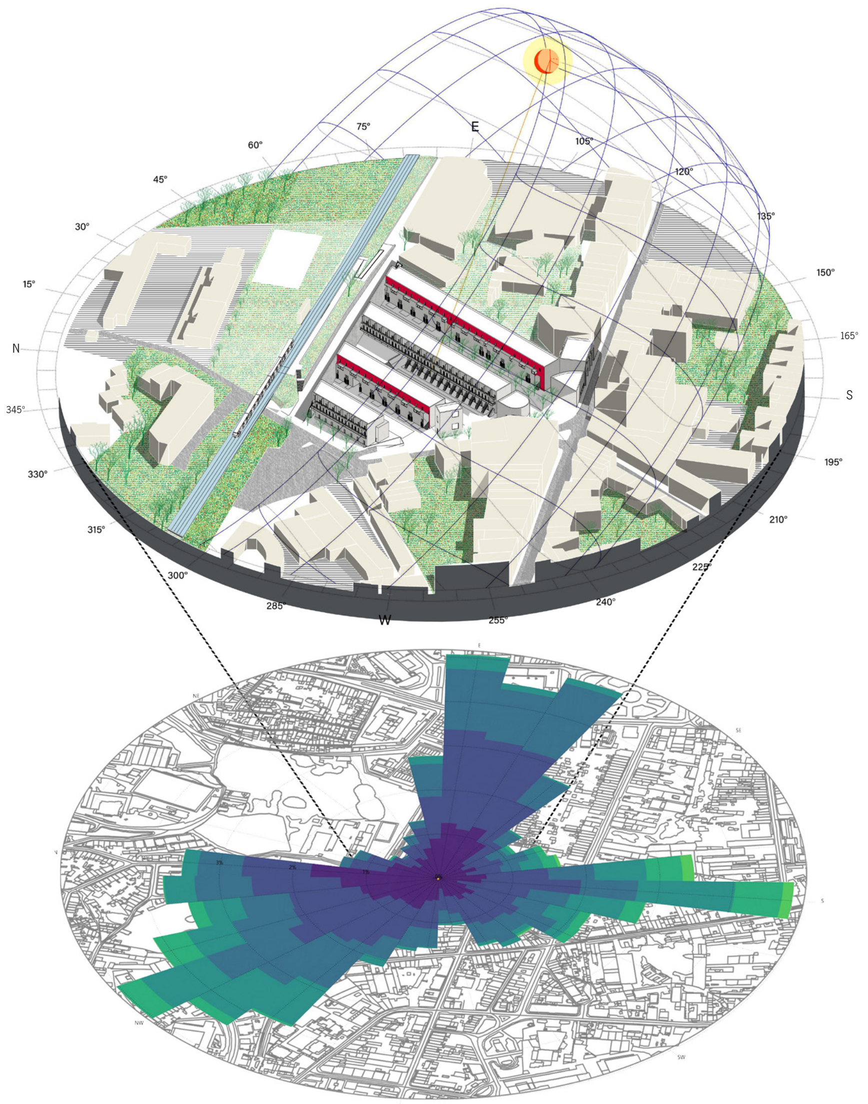


Figure 3.4.1.

The image 3.4.2. demonstrates the shadow and prevailing wind direction analysis of the neighbourhood during the winter and summer seasons. The cast shadows are shadows produced by Summer and Winter Solstice at 09:00 am, 12:00 am and 15:00 pm.
The solstice days give us two days with the longest and shortest cast shadow of a year, and thus these two extreme days were chosen for the analysis.
In summer solstice, the shadow created by neighbourhood buildings in the morning is projected from east to west and covers almost all the outdoor area between the building blocks. At midday, when the sun is at its highest position, the shadow cast by the building is significantly small and is oriented from south to north. In the afternoon, the cast shadow is bigger than the one projected by the building blocks at midday but smaller than the morning one, and it's orientated from west to east.
The cast shadow during the winter solstice at midday is way bigger than on the summer solstice.
In winter solstice the sun is lower creating a more prolongated shadow. In winter, the shadow cast by the building blocks covers not just all the outdoor area between the building blocks, but all the neighbourhood and its peripheries. At midday, the shadow is smaller but still covers a significant amount of outdoor space. During the afternoon, the sun's direction from west to the east creates a prolonged shadow, but due to the positioning of the building blocks and its surrounding buildings, the cast shadow doesn't completely cover the whole neighbourhood.
The prevailing wind direction is analysed for the summer and winter periods. During summer the prevailing wind direction is the northwest wind followed by the north and the south wind. During winter the prevailing wind direction is from the east followed by a southerly wind.
A conclusion can be drawn that the position of the neighbourhood in relation to its solar path and comps card.
In summer, the cast shadow from the building blocks is smaller and the building blocks themselves receive direct sunlight in the morning from the east facade and in the afternoon from the west facade.
In the winter, due to the lower position of the sun, the cast shadow of the building blocks is significantly bigger than in the summer. The building blocks receive direct sunlight from the east in the morning, from the south at midday and from the west in the afternoon. The prevailing wind direction, despite being from Northwest, East and South, doesn't create air draught in the outdoor space of the neighbourhood because of the position of the building blocks being perpendicular to Northwest and East. The wind from the South also doesn't create an air draught because of the wall's position perpendicular to the south wind. Thus, the position of the building blocks and the wall, together with the internal layout of the housing units being from one facade to another, create good conditions for cross-ventilation in the housing units.

Figure 3.4.1. Representation of the SunPath in Summer Solstice and an year average Wind Rose in the site

Figure 3.4.2. Composition of images showing the shadow during summer and winter solstice and the wind rose representing the average wind in summer and winter of the existing building.

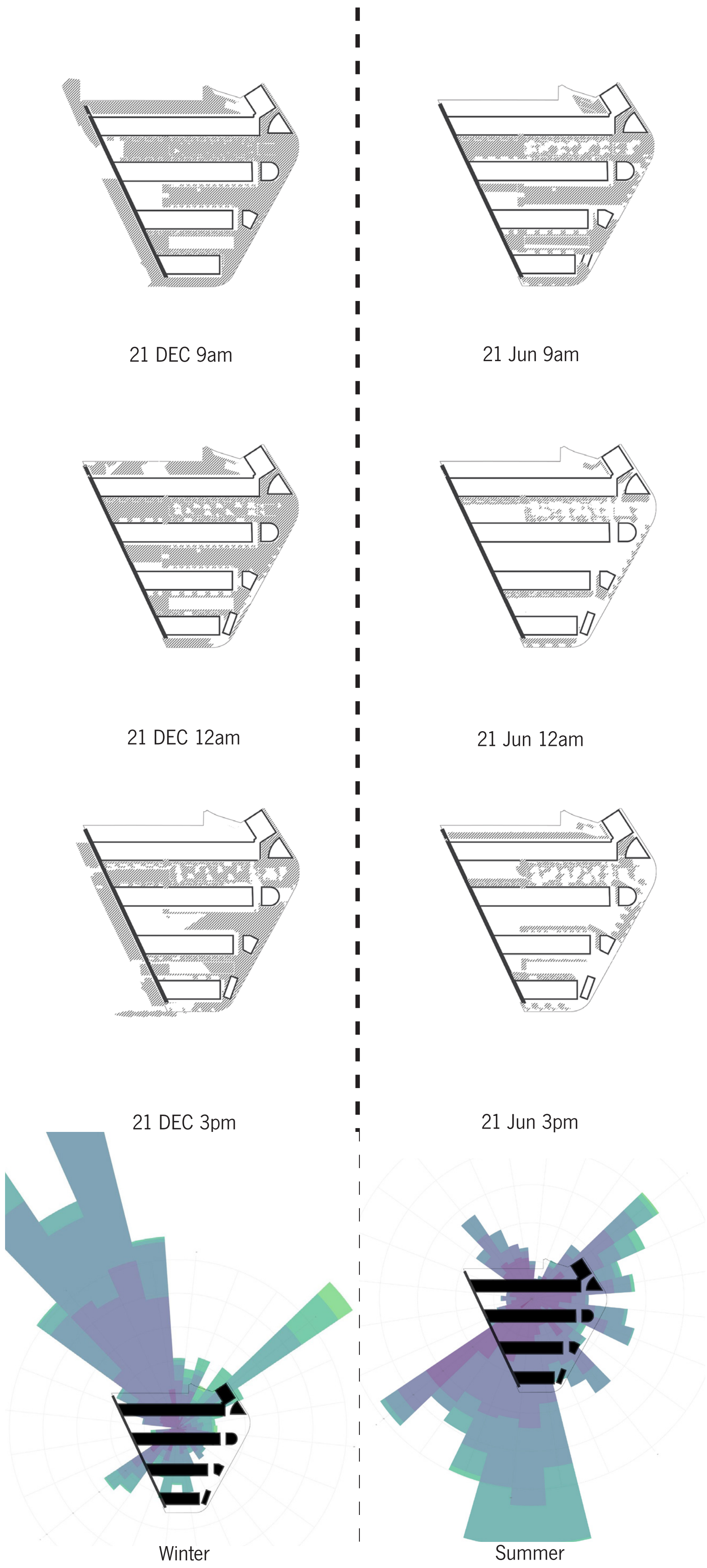

21 DEC 9am
21 Jun 9am
21 DEC 12am
21 Jun 12am
21 DEC 3pm
21 Jun 3pm
Winter
Summer

Figure 3.4.2.

3.5. Housing Analysis

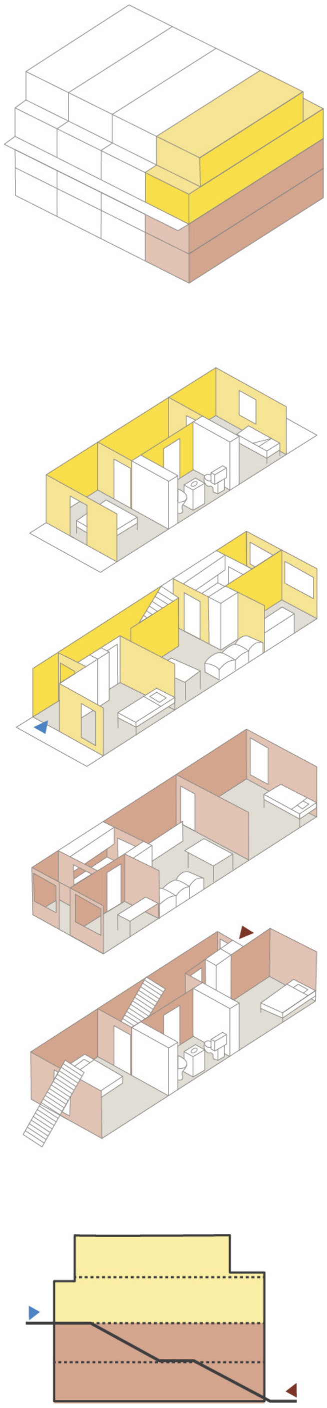


Figure 3.5.1 Analysis of the Boucs Residents' Association Housign layout

Bouça Residents' Association Housing is composed of 4 strips of housing units.

The bottom two and the upper two floors make up the two different duplex units, with each entrance located on the opposite facades. Unlike most apartments, the floors of the duplex units have a traditional day and night division. The day floors are sandwiched between the night floors to protect the bedrooms from the contact noises of the upper and downstairs neighbours.

The down-floor duplex has a total net area of 80m2 and the upper duplex units have a total net area of 74m2.

Bouça Residents' Association Housing is composed of 128 housing units, with 19 different typologies of housing units in the Bouça neighbourhood. Most of the housing units resemble the 8 prevalent typologies in the building complex. Siza mirrors the different house typologies to have the same facade composition on the exterior of the stripes that are facing each other. The other 11 typologies are mainly located in the corner of the stripes next to the wall and near the stairwell that gives access to the housing units on the upper level. Some typologies are located above the ground floor passage. These spaces above the passages are an extension of the existing side units above. (figure 3.5.1).

The identification of the different typologies in the neighbourhood supported, during the analysis and simulation process, the comparison of the performance in the different typologies.

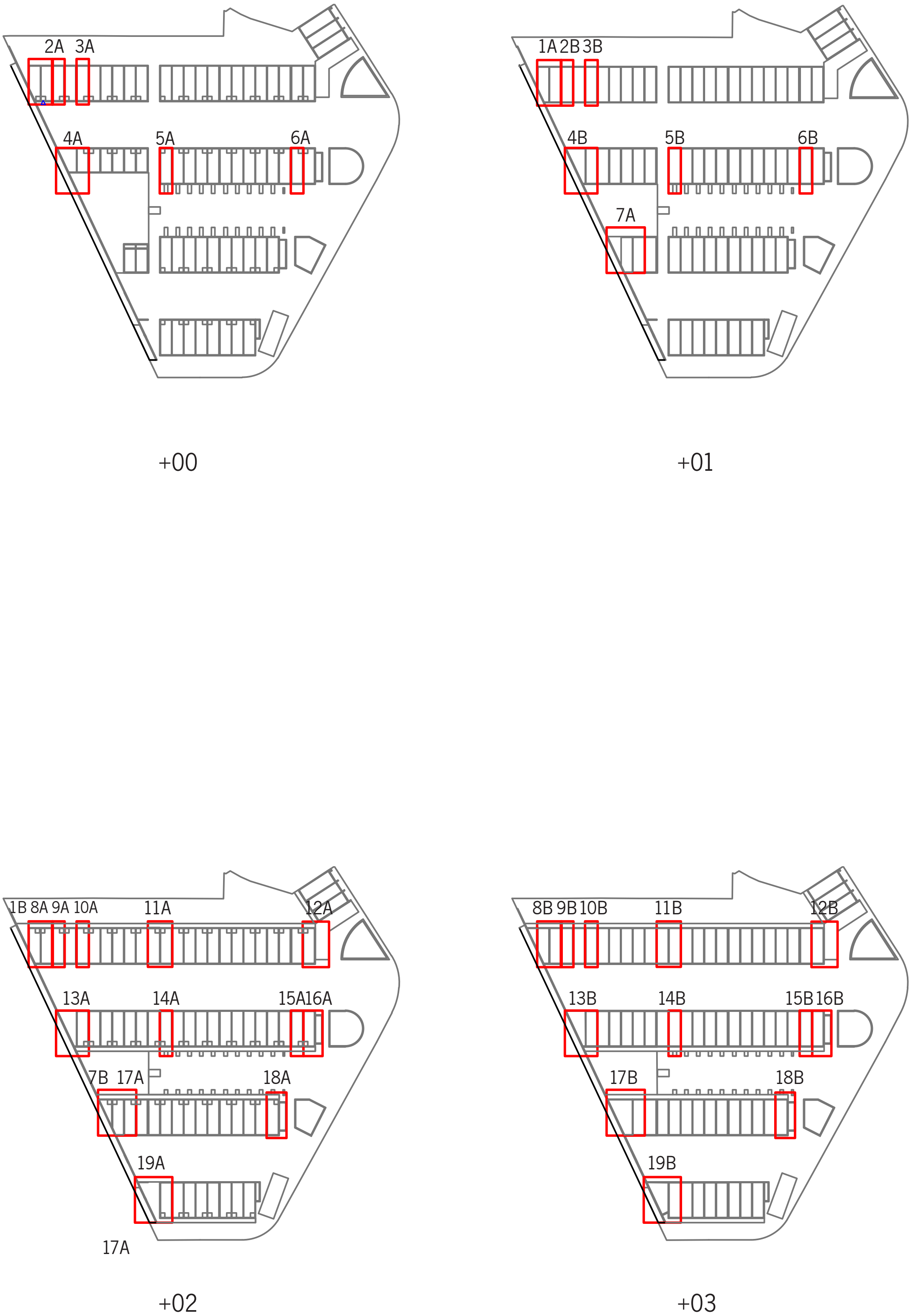


Figure 3.5.2. Representation of the different housing typologies in Bouça Residents' Association Housign

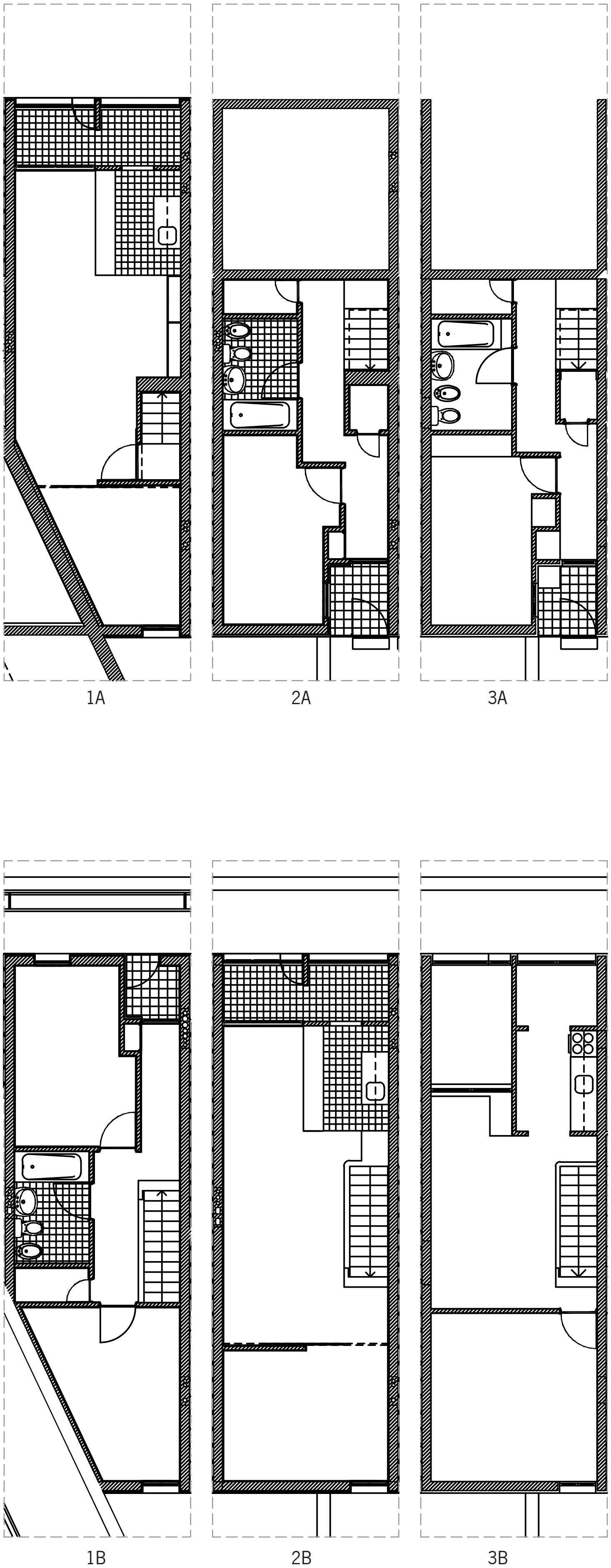
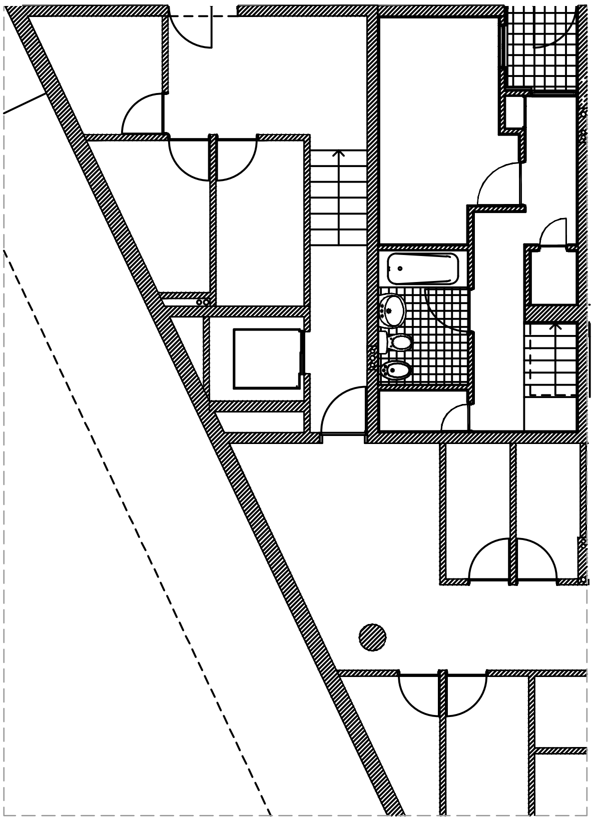
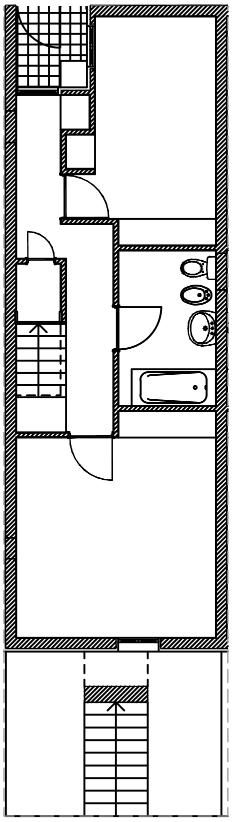


Figure 3.5.3. Plans of typologies 1, 2 and 3


4A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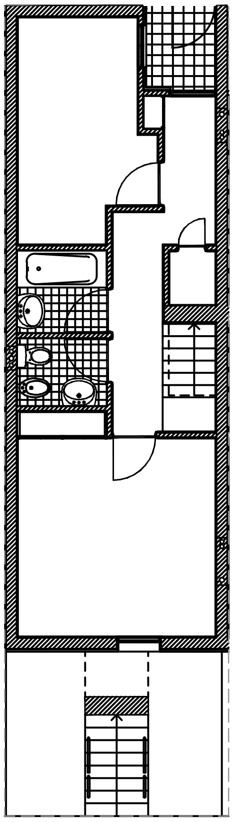
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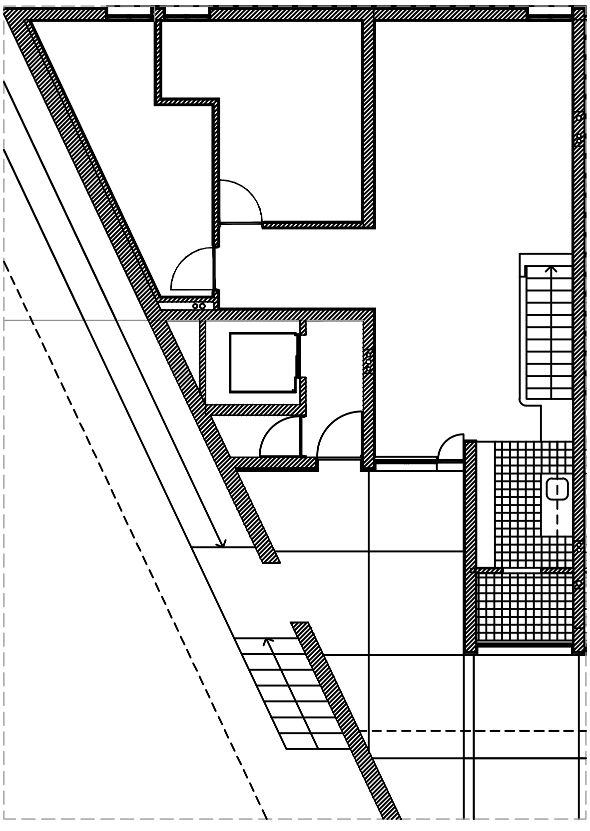
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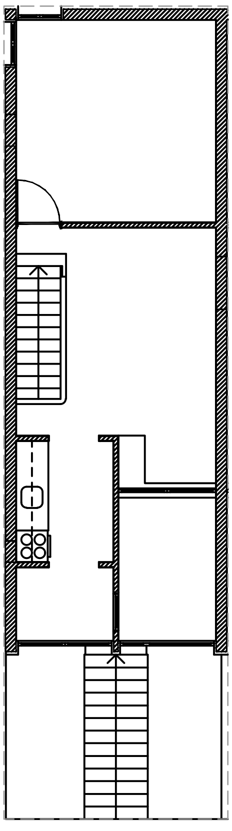
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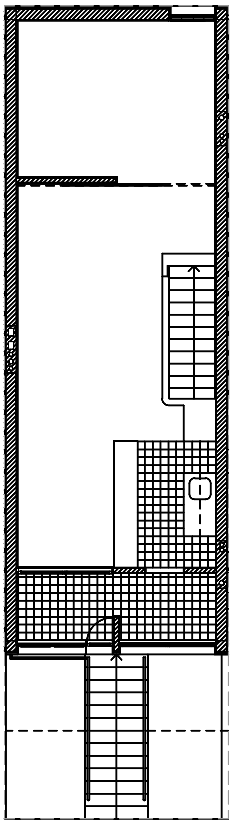
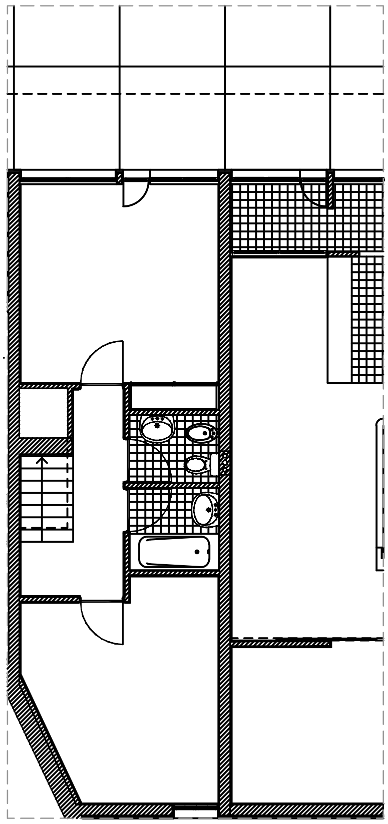

6B

Figure 3.5.4. Plans of typologies 4, 5 and 6



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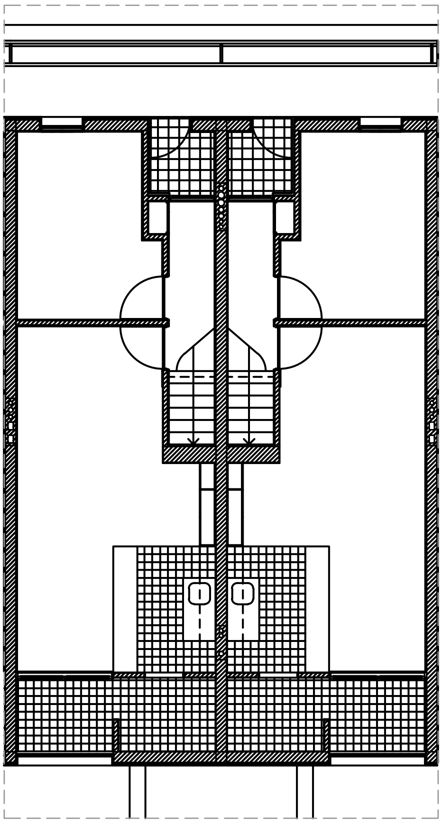

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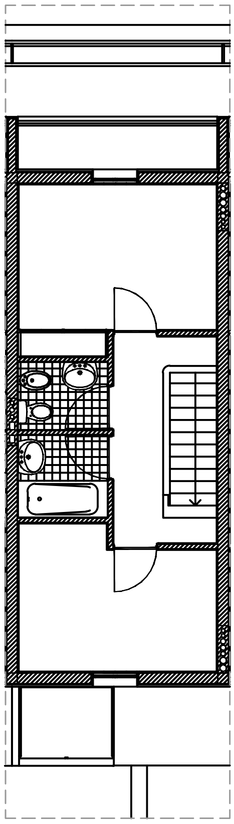

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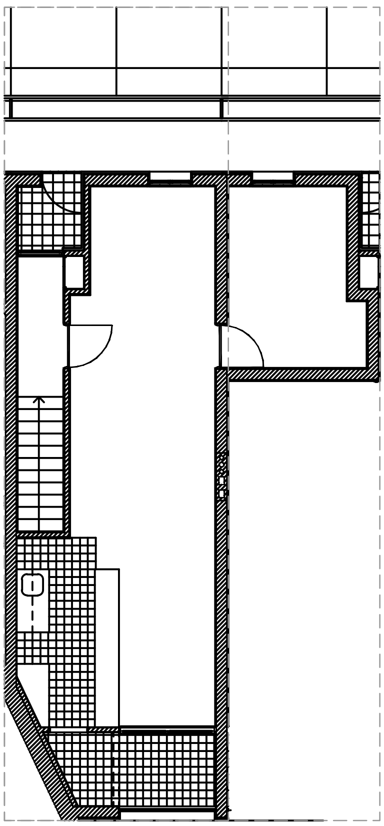

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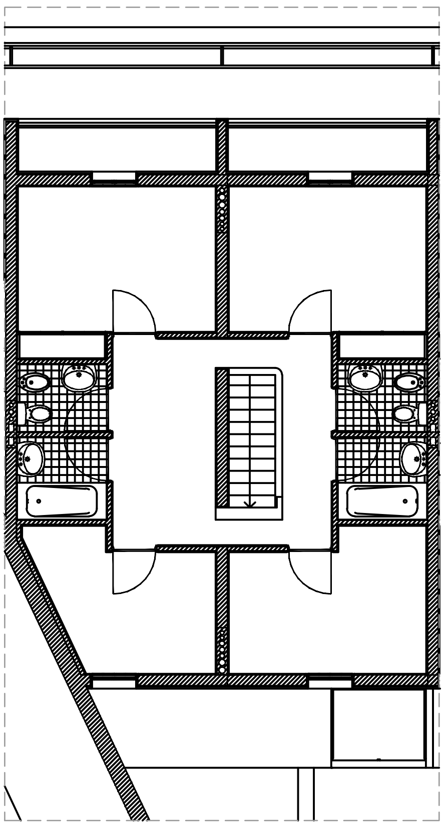

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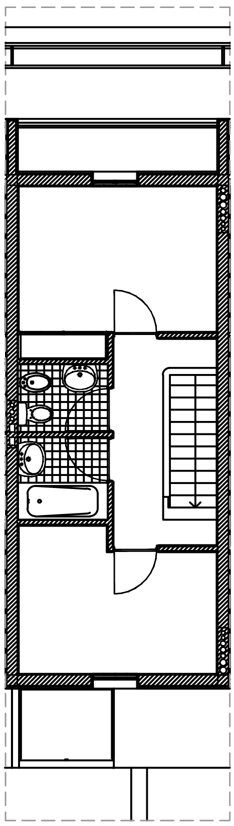
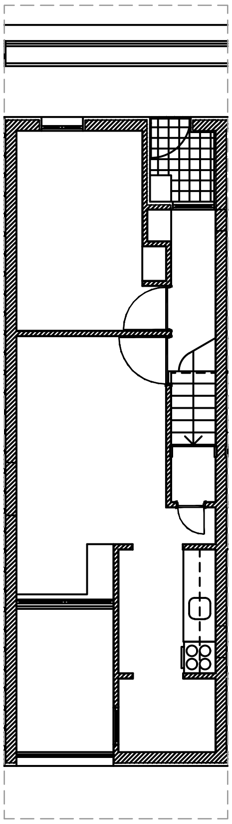


9B

Figure 3.5.5. Plans of typologies 7, 8 and 9



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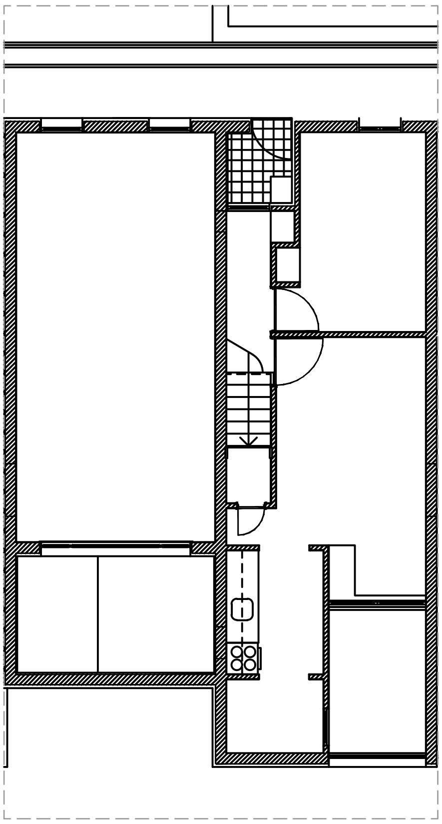

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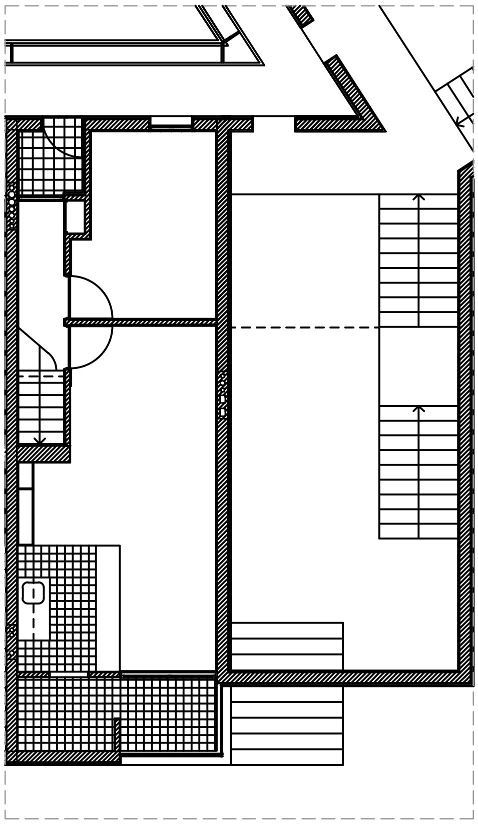
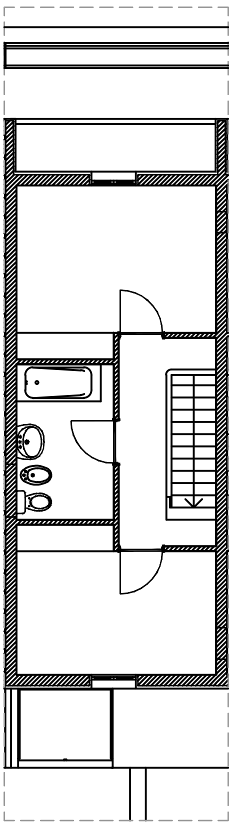
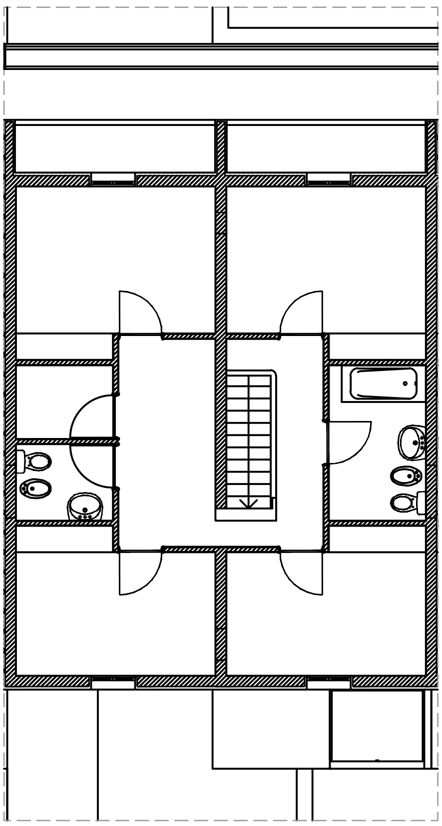


12A



10B



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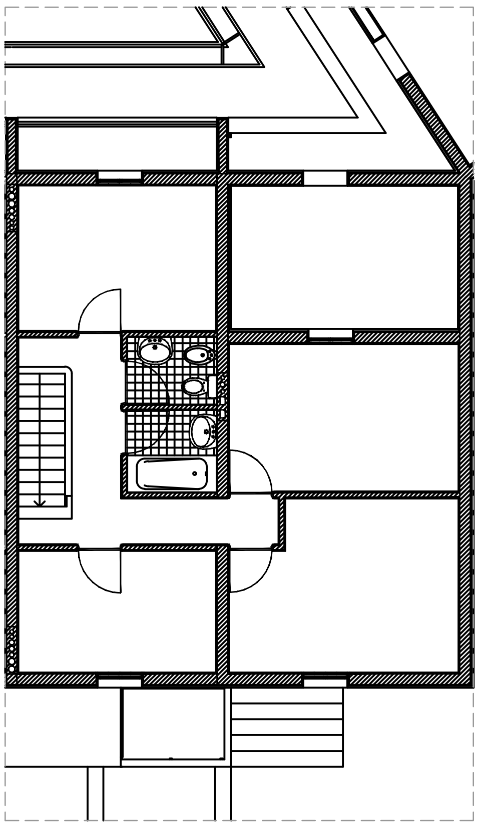
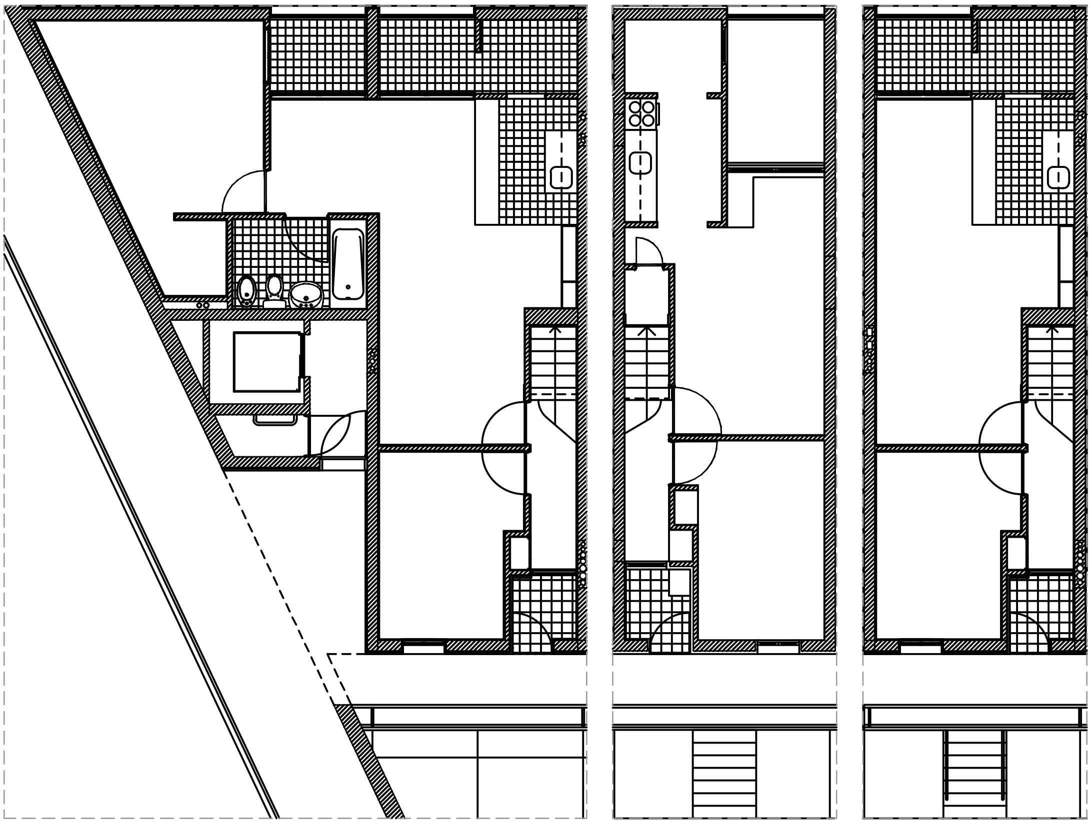
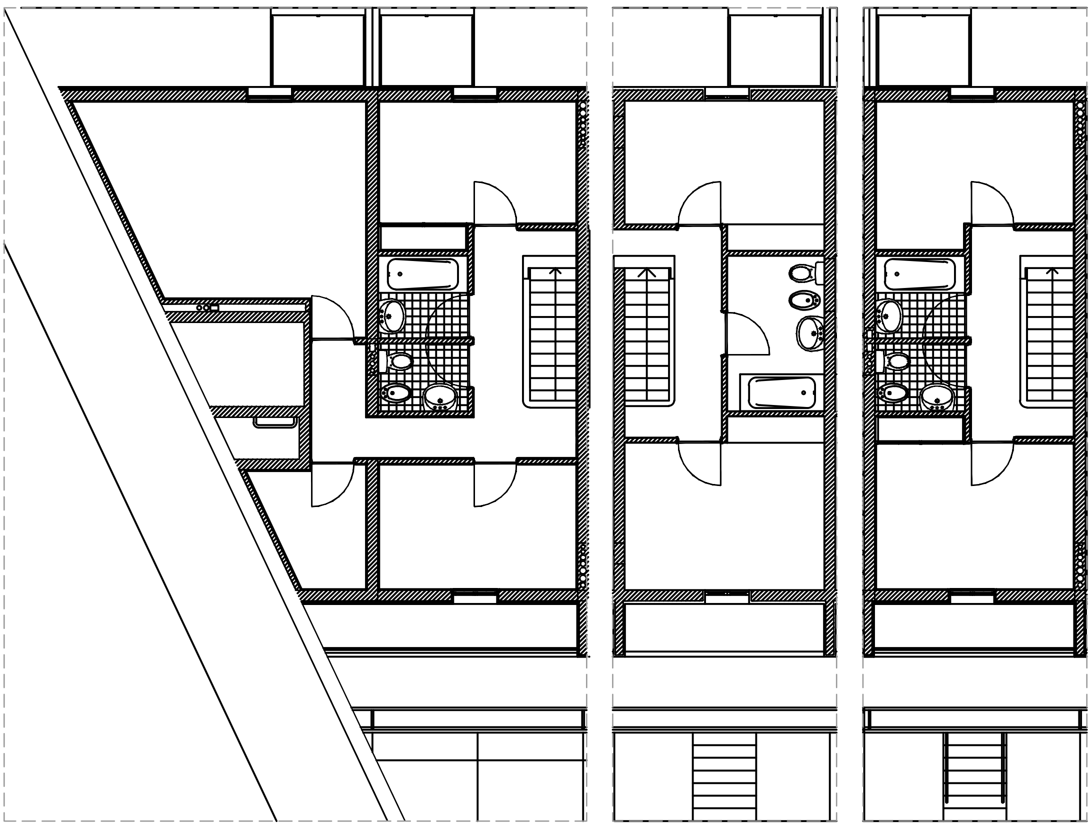


12B

Figure 3.5.6. Plans of typologies 10, 11 and 12

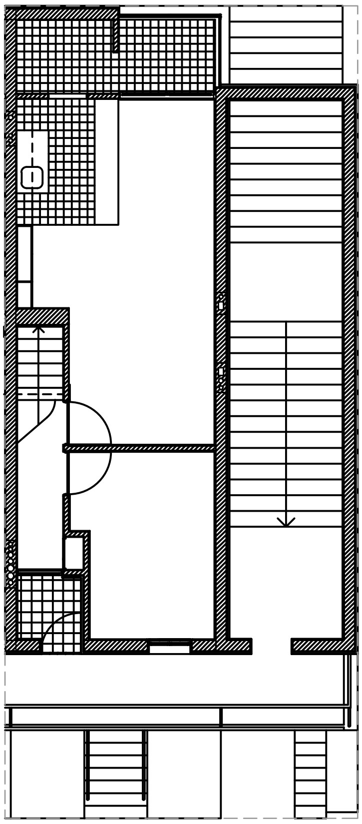


13A 14A 15A

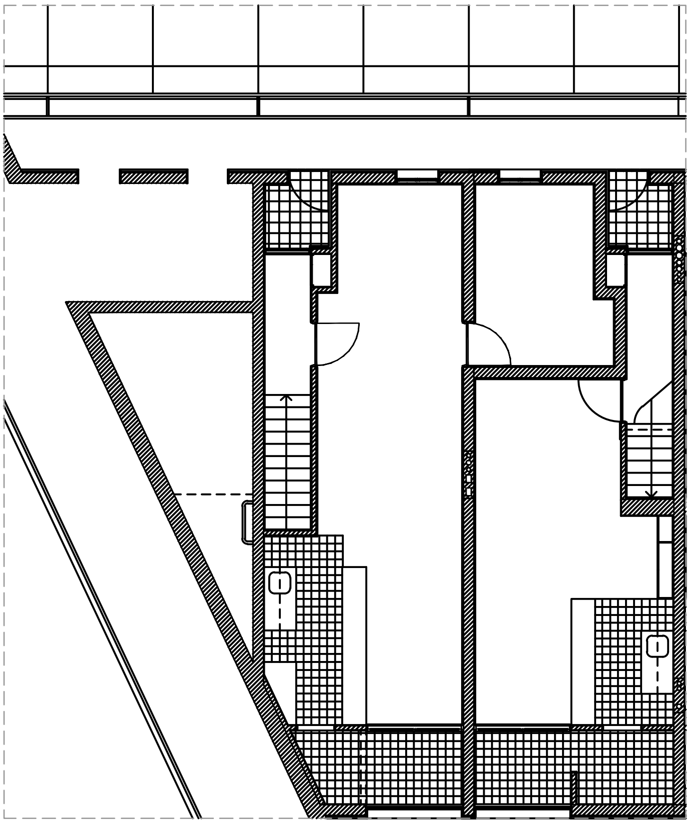


13B 14B 15B

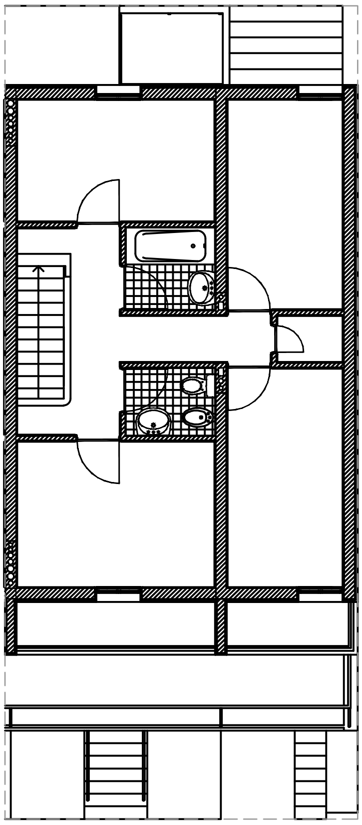
Figure 3.5.7. Plans of typologies 13, 14 and 15



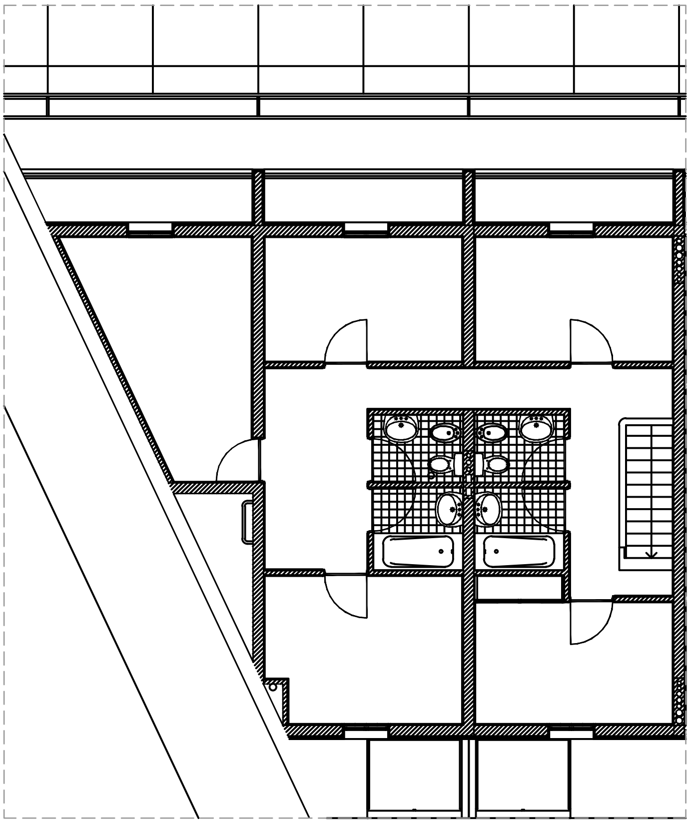
16A



17A

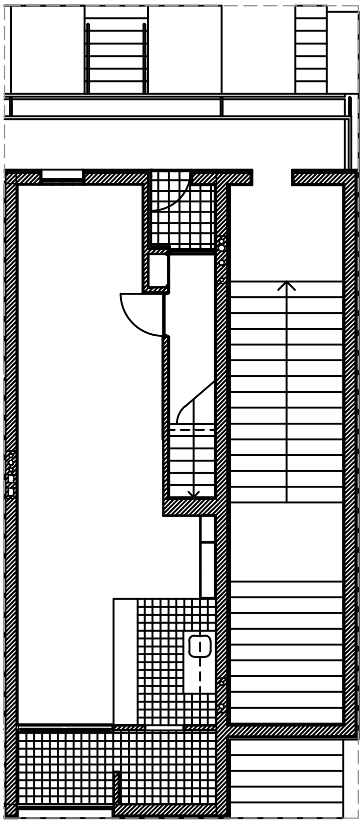


16B



17B

Figure 3.5.8. Plans of typologies 16 and 17



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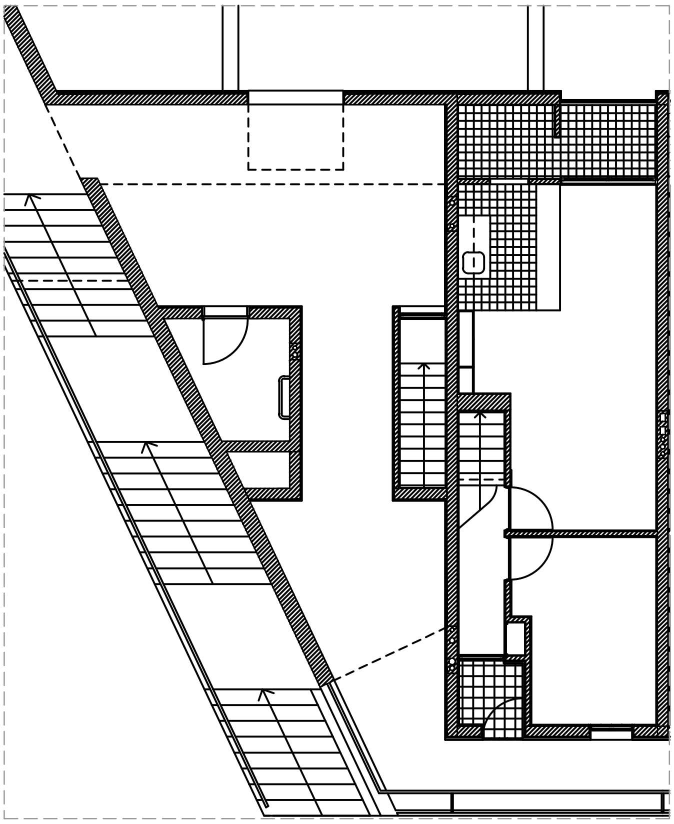
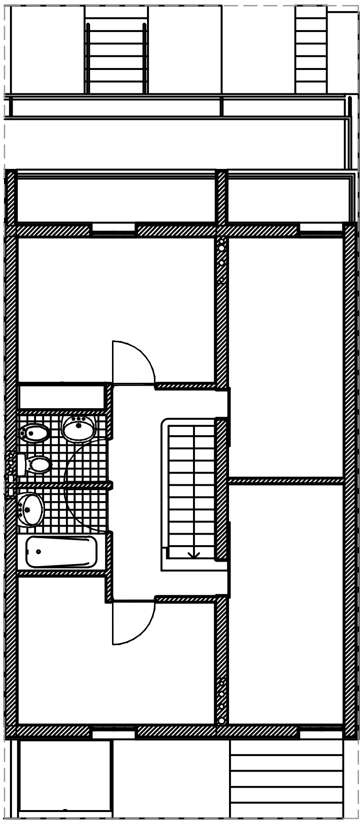


19A



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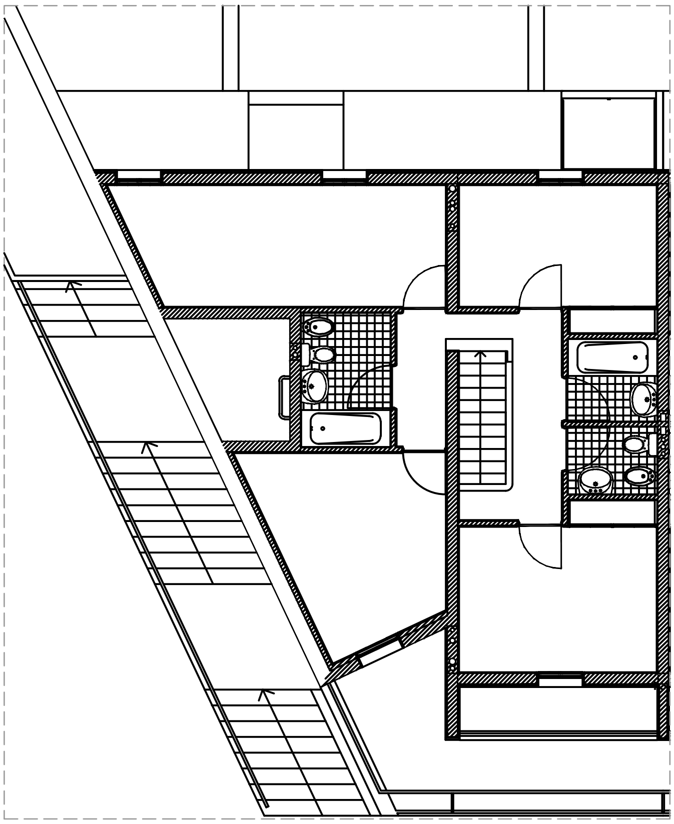


19B

Figure 3.5.9. Plans of typologies 18 and 19

4. Analysis and Simulation on the prevailing performance condition of the neighbourhood

Figure 4.1.Analysis, Simulation, Data Comparison.

4.1. Methodology

The analysis and simulation methodology used in this research is divided into five different phases, presented in figure 4.1.1. The process of each step and the results obtained are explained in the following texts.

This study does not intend to be an exhaustive evaluation but rather a quick approach to the performance of the software because the main goal is to reflect on the advantages and limitations of the simulation tool in current practice. However, due to time constraints and the size of the dissertation, only daylighting and thermal comfort simulation will be tested using *Climate Studio*.

It is important to highlight that this evaluation is not intended as a criticism of the project under study, but rather on the feasibility of using virtual models as architectural aids, in order to balance the necessary comfort and quality of the designed spaces.

Figure 4.1.1. Timeline of the methodology process.

4.2. Use of the Climate Studio Software

The software *Climate Studio* together with Rhino 3D was used to perform simulation analysis during this research project. As mentioned above, *Climate Studio* is one of the most recent simulation software available under student licence. The student version of the *Climate Studio* was explored in two different phases.

In the first phase, the different available features and usage scenarios were tested and experimented on to get familiar with the software. During this first phase of the learning process, it was necessary to contact the Solema team in order to clarify some doubts because of the lack of information, tutorials, or explanation about the use of the software.

The user-friendly, intuitive and simple interface was a big advantage during the learning process, because the results were easy to analyse and improve. This made the learning curve for the software fairly quick and simple.

After the initial exploration and getting familiar with the software Climate studio, a workshop "Energy Modeling: Early Design Analysis" was realized at the University of Minho during the teaching period of the Seminar and Atelier of the Module 2B (Innovation and Technology) courses of the academic year 2021/2022 second semester. During the workshop the students were introduced to *Climate Studio*, and its capabilities were explored. Under guidance and supervision, the students were able to learn and also explore on individual bases the software. They got a chance to test the software on their own project to learn the capabilities and also the advantages and disadvantages of the software. After which, they were able to make variations of their original design on the basis of parameters such as natural light, thermal and acoustic comfort, economic cost, among others. This meant that the design decision was not only motivated by formal and structural design, but also by the functional performance, as well as the environmental and economic costs of the building.

To accomplish their energy performance-based design, students were introduced to different simulation methods through video tutorials and oral presentations, with a special focus on the use of *Climate Studio* in rhino and in grasshopper. The software was used to conduct a set of simulations related to the project proposal under development in Module

2B. In addition, the students learned to do point-in-time illuminance analysis, daylight autonomy analysis, annual glare analysis, thermal analysis, radiance rendering, and define shading elements like curtains or blinds.

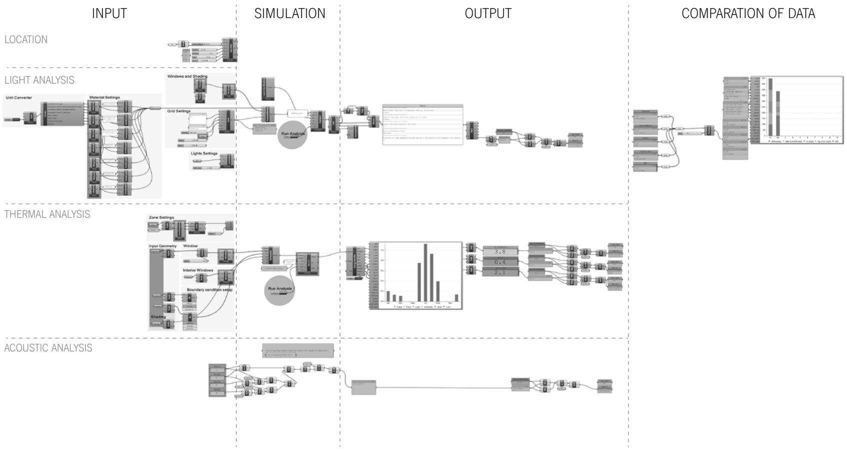


Figure 4.2.1.

Figure 4.2.1. *Grasshopper* model used during the workshop

The students first learned to perform different analyses using *Climate Studio* in Rhino 3D because of its intuitive and relatively easy-to-learn interface. After, a *Grasshopper* model (Figure 4.2.1) was given to the students to introduce them to the use of *Climate Studio* in *Grasshopper* and demonstrate the benefits of integrating it into a computational design workflow. In addition to offering a more diverse way to import and export data, it allowed the students to interactively compare their analysis data to understand the percentage of improvement of their different variations.
A code composed of four main parts was created in grasshopper for the preparation of the seminar and workshop for the students. The code (Figure 4.2.1) is divided into four parts, input, simulation, output, and data comparison. Each one of these parts represents a stage in the simulation process.
The code focuses on five parameters, Daylight autonomy related to natural light comfort, Site Energy Use Intensity, Economic Cost related to thermal comfort, Embodied Carbon and Exterior Walls Insulation.
It allowed the students to compare the different variations of a bar graph to understand which variation gave better results, considering all the other parameters.
The students were able to easily adopt the *Climate Studio* and Rhino workflow. The created grasshopper code was intuitive to use for the students, but not all of them were able to smoothly use due to complexities in their design project. This meant that some students had to figure out and learn how to adjust the code or add another part to the code. Therefore, most of the students adopted Rhino and *Climate Studio* workflow, instead of *Climate Studio* and grasshopper workflow. Using *Climate Studio* with the Rhino meant that students didn't have to learn the grasshopper visual code language and in the end, both workflows produced similar simulation data and results.

Figure 4.2.2. a) building axonometry; (b) building facade; (c) building standard plan.

In general, the students worked better with *Climate Studio* in Rhino. It was noted during the workshop that in the designs with curved geometries the thermal simulation couldn't be performed, which restricted the design process. To be able to perform the simulations, the students transformed their curved geometries into strait geometries.
At the end of the workshop, all students were able to improve their first design concept to an architectural design with an equally developed building performance.

4.2.1 Case Study: Example of a student work

This case study from student Julien Pinoteau had as a reference the social housing project by Lacaton & Vassal in Bordeaux (2016), where they attached a winter garden to the existing facade. Similarly, in this case study, the winter garden plays the role of thermal buffer and passive radiator. It is composed of two French sliding glass windows separated by a 1.20 m distance, sliding blinds with horizontal slats and an outdoor balcony.
So, depending on the season and time of day, the slats can be oriented, letting the sun penetrate the apartment through the winter garden or closed to block the sunlight. This means that the French windows can be opened or closed to cool or warm the student's room.
Ideally, during winter, the slats are oriented to let the sun enter the room, warming the winter garden, the ground, and then the CLT slab. The winter garden heats up and transmits its heat to the student's room because of the easy thermal conductivity of the glass separating the winter garden and the room. In the mid-season, the slats are oriented so that the sun warms the winter garden and the room. If it is too hot, the inhabitants can open the winter garden to the outside. In summer, the balcony prevents the sun from entering the winter garden, and the windows can be left open to allow a pleasant draught of air in the apartment. If necessary, the slats of the blinds can be closed to obtain darkness in the room. [36]

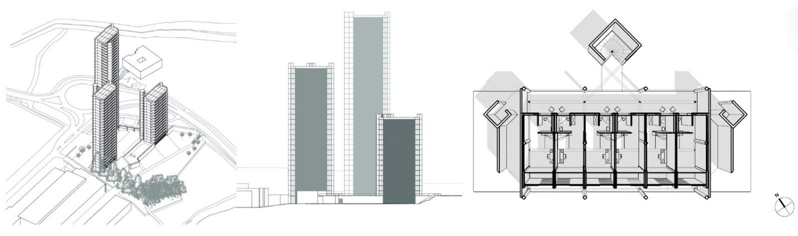


Figure 4.2.2

Useful Daylight Illuminance analyses

Figure 4.2.3. illustrates that, on the student's first try, there was a disturbing amount of light reaching the room's interior space from the south facade. Therefore, in the second option, the student added a shading element to the room's balcony to control the amount of light

entering the room, creating a semi-outdoor living space or a winter garden. The thermal and lighting results of the first and the second simulations were improved by making a winter garden. The winter garden controlled the amount of light entering the room by using shading blades that are entirely closed, half-open or at different angles.

The following figures demonstrate the variety in lighting intensity along with the different room options.

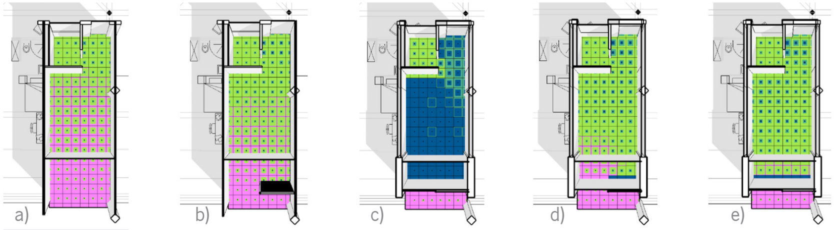


Figure 4.2.3.

Daylight Autonomy analyses

The figures 4.2.4, shows the daylight autonomy of the bedroom in different configurations. The values in option three and its variations are lower than in the first two variations. However, the values are still high, and the building is provided with sufficient daylight, even when the shading slats are semi-closed (Figure 4.2.4. (e)), which proves' effectiveness and evolution of the design variations.

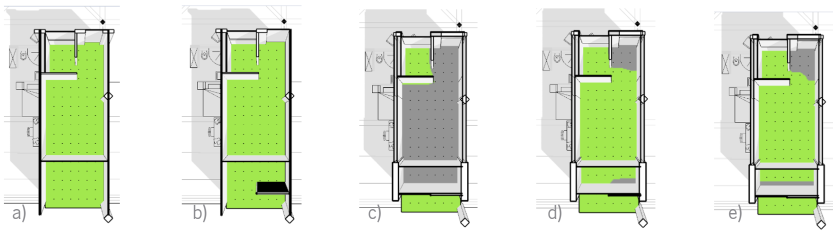


Figure 4.2.4.

Sunlight exposure analysis

The figures 4.2.5., shows the Sunlight exposure of the bedroom in different configurations. In the first option, direct light entered the room, heating the room and creating areas of disturbing light that were controlled when the student added shading to the second option. In the different variations of the third option, the direct light does not enter the room even when the shading blades are half-open (Figure 4.2.5. (e). The student has also created the possibility to let the shade be half-open (Figure 4.2.5. (d)), allowing direct light to penetrate the winter garden area and even the room.

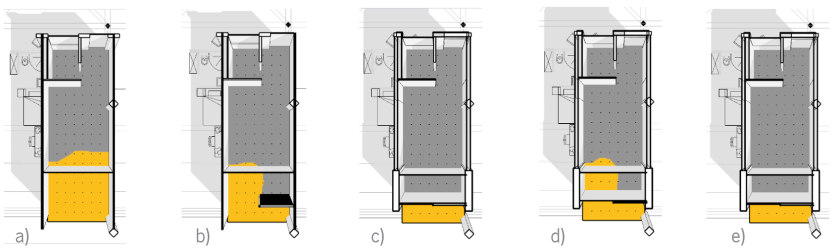


Figure 4.2.5.

Figure 4.2.3. Useful Daylight Illuminance analyses- (a) 1st option-open balcony; (b) 2nd option- open balcony with shading; (c) 3rd option- winter garden shading full closed; (d) 3rd option- winter garden with half shading opened; (e) 3rd option-winter garden with shading at 45°.

Figure 4.2.4. Daylight Autonomy analyses- (a) 1st option-open balcony; (b) 2nd option- open balcony with shading; (c) 3rd option- winter garden shading full closed; (d) 3rd option- winter garden with half shading opened; (e) 3rd option-winter garden with shading at 45°.

Figure 4.2.5. Sunlight exposes analyses- (a) 1st option-open balcony; (b) 2nd option- open balcony with shading; (c) 3rd option- winter garden shading full closed; (d) 3rd option- winter garden with half shading opened; (e) 3rd option-winter garden with shading at 45°.

Figure 4.2.6. (a) thermal analysis model; (b) thermal analysis results.

Figure 4.2.7. Comparison of the results of the several solutions regarding a reference solution.

Using the thermal analysis model, the student obtained results such as the relationship between the temperature and the humidity, the intensity of energy costs, the embodied carbon and others. Which proved that "the outer layer or the tempered glass protects the building from external conditions and provides additional sound insulation from external noise, while the inner layer consisting of double glass provides additional thermal insulation of the outer shells to reduce the heat transfer in winter." [37]. This method saves 8% compared to a standard variation generated by *Climate Studio* in Rhino.

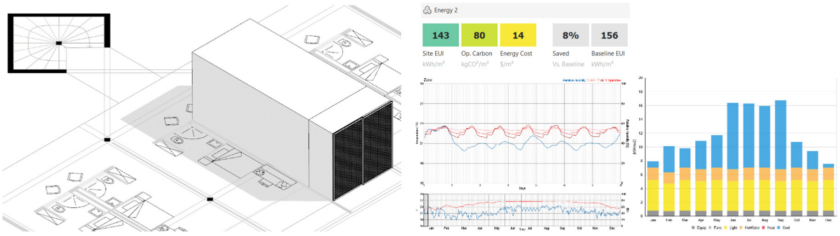


Figure 4.2.6.

Grasshopper code global results

Using the grasshopper code, the students could compare the different results and variations to a base variation (SB). The base variation was established using the results of a project created using the same project syllabus as given to the students using a standard constructive detail used in Portugal. The figure 4.2.7. shows the results for different variations of the case study and proves that, despite the first variation having good results, the third variation is better. This is because the graph is not considering the percentage of space in the room with disturbing light.

With the analysis and interpretation of the referred data, the student was able to improve the form of his building to have good results and reduce the amount of intolerable light and disturbing glare in the room.

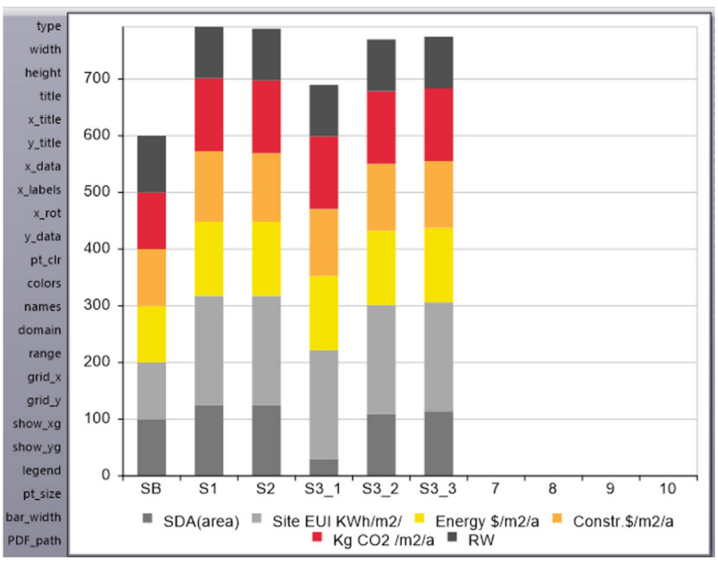


Figure 4.2.7.

4.3. Building modelling and characterization

Figure 4.3.1. Axonometry of the neighbourhood, highlighting the analysed building on the site.

Building modelling and characterization starts the process of analysis which will prove the accuracy of the simulation data. The first step is to develop the 3D model of the selected building, to be possible to analyse the thermal and light condition within the building through simulation.
The figure 4.3.1. shows the position of the housing unit analysed (the lower housing unit, composed by the first and second floor).

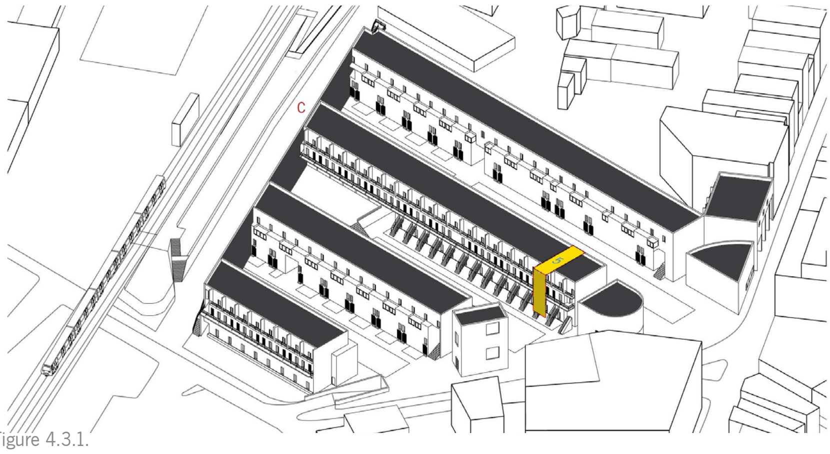


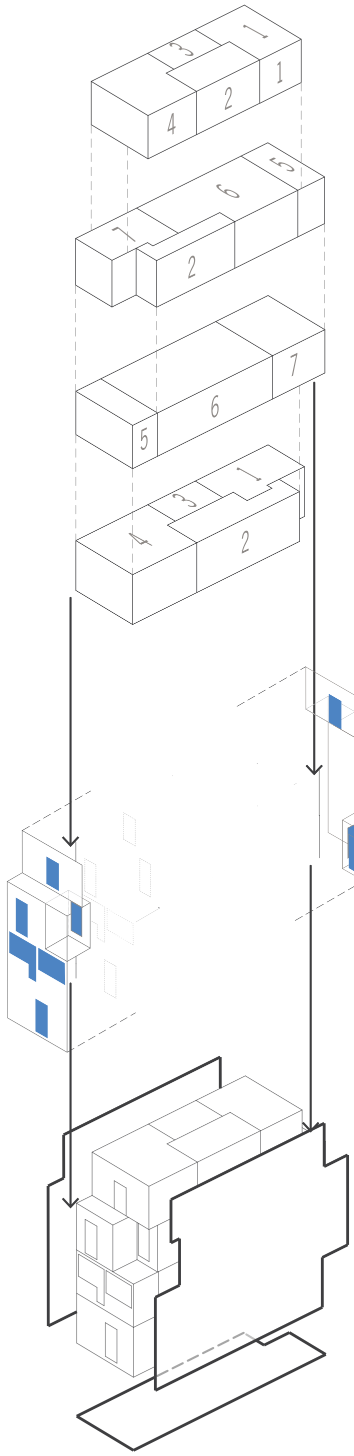
Figure 4.3.1.

Two different types of 3D model were made because the two simulation are different from each other and thus need different input of parameters. The theme of two different simulations are thermal comfort and natural light, which in this case the simulation that will be used is the point in time illuminance simulation, and thermal simulation.
For the natural light simulation the materials, the sky and weather conditions are considered as parameters.
In the thermal simulation, the parameters that interfere with the thermal comfort in a space are used: number of people in the space, the ventilation in the space, the windows, composition of the construction details etc.
The thermal and natural light simulation for the building requires an EPW file in the *Climate Studio* software to have accurate sunlight and location data. The EPW file with Porto data –, PRT_Porto.085450_IWEC – was downloaded from the *Ladybug* Tools website (https://www.ladybug.tools/epwmap/)

The Rhinoceros 3D model associated with the daylight simulation (figure 4.3.3.) requires accurate modeling of the building elements because the way light reacts with different elements depends on the material, composition and its geometry.
The material composition of the element needs to be specified in order to study the performance of the natural light in the space.
The Rhino model associated with thermal simulation (Figure 4.3.2.) is composed of boxes touching each other and surfaces. Each of the different boxes represents a building area, and the surfaces touching the boxes can be defined as boundaries or windows (Figure 4.3.2.). It is necessary to define and characterize the different boxes to perform the thermal simulation. The boxes represent the different areas of the building and according to the needs of the users, it is possible to add additional parameters to the software for more accurate simulation.
For the characterization of an area, it's necessary to define and schedule the occupancy, the equipment, the lighting, the use of hot water, heating, cooling, humidity control, mechanical ventilation, wind, natural ventilation. The exterior envelope of the building can also be inserted in the software along with the different layers of material used for the roof, the facade, the partitions, the slab, the external floor, the ground slab and the ground wall.

Figure 4.3.2. Representation of the thermal simulation model.

Figure 4.3.3. Representation of the natural light simulation model.



1- Bedroom 1
2- Corridor
3- Bathroom+ Sanitary unit
4- Bedroom 2
5- Sunroom
6- Living room
7- Bedroom 3

Figure 4.3.2

1- Beige painted plaster
2- Cork floor
3- Painted wooden frames
4- Single glazed glass
5- White tiles
6- ETICS

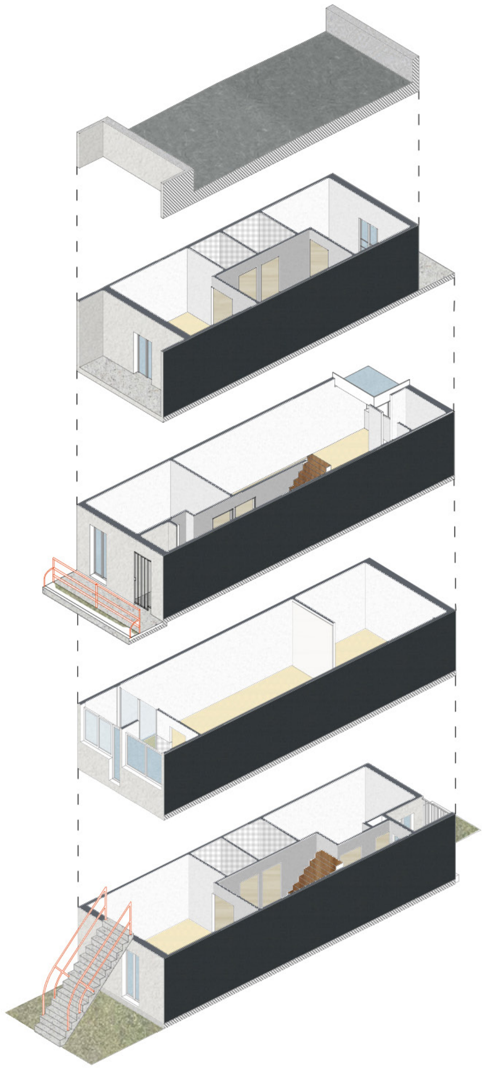


Figure 4.3.3

4.4. Data Colected on site

In the second phase, the accuracy of the data obtained through the *Climate Studio* software was validated using the data collected on-site.
The monitoring campaign was carried out in one of the housing units of the building complex, represented in the image 4.3.1. The selected housing unit shown was built in the second construction phase.
Both daylight and thermal models have different parameters for the simulation validation and therefore on-site different set of data was collected according to the analysis type. The data were collected on different dates because the visits to the housing unit depended on the availability of the household as well as the weather condition, which are different for both simulations. Before starting any of the in situ analysis, the housing unit was visited and the materials and details of the walls were studied in order to understand the different elements of the building. Presented below are some images of the housing unit understudy.

Figure 4.4.1. Photograph taken inside the analysed housing unit. Living room (6).

Figure 4.4.2. Photograph taken inside the analysed housing unit. Office (7).

Figure 4.4.3. Photograph taken by Professor João Cabeira inside the analysed housing unit. Bathroom (3).


Figure 4.4.4. Photograph taken by Professor João Cabeira inside the analysed housing unit. Bedroom (4).


Figure 4.4.5. Photograph taken by Professor João Cabeira inside the analysed housing unit. Sanitary unit (3).

4.4.1 Point in time iluminance analysis

The natural light analysis was performed on 29th of September 2022 which was an overcast day. In order to prove the accuracy of the natural light simulation analysis using *Climate Studio* a Daylight Factor analysis was made. According to CIE (Commission Internationale de l'Eclairage) Daylight Factor is the quotient (in percentage) of the illuminance at a point within a room (Eint.) and the simultaneous exterior illuminance (Eext.) from a clear sky hemisphere. The sky is assumed to be of the standard overcast type and the contribution of direct sunlight shall be excluded. [38]

DLF (Daylight Factor) is dependent on the measurement of the illuminance at a chosen indoor point and the outdoor illuminance on an overcast day. It is important to remember that, if possible, artificial lighting should be switched off.

The first step is to define an equally spaced grid of points in the room, where it's intended to take the measurements from. In this case the measurements were taken using a Delta Ohm HD2302.0 portable luxmeter, equipment for illuminance reading, placed at the level of sitting work height.

Outdoor, the luxmeter needs to be on a horizontal level and completely unobstructed from the entire sky hemisphere.

Inside, the luxmeter should be carefully placed on a leveled surface, especially if the room is illuminated from the side. While the measurement is taking place, the sensors ought not to be obstructed by any kind of body or elements from the surrounding for accurate data.

A one-by-one meter grid at a sitting work height of 75 cm was drawn on the second floor, where the space was analysed. Within the grid, ten different points in different parts of the space were selected and when possible they were aligned with the middle of the windows.

In the interior, eight points of measurements were selected where the luxmeter was placed at a sitting work height. The device projects the received amount of lux on its screen, which was noted down for each point. In the exterior, there were two points of measurement selected, one close to the building and one completely unobstructed. The first exterior point and the interior points are represented in the figure 4.4.1.1. for analysis. The process of noting down the analysis results of each point was repeated at different time intervals: at 10:00 am, 11:00 am 12:00 am, 13:00 pm and 14:00 pm solar time

The collected data is shown in the table 4.4.1.1.

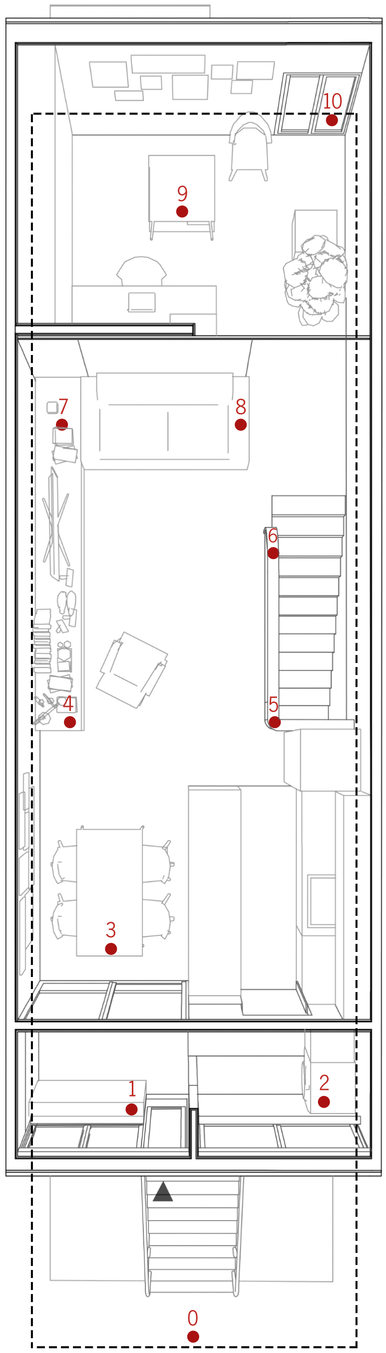


Figure 4.4.1.1

	POINT1	POINT2	POINT3	POINT4	POINT5	POINT6	POINT7	POINT8	POINT9	POINT10	0-1°Exterior	2°Exterior
09h	328	250	86	14	20	12	10	13	30	146	4692	65092
10h	457	375	126	30	33	21	28	23	58	234	6646	96715
11h	500	427	130	47	35	35	20	30	56	360	6222	11123
12h	556	382	139	64	45	23	20	22	36	270	6715	13416
13h	504	426	127	30	20	20	23	20	36	315	6636	12730

Table 4.4.1.1.

Figure 4.4.1.1. Axonometric plan which locates the analysed points in space

Figure 4.4.1.2. Axonometric plan showing the location of the thermal analysis devices in the space.

Table 4.4.1.1. Table with the data collected for each point at different times of the day.

4.4.2 Thermal analysis

The thermal analysis in this dissertation is done by comparing the result of the humidity and temperature in the space in order to understand the level of comfort in the building. These two factors were chosen because they play a big role in the thermal comfort in the space. There are many other factors that also define thermal comfort, like for example ASHRAE standard 55 defines thermal comfort as: "The state of mind that expresses satisfaction with the thermal environment". [39]

Manuel Correia presents the determinant factors to achieve comfort." The degree of thermal comfort experienced by man depends on humidity and air velocity, the exchange of radiant energy between the body and the environment, the metabolic rate and the clothes that are worn. It also depends on the age or degree of acclimatisation of the individual". [40]

The human body needs several factors in harmony with each other in order to define thermal sensation as comfort. These factors are divided into two main variables: individual and environmental, which are then further subdivided.

Individual variables are those that depend exclusively on a person and their metabolic rate, which is the set of processes through which the human body obtains and uses the energy it requires on a daily basis. This accounts for all the energy spent or produced for the activities that ensure the normal functioning of our body. Other than the metabolism, thermal sensation is influenced by the number of pieces of clothing that each person wears and which, depending on the type of clothing, can vary between higher or lower thermal resistance.

The environmental variables are conditioned by their environment, and it's relation to the construction of the building. This relationship is affected by its implantation to its construction details which have effect on air temperature, relative humidity, mean radiant temperature and air speed.

The thermal analysis in this dissertation considers the metabolic rate related to the activities performed by the occupants in the spaces, their clothing, the air temperature and the humidity. Along with others, the ventilation schedule of the different spaces, the lighting, the use of hot water, the use of equipment schedules and the construction detail were also considered for the thermal comfort analysis.

The thermal comfort analysis also consists of using the EPW file and the present construction detail of the building.

The analysis in situ was carried out using the extech 42270 device: Temperature/Humidity Datalogger, which was installed in the housing unit to measure the relative humidity and the temperature. In the housing units, three of these devices were placed in three separate parts of the house, one in the living room (5+6) on the second floor, another one in the bedroom (4) and the last one in the exterior entrance of the dwelling (figure 4.4.1.2.).

During the days that the measurement equipments were in the housing

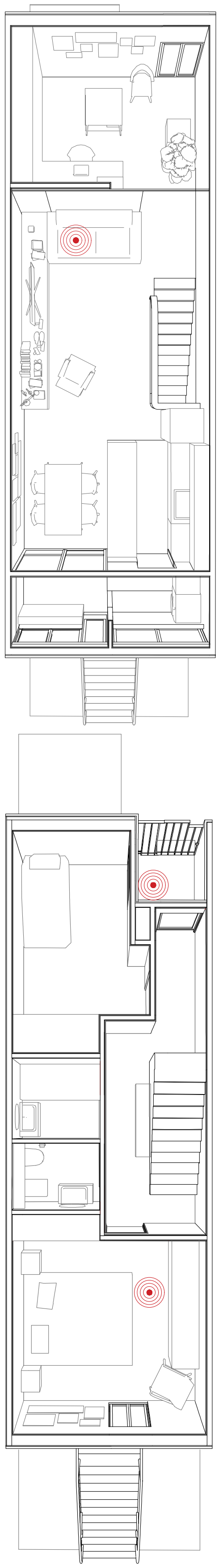


Figure 4.4.1.2.

unit, the inhabitants registered their activities to better understand the fluxes in data due to the human activities. The collected data is presented in the annex 8.13.

The thermal analysis needs to be performed for at least four continuous clear sunny days in order to have representative data.

The first analysis was performed between the 4th and 10th of May but because of the changes in the weather conditions, during that time period, the results were not considered. The thermal analysis was again performed between the 5th and 13th of July 2022, during which Portugal was passing through a heat wave, which means that despite the clear sky conditions the temperatures were abnormally higher than usual. The analysis was also performed during this period because of the availability of the householder.

The black globe (allowing to measure the mean radiant temperature) was placed for the data collection at the average head height of the human body, this is due to the greater sensitivity to thermal comfort in this area of the body.

4.5. Data insertion in software + simulation

Figure 4.5.1. Diagram showing the *Climate Studio* interface in Rhino

The data collected on the site was inserted into the *Climate Studio* software to perform simulations. The two simulations (thermal and daylight), needed a different set of data in *Climate Studio*. The *Climate Studio* workflow together with Rhino 3D was used because of the easy interface in Rhino 3D.

Climate studio allows different types of analysis as mentioned above. The figure 4.5.1 demonstrates the interface of *Climate Studio* in Rhino 3D and the parameter necessary to perform each one of the simulations.

In this case, the Point in-time Illuminance simulation will be performed to prove the accuracy of the daylight data and the thermal comfort analysis will be performed to prove the accuracy of the thermal data.

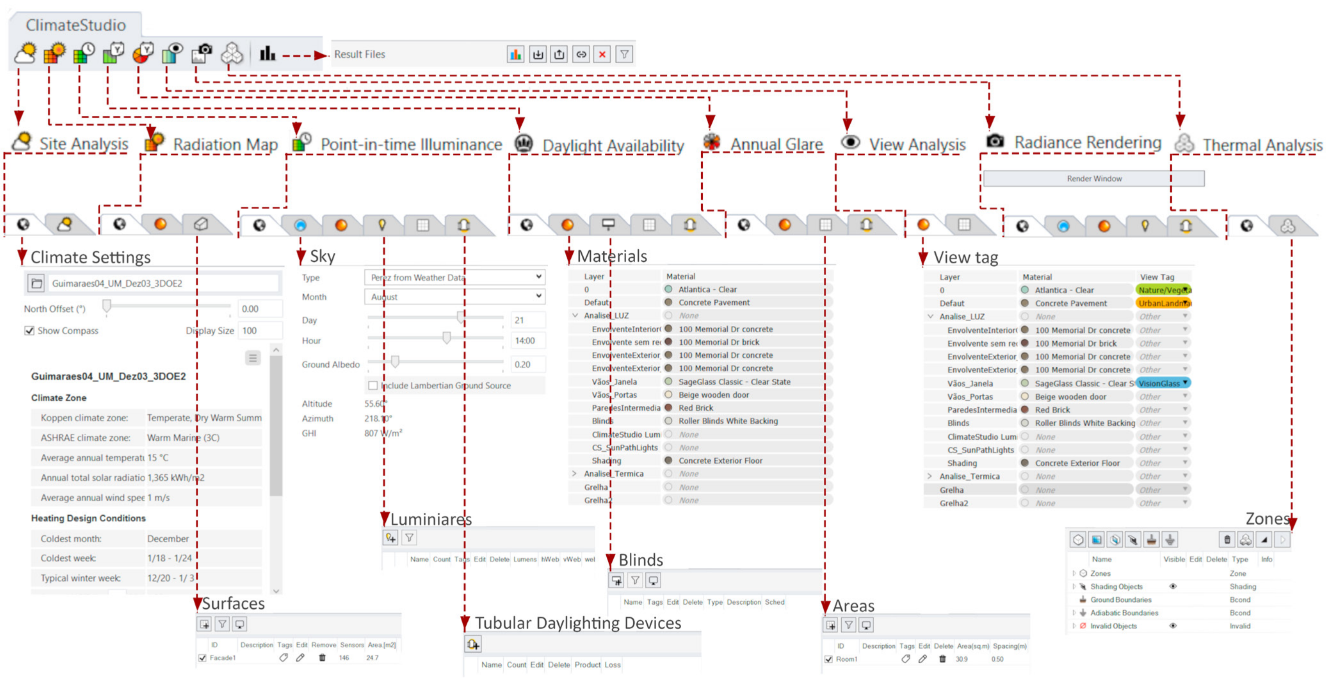
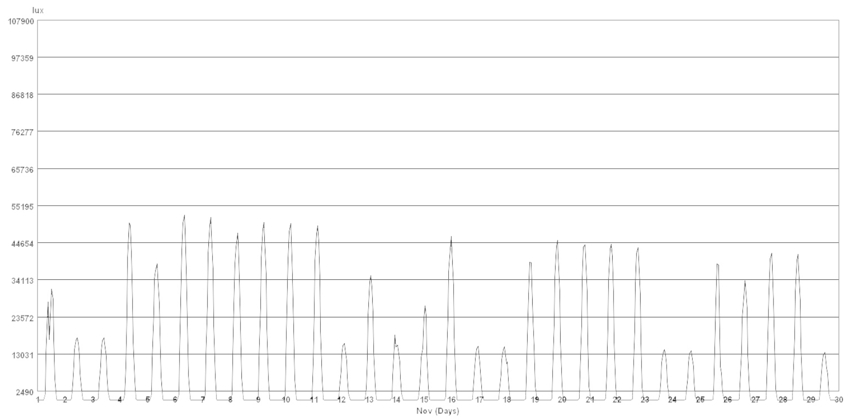


Figure 4.5.1.

4.5.1 Daylight Simulation

The Point in time illuminance simulation is realized in four steps.
The first step is the selection of a day in the weather file with similar exterior illumination conditions as the obtained in the analysis on-site. This was done using Climate Consultant, a software that reads and translates the EPW file into graphs. The graph presented below shows the exterior lux from EPW file, during the days in November. The analysis results had low exterior values, between 65092 and 13416 lux and therefore 24th of November was selected to use as an example since that day the lux reached over 13031 lux at 12 h Solar time.



Graph 4.5.1.1.

Graph 4.5.1.1. ClimateConsultant graphic showing the amount of lux outside - data taken from EPW file PRT_Porto.085450_IWEC

The second step was to introduce in *Climate Studio* the Climate Settings (symbol of the world). In this step the EPW file was inserted together with adjustment of the north direction.

EPW file:EPW file named PRT_Porto.085450_IWEC
North: 129°

In the second step, the type of sky, the day, the month and the hour were selected together with the ground Albedo.
Albedo is the fraction of incident radiation that is reflected from a surface, measured on a scale of 0 to 1. 0 corresponds to a black body absorbing all incident radiation and 1 corresponds to a body reflecting all incident radiation.[41]

Type: Overcast CIE
Day: 24
Month: November
Hour: 10:00h, 11:00h, 12:00h, 13:00h and 14:00h (one hour for each simulation)
Ground Albedo:0.2

Table 4.5.1.1. Data obtained from the Time in point simulation, for the different points at different times of the day.

Figure 4.5.1.1. Daylight autonomy simulation plans.

The third step is the insertion of the different materials in the 3D model. Therefore, it is important to separate all the materials by layer when modelling the building into 3D model. In this step, it is necessary to attribute one material to each layer by selecting the materials from the vast amount of materials in *Climate Studio* Materials Library which has accurate material properties.

The fourth and last step is defining the simulation area by creating a surface in the 3D model at the base floor of the second-floor ground. The grid is defined by the spacing of the sensor spacing and the work plane offset. Beside these two, it is also possible to define the grid with the ID, the description and the sensor inset. In this case, these last three were set as default.

Sensor spacing: 0.5 m
Work plane offset: 0.762 m (height of a working table)

After setting up all the data, the simulation was performed and the data was collected and organized in the table 4.5.1.1.

	POINT1	POINT2	POINT3	POINT4	POINT5	POINT6	POINT7	POINT8	POINT9	POINT10	0-1°Exterior	2°Exterior
09h	456	370	113	28	30	16	20	15	30	233	4692	5617
10h	559	469	138	34	42	22	24	22	33	270	6646	6852
11h	621	504	158	47	38	25	26	23	42	327	6222	7668
12h	621	496	162	38	44	24	21	19	35	300	6715	7486
13h	562	418	141	37	37	22	22	19	33	270	6636	6747

Tabel 4.5.1.1.

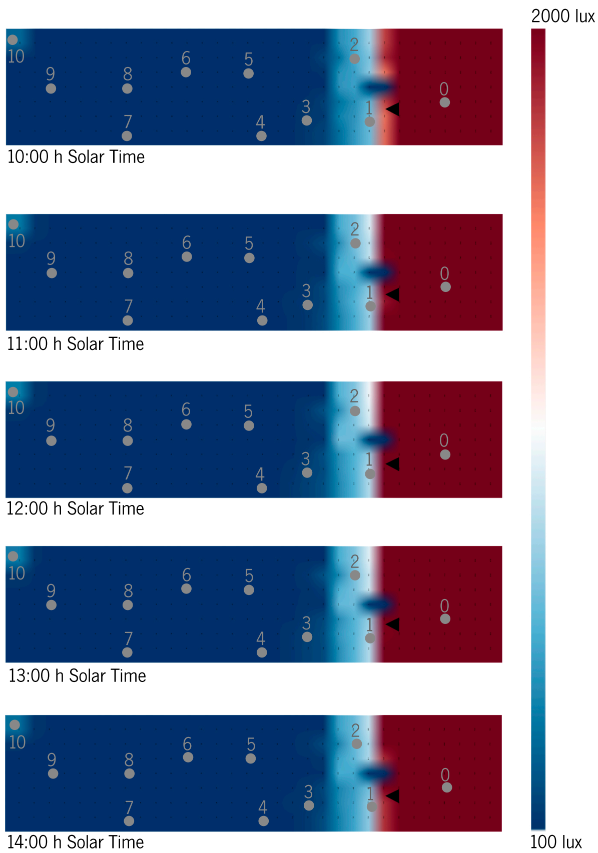
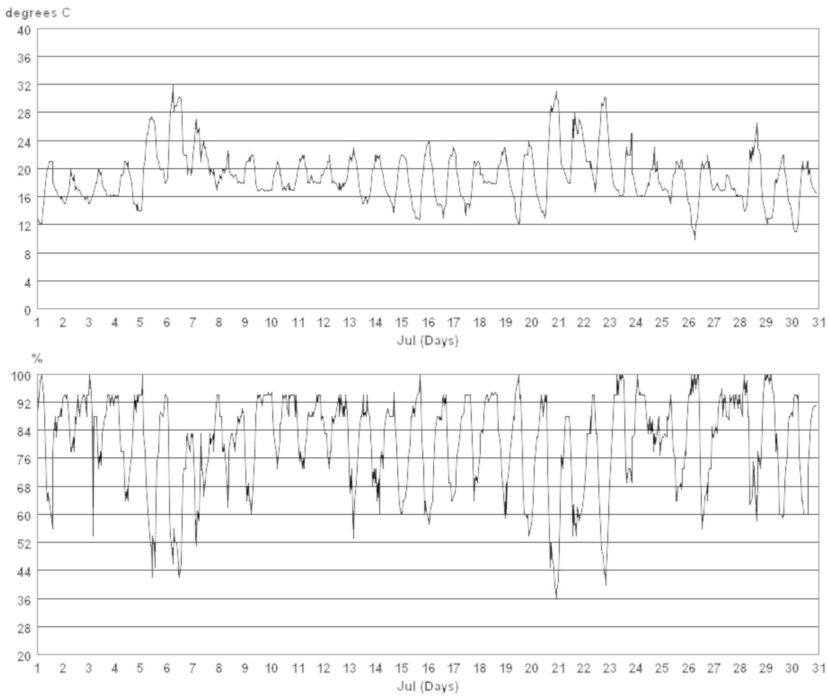


Figure 4.5.1.1.

4.4.2 Thermal simulation

Graph 4.5.2.1. ClimateConsultant graphic showing the outside temperature (C°) and the percentahe of humidity (%) - data taken from EPW file PRT_Porto.085450_IWEC.

The thermal simulation was performed in six steps. The first step is to find days in EPW file with matching data. As mentioned above, the data was collected during the period when Portugal was facing a heat wave. Therefore, in the EPW file, there were no days that matched the in situ recorded temperatures.
Hence, a different approach was taken and instead of finding days with similar temperatures, a group of consecutive days with similar temperature and humidity range was selected for the simulation and comparison. The following graph shows the set of days that were selected during the month of July, which was from the 7th till 12th of July. These days were selected because they have a similar temperature and humidity range as the monitored days, even if the temperatures are different.



Graph 4.5.2.1.

The second step is defining the different areas. As shown before, each space is modelled as a box that defines an area in the *Climate Studio*. These areas are given different parameters that are customizable like: density of people, occupancy schedule, equipment power density and availability schedule, lighting power density and availability schedule, supply water temperature, and water schedule, heating and cooling set points, supply, capacity, heat flow and schedule. It is also possible to set the humidity control, mechanical ventilation, wind, stack natural ventilation, schedule natural ventilation, construction details, air infiltration, additional internal mass, foundation, carbon, cost factors and zone behaviour.

The third step is to define the windows by creating surfaces that represent the windows. The properties of the windows like the type of glass, shading system, ventilation setting and the type of window frames can all be modified. In this case, the following data was used to set the windows.

Glazing Material:	
Type	Simple
U-Value [W/(m2.K)]	5.894
SHGC	0.905
TVIS	0.913
Embodied Energy [MJ/m2]	225
Embodied Carbon [kgCO2/m2]	13.65
Shading System Settings	OFF
Ventilation Settings:	
Operable Area	0.8
Discharge Coefficient [Unitless]	0.65
AFN Temperature Setpoint [°C]	20
AFN Window Availability	All on
VentControl	Temperature

The fourth step was to define the surfaces that define the Ground and Adiabatic boundaries. The ground boundaries represent the surface that is in contact with the ground. The adiabatic boundaries are a surface between two thermodynamic systems that do not allow heat or chemical substances to pass across it.
The data collected on-site allowed to customize each of the areas, making the simulation more accurate.

4.6. Results Comparation

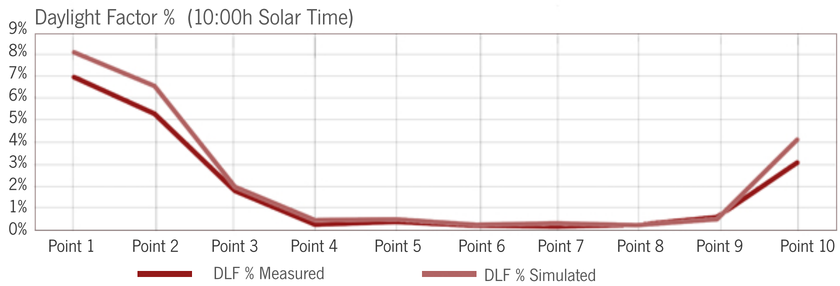
The final step of this analysis is to compare the in situ and simulation data, in order to understand if the simulation is accurate with the real conditions.

4.6.1 Dayight-monitoring vs Simulation
The daylight factor of both the simulation and data collected in situ were calculated using the quotient between the illuminance at each different interior point and the exterior point at the same time.
The recommended values of daylight factor are different according to the space and the type of activity performed in those spaces, and because of that, the recommended values for each analysed space is presented below.

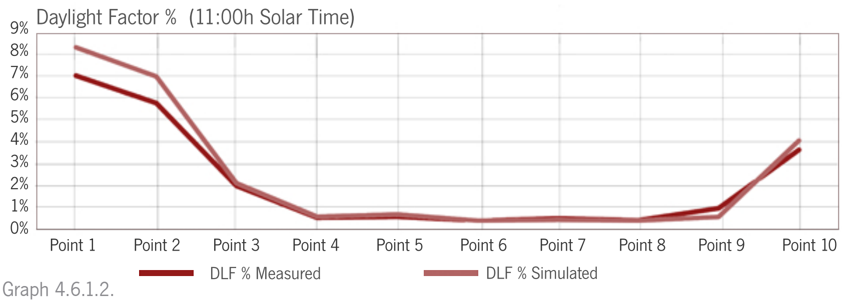
Living room- 1%
Kitchen- 2%
Office- 2%
Bedroom -0.5%
[42]

The graphs (4.6.1.1. to 4.6.1.5.) represent the comparison of the different DLF values calculated for the analysis in situ and the simulation for the five different analysed hours : 10:00am, 11:00am, 12:00am, 13:00 pm and 14:00 pm.
In the graphs, the values obtained in the simulation and in situ are similar in the different hours, which allows making conclusion where the simulation is accurate with the collected data.
The daylight factor in the grid points four to eight, located in the middle space of the apartment, is less than the recommended value at different times of the day. In these points, the values are between 0.3% and 0.6%, but it's recommended to be 1% measured in the middle of the compartment of the living room (Point 6). In the kitchen (Point 3) the recommended DLF value is 2% but in reality, the values are between 1.8% and 1.9% for the first two hours and in the last hours it is between 2.0 and 2.2 which approaches the recommended values.

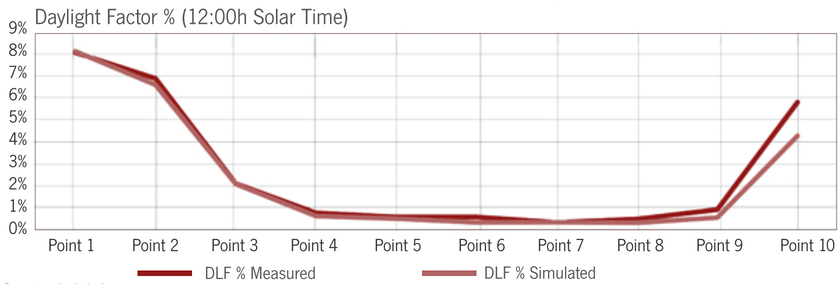
The Point 9 is situated in the work space (office) next to the living room. The recommended DLF value for an office is 2%. If this space was used as a bedroom, the recommended DLF would be 0.5%. The graphs show that the DLF values in the middle of the space are between 0.5% and 0.9 %. Therefore, it can be concluded that in the middle space of the apartment floor (living room) the DLF is low, in the workspace the daylight factor is also low to be used as an office, but if it was a bedroom like it was designed, the daylight factor would be as recommended.
In the points near the windows (Point 1,2 and 10), the Daylight Factor is, as expected, higher than the recommended.



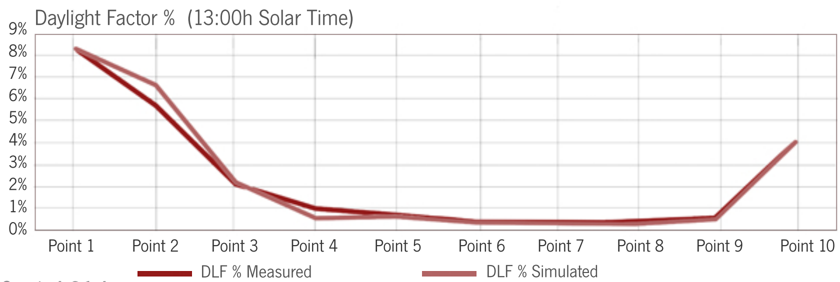
Graph 4.6.1.1



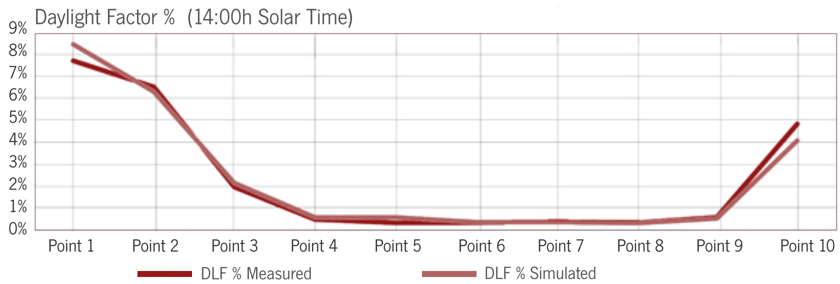
Graph 4.6.1.2.



Graph 4.6.1.3.



Graph 4.6.1.4.



Graph 4.6.1.5.

Graph 4.6.1.1. Comparation between the Daylight factor (%) collected on site and the simulated Daylight factor (%) in the different analysed points at 10:00 h solar time.

Graph 4.6.1.2. Comparation between the Daylight factor (%) collected on site and the simulated Daylight factor (%) in the different analysed points at 11:00 h solar time.

Graph 4.6.1.3. Comparation between the Daylight factor (%) collected on site and the simulated Daylight factor (%) in the different analysed points at 12:00 h solar time.

Graph 4.6.1.4. Comparation between the Daylight factor (%) collected on site and the simulated Daylight factor (%) in the different analysed points at 13:00 h solar time.

Graph 4.6.1.5. Comparation between the Daylight factor (%) collected on site and the simulated Daylight factor (%) in the different analysed points at 14:00 h solar time.

Graph 4.6.2.1. Comparation between the Air temperture (C°) collected on site and the simulated Air temperture (C°) in the Exterior at different hours of 10/07/2022.

Graph 4.6.2.2. Comparation between the Air temperture (C°) collected on site and the simulated Air temperture (C°) in the Living room at different hours of 10/07/2022.

Graph 4.6.2.3. Comparation between the Air temperture (C°) collected on site and the simulated Air temperture (C°) in the Bedroom at different hours of 10/07/2022.

Graph 4.6.2.4. Comparation between the Relative Humidity (%) collected on site and the simulated Relative Humidity(%) in the Exterior at different hours of 10/07/2022.

Graph 4.6.2.5. Comparation between the Relative Humidity (%) collected on site and the simulated Relative Humidity(%) in the Living room at different hours of 10/07/2022.

Graph 4.6.2.6. Comparation between the Relative Humidity (%) collected on site and the simulated Relative Humidity(%) in the Bedroom at different hours of 10/07/2022.

4.6.2 Thermal-Analysis vs Simulation

The accuracy of thermal simulation data was analysed by comparing the humidity and temperature percentage data from the simulation and the data collected on-site.

In order to confirm the simulation results, a graph was made for each one of the three analyzed spaces (exterior, living room and bedroom). Using these graphs, the humidity, and temperature range of each space was compared. The temperature and humidity data from the simulation and on-site were not compared directly due to the weather anomaly. Instead, the difference in temperature in percentage was compared for the confirmation of the data.

The graphs 4.6.2.1. to 4.6.2.6. are a part of the graph showing only the results for the 10th of July. The complete graph is in the Annex 8.5 and 8.6.

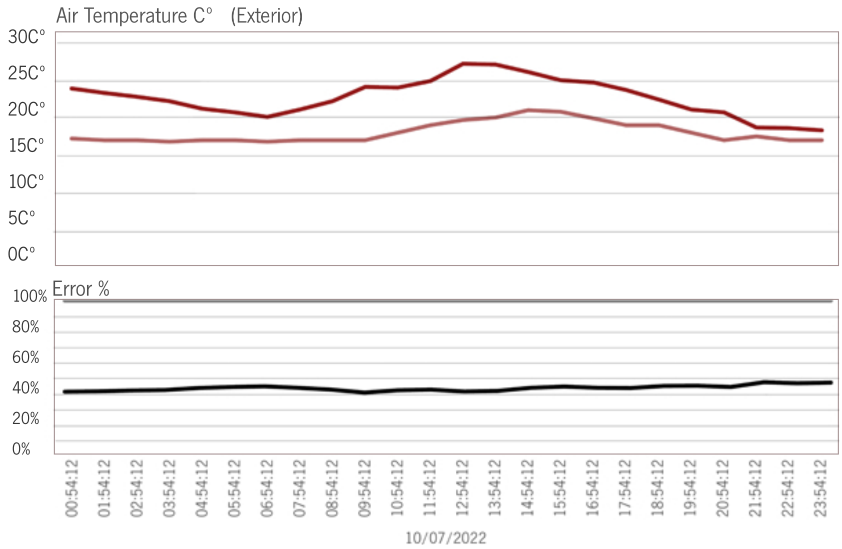
In the temperature graph, the results on site are significantly higher than the simulated temperatures, but the graph line of the simulation and onsite measurements have a similar oscillation to each other. This can be explained by the weather anomaly, the heatwave, that Portugal and the whole of Europe faced during the summer of 2022.

The difference in the two graph lines was compared using a 100% stacked line graph, to account for the difference in temperature due to the weather anomaly. The graph highlights the magnitude of change in temperature to the percentage that each value contributes over a period of time. Which means the closer the oscillation pattern of the both measurements are, the straighter and similar the both lines are, and the spacing between the two lines indicates the weather anomaly.

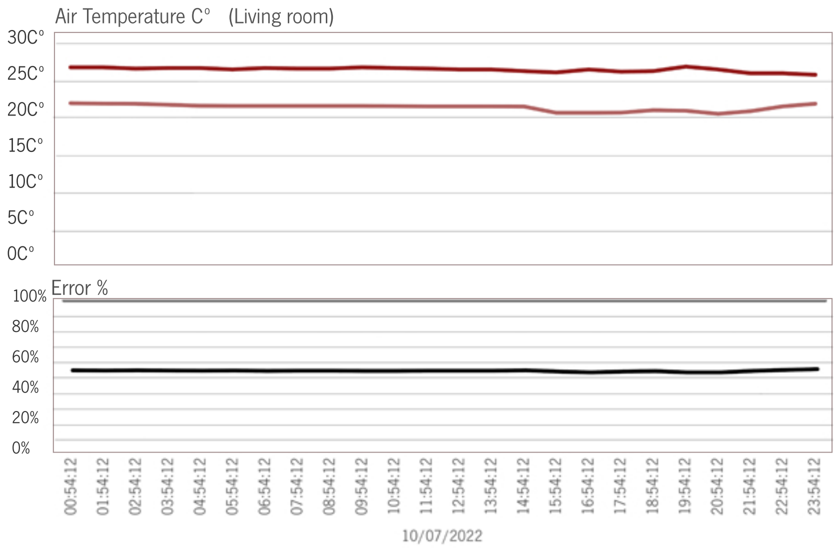
In the graph, the measurements collected in the building are taken as a whole (100%) because the main goal of the graph is to compare the simulation data with the data collected on site, to validate the accuracy of the simulation data. The simulated data is compared to the on site measurements by comparing the percentage of variation between the simulated data and on-site data. The on-site data is shown in the dark grey line, which marks the percentage of variation.

If the variation line is straight even if there is distance between the 100% line and the variation line, it means that the oscillation in the both values between the two lines are the same.

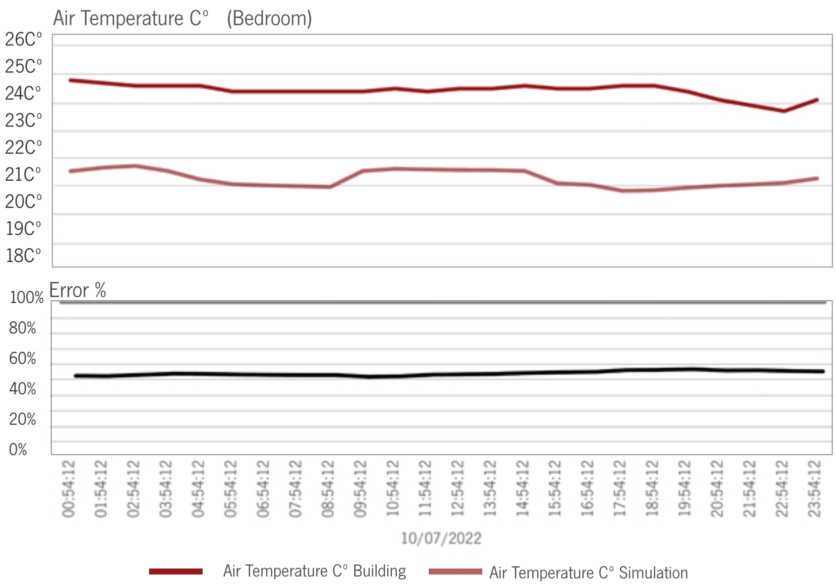
In the exterior graph, the variation line oscillates between 41.5% and 48.5% percent, which means that the maximum oscillation between the two graph lines is 7%. The 7% oscillation difference can thus be taken as the real (maximum) percentage of error in the simulation data in comparison to the real measurements, taking into account the extra temperature values due to the weather anomaly. Despite the difference in temperature, the oscillation pattern or the form are similar to each other for the simulation and the on-site measurements and therefore these data are considered good for use.



Graph 4.6.2.1.



Graph 4.6.2.2.



Graph 4.6.2.3.

The graph for the living room shows a similar oscillation pattern between the collected on site and simulated temperature. The variation line that compares the change in the both data are between 43.5% and 46% percent, which means that the maximum oscillation percentage value between the two graph lines is 2.5% and thus an error percentage of 2.5%.

The graph for the bedroom shows the difference in the oscillation temperature between collected on site and the simulated data, but the lines show a similar oscillation pattern. When compared in percentage the obtained variation line between the two values, changes between 46% and 47% percent, which means that the oscillation difference between the two graph lines is 1% and thus an error percentage of 1%.

In the humidity graphs, the humidity measured on site is lower than that of the simulated in *Climate Studio*. This can be explained due to the heat wave, that increased the temperature and reduced humidity. Similar to the temperature graph, in the humidity graphs the variation between the simulation data and the data collected on-site have a similar oscillation form or pattern.

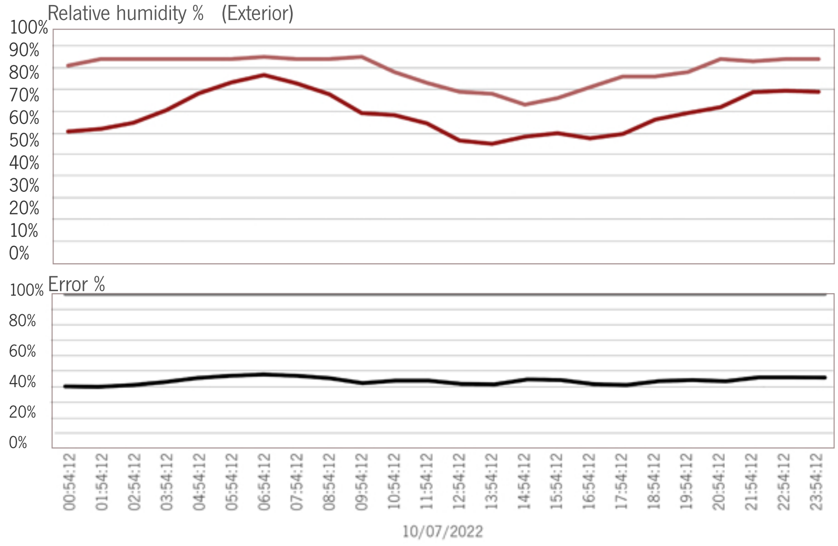
The exterior graph shows a variation in percentage of humidity in the first five hours of the day. The temperature graph in this period of time shows a higher than normal temperature, which explains the percentage of humidity being lower than normal in the humidity graph. The variation line for the first five hours of the day oscillates between 39.5% to 48%, wich means that the oscillation is 8.5%. Disregarding the first 5 hours of the day the values oscillation is between 41.5% and 48.5% percent, which means that in general the oscillation of values between the two graph lines is 7% and thus an error percentage of 7%, but because the is to low in the first five hours of the day the error percentage is 8.5%.

The living room graph shows two similar humidity ranges lines. The variation line oscillates between 55% and 58% percent, which means that the oscillation values between the two graph lines is 3%, thus an error percentage of 3%.

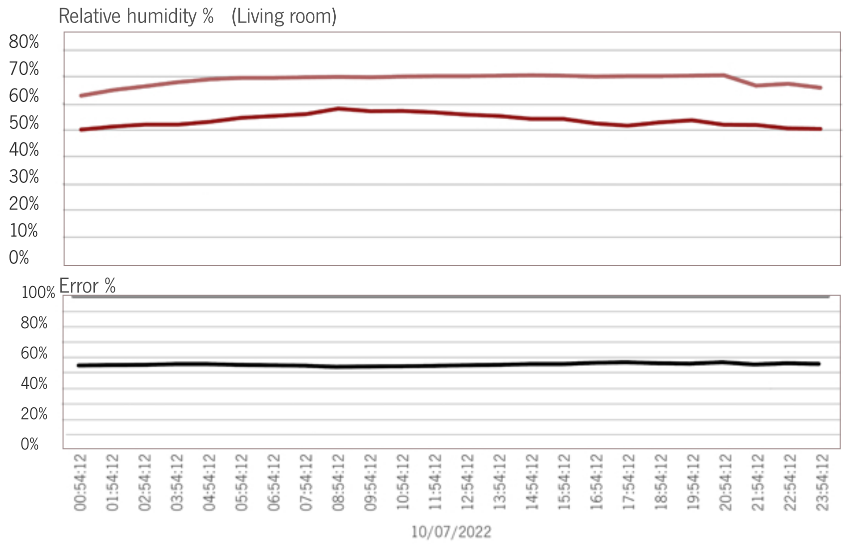
The bedroom graph shows that the variation line oscillates between 52% and 57%, which means that the oscillation difference between the two graph lines is 5%.

Despite the temperature and percentage of humidity from the simulation being different from the on site data, when compared, the two ranges have a similar oscillation pattern.

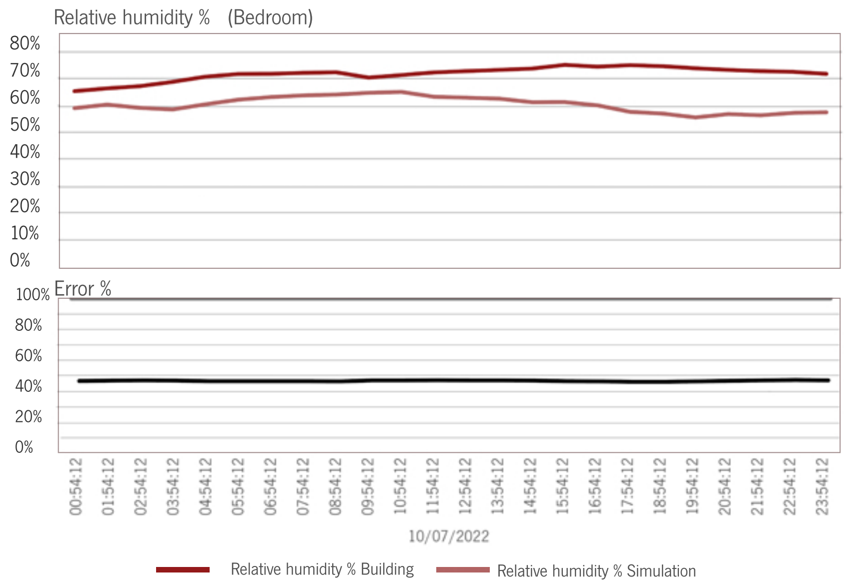
This step was essential for the research in order to prove the consistency of the simulation data from Climate studio with the data collected on site. Despite the extra temperature in the on site measured data due to the heat wave, the consistency and the accuracy of the data was confirmed using the 100% stacked line graph. Which proved that the data generated using the *Climate Studio* simulation was reliable and approximates to reality. This means that the *Climate Studio* simulation can be carried out for the remaining of the buildings and also for the realization of a new design without worrying about the accuracy of the generated data.



Graph 4.6.2.4.



Graph 4.6.2.5.



Graph 4.6.2.6.

5. Third Design Phase: Design Variations

Figure 5.1.Design in dialogue, Cicle, Changes.

5.1 Context

The various design solutions presented in this chapter are suggested as alternatives that consider the study of the performance of a building, when a design element is manipulated or changed, to study, using the simulation, the difference in the performance of the building.
This iconic project and building symbolises a shift in how the practice of architecture in Portugal can have a significant social and political intervention. It is also designed in an era when the energy crisis and climate problems were not as urgent as today. The restoration and possible redesign in itself would probably give rise to a different research and project, which I can acknowledge.
The design variations presented are not a criticism of the design of the Bouça neighbourhood, but rather a means to study and explore the full potential of the simulation software and technology. Therefore, this chapter can be seen rather as an exploration of the potentiality of the simulation software, than a criticism.
The design of the Bouça neighbourhood can be grouped into different design phases throughout the different decades. Similarly, this research phase can be seen as a third design phase, where the main focus lies on the new technology and the definition of what comfort means for today's and future inhabitants.
As mentioned above, the third design phase of the Bouça by Álvaro Siza can be a sensitive topic but for this dissertation, the design choices were mostly based upon the performance of the building.
Jean-Nicolas-Louis Durand (1760-1834) was a French rationalist architect but even though he was a rationalist architect, he saw his design as a continuation of the rich architectural history. His book 'Recueil et parallèle des édifices de tout genre anciens et modernes' (Collection and parallel of all kinds of ancient and modern buildings) showed that even though he was a rationalist architect fascinated with standardization, he saw his design as a continuation of the history. Therefore, the design of the Bouça buildings can't only be justified purely on rational technical merit. It also has to try to continue further the Bouça's architectural history from the past to the present and with future in mind. [43]

5.2 Design in Dialogue

The design of Bouça marked a unique time in the history of Portugal. It was a social housing scheme developed under SAAL (Serviço de Apoio Ambulatório Local) after the revolution of April 1974. Like in other operations under SAAL, the project was developed in a close collaboration between the future inhabitants and the designers. Similarly, for this project, Design in dialogue is essential because the neighbourhood was designed in close collaboration with the inhabitants. “Design in dialogue creates the possibility to collectively redefine the expectations and limits of urban transformation”.[44] During this research of the developed project, the neighbourhood was visited in order to discuss with the inhabitants and the passer-by their experience in the neighbourhood because it is used by the inhabitants and the people living nearby to pass through to the metro or to walk their dogs. Designing is thus seen as a way “to collectively redefine the expectations and limits of urban transformation.” [44] During the dialogue with the neighbours and the passer-by, the question was raised about their needs and expectations from the neighbourhood and their experience of the neighbourhood. The dialogues become an integral part of the dynamic learning process, where both the output of the dialogue and the ways of working together are an essential part of designing.

An architectural scale 1:250 maquette of the whole neighbourhood and plans were made to be used during the conversation with the people from the neighbourhood and also people passing through the neighbourhood. During the conversations with the people, the maquette was helpful to not only point out their house but also to add their own thoughts about the thermal conditions, lighting and also design elements. The maquette helped people visualize better and bring forward their opinions. Beside the maquette, the plans were also used during the conversation and the people were able to comment concerns and their opinion in terms of lighting and thermal conditions, but also their opinion about the design elements which may or not interfere with the comfort.


Figure 5.2.1. Photograph taken by Lama in Bouça neighbourhood during the design in dialogue process-1


Figure 5.2.2. Photograph taken by Lama in Bouça neighbourhood during the design in dialogue process-2


Figure 5.2.3. Photograph taken by Lama in Bouça neighbourhood during the design in dialogue process-3


Figure 5.2.4. Photograph taken by Lama in Bouça neighbourhood during the design in dialogue process-4

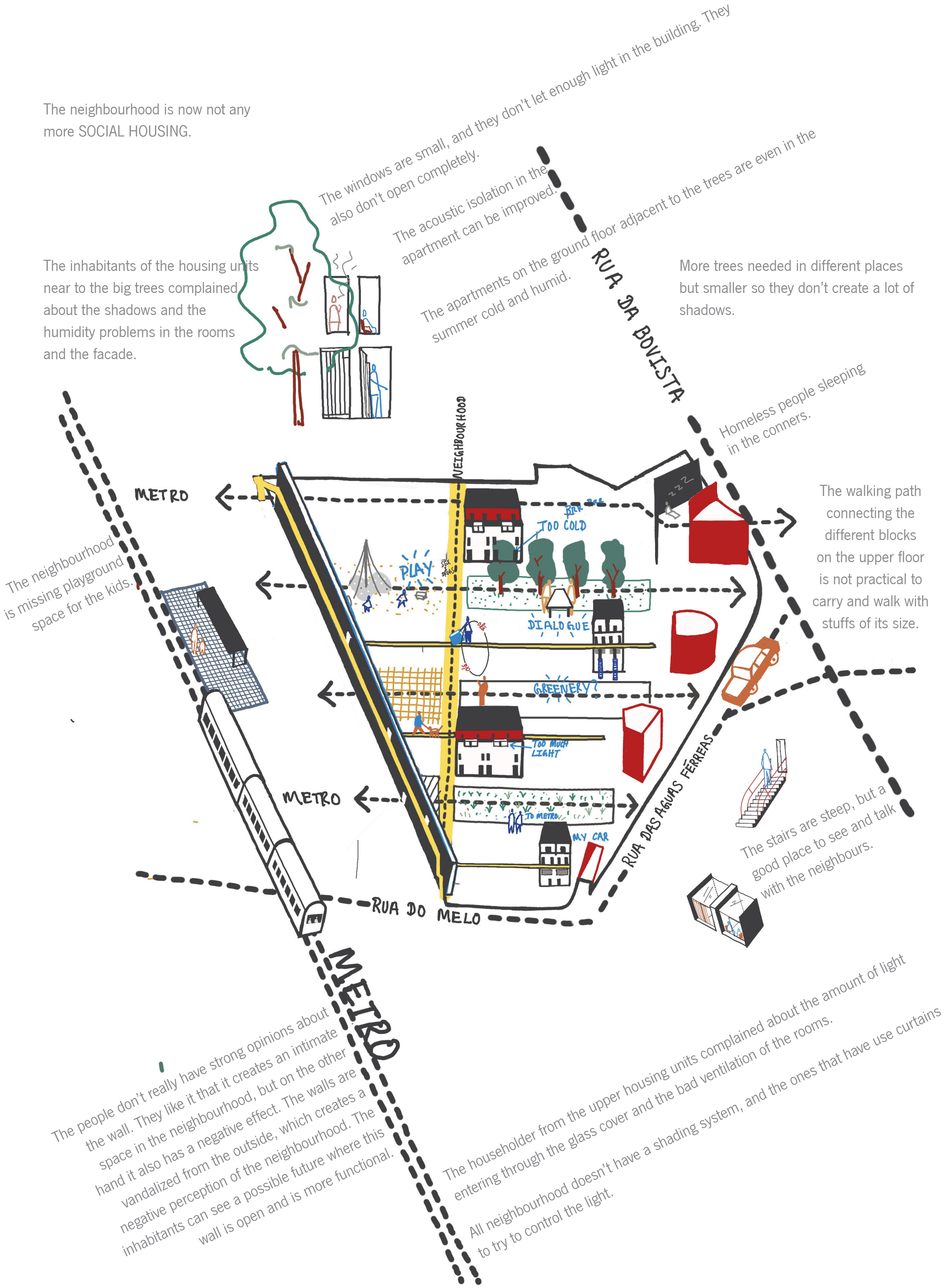


Figure 5.2.5. Situationist mapping

This process was necessary for the investigation to determine the further course of the research and to gather real opinions from the inhabitants and passer-by, who in some sense are in daily contact with the neighbourhood and the buildings. During the conversations about the history of the neighbourhood, the original inhabitants pointed out that they were actively engaged in the design process with the architects since the beginning. Which was an unknown fact before visiting the neighbourhood. The opinions and the personal experience of the inhabitants helped to understand and decide the possible thermal and daylight parameters that could be analysed in this research. The image 5.2.5. demonstrated the most talked subjects, which were related mostly about the proportion of the opening in relation to the necessity for natural light inside the spaces, the difference of the thermal comfort inside housing units, and the accessibilities to the different spaces.

5.3 Improvement of the existing building

In this subchapter, ten different variations of the existing building are presented in order to explore the potentialities of the Climate studio software and understand the design rationally by comparing the thermal and natural lighting performance of the buildings. The selection of the explored variations were made taking into consideration the opinions of the inhabitants and their concerns related to thermal and daylighting comfort, but also accessibility. The performance of the buildings were analyzed using the Daylight autonomy simulation and a Thermal comfort simulation.
The design variations are made not merely autonomous decisions, but rather variations informed by inhabitants suggestions and prior knowledge as master student in architecture about buildings performance.
During the research, not only the advantages of *Climate Studio* were clear, but also its limitations. Due to the size of the building and there being 128 housing units, the simulation software was not able to perform the thermal simulation, for all the neighbourhood. Therefore, for the daylight and thermal simulation, fifteen housing units were selected from the eight different sections of the building blocks. The fact that most of the selected units have different typologies and are located at different points in the neighbourhood makes the sample size for the simulation more diverse and the results more accurate.

1- Two housing units in the middle of the building block A constructed in the second phase (typologies 6A, 6B, 15A and 15B).
2-Two housing units in the middle of the building block B, constructed in the second phase (typologies 6A, 6B, 15A and 15B).
3- A pavilion where the kindergarten/nursery was located. From all other pavilions on the street side, this pavilion was chosen because of its regular planar geometry which doesn’t restrain the thermal simulation in *Climate Studio*.
4- Two housing units in the building block C constructed in the second phase, that has one less room in the down unit due to their being the neighbourhood storage units (typologies 4A, 4B, 13A and 13B).
5-Two housing units in the building block C constructed in the second

phase, the down housing unit is used for analysis of case study.(typologies 6A, 6B, 15A and 15B)

6- Two housing units in the building block D constructed in the second phase, the down housing unit has one less room due to the due to the slope of the terrain (typologies 3A, 3B, 10A and 10B).

7- Two housing units in the building block D, constructed in the first phase (typologies 6A, 6B, 15A and 15B).

8- Storage unit, and one housing unit facing the Boavista Street .

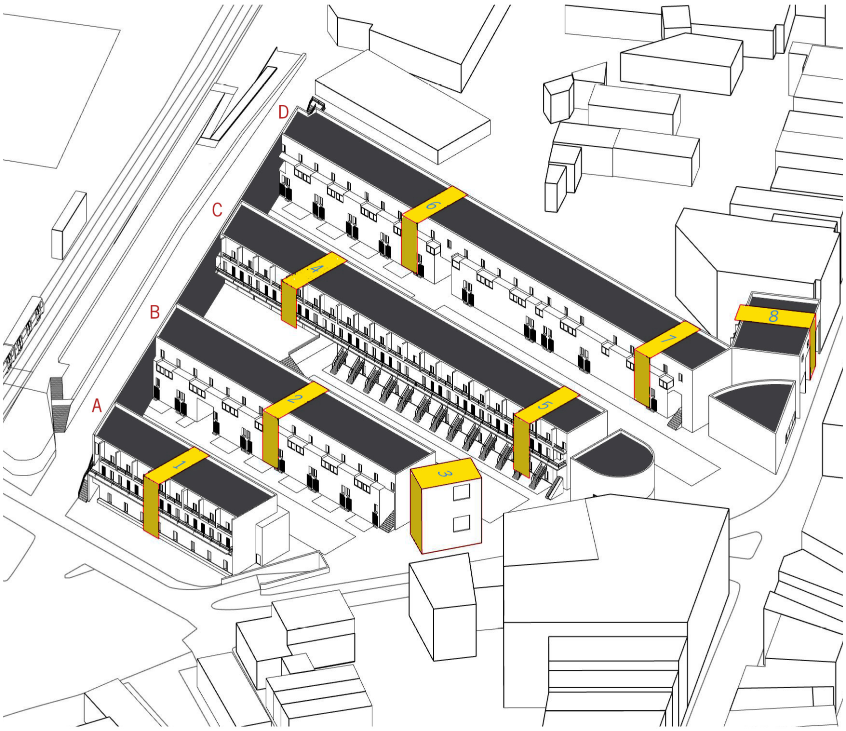


Figure 5.3.1.

Figure 5.3.1. Axonometry of the neighbourhood, highlighting the building select to be analysed in the different variations.

Figure 5.3.2. Plan highligting the section line.

Before presenting the variations, the data of the simulation made of the existing building is presented to be easier to compare the data.

For all the variation presented, a section perpendicular to the neighbourhood is presented, showing the penetration of the natural light and it spreads in the spaces. The figure 5.3.2 presents the section cut made for the existing building.

In the section, different gradients of colours are used to represent from direct light to shadow and how the light spreads through the spaces. This gradient is composed of four colours: light yellow (excessive light over 3000lux), yellow (Acceptable light from 300 to 3000 lux), green (supplemental light from 100 to 300 lux) and dark blue (Failing light (from 0 to 100 lux).

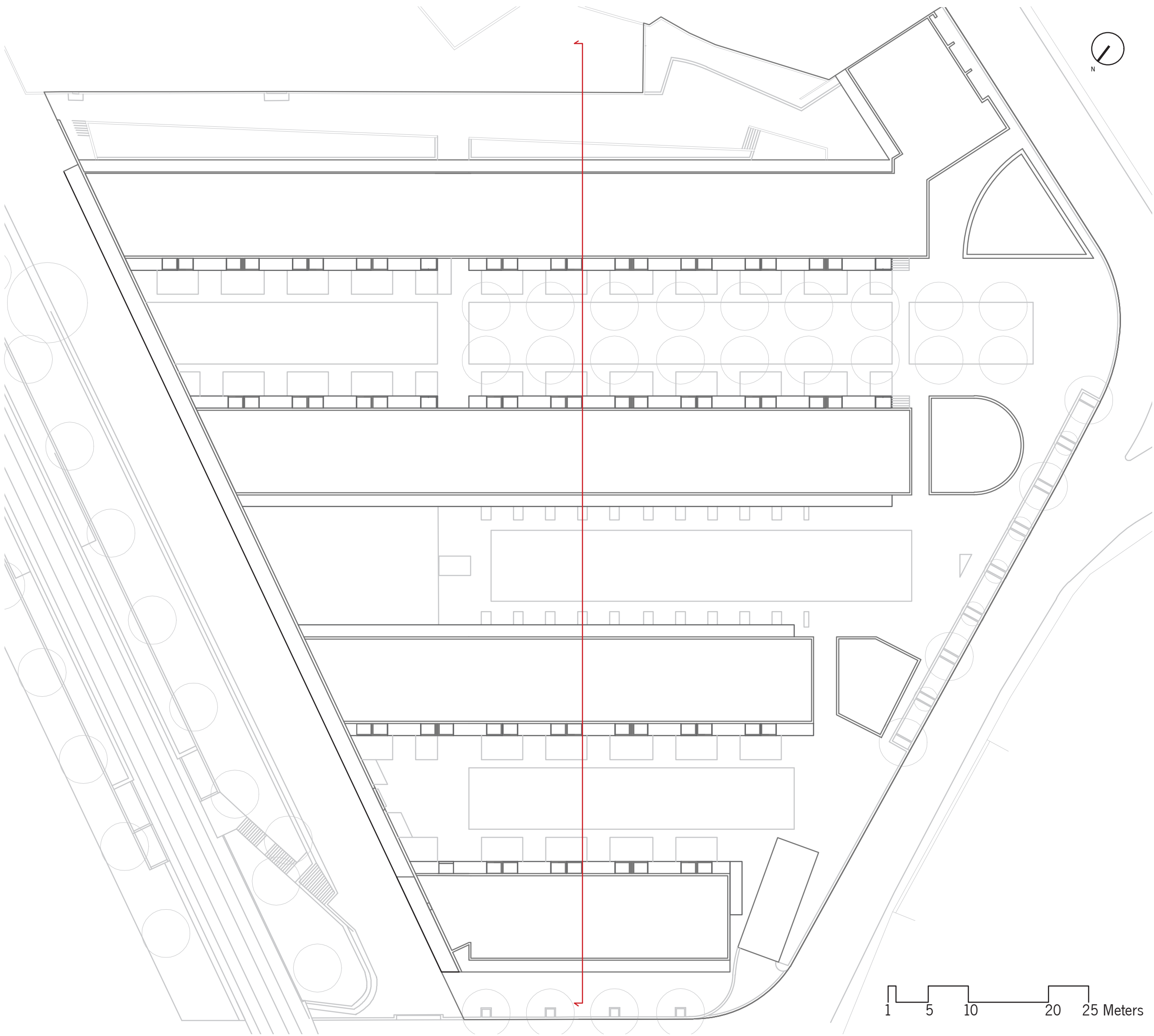


Figure 5.3.2.

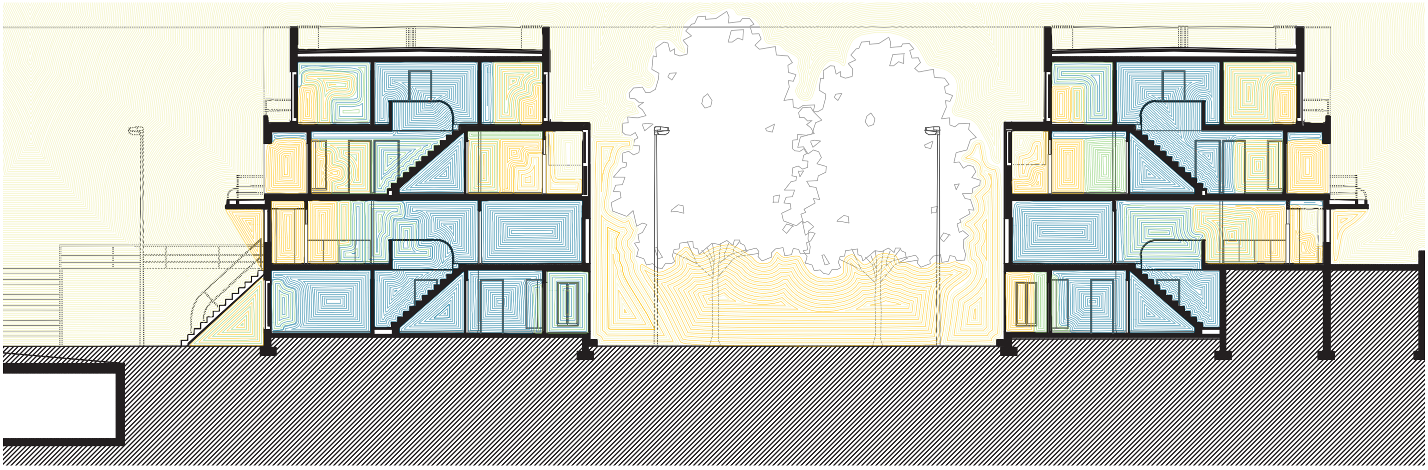
Figure 5.3.3. Section showing the amount of natural light entering the building (Simulation results of the existing building).

The image 5.3.3 shows the amount of natural light entering the building through the openings in the two façades, and how light spreads through the spaces without reaching the interior of the building. In the central space of the building, the natural light is very limited.

On the façades of the residential units in building blocks C and D adjacent to the trees, there is not enough light entering through the façades on the first two floors.

In building block D, where only the first floor façade is facing the building block C, the amount of light entering the space is low.

In the sun room of the third floor, there is a high incidence of direct sunlight entering the spaces behind through the windows and the glass roof.



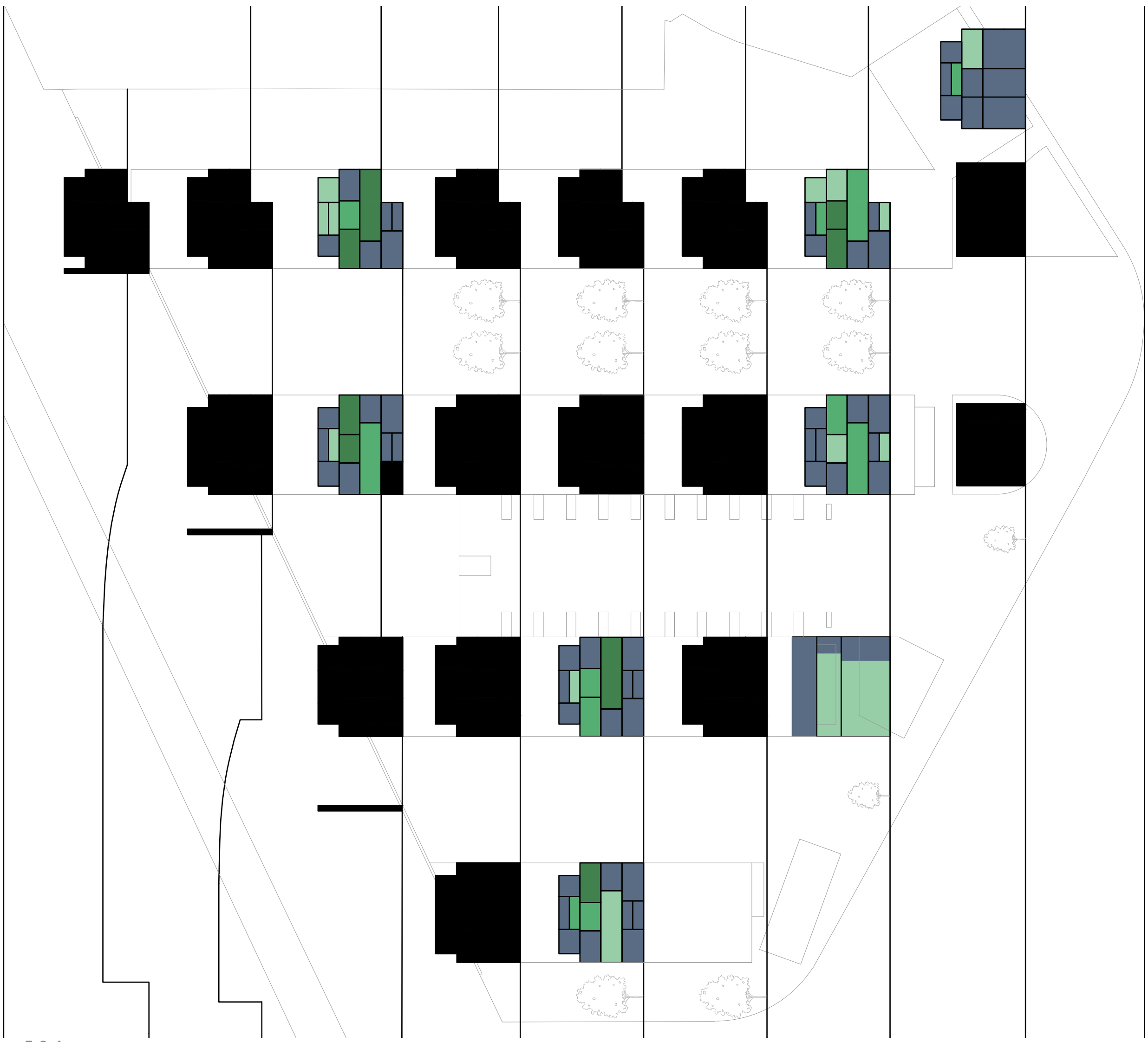
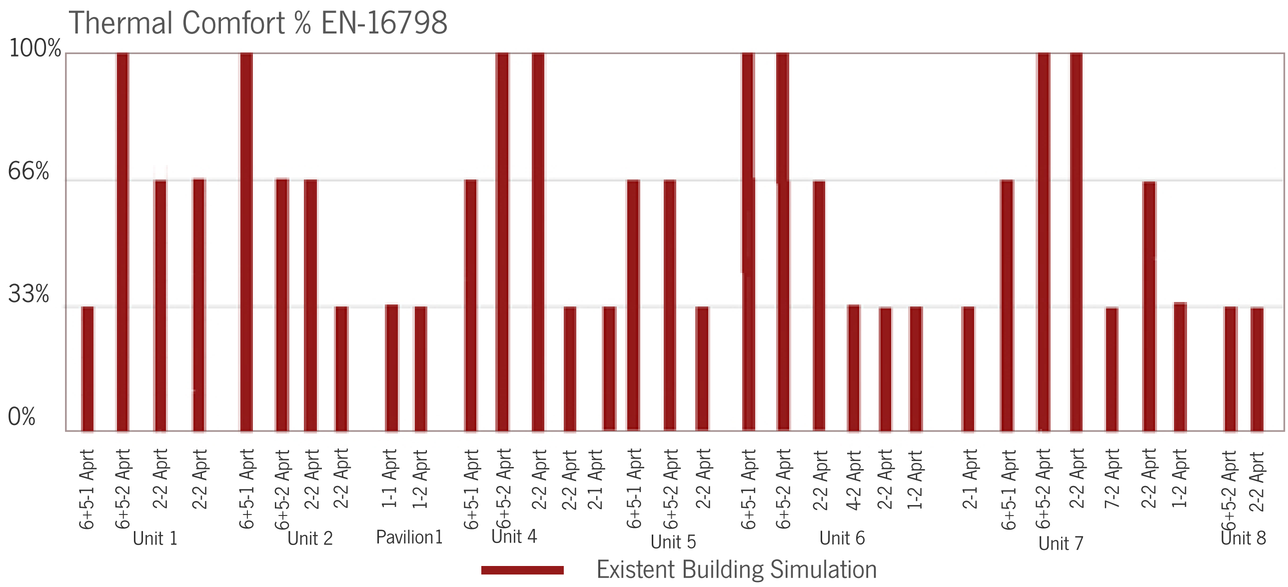


Figure 5.3.4.



Graph 5.3.1.

Figure 5.3.4. Representative sections of the thermal comfort in the different compartments of the eight selected housing units (Simulation results of the existent building).

Figure 5.3.5. Representative axonometry of the daylight autonomy percentage on each floor of the eight selected housing units. (Simulation results of the existent building).

Graph 5.3.1. Graph of the thermal comfort in the different compartments of the eight selected housing units (Simulation results of the existent building).

Graph 5.3.2. Graph of the daylight autonomy percentage on each floor of the eight selected housing units. (Simulation results of the existent building).

The thermal comfort simulation was performed by characterizing the different areas. The values to fill the required parameters used for the simulation were based upon the values measured on site in the selected housing units.

The following parameters were those used in the simulation: the density of occupation, the occupancy schedule, the equipment power density and the availability schedule, lighting power density and availability schedule, intel and supply water temperature, the water schedule, the water heating and cooling set points, the water supply, the water capacity, the heat flow schedule, the humidity control, the mechanical ventilation, the wind, the stack natural ventilation, the natural ventilation schedule and the construction details.

The data in the tables presented in the annex 8.12 was considered for the different areas.

The figure 5.3.4. represents the thermal comfort in the different spaces of the different housing units of the 8 chosen building sections for the simulation.

Together with a column graph 5.3.1., the above image allows a comparison of the comfort level in the different zones of the neighbourhood and in the different zones of the housing units.

The comfort analysis was done using the CBE Thermal Comfort Tool, a tool which uses the following parameters, the operative temperature, the relative humidity percentage, the metabolic rate and the dynamic clothing insulation to confirm the compliance of the space with the EN-16798.

The European standard, EN-16798, covers the environmental criteria for the design of buildings, room conditioning systems, and lighting systems for both residential and non-residential structures. [45]

The CBE Thermal Comfort Tool generates a graph related to the different values and places the comfort of the room, represented by a red dot, in one of the four areas of the graph. The white area represents the space that doesn't comply with the norm and is thus not comfortable. The other three areas represent 3 different levels of comfort: high (100%), medium (66%) and low (33%), respectively by the colours dark green, green and light green.

For easy understanding, the colour blue in the image 5.3.4 was used to represent the spaces that don't comply with the norm.

The graphs, presenting the different variations, show only partial data from the simulation. The full data can be consulted in the annex 8.10.

The graph 5.3.2 and the figure 5.3.5 show that units five and seven have higher number of spaces that are comfortable than in the rest of the units.

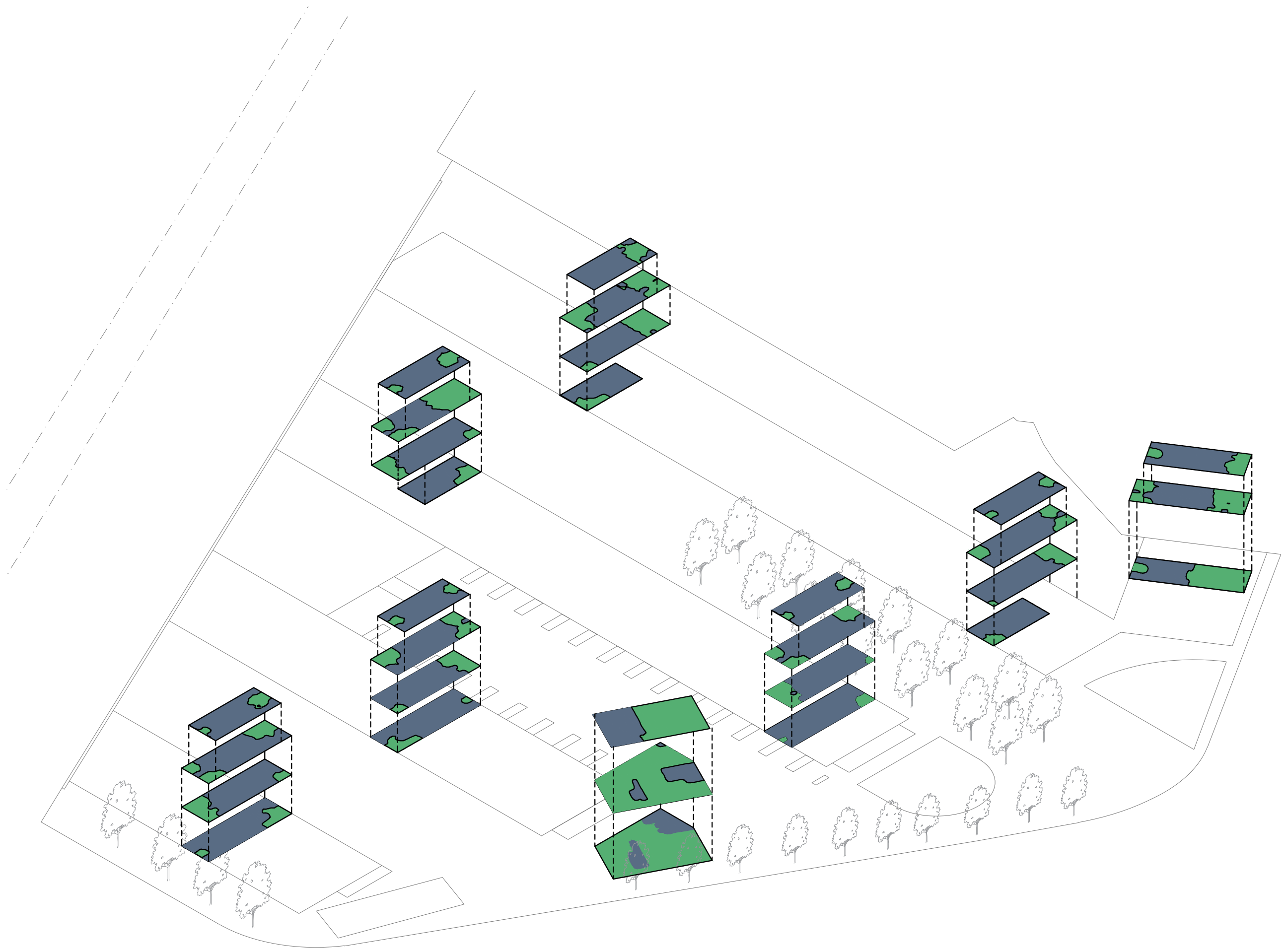
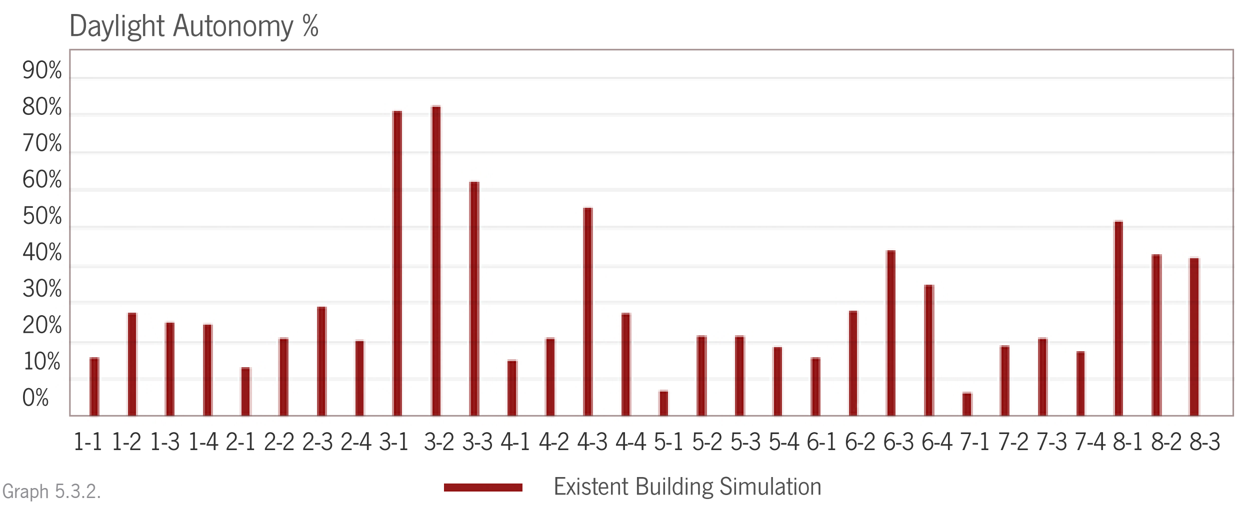


Figure 5.3.5.



Graph 5.3.2.

The image 5.3.5. shows the daylight autonomy of each floor of the 8 analysed housing units. The plans were also made for all other variations in order to be compared to each other. The graph x shows the percentage of daylight autonomy in the space, and it can also be used for the comparison of the data of the different variation with the existent building data. In the graph x the percentage of daylight autonomy in the different units varies from 5% to 80%. The building units 3 and 8 are the ones with more percentage of daylight autonomy.

5.3.1 Variation1: Rotation of the north from 129° to 90°

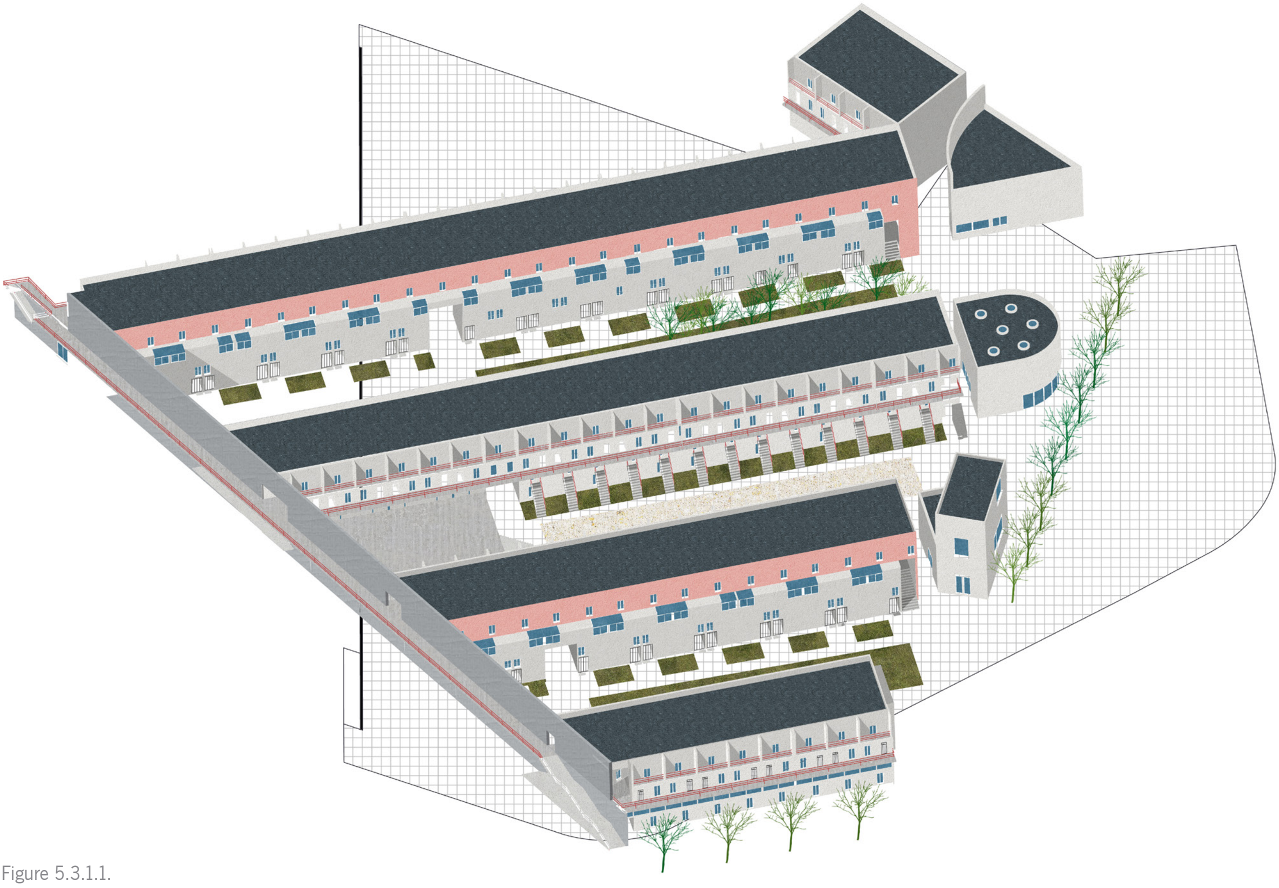


Figure 5.3.1.1.

Figure 5.3.1.1. Collage representing the difference between the existing buillding and the variation 1.

The first three variations explore the position of the neighbourhood in its context. The three variations explore the impact of the orientation and the building layout on the thermal and natural lighting conditions by analysing the difference in each rotation variation. Thus, when rotating, the building's internal layout states the same, and it wasn't adapted to the site.

This first variation rotates the neighbourhood in a way that the north points directly to the wall. In this variation, the north is parallel with the building block's direction. This rotation was explored to understand the influence of the south wind on the ventilation in the building blocks and how the light enters the building if the sun in the morning reaches the east facades and in the afternoon the west facades.

Wind:

In these three variations, the behaviour of the wind and its relationship with the thermal of the buildings are explored. When the wind direction is perpendicular to the building's facade, it causes positive pressures on the windward facade and negative pressures on the leeward facade. The difference in dynamic wind pressure creates zones near the windward with high-pressure rises and zones near the leeward with low-pressure. This causes the air to flow from the high pressure zone (windward) to a low-pressure zone (leeward). [46] Depending on the position of the facade to the wind direction, natural ventilation via cross-ventilation can be more or less guaranteed. This is an important factor to explore because it not only influences the thermal comfort in the different spaces of the building but also influences the amount of energy needed to achieve comfort in case it is not possible to achieve it only through natural ventilation.

The image 5.3.1.2. represents the average of wind entering the building when rotated in this position, both in summer and winter.

In summer the wind comes from the northwest which reduces the cross-ventilation efficiency despite the facade facing the west, it sits at an angle to the wind direction. The current layout of the buildings in the neighbourhood is oriented directly to the wind direction, which makes cross-ventilation easier and more efficient.

In winter, the east wind can improve cross ventilation together with the south wind that penetrates the outdoor spaces between the building blocks. The wind in the current orientation of the building blocks hits the corner of the neighbourhood.

The orientation variation creates a high level of wind penetrating the neighbourhood, which means that the applied ventilation schedule in the simulation needs to be rescheduled in order to control the amount of wind penetrating the spaces. This means that people will need to let their windows be closed for longer periods.

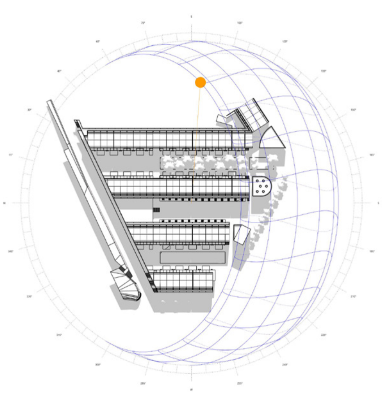
Sun:

The cast shadow from the winter and summer solstice, presented in the image 5.3.1.2. looks similar to that of the existing neighbourhood, but is smaller and has a different direction.

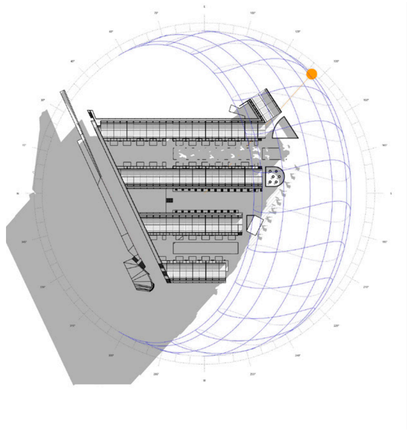
During the morning of the summer solstice, the sun is oriented to the east facade and creates a short shadow in the west one. In the afternoon, the sun is oriented to the west facade and creates a shadow in the east facade.

During the morning of the winter solstice, the sun is oriented to the southeast facade and creates a long shadow. Due to the angular direction of the sun in relation to the building blocks, there is no direct light from the sun in any of the facades. In the midday, the sun is oriented to the south facades, creating a prolonged shadow on the main facades of the building blocks. In the afternoon, the sun is located southwest, which gives no direct sunlight to any facades of the building block, creating big shadows in the outdoor areas.

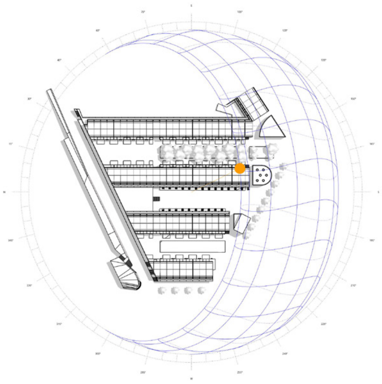
Figure 5.3.1.2. Composition of images showing the shadow during summer and winter solstice and the wind rose representing the average wind in summer and winter of the variation 1.



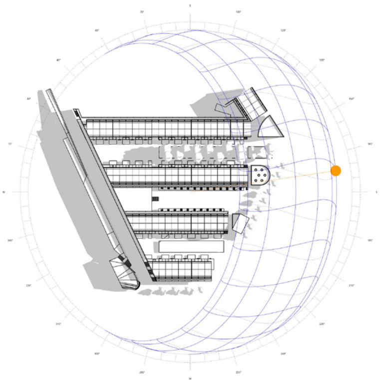
21 JUN 09 am



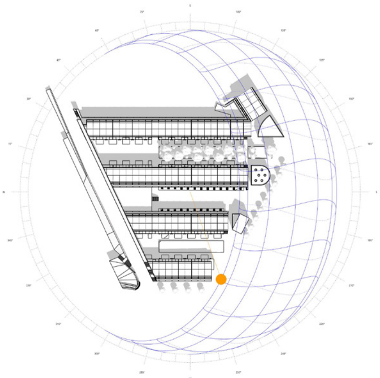
21 DEC 09 am



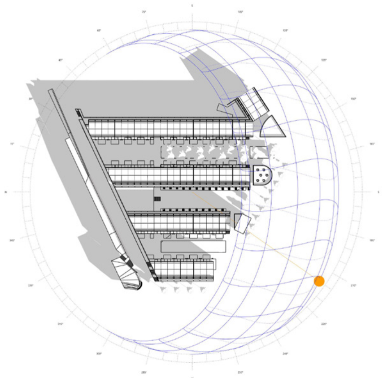
21 JUN 12 am



21 DEC 12 am

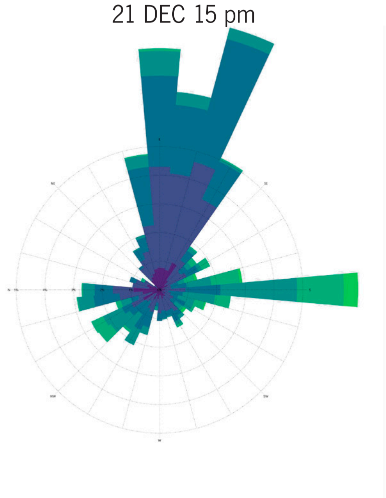


21 JUN 15 pm



21 DEC 15 pm

Summer



Winter

Figure 5.3.1.2.

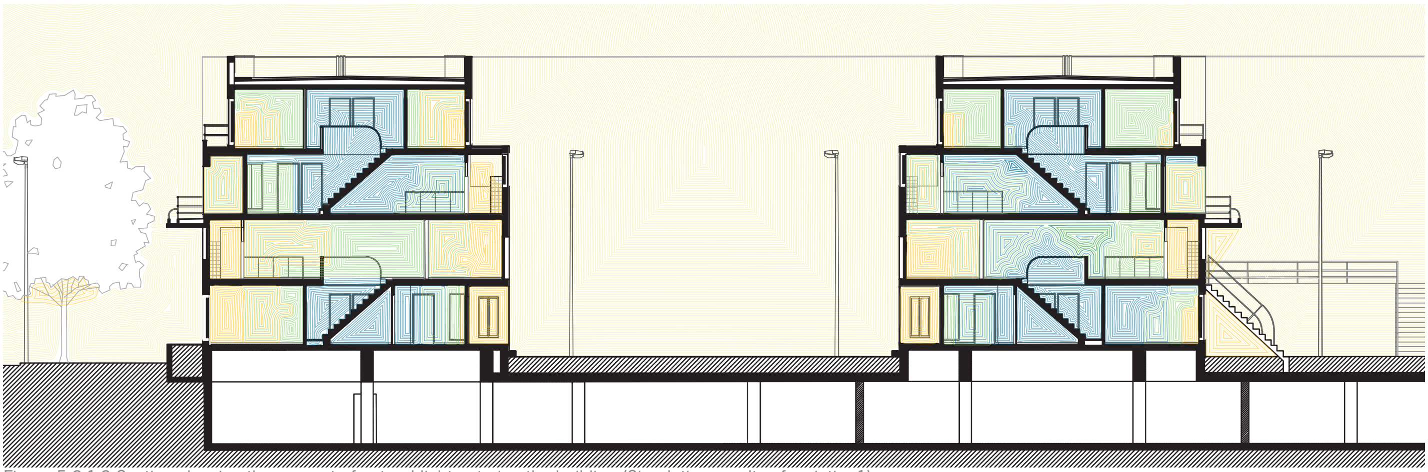
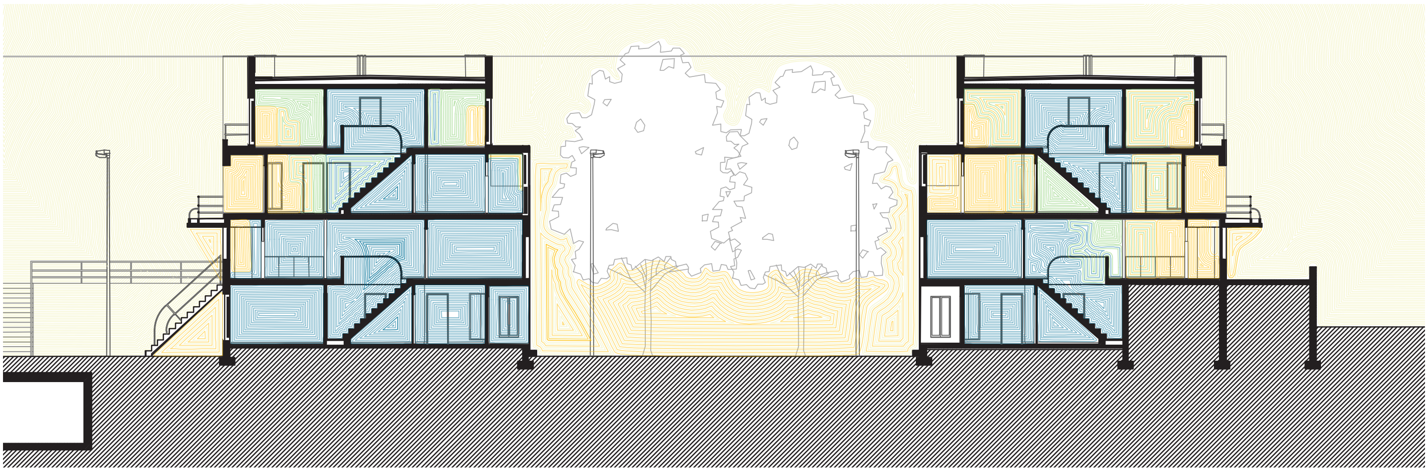


Figure 5.3.1.3.Section showing the amount of natural light entering the building (Simulation results of variation1).

In comparison to the perpendicular section (figure 5.3.2.3) of the existing neighbourhood, this section shows some light penetrating the windows in building blocks A and B. In building block C located in the east, the section shows that the big trees block the light entering the housing units. Similarly, in the west facade of building block D the trees are blocking the light.



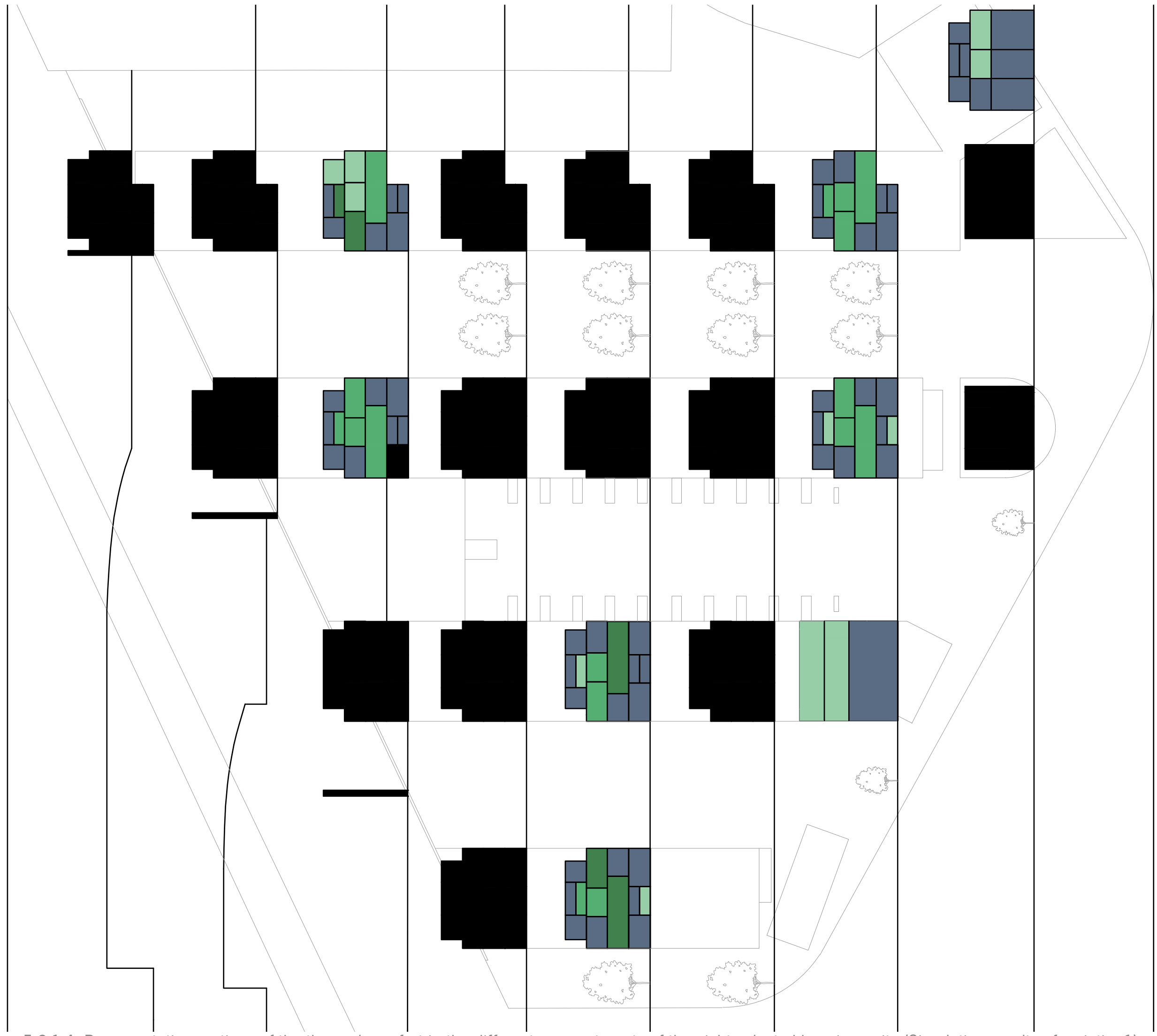
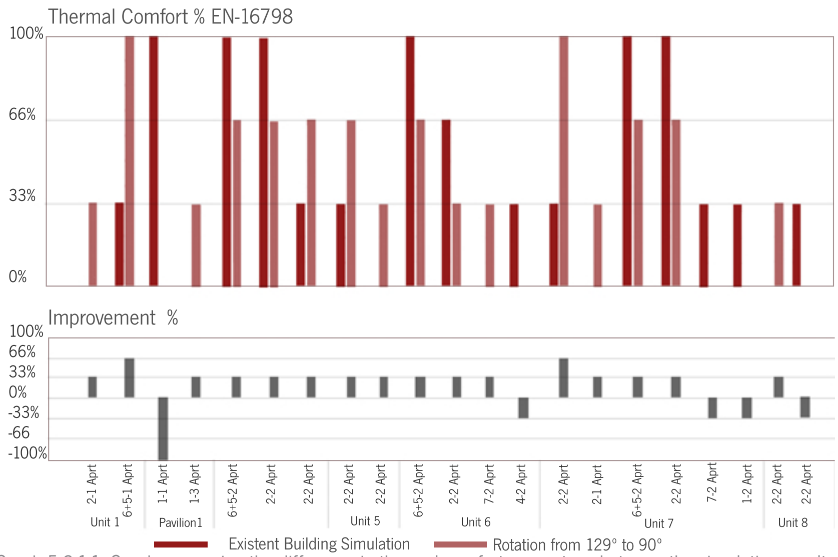


Figure 5.3.1.4. Representative sections of the thermal comfort in the different compartments of the eight selected housing units (Simulation results of variation1).



Graph 5.3.1.1. Graph comparing the difference in thermal comfort percentage between the simulation results for the existing building and for variation 1.

The comfort analysis shows that in housing units 1,4,5,6,7 and 8, the thermal comfort is improved in the living room and all the adjacent rooms and in the corridors. On the first floor of the pavilion1 (building unit 3), the spaces are not comfortable any more, compared to the existing building. In housing units five and six, the spaces near the trees are not comfortable any more, but in the spaces that don't receive shadow from the trees the thermal comfort improved.

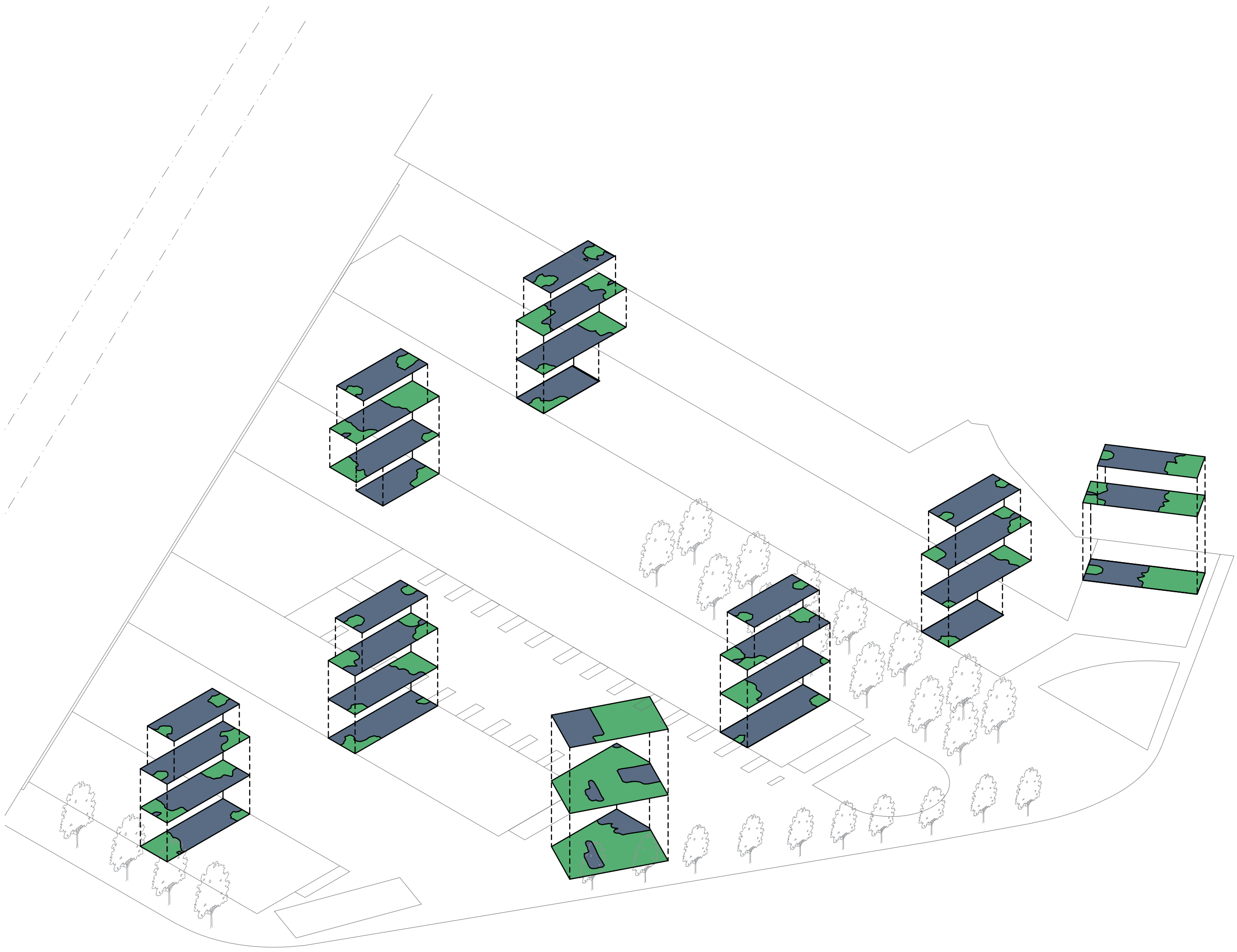
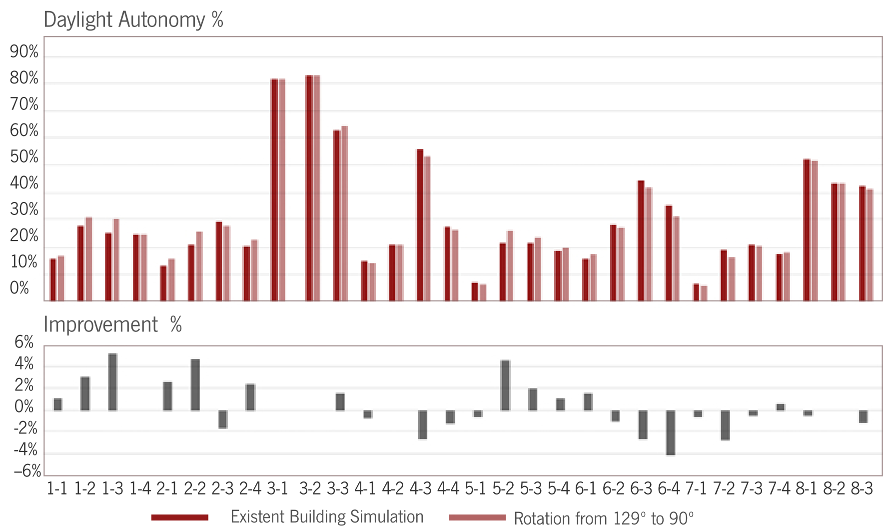


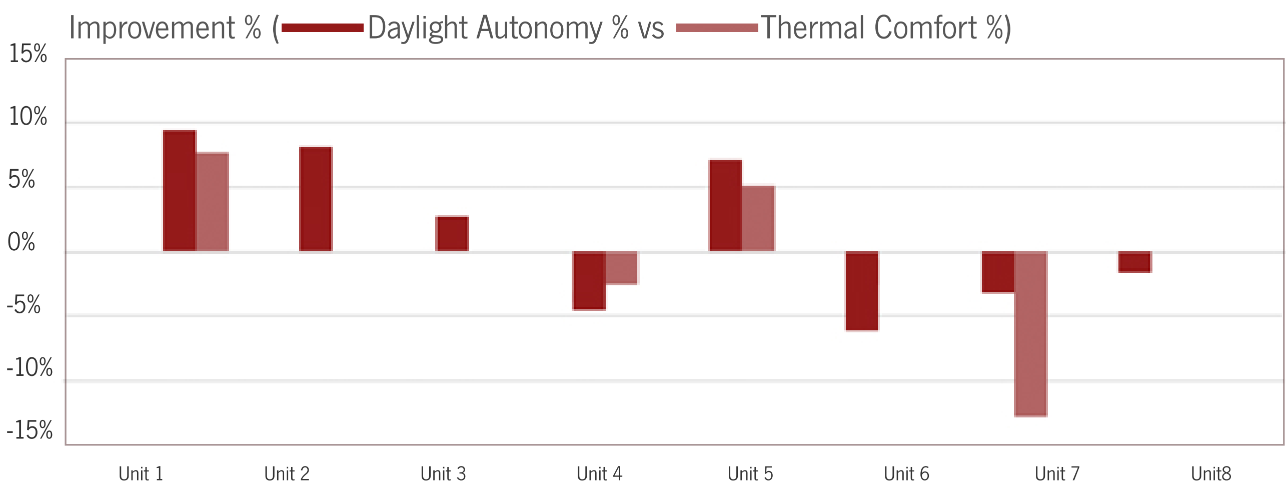
Figure 5.3.1.5.Representative axonometry of the daylight autonomy percentage on each floor of the eight selected housing units. (Simulation results of variation1).

In the image 5.3.1.5. and graph 5.3.1.2., the daylight percentage improved in the units one, two, and five between 0% and 5% and reduced in the units four, six, seven, and eight between 0% and 4%. The unit one and unit two show an increase in the percentage of daylight autonomy because of their orientation towards the sun. The unit five despite having the worst results due to the trees in the east facade, the results obtained in the west facade show in general an improvement in daylight autonomy.

In the units four and six the graph shows a 2% to 4% reduction in the percentage of daylight autonomy on the top floors and in units seven and eight a reduction of around 1%.



Graph 5.3.1.2. Graph comparing the difference in daylight autonomy percentage between the simulation results for the existing building and for variation 1.



Graph 5.3.1.3. Comparison of the percentage improvement in daylight autonomy and thermal comfort in variation 1.

Improvement percentage (%)

	Total	Average per unit
Daylight Autonomy:	11.9%	1.5%
Thermal Comfort:	-2.6 %	-0.3%

5.3.2. Variation 2: Rotation of the north from 129° to174°

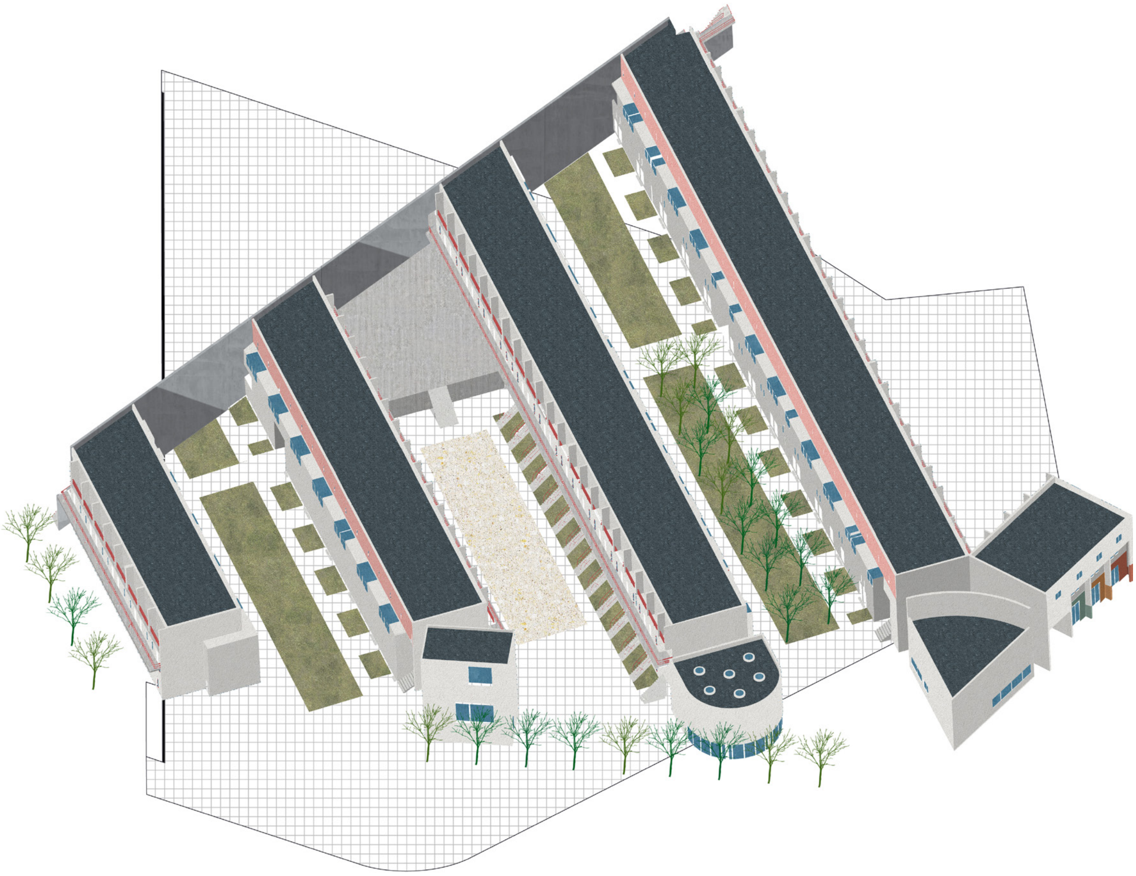


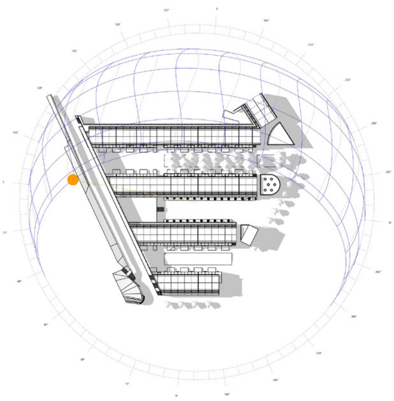
Figure 5.3.2.1

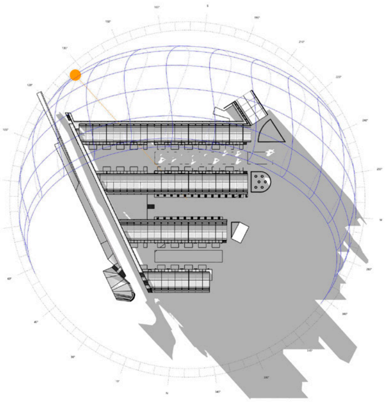
As Figure 5.3.2.1. shows in this variation, the neighbourhood was rotated 45° counterclockwise. This variation was made to understand the effect of the sun if the main facades were facing north and south. In this variation, the sun rises facing the concrete circulation wall and sets facing the pavilions near the street.

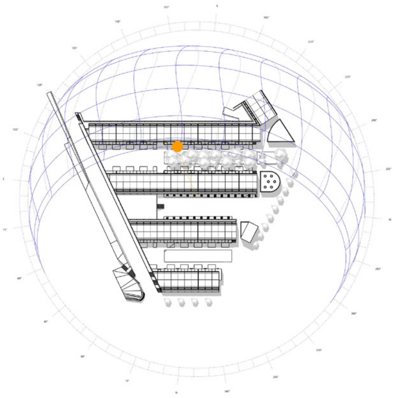
Figure 5.3.2.1. Collage representing the difference between the existing buillding and the variation 2.

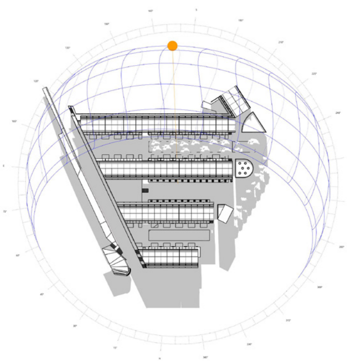
Figure 5.3.2.2. Composition of images showing the shadow during summer and winter solstice and the wind rose representing the average wind in summer and winter of the variation 2.

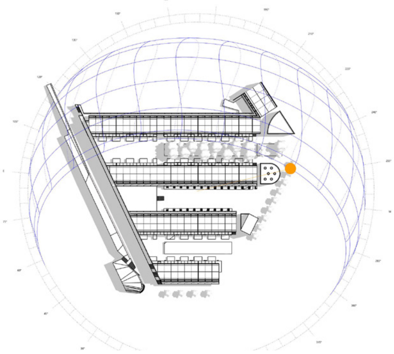
Wind:
In summer, the wind from the northwest will hit the building blocks' west facades at an angle, but the wind coming from the north will hit the west facade directly. This ensures natural ventilation of the building during the summer. In the winter, the strong east wind hits the wall and thus minimizing the draughts during the winter in the outdoor spaces of the neighbourhood. This also makes it possible to use the southerly winds to achieve cross-ventilation in the building without making the space uncomfortable due to excessive wind.
Sun:
The cast shadow in the summer and winter solstice gives in the summer a shorter cast shadow and in the winter a longer cast shadow than shadows from the existing buildings. On the morning of the summer solstice, the wall casts a shadow on the buildings and outdoor areas near the wall. At midday, the sun is on top of the neighbourhood, creating an almost non-existent shadow. In the afternoon, the sun is facing the pavilions and the shadow of the wall is projected onto the street. On the morning of the winter solstice with the sun in a lower position, the sun is facing the building from southeast, which creates a big cast shadow that covers all the neighbourhood. During the midday, the sun faces the buildings from the south and the cast shadow is thus small. In the afternoon, the sun cast a shadow from southwest to east that covers the whole neighbourhood.

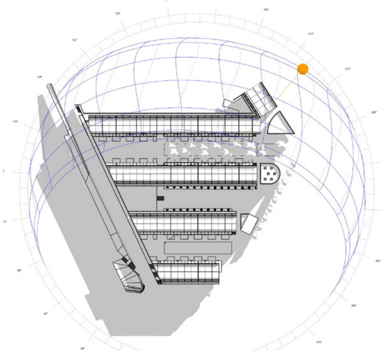

21 JUN 09 am

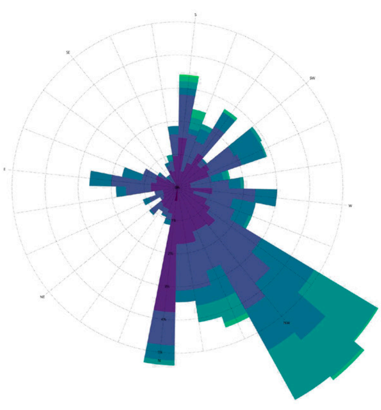

21 DEC 09 am


21 JUN 12 am


21 DEC 12 am


21 JUN 15 pm


21 DEC 15 pm


Summer

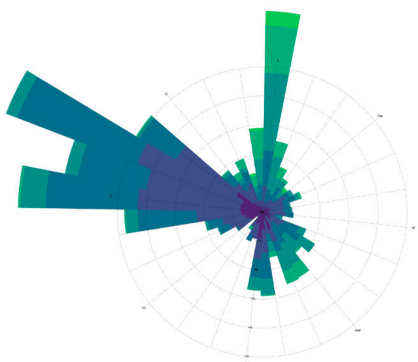

Winter

Figure 5.3.2.2.

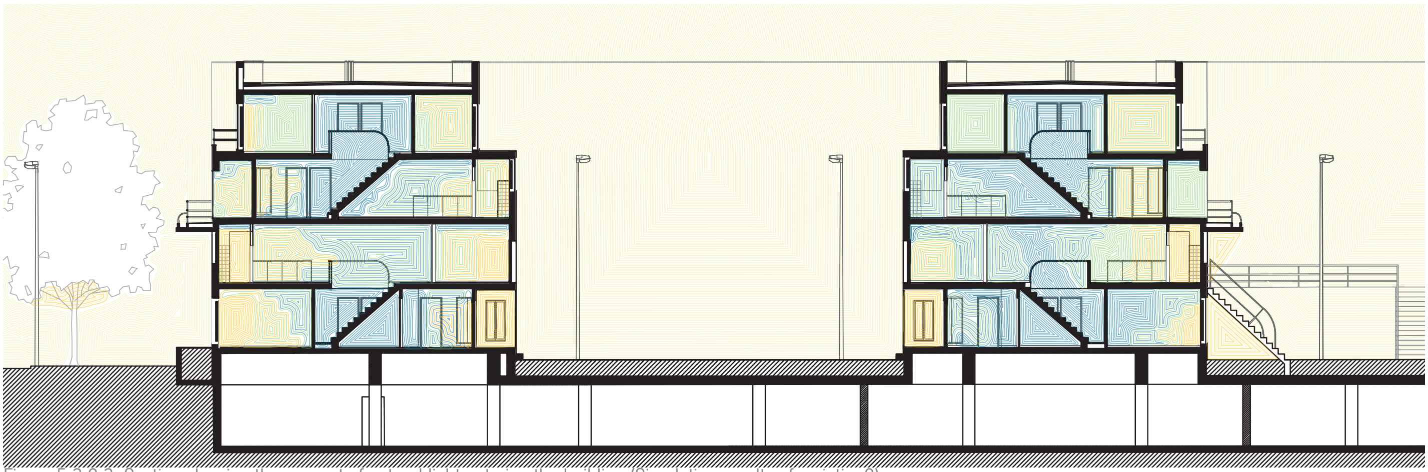
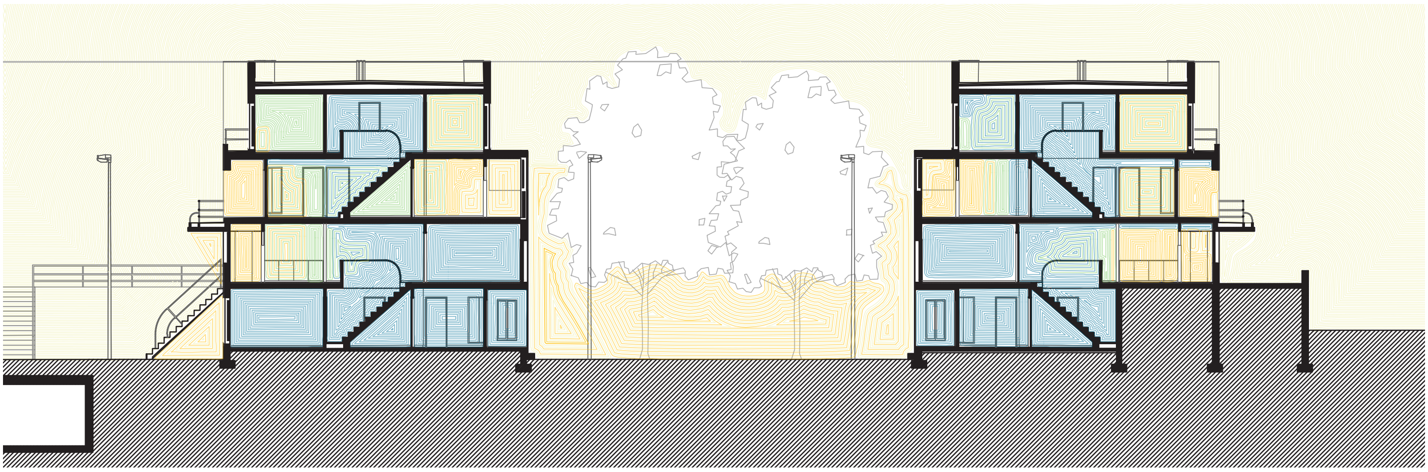


Figure 5.3.2.3. Section showing the amount of natural light entering the building (Simulation results of variation2).

When compared with the section of the existing building, the section (figure 5.3.2.3.) shows the amount of natural light, which almost doesn't change compared to the existent building. The improvement is not significant.



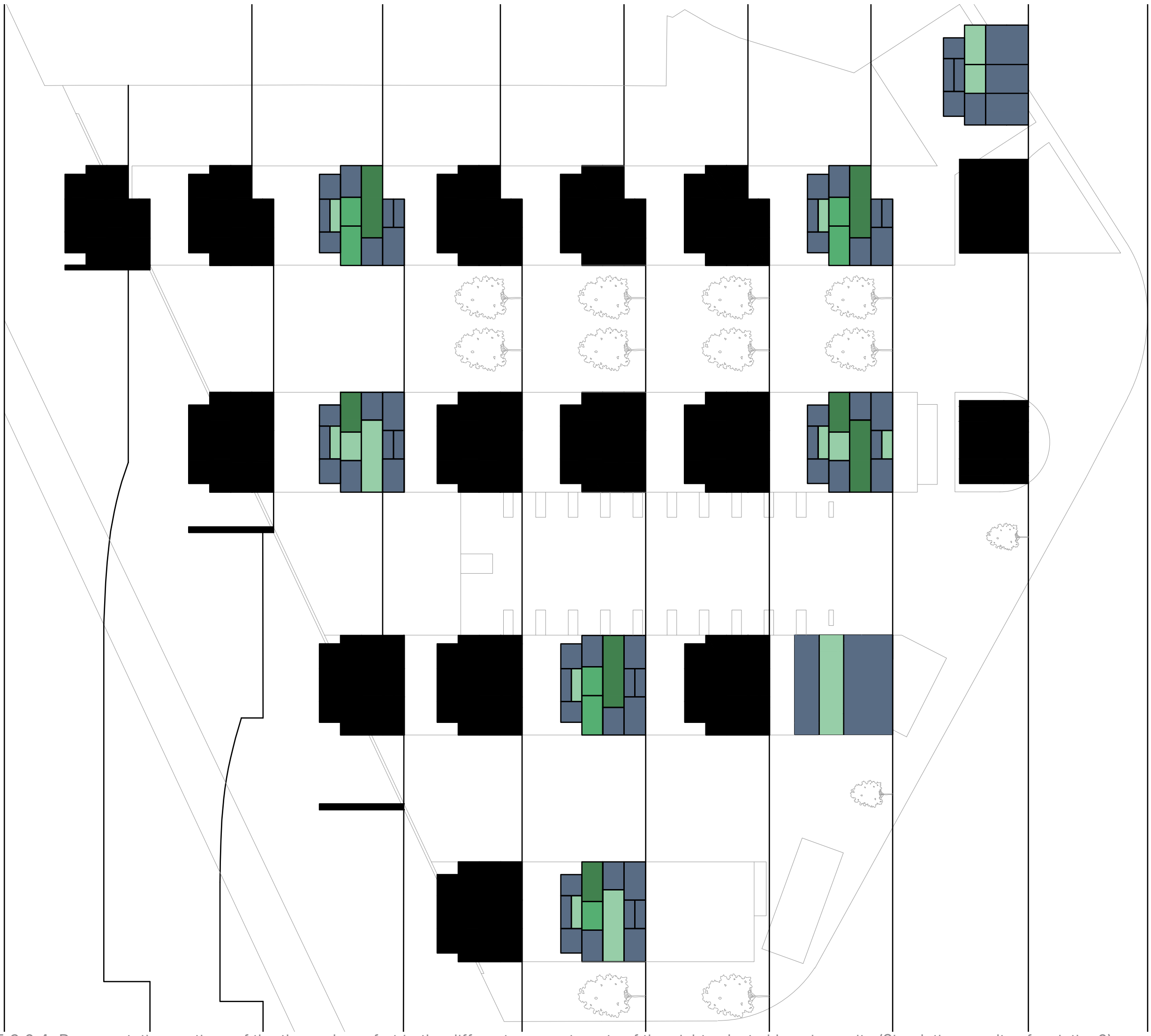
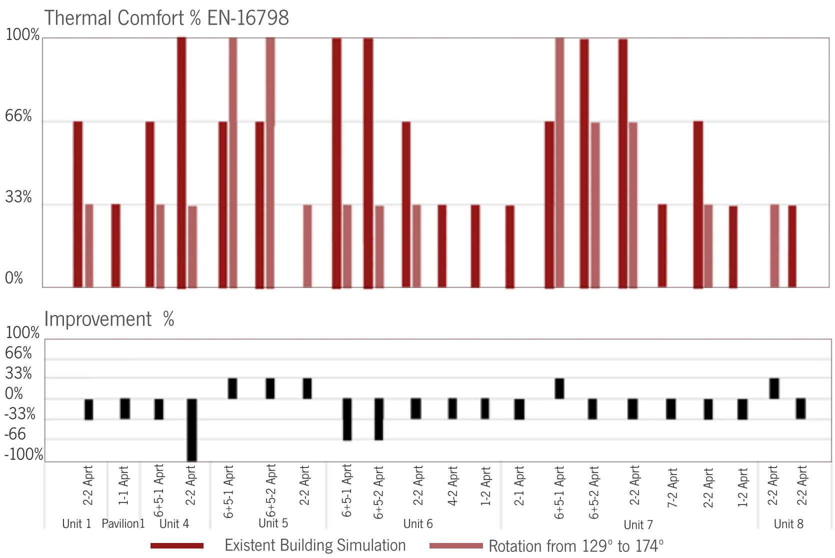


Figure 5.3.2.4. Representative sections of the thermal comfort in the different compartments of the eight selected housing units (Simulation results of variation2).



Graph 5.3.2.1.Graph comparing the difference in thermal comfort percentage between the simulation results for the existing building and for variation 2.

The figure 5.3.2.4 and graph 5.3.2.1 show that the unit one, four, six, seven, eight, and the pavilion 1 are not comfortable any more. The results can be explained by the amount of air that this rotation variation gives. There are improvements in some spaces which are protected from the high winds, like in the living room of the unit seven, the corridor of unit eight, living room and corridor of units five.

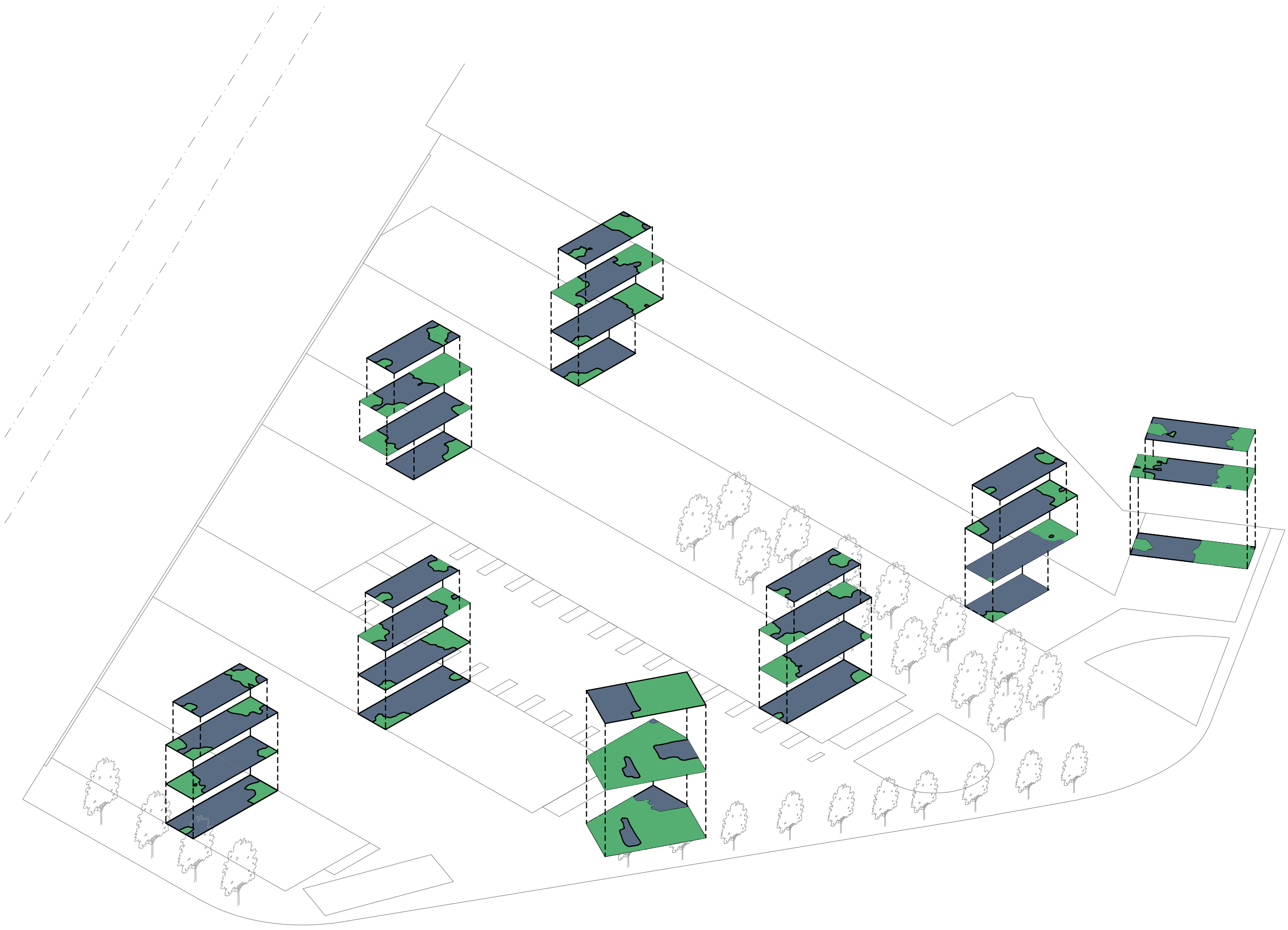
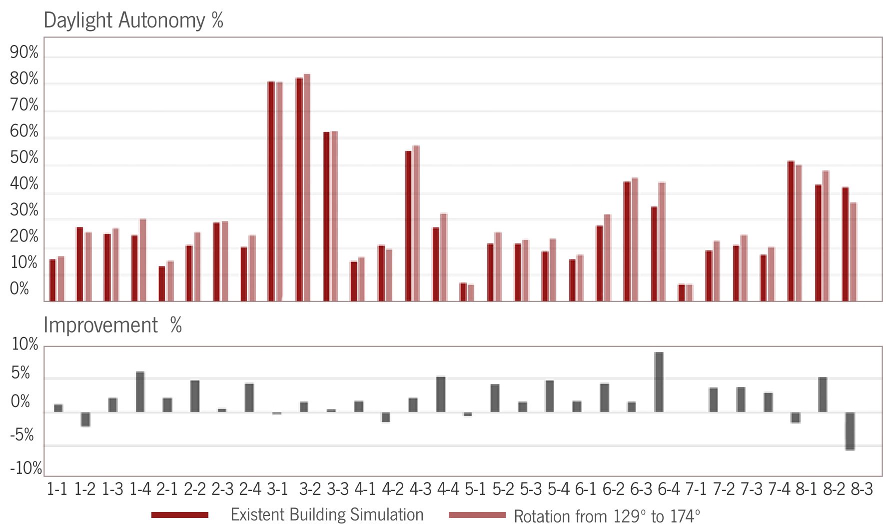
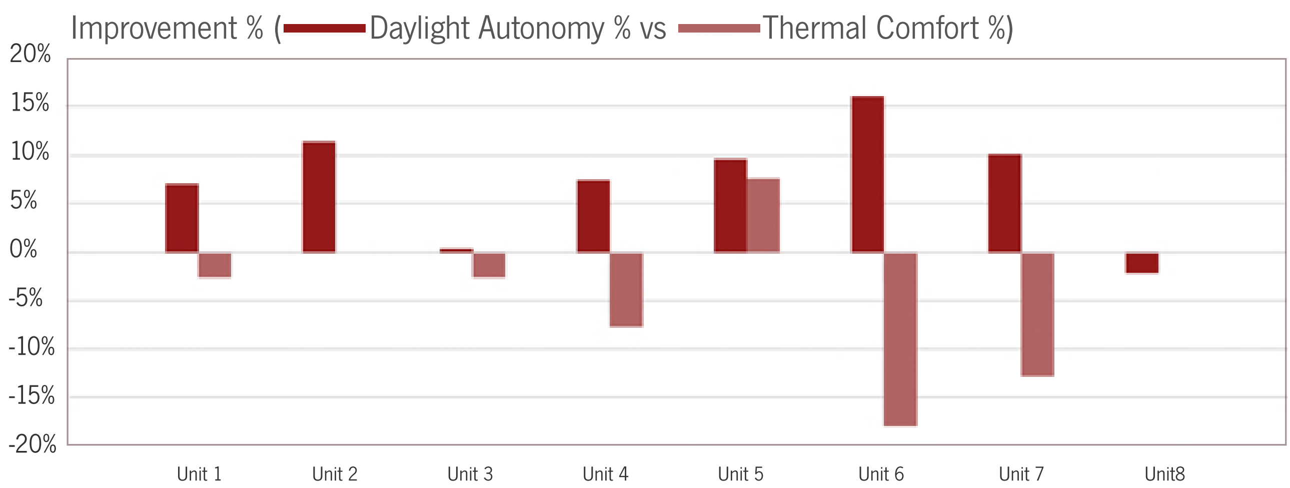


Figure 5.3.2.5.Representative axonometry of the daylight autonomy percentage on each floor of the eight selected housing units. (Simulation results of variation2).

The figure 5.3.2.5 and graph 5.3.2.2 show that the daylight autonomy percentage improved in all the building units from 1% to 9% decides in the units 8 where the daylight autonomy percentage reduced from 2% to 6%.



Graph 5.3.2.2.Graph comparing the difference in daylight autonomy percentage between the simulation results for the existing building and for variation 2.



Graph 5.3.2.3. Comparison of the percentage improvement in daylight autonomy and thermal comfort in variation 2.

Improvement percentage (%)

	Total	Average per unit
Daylight Autonomy:	60.5%	8%
Thermal Comfort:	-35.9 %	-4.5%

5.3.3. Variation 3: Rotation of the north from 129° to 219°

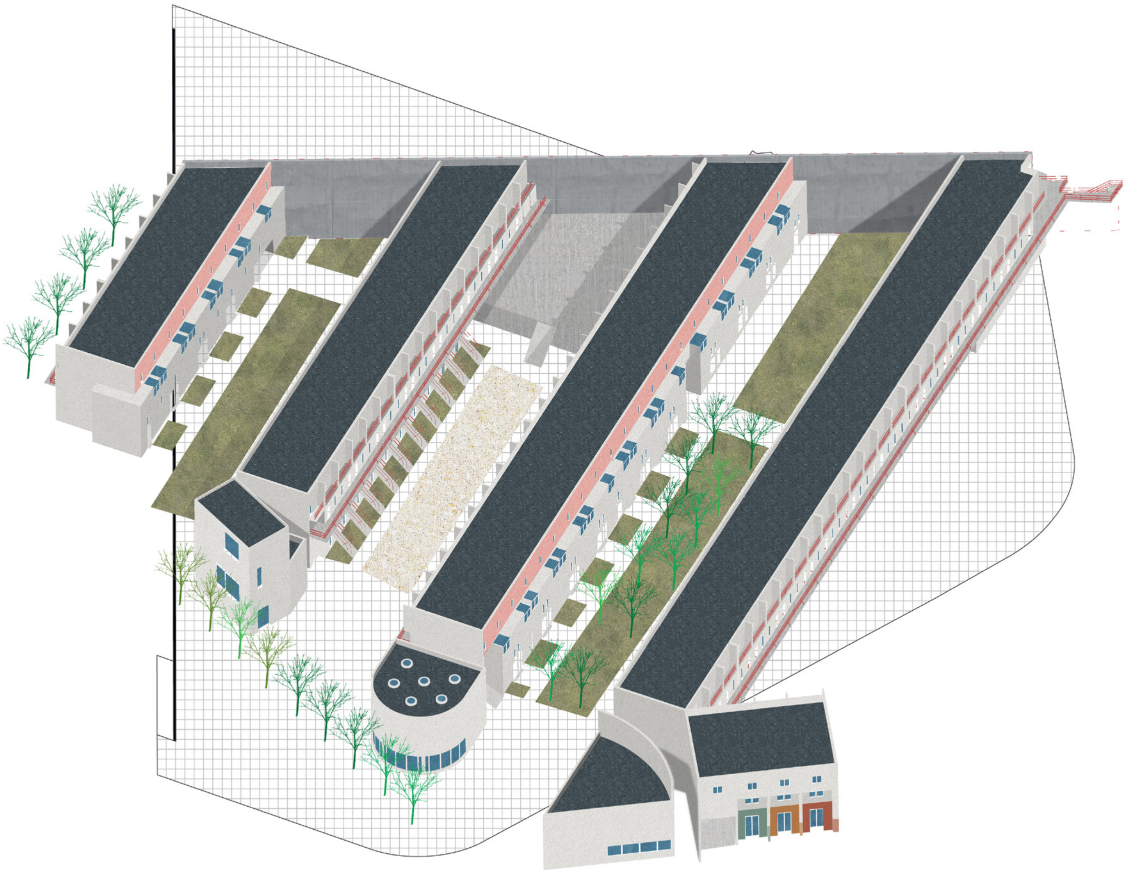


Figure 5.3.3.1.

In this variation, the neighbourhood was rotated 90° clockwise (figure 5.3.3.1).

This variation was made to understand the effect of the sun if the main facades were facing northeast and southwest.

Figure 5.3.3.1. Collage representing the difference between the existing buillding and the variation 3.

Figure 5.3.3.2. Composition of images showing the shadow during summer and winter solstice and the wind rose representing the average wind in summer and winter of the variation 3.

Wind:
In summer the wind coming from northwest will penetrate the outer spaces of the neighbourhood, and the wind coming from north will hit the facade of the building blocks, what ensures natural ventilation of the buildings during summer.In the winter the strong East wind hits the concrete wall from an angle, this minimizes draughts during the winter in the outer spaces of the neighbourhood and makes it possible to use the southerly winds to achieve cross-ventilation in the building without making the space uncomfortable due to excessive wind even if the south wind also hits the building blocks from an angle.
Sun:
During the summer solstice, the sun at 09:00am is oriented to the northeast facade from an angle, creating a prolonged shadow. At midday, the sun oriented to the southwest creates in the neighbourhood a cast shadow that is almost non-existent. In the afternoon, the cast shadow that was before covering the buildings near to the concrete wall is being projected into the streets. Due to the fact that the sun is facing the southwest, the facade in an angular direction creates a cast shadow in the neighbourhood covering the northeast. In the winter solstice, the sun is facing the buildings from southeast, creating a cast shadow on the concrete wall and the building blocks to the northwest. During midday, the cast shadow covers a big part of the outdoor spaces, between the neighbourhood from south to north. In the afternoon, the sun facing the southwest facades of the building blocks

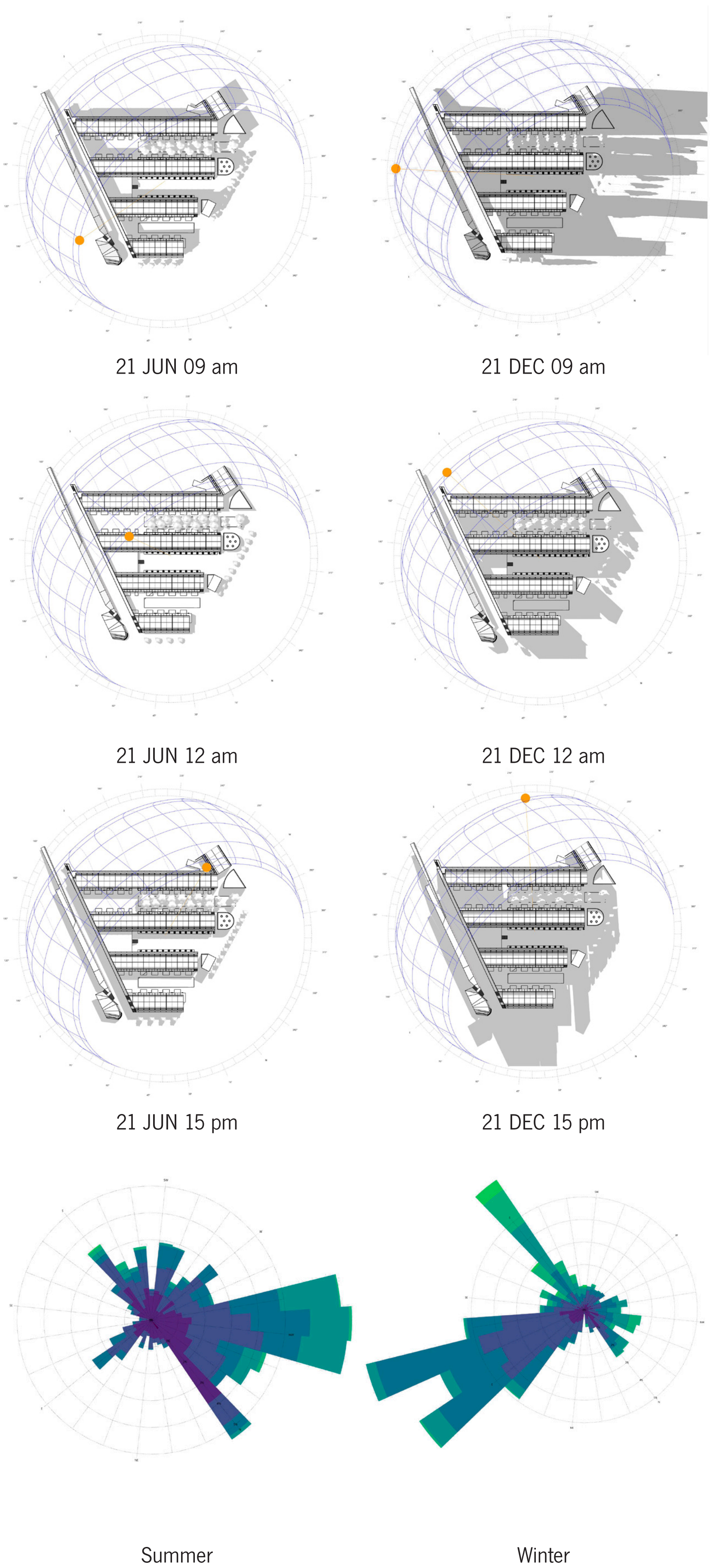


Figure 5.3.3.2.

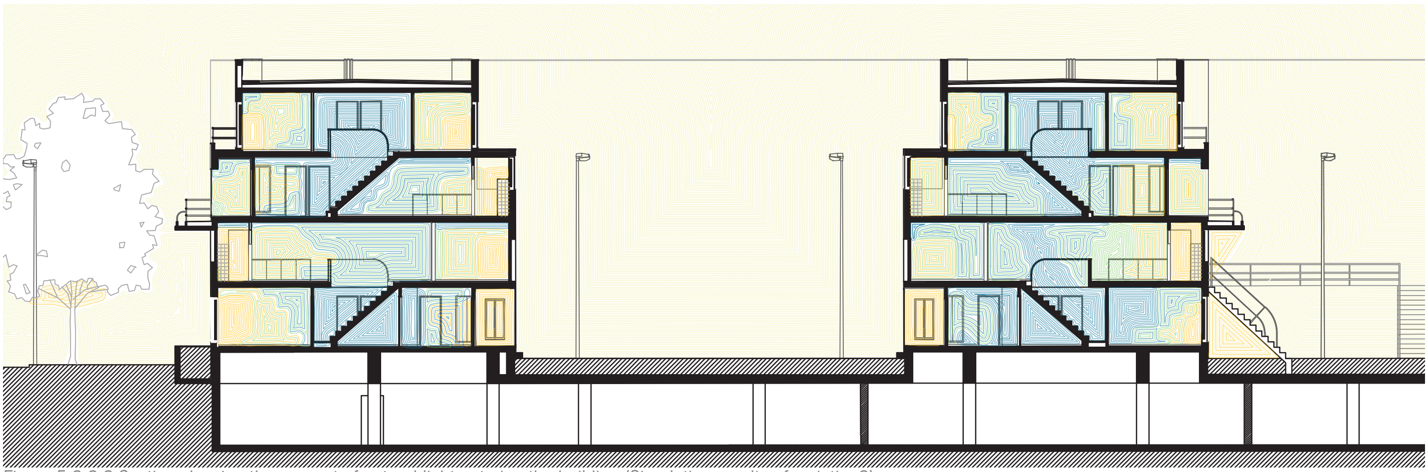
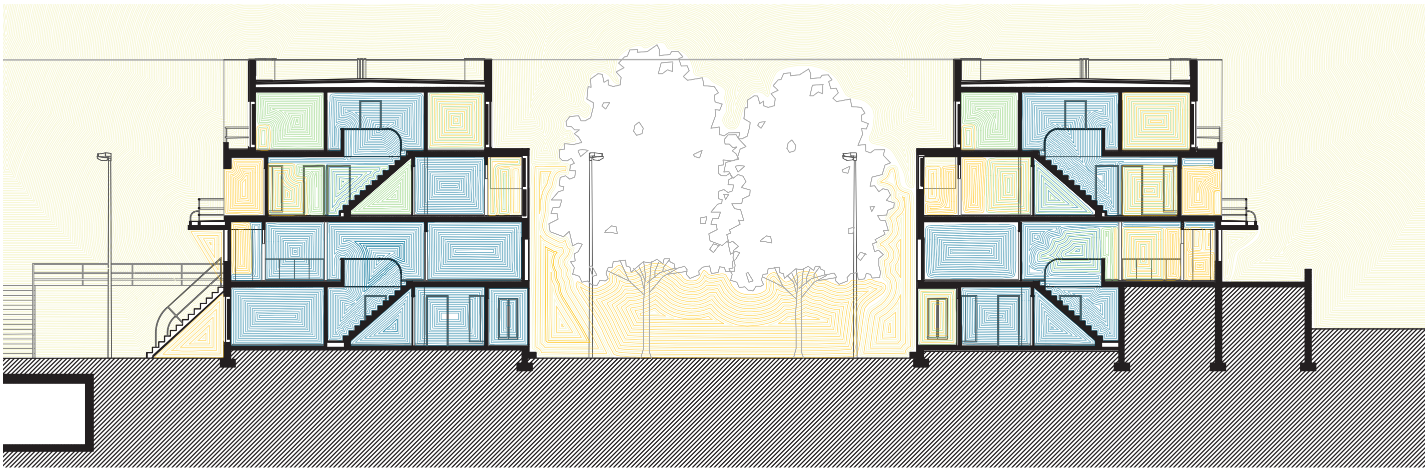


Figure 5.3.3.3.Section showing the amount of natural light entering the building (Simulation results of variation3).

The section through the whole neighbourhood (figure 5.3.3.3.) shows an average of light flowing during the year in the spaces within the building blocks and outside. In this variation, the amount of light penetrating the building from the south facade is higher and lower in the northeast facade.



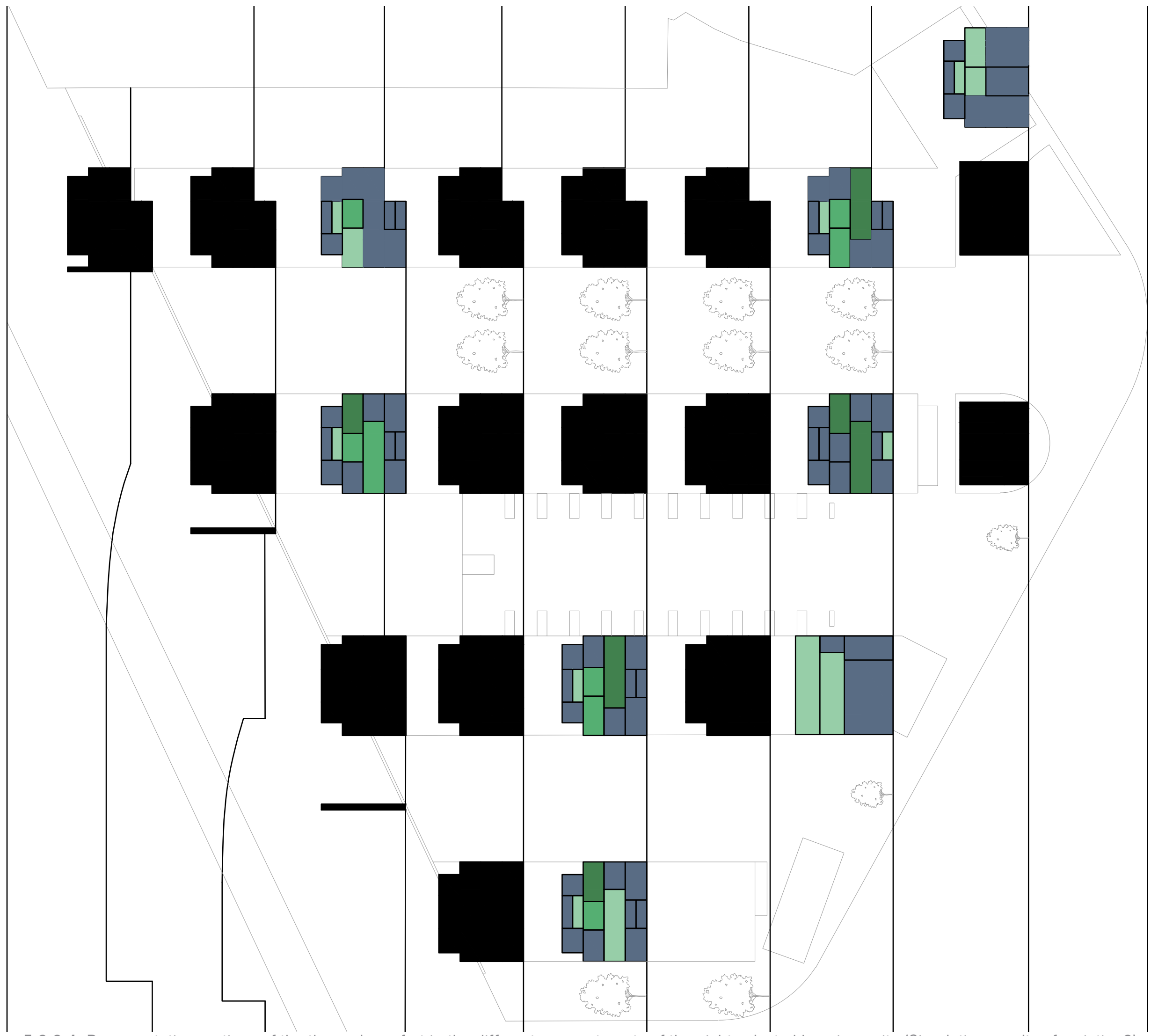
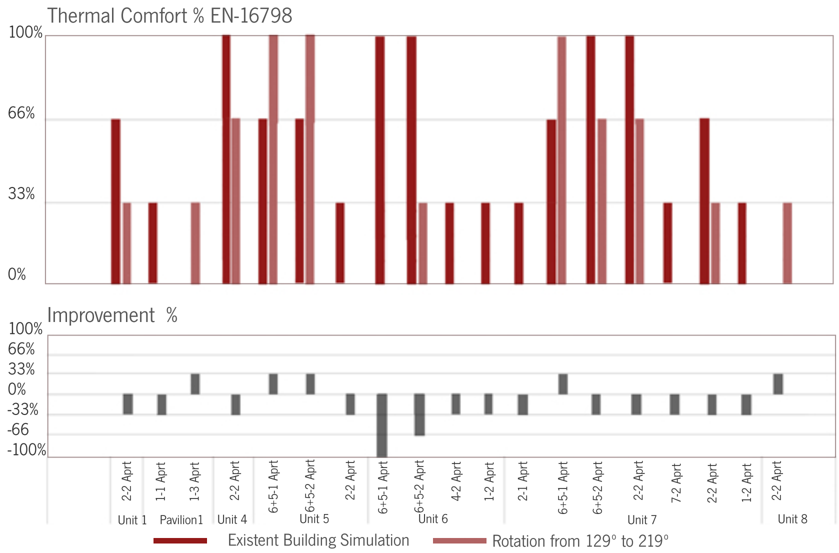


Figure 5.3.3.4. Representative sections of the thermal comfort in the different compartments of the eight selected housing units (Simulation results of variation3).



Graph 5.3.3.1.Graph comparing the difference in thermal comfort percentage between the simulation results for the existing building and for variation 3.

In this variation, the thermal comfort, in comparison to the existing situation, is lower in 14 out of the 88 analysed spaces and higher in just 5 of them. The graph 5.3.3.1. and image 5.3.3.4. shows an improvement of 33% in the living rooms and corridors of the unit one, five, seven, and eight due to the increase in solar exposure in the respective areas. In 14 other spaces, there is a decrease between one and three levels of comfort due to the lack of solar exposure and the increase in the amount of wind penetrating the outdoor space of the neighbourhood.

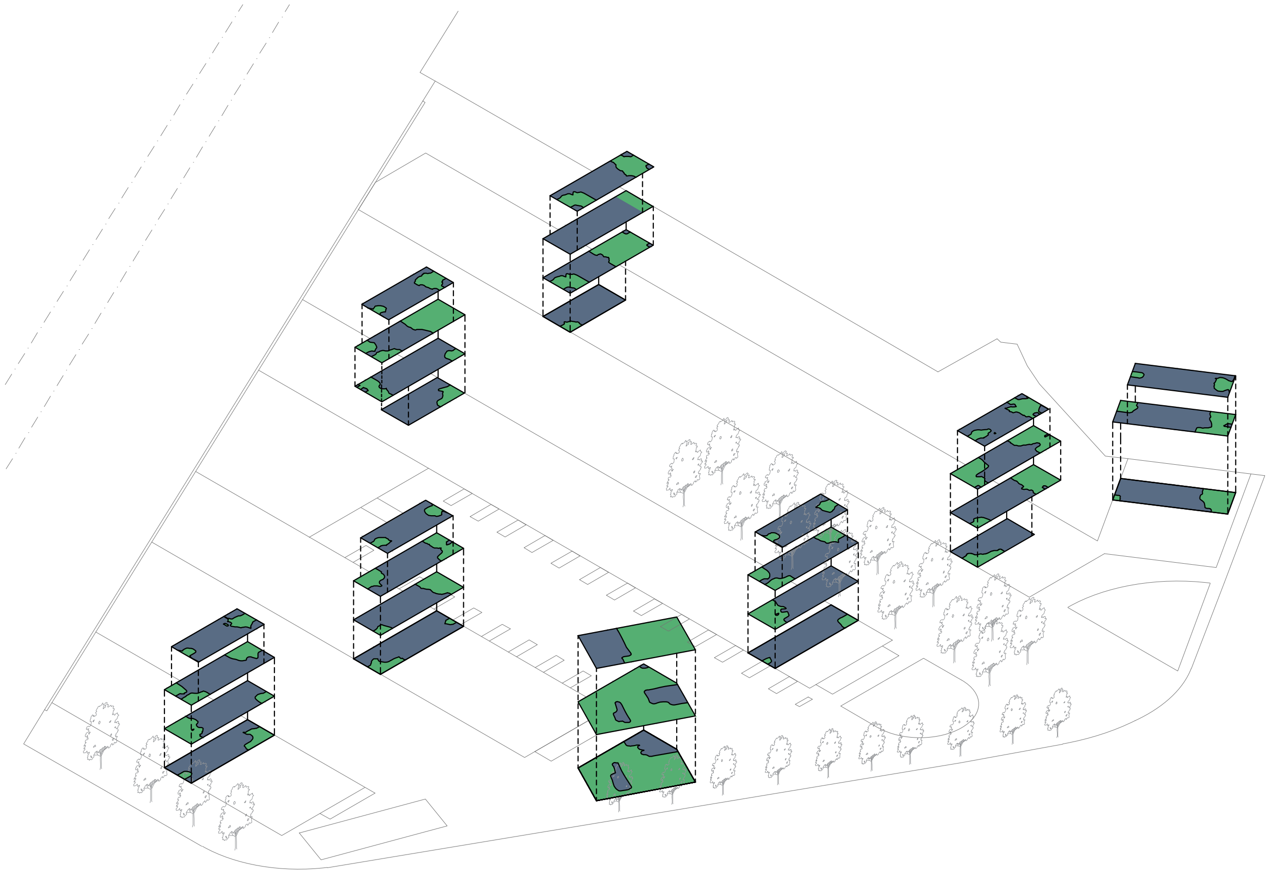
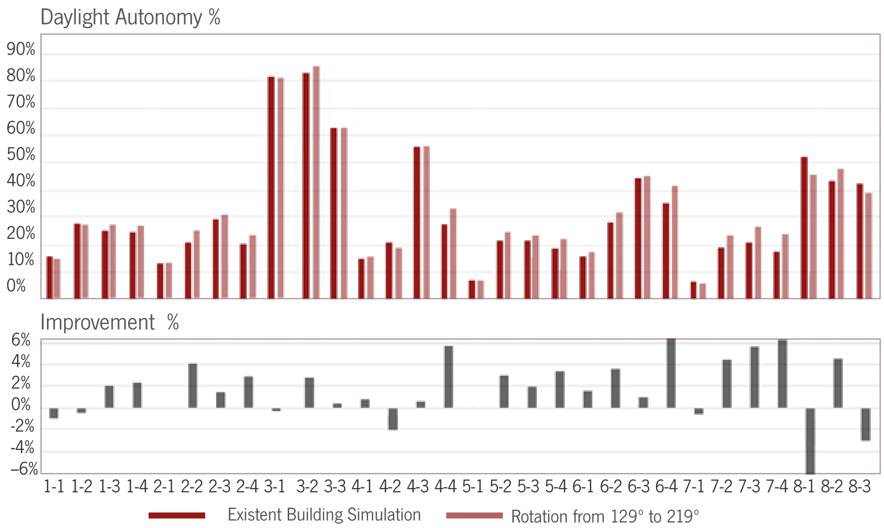
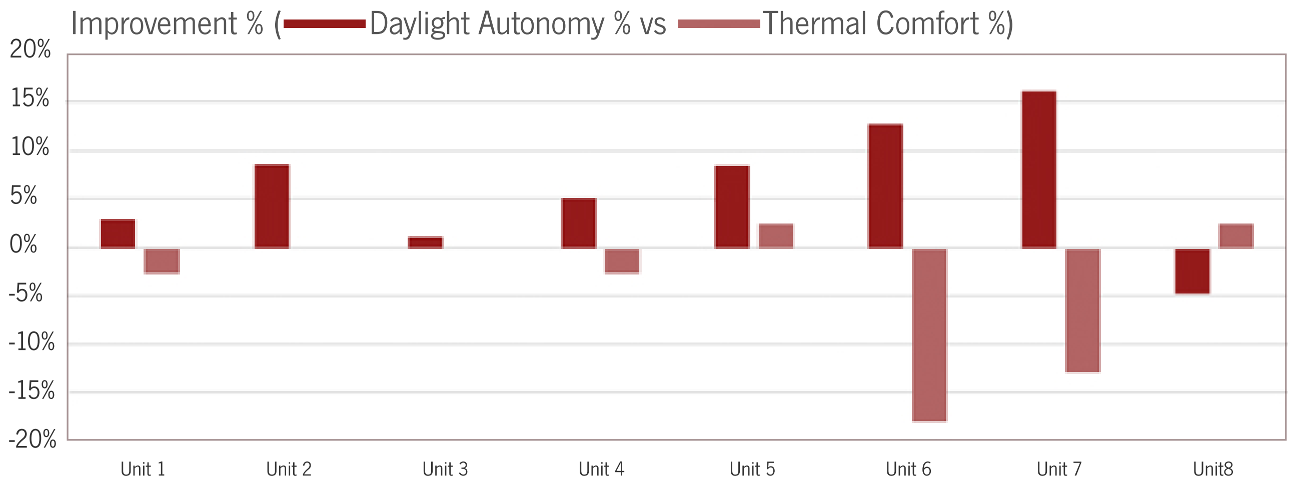


Figure 5.3.3.5.Representative axonometry of the daylight autonomy percentage on each floor of the eight selected housing units. (Simulation results of variation3).

In comparison to the thermal image 5.3.3.4. and graph 5.3.3.1., the daylight autonomy graph 5.3.3.2. shows an improvement between 1% and 6% on almost all the floors. This change is clearly visible when comparing the image 5.3.3.5. with the one made for the data of the existing building.



Graph 5.3.3.2. Graph comparing the difference in daylight autonomy percentage between the simulation results for the existing building and for variation 3.



Graph 5.3.3.3. Comparison of the percentage improvement in daylight autonomy and thermal comfort in variation 3.

Improvement percentage (%)

	Total	Average per unit
Daylight Autonomy:	51.2%	6%
Thermal Comfort:	-308%	-3.8%

5.3.4. Variation 4: Removing the outdoor stairs of the unit

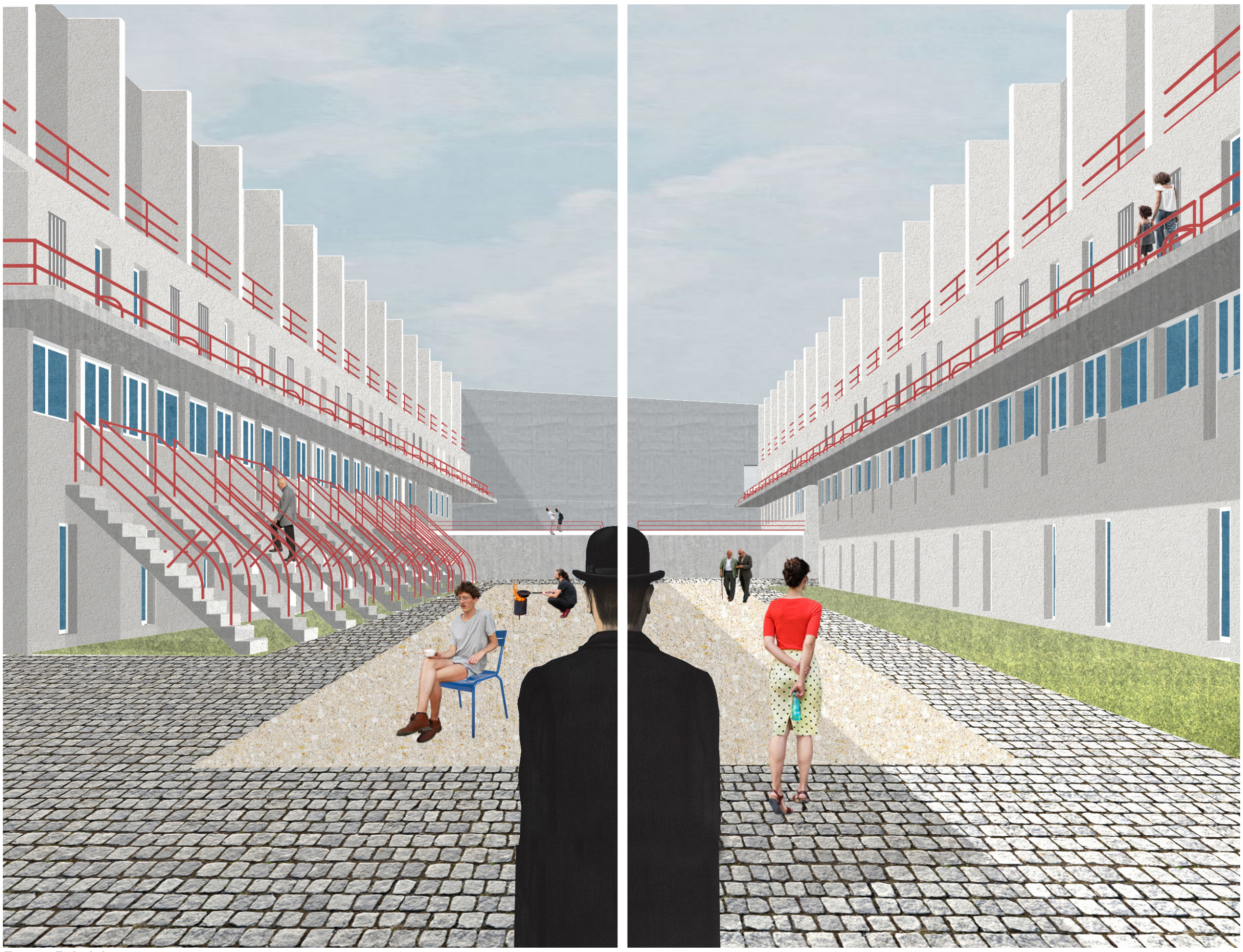


Figure 5.3.4.1.

When talking with the inhabitants of the neighbourhood in the design and dialogue phase, one of the concerns was the amount of light entering the first floor of the building blocks B and C that have stairs outside the facade. The fact that the window is located behind the stairs and are small and narrow, makes the spaces on the ground floor dark. This variation explores the possibility of housing units without the stairs, to show the difference in lightning and thermal condition in the housing units.

Figure 5.3.4.1. Collage representing the difference between the existing buillding and the variation 4.

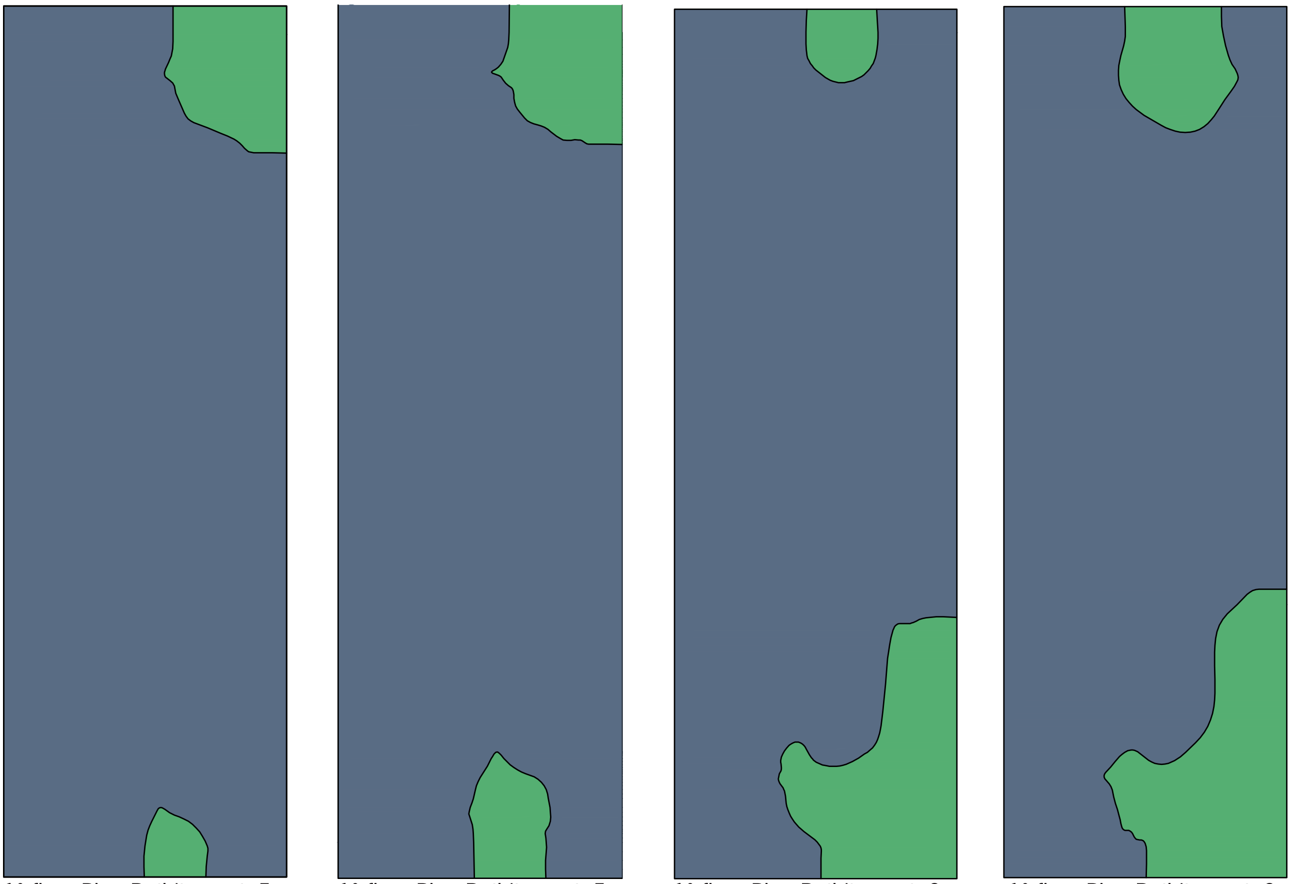


Figure 5.3.4.2.

Figure 5.3.4.2. Comparison between daylight autonomy plans of the second floor of building units 2 and 5 in the existing building and in variation 4.

The image 5.3.4.2. compares the first floor plans of the units two and five with stairs and without the stairs.

The image shows an improvement in the daylight autonomy percentage, which is represented by a green hatch in the plan. The difference is visible in the image, but it isn't a significant amount of light in the space.

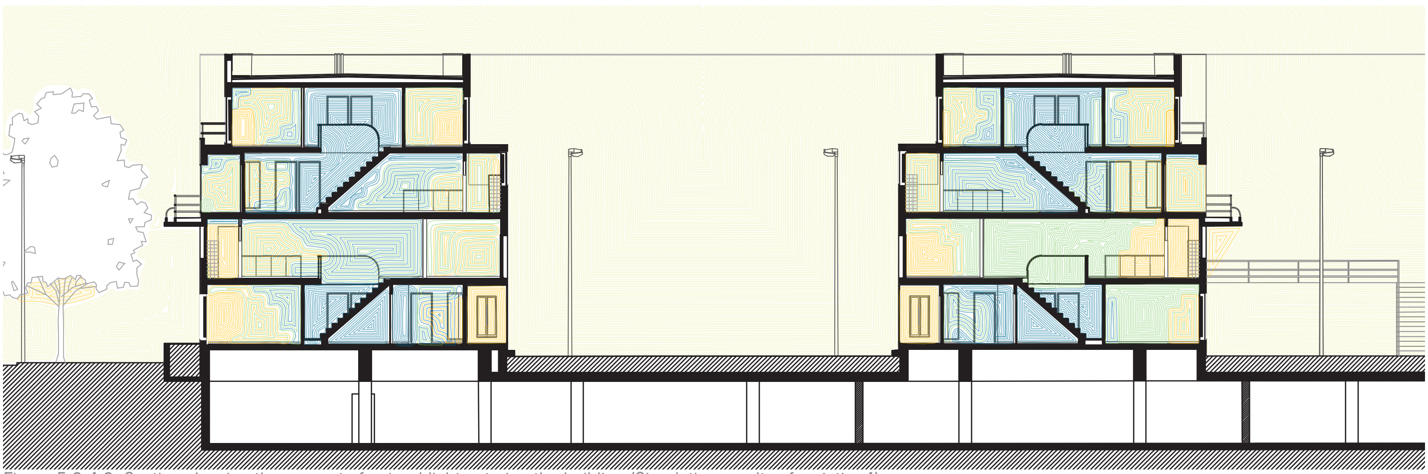
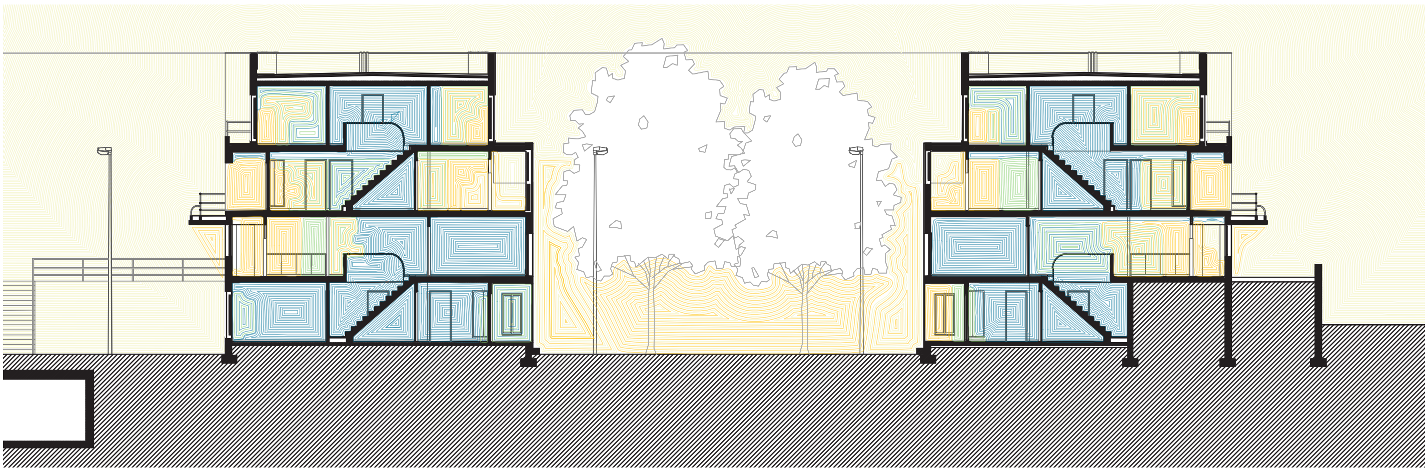


Figure 5.3.4.3. Section showing the amount of natural light entering the building (Simulation results of variation4).

The section (figure 5.3.4.3.) shows an improvement in the light condition in the room on the first floor of the building blocks B and C, but the amount of light penetrating the room in the building block C is higher than in the building block B.



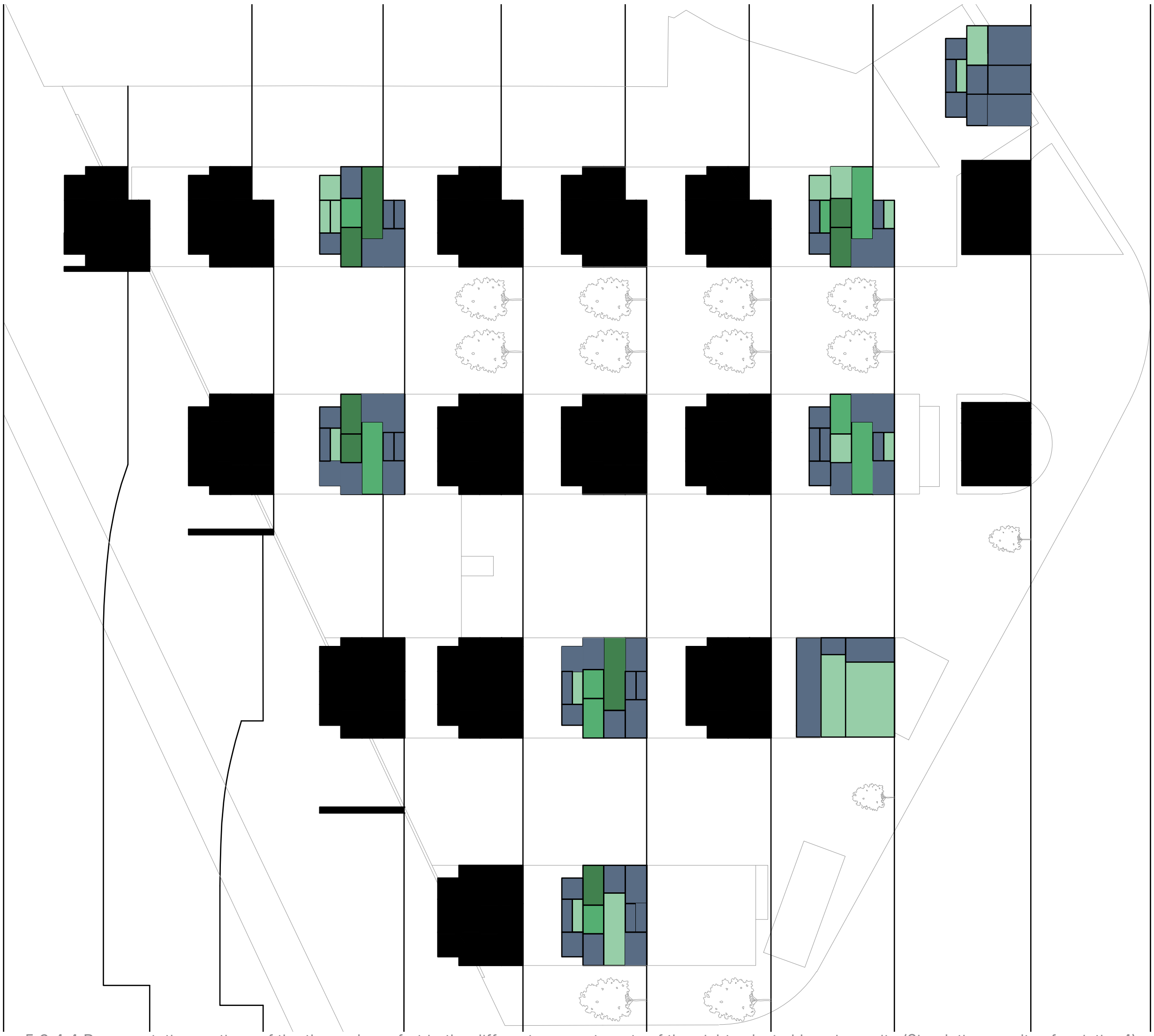
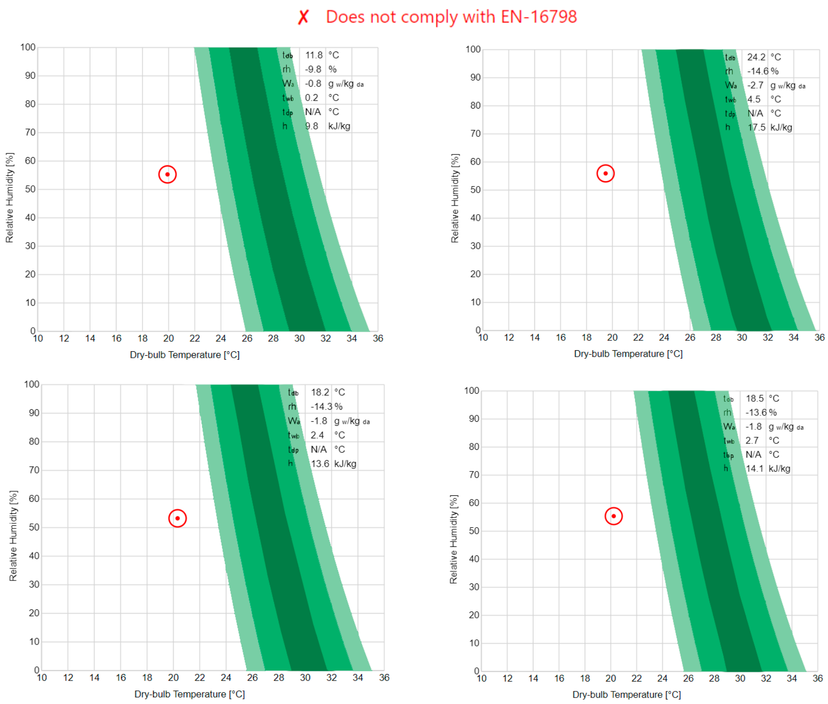


Figure 5.3.4.4.Representative sections of the thermal comfort in the different compartments of the eight selected housing units (Simulation results of variation4).



Graph 5.3.4.1. Set of graphs comparing operating temperature and relative humidity in order to understand the comfort level of the bedroom space (4) according to EN-16798

The image 5.3.4.4. and the graphs 5.3.4.1. shows that despite the changes, the amount of light penetrating the building units isn't enough to achieve thermal comfort in the building units. The simulation data was used to generate four graphs that correlate the data to analyse the comfort conditions in the space. The data shows that the variation doesn't make any significant changes in the comfort of the spaces. Despite some small improvements, the parameters of the spaces are not adequate in accordance with the norm EN-16798 for the room to be labelled as comfortable.

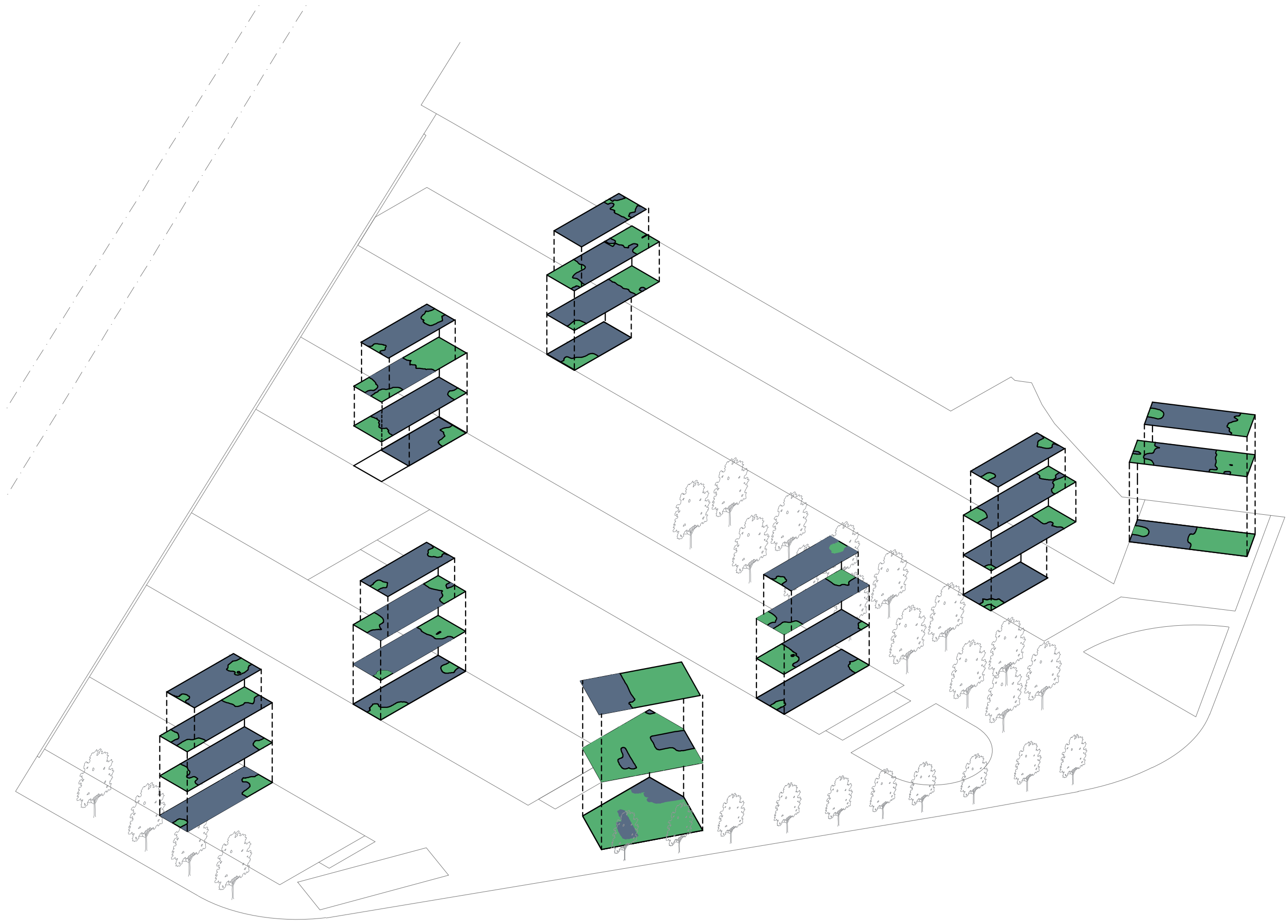
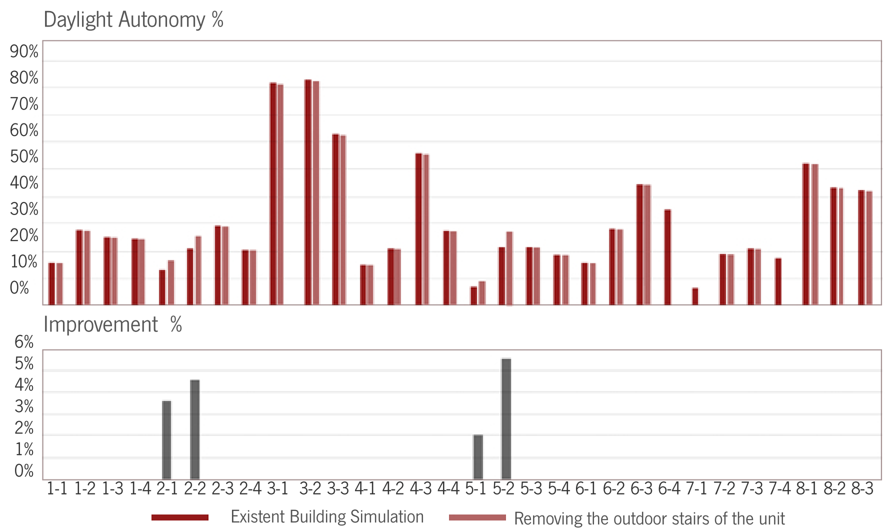
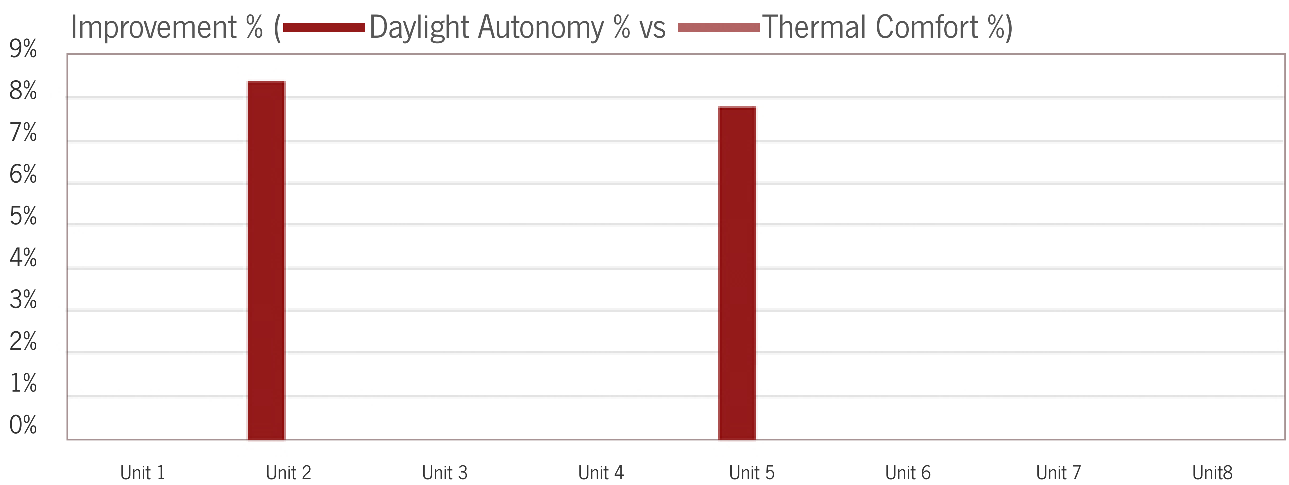


Figure 5.3.4.5.Representative axonometry of the daylight autonomy percentage on each floor of the eight selected housing units. (Simulation results of variation4).

As mentioned above, the only two units that show significant improvement in their thermal and lighting conditions are units two and five. In these units, both the ground floor with stairs in front of the window and first floor show an improvement in the amount of light entering the rooms. As the figure 5.3.4.5. and the graph 5.3.4.2. show, despite improving the daylight autonomy of the spaces between 2% and 6% this variation alone doesn't make a significant change in the amount of light penetrating the space.



Graph 5.3.4.2.Graph comparing the difference in daylight autonomy percentage between the simulation results for the existing building and for variation 4.



Graph 5.3.4.3. Comparison of the percentage improvement in daylight autonomy and thermal comfort in variation 4.

Improvement percentage (%)

	Total	Average per unit
Daylight Autonomy:	16.2%	2%
Thermal Comfort:	0%	0%

Figure 6.5.Final Collage. Technology enables the reinvention of the design process.

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8.ANNEX

8.1 Calculation of the thermal transmittance coefficient (U-value) of the existing building

	External Envelope (Roof)				
	Thickness	ITE.50 Thermal conductivity	Thermal resistance	Density	Weight
	e(m2)	ʎ(W/m2.C°)	Tr(m2.C/W)	(Kg/m3)	(Kg/m2)
Gravel	0.06	2.00	0.03	2000	120
Geotextile Membrane	0.001			0.25	0.000
Insulation (EPS)	0.04	0.042	0.11	14	0.56
Geotextile Membrane	0.001			0.25	0.000
2xWaterproofing Membrane	0.012	0.23	0.052	0.94	0.011
Manta Geotextil	0.001			0.25	0.000
Regularization layer	0.03	1.30	0.023	1900	57
Concrete	0.18	2.00	0.090	2300	414
Plaster	0.01	1.30	0.008	1900	19
Paint	0.001			1.5	0.002
Rse	0.04				
Rsi	0.1				
		Tr total	0.313		
		U (W/m2.C°)	2.208	Msi	490.01

	External Envelope (FacadeWall-Paint)				
	Thickness	ITE.50 Thermal conductivity	Thermal resistance	Density	Weight
	e(m2)	ʎ(W/m2.C°)	Tr(m2.C/W)	(Kg/m3)	(Kg/m2)
Plaster	0.01	1.30	0.008	1900	19.00
Insulation (EPS)	0.06	0.042	1.43	14.00	0.84
Regularization layer	0.04	1.30	0.11	1900	76.00
Cerezite	0.01	1.30	0.008	1900	19.00
Concrete masonry	0.12	0.30	0.40	500	60.00
Plaster	0.01	1.30	0.008	1900	19.00
Paint	0.001			1.50	0.00
Rse	0.04				
Rsi	0.13				
		Tr total	1.962		
		U (W/m2.C°)	0.469	Msi	174.00

	External Envelope (FacadeWall-Tiles)				
	Thickness	ITE.50 Thermal conductivity	Thermal resistance	Density	Weight
	e(m2)	ʎ(W/m2.C°)	Tr(m2.C/W)	(Kg/m3)	(Kg/m2)
Plaster	0.01	1.30	0.01	1900	19.00
Insulation (EPS)	0.06	0.042	1.43	14	0.84
Regularization layer	0.04	1.30	0.11	1900	76.00
Cerezite	0.01	1.30	0.008	1900	19.00
Concrete masonry	0.12	0.30	0.40	500	60.00
Plaster	0.01	1.30	0.008	1900	19.00
Tile	0.005	0.34	0.015	900	4.50
Rse	0.04				
Rsi	0.13				
		Tr total	1.976		
		U (W/m2.C°)	0.466	Msi	178.50

	Envelope without thermal requirements (WallBetweenFlats-Tiles)				
	Thickness	ITE.50 Thermal conductivity	Thermal resistance	Density	Weight
	e(m2)	ϰ(W/m2.C°)	Tr(m2.C/W)	(Kg/m3)	(Kg/m2)
Paint	0.001	0.003	0.333	750	0.75
Plaster	0.01	1.30	0.008	1900	19
Concrete	0.12	2.00	0.06	500	60
Plaster	0.01	1.30	0.008	1900	19
Paint	0.001			1.50	0.002
Rsi	0.13				
Rsi	0.13				
		Tr total	0.409		
		U (W/m2.C°)	1.495	Msi	98.75

	Envelope without thermal requirements (WallBetweenFlats-Paint)				
	Thickness	ITE.50 Thermal conductivity	Thermal resistance	Density	Weight
	e(m2)	ϰ(W/m2.C°)	Tr(m2.C/W)	(Kg/m3)	(Kg/m2)
Paint	0.001	0.003	0.33	1.50	0.00
Plaster	0.01	1.30	0.01	1900	19
Concrete	0.18	2.00	0.09	500	90
Plaster	0.01	1.30	0.01	1900	19
Paint	0.001			1.50	0.00
Rsi	0.13				
Rsi	0.13				
		Tr total	0.44		
		U (W/m2.C°)	1.43	Msi	128.00

	Envelope without thermal requirements+Not measured (SlabBetweenFlats+Slab-Tiles)				
	Thickness	ITE.50 Thermal conductivity	Thermal resistance	Density	Weight
	e(m2)	ϰ(W/m2.C°)	Tr(m2.C/W)	(Kg/m3)	(Kg/m2)
Tile	0.005	0.34	0.01	900	4.50
Regularization layer	0.04	1.30	0.03	1900	76
Concrete masonry	0.12	0.30	0.40	500	60
Plaster	0.01	1.30	0.01	1900	19
Paint	0.001			14.00	0.01
Rse	0.17				
Rsi	0.17				
		Tr total	0.453		
		U (W/m2.C°)	1.261	Msi	159.51

	Envelope without thermal requirements+Not measured (SlabBetweenFlats+Slab-Corck)				
	Thickness	ITE.50 Thermal conductivity	Thermal resistance	Density	Weight
	e(m2)	ϰ(W/m2.C°)	Tr(m2.C/W)	(Kg/m3)	(Kg/m2)
Corck	0.025	0.045	0.556	115	2.88
Regularization layer	0.04	1.300	0.031	1,900	76
Concrete masonry	0.12	0.300	0.400	500	60
Plaster	0.01	1.300	0.008	1,900	19
Paint	0.001			1.5	0.002
Rse	0.17				
Rsi	0.17				
		Tr total	0.99		
		U (W/m2.C°)	0.75	Msi	157.88

	Indoor envelope with thermal indoor requirements <0.7 (Slab-Tiles)				
	Thickness	ITE.50 Thermal conductivity	Thermal resistance	Density	Weight
	e(m2)	λ(W/m2.C°)	Tr(m2.C/W)	(Kg/m3)	(Kg/m2)
Tile	0.005	0.340	0.015	900	4.50
Regularization layer	0.04	1.300	0.031	1900	76.0
Concrete masonry	0.12	0.30	0.400	500	60.0
Plaster	0.01	1.300	0.008	1900	19.0
Paint	0.001			14	0.014
Rse	0.17				
Rsi	0.17				
		Tr total	0.453		
		U (W/m2.C°)	1.261	Msi	159.51

	Indoor envelope with thermal indoor requirements <0.7 (Slab-Corck)				
	Thickness	ITE.50 Thermal conductivity	Thermal resistance	Density	Weight
	e(m2)	λ(W/m2.C°)	Tr(m2.C/W)	(Kg/m3)	(Kg/m2)
Cortiça	0.025	0.05	0.556	115	2.88
Regularization layer	0.04	1.30	0.031	1900	76
Concrete masonry	0.12	0.30	0.400	500	60
Plaster	0.01	1.30	0.008	1900	19
Paint	0.001			1.50	0.002
Rse	0.17				
Rsi	0.17				
		Tr total	0.99		
		U (W/m2.C°)	0.75	Msi	157.88

	Partition (SameFlat-Paint | Paint)				
	Thickness	ITE.50 Thermal conductivity	Thermal resistance	Density	Weight
	e(m2)	λ(W/m2.C°)	Tr(m2.C/W)	(Kg/m3)	(Kg/m2)
Paint	0.001			1.50	0.002
Plaster	0.01	1.30	0.008	1900	19.00
Ceramic brick masonry	0.08	0.19	0.421	750	60.00
Plaster	0.01	1.30	0.008	1900	19.00
Paint	0.001			1.50	0.002
		Tr total	0.44	Msi	98.00

	Partition (SameFlat-Tiles | Paint)				
	Thickness	ITE.50 Thermal conductivity	Thermal resistance	Density	Weight
	e(m2)	λ(W/m2.C°)	Tr(m2.C/W)	(Kg/m3)	(Kg/m2)
Tile	0.005	0.34	0.015	900	4.50
Plaster	0.01	1.30	0.008	1900	19.00
Ceramic brick masonry	0.08	0.19	0.421	750	60.00
Plaster	0.01	1.30	0.008	1900	19.00
Paint	0.001			174	0.17
		Tr total	0.436	Msi	102.67

	Partition (SameFlat-Tiles | Tiles)				
	Thickness	ITE.50 Thermal conductivity	Thermal resistance	Density	Weight
	e(m2)	λ(W/m2.C°)	Tr(m2.C/W)	(Kg/m3)	(Kg/m2)
Tile	0.005			900.00	4.50
		Tr total	1.286	Msi	268.50

8.2 Data collected on site and simulated data - Point In Time Illuminance

POINT1

	Building	Simulation	Exterior-Bdg	Exterior-Sml	DLF-Bdg	DLF-Sml
09:00	328	456	4692	5617	7.0%	8.1%
10:00	457	559	6646	6852	6.9%	8.2%
11:00	500	621	6222	7668	8.0%	8.1%
12:00	556	621	6715	7486	8.3%	8.3%
13:00	504	562	6636	6747	7.6%	8.3%

POINT2

	Building	Simulation	Exterior-Bdg	Exterior-Sml	DLF-Bdg	DLF-Sml
09:00	250	370	4692	5617	5.3%	6.6%
10:00	375	469	6646	6852	5.6%	6.8%
11:00	427	504	6222	7668	6.9%	6.6%
12:00	382	496	6715	7486	5.7%	6.6%
13:00	426	418	6636	6747	6.4%	6.2%

POINT3

	Building	Simulation	Exterior-Bdg	Exterior-Sml	DLF-Bdg	DLF-Sml
09:00	86	113	4692	5617	1.8%	2.0%
10:00	126	138	6646	6852	1.9%	2.0%
11:00	130	158	6222	7668	2.1%	2.1%
12:00	139	162	6715	7486	2.1%	2.2%
13:00	127	141	6636	6747	1.9%	2.1%

POINT4

	Building	Simulation	Exterior-Bdg	Exterior-Sml	DLF-Bdg	DLF-Sml
09:00	14	28	4692	5617	0.3%	0.5%
10:00	30	34	6646	6852	0.5%	0.5%
11:00	47	47	6222	7668	0.8%	0.6%
12:00	64	38	6715	7486	1.0%	0.5%
13:00	30	37	6636	6747	0.5%	0.5%

POINT5

	Building	Simulation	Exterior-Bdg	Exterior-Sml	DLF-Bdg	DLF-Sml
09:00	20	30	4692	5617	0.4%	0.5%
10:00	33	42	6646	6852	0.5%	0.6%
11:00	35	38	6222	7668	0.6%	0.5%
12:00	45	44	6715	7486	0.7%	0.6%
13:00	20	37	6636	6747	0.3%	0.5%

POINT6

	Building	Simulation	Exterior-Bdg	Exterior-Sml	DLF-Bdg	DLF-Sml
09:00	12	16	4692	5617	0.3%	0.3%
10:00	21	22	6646	6852	0.3%	0.3%
11:00	35	25	6222	7668	0.6%	0.3%
12:00	23	24	6715	7486	0.3%	0.3%
13:00	20	22	6636	6747	0.3%	0.3%

POINT7

	Building	Simulation	Exterior-Bdg	Exterior-Sml	DLF-Bdg	DLF-Sml
09:00	10	20	4692	5617	0.2%	0.4%
10:00	28	24	6646	6852	0.4%	0.4%
11:00	20	26	6222	7668	0.3%	0.3%
12:00	20	21	6715	7486	0.3%	0.3%
13:00	23	22	6636	6747	0.3%	0.3%

POINT8

	Building	Simulation	Exterior-Bdg	Exterior-Sml	DLF-Bdg	DLF-Sml
09:00	13	15	4692	5617	0.3%	0.3%
10:00	23	22	6646	6852	0.3%	0.3%
11:00	30	23	6222	7668	0.5%	0.3%
12:00	22	19	6715	7486	0.3%	0.3%
13:00	20	19	6636	6747	0.3%	0.3%

POINT9

	Building	Simulation	Exterior-Bdg	Exterior-Sml	DLF-Bdg	DLF-Sml
09:00	30	30	4692	5617	0.6%	0.5%
10:00	58	33	6646	6852	0.9%	0.5%
11:00	56	42	6222	7668	0.9%	0.5%
12:00	36	35	6715	7486	0.5%	0.5%
13:00	36	33	6636	6747	0.5%	0.5%

POINT10

	Building	Simulation	Exterior-Bdg	Exterior-Sml	DLF-Bdg	DLF-Sml
09:00	146	233	4692	5617	3.1%	4.1%
10:00	234	270	6646	6852	3.5%	3.9%
11:00	360	327	6222	7668	5.8%	4.3%
12:00	270	300	6715	7486	4.0%	4.0%
13:00	315	270	6636	6747	4.7%	4.0%

8.3 Comparison of collected and simulated data- Point In Time Illuminance

09:00

	Point1	Point2	Point3	Point4	Point5	Point6	Point7	Point8	Point9	Point10
DLF-Bdg	7.0%	5.3%	1.8%	0.3%	0.4%	0.3%	0.2%	0.3%	0.6%	3.1%
DLF-Sml	8.1%	6.6%	2.0%	0.5%	0.5%	0.3%	0.4%	0.3%	0.5%	4.1%

10:00

	Point1	Point2	Point3	Point4	Point5	Point6	Point7	Point8	Point9	Point10
DLF-Bdg	6.9%	5.6%	1.9%	0.5%	0.5%	0.3%	0.4%	0.3%	0.9%	3.5%
DLF-Sml	8.2%	6.8%	2.0%	0.5%	0.6%	0.3%	0.4%	0.3%	0.5%	3.9%

11:00

	Point1	Point2	Point3	Point4	Point5	Point6	Point7	Point8	Point9	Point10
DLF-Bdg	8.0%	6.9%	2.1%	0.8%	0.6%	0.6%	0.3%	0.5%	0.9%	5.8%
DLF-Sml	8.1%	6.6%	2.1%	0.6%	0.5%	0.3%	0.3%	0.3%	0.5%	4.3%

12:00

	Point1	Point2	Point3	Point4	Point5	Point6	Point7	Point8	Point9	Point10
DLF-Bdg	8.3%	5.7%	2.1%	1.0%	0.7%	0.3%	0.3%	0.3%	0.5%	4.0%
DLF-Sml	8.3%	6.6%	2.2%	0.5%	0.6%	0.3%	0.3%	0.3%	0.5%	4.0%

13:00

	Point1	Point2	Point3	Point4	Point5	Point6	Point7	Point8	Point9	Point10
DLF-Bdg	7.6%	6.4%	1.9%	0.5%	0.3%	0.3%	0.3%	0.3%	0.5%	4.7%
DLF-Sml	8.3%	6.2%	2.1%	0.5%	0.5%	0.3%	0.3%	0.3%	0.5%	4.0%

8.4 Data collected on site and simulated data -Thermal comfort (AirT-C°+RH%)

	Bedroom 4		B-Air C°	B-RH%	S-Air C°	S-RH%
1	05/07/2022	09:54:12	26.8	55	20.8	67.5
2		10:54:12	22.1	68.3	20.7	66.9
3		11:54:12	21.9	69.2	20.7	66.9
4		12:54:12	22.1	68.9	20.6	66.6
5		13:54:12	22.2	68.5	20.6	66.2
6		14:54:12	22.2	68.4	20.5	65.8
7		15:54:12	22.3	68.5	20.7	66.0
8		16:54:12	22.4	68.8	20.3	71.0
9		17:54:12	22.5	68.5	20.4	73.8
10		18:54:12	22.5	68	20.6	75.9
11		19:54:12	22.6	67.9	20.8	77.6
12		20:54:12	22.5	68.1	20.9	78.8
13		21:54:12	22.5	68.2	21.0	78.3
14		22:54:12	22.5	68.3	21.1	77.0
15		23:54:12	22.4	68.9	21.3	75.0
16	06/07/2022	00:54:12	22.7	70.2	21.5	72.4
17		01:54:12	22.7	70.7	21.7	68.7
18		02:54:12	22.7	71.6	21.8	69.0
19		03:54:12	22.7	71.1	21.8	68.4
20		04:54:12	22.7	71.4	21.5	67.7
21		05:54:12	22.6	71.5	21.2	70.6
22		06:54:12	22.6	71.3	21.0	73.5
23		07:54:12	22.7	70.1	20.9	75.8
24		08:54:12	22.5	65.1	21.5	76.2
25		09:54:12	22.6	66.9	21.5	78.5
26		10:54:12	22.6	68.9	21.5	80.4
27		11:54:12	22.6	69	21.5	81.6
28		12:54:12	22.6	69.5	21.4	82.0
29		13:54:12	22.6	69.3	21.3	81.7
30		14:54:12	23.3	64.3	21.1	81.7
31		15:54:12	23.5	60.7	21.5	80.7
32		16:54:12	22.9	64.5	21.2	83.6
33		17:54:12	22.9	65.8	21.4	82.1
34		18:54:12	23	66.6	21.6	80.7
35		19:54:12	23	66.6	21.8	80.0
36		20:54:12	23	66.2	21.8	81.1
37		21:54:12	22.9	66.2	21.7	81.6
38		22:54:12	22.9	66.5	21.8	80.9
39		23:54:12	23	67.5	21.9	79.5
40	07/07/2022	00:54:12	23.2	68.3	22.2	77.4
41		01:54:12	23.2	68.7	22.4	74.6
42		02:54:12	23.1	69.9	22.6	71.8
43		03:54:12	23.2	70.2	22.5	70.4
44		04:54:12	23.2	69.5	22.2	72.2
45		05:54:12	23.1	69.9	21.8	75.2
46		06:54:12	23.1	69.4	21.6	75.9
47		07:54:12	23.2	67.1	21.5	75.7
48		08:54:12	23.2	66	22.1	74.4
49		09:54:12	23.2	61.5	22.1	77.2
50		10:54:12	23.1	63.4	22.0	77.9
51		11:54:12	23.1	64.3	21.9	76.9
52		12:54:12	23.1	64.7	22.0	76.1
53		13:54:12	23.1	65	21.9	75.6
54		14:54:12	23.2	65.1	21.9	75.3
55		15:54:12	23.2	65.1	21.9	75.8
56		16:54:12	23.3	64.2	22.2	77.8

	Bedroom 4		B-Air C°	B-RH%	S-Air C°	S-RH%
57	07/07/2022	17:54:12	23.8	63.9	21.8	79.6
58		18:54:12	23.9	58.9	21.9	76.5
59		19:54:12	23.8	60.6	21.9	74.7
60		20:54:12	23.6	61.9	21.8	74.5
61		21:54:12	23.5	62.7	21.7	74.6
62		22:54:12	23.5	63.2	21.5	76.0
63		23:54:12	23.5	63.5	21.6	76.7
64	08/07/2022	00:54:12	23.7	65.4	22.0	75.5
65		01:54:12	23.7	66.5	22.3	74.6
66		02:54:12	23.7	66.7	22.3	73.7
67		03:54:12	23.7	67.8	22.2	73.4
68		04:54:12	23.7	67.3	22.0	74.0
69		05:54:12	23.7	68.6	21.8	74.4
70		06:54:12	23.6	68.4	21.7	74.2
71		07:54:12	23.6	67.6	21.5	73.6
72		08:54:12	23.6	66.3	22.1	71.3
73		09:54:12	23.6	64.9	22.1	71.9
74		10:54:12	23.6	63.9	22.1	72.4
75		11:54:12	23.6	64	22.1	72.7
76		12:54:12	23.6	64	22.0	73.5
77		13:54:12	23.6	63.8	21.9	74.0
78		14:54:12	23.6	63.7	21.3	76.3
79		15:54:12	23.7	63.6	21.2	76.6
80		16:54:12	23.7	63.6	21.2	76.8
81		17:54:12	23.8	63.4	21.2	76.5
82		18:54:12	23.9	63.2	21.2	75.5
83		19:54:12	24	62.3	21.3	74.2
84		20:54:12	24	62.4	21.3	73.5
85		21:54:12	23.9	62.8	21.3	72.4
86		22:54:12	23.9	63.1	21.4	70.5
87		23:54:12	23.9	63.6	21.6	68.8
88	09/07/2022	00:54:12	23.9	64.1	21.8	67.6
89		01:54:12	24.2	65.6	21.7	68.7
90		02:54:12	24.2	64.9	21.4	70.2
91		03:54:12	24.2	63.2	21.3	71.1
92		04:54:12	24.1	61.9	21.3	71.6
93		05:54:12	24.2	61.3	21.2	71.8
94		06:54:12	24.1	58.8	21.2	71.1
95		07:54:12	24.2	59.1	21.2	70.6
96		08:54:12	24.3	50.8	21.1	71.2
97		09:54:12	24.2	53.5	21.6	69.7
98		10:54:12	24.2	57.3	21.7	70.9
99	09/07/2022	11:54:12	24.2	59.4	21.7	71.9
100		12:54:12	24.2	60.4	21.7	72.5
101		13:54:12	24.2	60.8	21.7	73.1
102		14:54:12	24.3	60.8	21.6	73.6
103		15:54:12	24.3	61.1	21.6	74.1
104		16:54:12	24.4	61.4	20.9	76.1
105		17:54:12	24.6	61.5	21.1	74.0
106		18:54:12	24.9	61.7	21.1	71.9
107		19:54:12	24.9	60.5	21.2	69.6
108		20:54:12	24.8	53.7	21.2	68.7
109		21:54:12	24.7	52.2	21.2	67.4
110		22:54:12	24.6	56.5	21.3	66.0
111		23:54:12	24.7	58.9	21.4	64.8
112	10/07/2022	00:54:12	24.8	59.2	21.6	65.6

	Bedroom 4		B-Air C°	B-RH%	S-Air C°	S-RH%
113	10/07/2022	01:54:12	24.7	60.6	21.7	66.6
114		02:54:12	24.6	59.4	21.8	67.5
115		03:54:12	24.6	58.8	21.6	69.1
116		04:54:12	24.6	60.7	21.3	70.9
117		05:54:12	24.4	62.4	21.1	71.9
118		06:54:12	24.4	63.4	21.1	72.0
119		07:54:12	24.4	64	21.0	72.4
120		08:54:12	24.4	64.3	21.0	72.6
121		09:54:12	24.4	65	21.6	70.7
122		10:54:12	24.5	65.3	21.6	71.6
123		11:54:12	24.4	63.5	21.6	72.5
124		12:54:12	24.5	63.2	21.6	73.1
125		13:54:12	24.5	62.8	21.6	73.5
126		14:54:12	24.6	61.4	21.6	74.0
127		15:54:12	24.5	61.5	21.1	75.4
128		16:54:12	24.5	60.3	21.1	74.7
129		17:54:12	24.6	57.9	20.9	75.2
130		18:54:12	24.6	57.2	20.9	74.9
131		19:54:12	24.4	55.8	21.0	74.1
132		20:54:12	24.1	57	21.0	73.5
133		21:54:12	23.9	56.6	21.1	73.1
134		22:54:12	23.7	57.5	21.1	72.8
135		23:54:12	24.1	57.7	21.3	72.1
136	11/07/2022	00:54:12	24.5	59.3	21.4	72.0
137		01:54:12	24.6	62.9	21.2	73.4
138		02:54:12	24.6	62.5	21.1	74.5
139		03:54:12	24.6	62.2	21.0	75.1
140		04:54:12	24.6	62.3	20.9	75.1
141		05:54:12	24.4	62.6	20.8	75.0
142		06:54:12	24.3	61.9	20.8	75.2
143		07:54:12	24.3	61.4	20.7	75.2
144		08:54:12	24.2	61.3	21.3	72.8
145		09:54:12	24.2	62.5	21.5	73.0
146		10:54:12	24	59	21.4	73.7
147		11:54:12	23.9	57.5	21.4	74.5
148		12:54:12	23.9	57.3	21.4	75.0
149		13:54:12	23.9	57.9	21.3	75.3
150		14:54:12	24	59	21.3	75.4
151		15:54:12	24	59	20.7	77.8
152		16:54:12	24.2	62.6	20.4	77.6
153		17:54:12	24.2	60.7	20.5	77.3
154		18:54:12	24.3	60.3	20.7	78.0
155		19:54:12	24.3	60.1	20.8	77.7
156		20:54:12	24.2	60.4	20.9	76.7
157		21:54:12	24.1	60.7	20.9	76.8
158		22:54:12	24.1	60.9	21.0	77.0
159		23:54:12	24.1	61	21.1	76.5
160	12/07/2022	00:54:12	24.3	63.3	21.4	75.8
161		01:54:12	24.3	65.3	21.6	74.7
162		02:54:12	24.4	65.9	21.7	74.4
163		03:54:12	24.4	67.8	21.5	75.0
164		04:54:12	24.5	68.2	21.2	76.1
165		05:54:12	24.5	69.1	21.0	76.0
166		06:54:12	24.5	69.1	21.0	75.5
167		07:54:12	24.4	68.4	21.0	75.1
168		08:54:12	24.5	68.2	21.6	73.6

	Bedroom 4		B-Air C°	B-RH%	S-Air C°	S-RH%
169	12/07/2022	09:54:12	24.3	68.1	21.6	74.5
170		10:54:12	24.4	74.5	21.6	74.7
171		11:54:12	24.4	68.6	21.6	74.8
172		12:54:12	24.5	65.4	21.6	75.4
173		13:54:12	24.5	66.7	21.5	76.3
174		14:54:12	24.5	68	21.5	77.2
175		15:54:12	24.6	67.4	21.5	77.6
176		16:54:12	24.7	66.9	20.9	80.6
177		17:54:12	24.7	66.2	20.8	80.3
178		18:54:12	24.7	65.6	20.8	79.4
179		19:54:12	24.8	65.5	20.8	79.0
180		20:54:12	24.8	65.2	20.9	78.7
181		21:54:12	24.8	66.7	20.9	78.4
182		22:54:12	25	69.9	21.0	78.2
183		23:54:12	24.8	71.8	21.1	77.4
184	13/07/2022	00:54:12	24.9	70.5	21.4	75.6
185		01:54:12	25	70.8	21.6	73.6
186		02:54:12	25.1	71.1	21.7	73.0
187		03:54:12	25.2	71.6	21.5	73.4
188		04:54:12	25.3	71.8	21.2	73.9
189		05:54:12	25.3	71.8	21.1	74.0
190		06:54:12	25.3	71.8	21.0	73.5
191		07:54:12	25.4	71.8	21.0	73.4
192		08:54:12	25.3	70.9	22.1	70.0
193		09:54:12	25.2	67.6	22.2	72.2
194		10:54:12	25.2	69.1	22.2	73.9
195		11:54:12	25.2	66.6	22.2	75.0
196		12:54:12	25.2	64.3	22.2	76.1
197		13:54:12	25.2	63.6	21.9	76.0
198		14:54:12	27.3	45.5	21.8	74.0
199		15:54:12	26.5	43.5	21.8	73.2
200		16:54:12	25.8	52	20.8	77.3
201		17:54:12	25.6	56.8	20.8	77.6
202		18:54:12	25.5	57.8	20.9	77.5
203		19:54:12	25.5	59	21.1	76.7
204		20:54:12	25.5	56.6	21.2	74.9
205		21:54:12	25.5	56.5	21.2	73.1
206		22:54:12	25.9	60.2	21.2	71.8
207		23:54:12	25.8	54.8	21.4	67.8

	Kitchen+Livingroom+Bedroom (5+6)		B-Air C°	B-RH%	S-Air C°	S-RH%
1	05/07/2022	09:53:19	26.3	59.6	20.6	65.8
2		10:53:19	22.7	67.1	20.6	64.9
3		11:53:19	22.7	67.2	20.6	64.8
4		12:53:19	22.9	67.6	20.5	64.3
5		13:53:19	23	66.8	20.5	63.7
6		14:53:19	23.2	66.2	20.5	63.3
7		15:53:19	23.1	66.7	20.5	63.9
8		16:53:19	23.4	65.7	20.7	66.8
9		17:53:19	23.1	65.8	21.0	69.8
10		18:53:19	23.3	65.6	21.2	72.3
11		19:53:19	23.7	64.1	22.1	72.4
12		20:53:19	24.1	68.4	22.4	74.8
13		21:53:19	23.9	65.1	22.5	75.8
14		22:53:19	23.9	65.9	22.0	77.6
15		23:53:19	23.9	65.9	21.7	76.1
16	06/07/2022	00:53:19	23.7	66.1	21.7	73.6
17		01:53:19	23.5	66.5	21.7	70.1
18		02:53:19	23.5	66.5	21.7	70.4
19		03:53:19	23.4	66.3	22.6	67.0
20		04:53:19	23.5	65.9	22.7	66.8
21		05:53:19	23.4	65.3	22.5	70.2
22		06:53:19	23.4	63.1	22.1	73.5
23		07:53:19	23.4	62.2	21.4	76.9
24		08:53:19	23.6	60.1	21.3	78.2
25		09:53:19	23.8	57.9	21.3	79.3
26		10:53:19	23.7	64.3	21.3	80.0
27		11:53:19	23.9	66	21.3	80.4
28		12:53:19	24.2	68.4	21.2	80.3
29		13:53:19	24.4	64	21.1	79.7
30		14:53:19	24.2	63.9	21.1	79.1
31		15:53:19	24.5	57.1	21.3	79.3
32		16:53:19	24.3	59.5	21.6	79.5
33		17:53:19	24.5	57.2	21.8	78.6
34		18:53:19	24.6	56.9	22.0	77.9
35		19:53:19	25	55.9	22.1	77.8
36		20:53:19	24.9	51.2	22.1	79.0
37		21:53:19	24.7	56.3	22.0	79.6
38		22:53:19	24.5	60	22.1	79.1
39		23:53:19	24.5	58.1	22.1	78.6
40	07/07/2022	00:53:19	24.3	59.8	22.2	77.4
41		01:53:19	24.2	60.4	22.2	75.6
42		02:53:19	24.3	60.3	22.2	73.1
43		03:53:19	24.2	57.1	23.5	67.7
44		04:53:19	24.2	55.6	23.7	69.8
45		05:53:19	24.2	53.2	23.5	72.3
46		06:53:19	24.1	50	23.0	68.5
47		07:53:19	24.2	49.2	22.0	73.2
48		08:53:19	24.2	47.3	21.9	74.1
49		09:53:19	24.2	52.5	21.8	76.2
50		10:53:19	24.4	47.5	21.7	76.2
51		11:53:19	24.7	47.3	21.6	74.7
52		12:53:19	25	45	21.7	73.5
53		13:53:19	25.4	46.9	21.6	72.8
54		14:53:19	25.4	43.9	21.6	72.3
55		15:53:19	25.7	47.2	21.7	72.6
56		16:53:19	26.3	45	21.9	74.8

	Kitchen+Livingroom+Bedroom 5+6		B-Air C°	B-RH%	S-Air C°	S-RH%
57	07/07/2022	17:53:19	26.8	42.8	22.1	74.7
58		18:53:19	26.6	45.2	22.3	72.6
59		19:53:19	26.5	45.2	22.2	71.6
60		20:53:19	25.8	48.2	22.6	71.4
61		21:53:19	25.6	50	22.2	74.0
62		22:53:19	25.5	51.2	21.9	75.1
63		23:53:19	26.1	51.2	21.9	76.1
64	08/07/2022	00:53:19	25.7	52.9	22.0	75.8
65		01:53:19	25.4	54.3	22.1	75.6
66		02:53:19	25.4	51.9	22.1	74.8
67		03:53:19	25.3	50.7	22.1	74.0
68		04:53:19	25.2	49.7	22.0	73.7
69		05:53:19	25.4	50.8	22.0	73.6
70		06:53:19	25.2	49	21.9	73.1
71		07:53:19	25.1	47	21.8	72.5
72		08:53:19	25.3	41.1	21.8	71.8
73		09:53:19	25.4	38.4	21.8	71.5
74		10:53:19	25.6	38	21.8	71.1
75		11:53:19	25.8	37.9	21.8	70.7
76		12:53:19	28.9	38.2	21.7	71.0
77		13:53:19	26.2	37.5	21.6	71.2
78		14:53:19	26.2	40.2	21.6	71.4
79		15:53:19	26.2	41.3	21.6	72.5
80		16:53:19	26.5	41	21.6	73.3
81		17:53:19	26.4	42.9	21.6	73.6
82		18:53:19	26.5	44.9	21.7	73.0
83		19:53:19	27	44.9	21.7	71.9
84		20:53:19	26.3	47.1	21.7	71.4
85		21:53:19	26.1	48.9	21.7	70.5
86		22:53:19	26.1	50	21.8	68.9
87		23:53:19	25.9	51.4	21.9	67.5
88	09/07/2022	00:53:19	25.9	52.2	22.0	66.7
89		01:53:19	25.9	52.3	21.9	67.8
90		02:53:19	25.8	51.5	21.7	69.0
91		03:53:19	25.9	52.8	21.7	69.4
92		04:53:19	25.8	54.3	21.7	69.7
93		05:53:19	25.7	48.9	21.7	69.7
94		06:53:19	25.8	44.7	21.7	69.0
95		07:53:19	25.9	40.4	21.7	68.3
96		08:53:19	26.3	39.7	21.7	68.8
97		09:53:19	26.5	39.4	21.6	69.1
98		10:53:19	26.6	43.8	21.6	69.6
99	09/07/2022	11:53:19	26.5	52	21.6	69.8
100		12:53:19	26.6	57.1	21.6	69.9
101		13:53:19	26.9	55.4	21.6	70.1
102		14:53:19	26.9	52.6	21.6	70.4
103		15:53:19	27	51.7	20.4	77.0
104		16:53:19	27.1	49	20.7	75.2
105		17:53:19	27.2	46.3	21.6	70.6
106		18:53:19	27.3	44.7	21.7	68.7
107		19:53:19	27.8	43.9	21.8	66.7
108		20:53:19	27.6	41.2	22.4	63.6
109		21:53:19	27.1	37.8	22.2	61.7
110		22:53:19	26.9	43.9	21.9	61.1
111		23:53:19	26.7	47.9	21.9	61.2
112	10/07/2022	00:53:19	26.7	50.3	21.9	63.2

	Kitchen+Livingroom+Bedroom 5+6		B-Air C°	B-RH%	S-Air C°	S-RH%
113	10/07/2022	01:53:19	26.7	51.5	21.8	65.3
114		02:53:19	26.5	52.3	21.8	66.8
115		03:53:19	26.6	52.3	21.7	68.3
116		04:53:19	26.6	53.3	21.6	69.4
117		05:53:19	26.4	54.8	21.5	70.0
118		06:53:19	26.6	55.5	21.5	69.9
119		07:53:19	26.5	56.2	21.5	70.2
120		08:53:19	26.5	58.3	21.5	70.3
121		09:53:19	26.7	57.3	21.5	70.2
122		10:53:19	26.6	57.4	21.5	70.5
123		11:53:19	26.5	56.9	21.5	70.7
124		12:53:19	26.4	56	21.5	70.7
125		13:53:19	26.4	55.5	21.5	70.8
126		14:53:19	26.2	54.4	21.4	71.0
127		15:53:19	26	54.4	18.6	70.8
128		16:53:19	26.4	52.7	18.6	70.5
129		17:53:19	26.1	51.8	18.6	70.7
130		18:53:19	26.2	53.1	18.9	70.7
131		19:53:19	26.8	53.9	19.9	70.8
132		20:53:19	26.4	52.2	20.5	71.0
133		21:53:19	25.9	52.1	20.8	72.0
134		22:53:19	25.9	50.8	21.5	72.7
135		23:53:19	25.7	50.6	21.8	71.3
136	11/07/2022	00:53:19	26	50.6	21.3	74.8
137		01:53:19	27.9	50.5	20.4	75.0
138		02:53:19	25.8	51	20.1	76.0
139		03:53:19	25.8	50.3	19.7	75.0
140		04:53:19	25.8	50.4	21.0	73.1
141		05:53:19	25.6	51.7	21.3	72.2
142		06:53:19	25.6	51.4	21.3	72.4
143		07:53:19	25.7	51.4	21.3	72.4
144		08:53:19	25.6	52.9	21.3	72.2
145		09:53:19	25.9	55.1	21.3	71.8
146		10:53:19	25.4	52	21.3	71.9
147		11:53:19	25.1	53.4	21.3	72.1
148		12:53:19	25	53.7	21.3	72.3
149		13:53:19	25.3	60	21.2	72.4
150		14:53:19	25	55.1	21.2	72.3
151		15:53:19	25.3	55.3	21.2	72.3
152		16:53:19	25.8	52.4	21.3	72.2
153		17:53:19	25.6	55	21.3	72.4
154		18:53:19	25.5	55.9	21.4	73.6
155		19:53:19	25.6	55.5	20.9	77.0
156		20:53:19	25.7	54.9	21.7	73.5
157		21:53:19	25.5	55	22.0	74.8
158		22:53:19	25.6	54.8	22.5	73.2
159		23:53:19	25.5	55.5	22.7	72.9
160	12/07/2022	00:53:19	25.5	59.9	22.7	72.7
161		01:53:19	25.5	62.1	23.2	74.3
162		02:53:19	25.3	64.6	22.0	81.6
163		03:53:19	25.5	63.9	21.7	80.1
164		04:53:19	25.4	63.5	21.6	78.4
165		05:53:19	25.3	62.7	21.5	76.5
166		06:53:19	25.5	58.8	21.5	74.9
167		07:53:19	25.6	53.5	21.5	73.8
168		08:53:19	25.8	50.3	21.5	73.9

	Kitchen+Livingroom+Bedroom 5+6		B-Air C°	B-RH%	S-Air C°	S-RH%
169	12/07/2022	09:53:19	26.1	54.4	21.5	73.9
170		10:53:19	26.5	50.7	21.5	73.1
171		11:53:19	26.5	51.7	21.5	72.5
172		12:53:19	26.2	58.2	21.5	72.7
173		13:53:19	26.7	62.6	21.5	73.3
174		14:53:19	26.6	61.4	21.4	74.0
175		15:53:19	26.8	59	22.3	74.6
176		16:53:19	26.8	56.3	22.5	81.4
177		17:53:19	26.7	55.3	22.6	82.7
178		18:53:19	26.8	53.7	22.6	80.8
179		19:53:19	26.9	53.4	22.7	79.7
180		20:53:19	26.8	59.7	22.7	78.9
181		21:53:19	26.8	61.5	23.1	79.7
182		22:53:19	26.8	64.4	23.2	84.2
183		23:53:19	27	62.5	23.3	87.1
184	13/07/2022	00:53:19	27.1	54.2	23.3	88.5
185		01:53:19	26.8	52.6	23.4	88.9
186		02:53:19	26.8	52.7	23.4	89.8
187		03:53:19	26.8	52.6	23.4	90.0
188		04:53:19	26.6	52.5	22.1	91.9
189		05:53:19	26.7	53.6	21.8	85.9
190		06:53:19	26.7	53.9	21.7	80.5
191		07:53:19	26.7	52.6	21.7	77.0
192		08:53:19	26.9	56.3	21.7	74.7
193		09:53:19	26.9	57.1	21.6	73.4
194		10:53:19	27.1	55.2	21.6	72.4
195		11:53:19	27.7	38	21.7	71.6
196		12:53:19	28.2	40.6	21.6	71.5
197		13:53:19	28.7	41.1	21.6	71.2
198		14:53:19	29	40.7	21.6	70.9
199		15:53:19	28	40.9	19.4	81.3
200		16:53:19	27.8	47	19.4	83.8
201		17:53:19	27.5	50.5	21.2	77.4
202		18:53:19	27.5	49.5	21.6	75.6
203		19:53:19	27.8	52.8	21.7	74.6
204		20:53:19	28.4	34.6	21.8	72.5
205		21:53:19	28.3	37.8	21.8	70.6
206		22:53:19	28	41.6	21.8	69.3
207		23:53:19	28	43.7	21.9	65.7

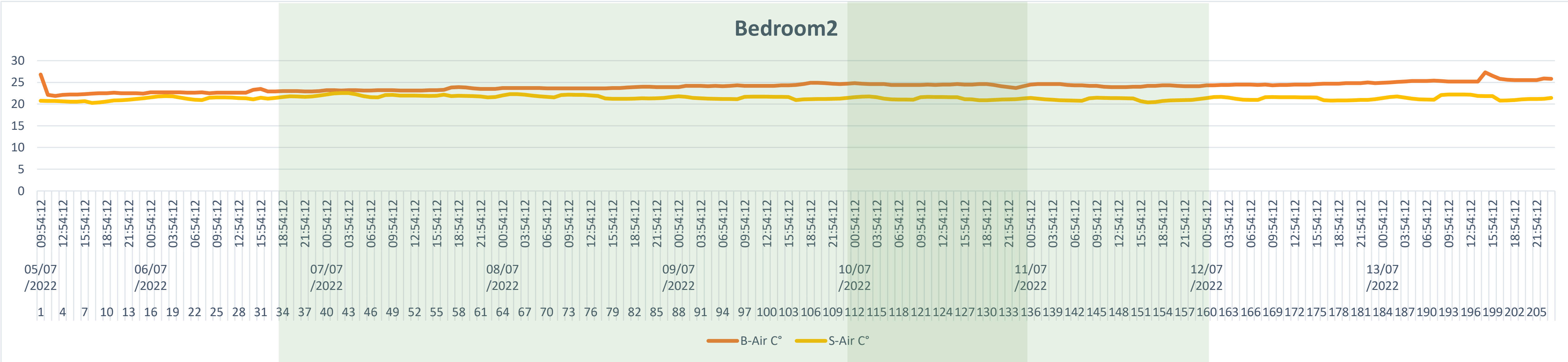
	Exterior		B-Air C°	B-RH%	S-Air C°	S-RH%
1	05/07/2022	09:54:43	25.4	62.3	21.2	78
2		10:54:43	21.3	75.6	24	69
3		11:54:43	22.5	71.3	25	65
4		12:54:43	24.9	63.5	25	61
5		13:54:43	24.5	64.7	27	54
6		14:54:43	25.2	62.4	27	51
7		15:54:43	24.5	64.7	27.4	51
8		16:54:43	24.5	63.2	27	42
9		17:54:43	23.6	66	27	54
10		18:54:43	22.4	69.6	26.7	51
11		19:54:43	24.1	62.1	26	45
12		20:54:43	24.8	55.5	23.8	64
13		21:54:43	21.9	73.3	21.6	75
14		22:54:43	21.9	76	21	78
15		23:54:43	21.6	77	20	88
16	06/07/2022	00:54:43	20.9	80.8	19.9	89
17		01:54:43	20.1	84.2	20	88
18		02:54:43	19.9	84.2	20	88
19		03:54:43	20	83.7	19.1	90
20		04:54:43	19.8	82.4	18	94
21		05:54:43	19.7	79.6	18	94
22		06:54:43	20	72	18.8	93
23		07:54:43	20.6	72	22	83
24		08:54:43	23.3	59.2	26	61
25		09:54:43	26.6	49.7	28	54
26		10:54:43	22.8	71.4	30	49
27		11:54:43	24.5	66	32	46
28		12:54:43	27.5	58.2	28	56
29		13:54:43	28.7	51.1	29	52
30		14:54:43	29.5	44.3	29	52
31		15:54:43	28.7	45.7	29.6	49
32		16:54:43	28.4	44	30	46
33		17:54:43	28.2	43.6	30	43
34		18:54:43	27.8	45.6	30.2	42
35		19:54:43	27.1	45.7	30	46
36		20:54:43	26.3	48.5	27	58
37		21:54:43	25.3	56.3	22.2	71
38		22:54:43	24.4	65.8	22	73
39		23:54:43	24.3	58.9	22	73
40	07/07/2022	00:54:43	24.2	58.5	21.9	82
41		01:54:43	23.9	61.6	20	83
42		02:54:43	24.1	63.3	19	83
43		03:54:43	24.7	44.7	20	80
44		04:54:43	24.2	45.2	20	78
45		05:54:43	23.7	43.8	19	83
46		06:54:43	23.3	42.1	19.5	82
47		07:54:43	23.7	40.7	22	83
48		08:54:43	24.9	35	24	69
49		09:54:43	27.3	31.4	26.6	53
50		10:54:43	27.9	31.6	27	51
51		11:54:43	29.7	30.3	25	61
52		12:54:43	32.6	26.1	25.8	58
53		13:54:43	33.8	25.8	23	69
54		14:54:43	34.2	27.2	21	83
55		15:54:43	33.7	31.7	22.4	74
56		16:54:43	31.8	34.9	24	69

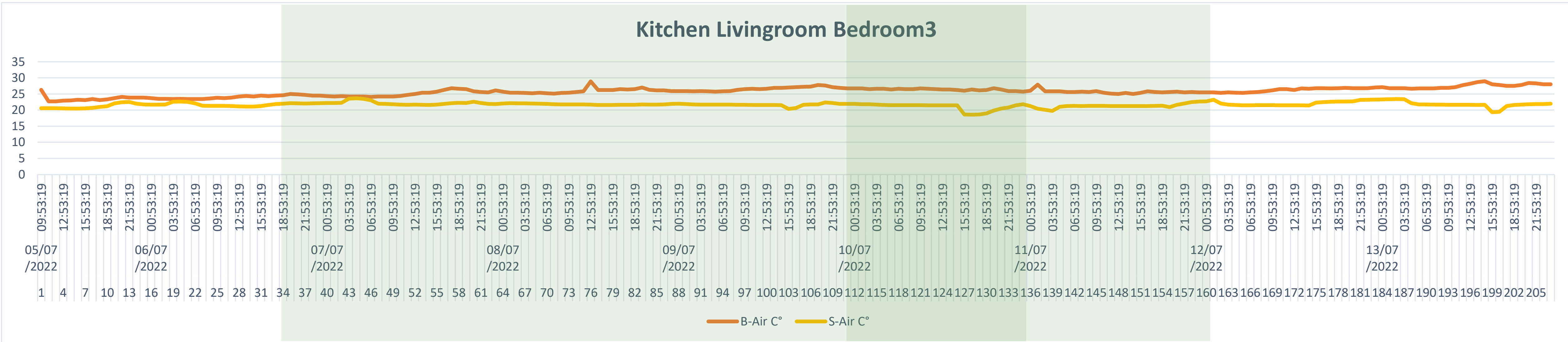
	Exterior		B-Air C°	B-RH%	S-Air C°	S-RH%
57	07/07/2022	17:54:43	30.7	36.6	24	65
58		18:54:43	30.2	36.7	22.9	68
59		19:54:43	29.5	36.6	23	69
60		20:54:43	28.3	42.3	22	73
61		21:54:43	27.4	46.6	21.2	75
62		22:54:43	26.9	50.7	20	78
63		23:54:43	26.6	50.8	19	83
64	08/07/2022	00:54:43	25.8	52.9	19.9	80
65		01:54:43	25	49.9	19	83
66		02:54:43	25.3	40.1	20	78
67		03:54:43	25.5	40.3	19.2	83
68		04:54:43	25.4	39.4	18	88
69		05:54:43	24.9	35.2	17	94
70		06:54:43	24.7	33.2	18.1	94
71		07:54:43	25.2	30.2	18	94
72		08:54:43	26.5	28.8	19	88
73		09:54:43	29.2	27.1	18.4	88
74		10:54:43	29.7	25.6	20	78
75		11:54:43	31.7	24.5	20	78
76		12:54:43	34.8	24.5	19.4	80
77		13:54:43	35.9	20.8	20	73
78		14:54:43	35.6	22.5	21.3	69
79		15:54:43	35	24.5	22.6	62
80		16:54:43	34.1	27.6	22	69
81		17:54:43	33	29.6	20	78
82		18:54:43	32.4	32.9	19.1	82
83		19:54:43	30.6	37.5	19	83
84		20:54:43	29.1	41.3	19	83
85		21:54:43	28.2	46.3	18.7	81
86		22:54:43	27.3	52.6	19	78
87		23:54:43	26.7	54.4	19	83
88	09/07/2022	00:54:43	26.5	51.2	18.6	83
89		01:54:43	25.7	53.5	18	88
90		02:54:43	25	55.8	18	88
91		03:54:43	24.5	55.7	18.2	86
92		04:54:43	23.9	55.8	18	88
93		05:54:43	25.3	38.2	18	88
94		06:54:43	25.4	37.8	17.9	90
95		07:54:43	26.3	39.2	18	88
96		08:54:43	37.8	37.6	20	78
97		09:54:43	31	27.5	20.6	71
98		10:54:43	31.8	26.1	21	64
99	09/07/2022	11:54:43	30.9	37.7	21	69
100		12:54:43	32.4	34.5	21.6	64
101		13:54:43	33.6	30.3	21	64
102		14:54:43	33.5	28.7	22	60
103		15:54:43	33.4	28.7	22	67
104		16:54:43	32.9	29.5	21	73
105		17:54:43	32	29.7	21	73
106		18:54:43	31	29.5	20.2	77
107		19:54:43	30.2	30.9	18	88
108		20:54:43	28.8	34.1	17	94
109		21:54:43	27.5	35.7	16.8	93
110		22:54:43	26.6	53.3	17	94
111		23:54:43	25	54.2	17	94
112	10/07/2022	00:54:43	23.9	60.7	17.2	91

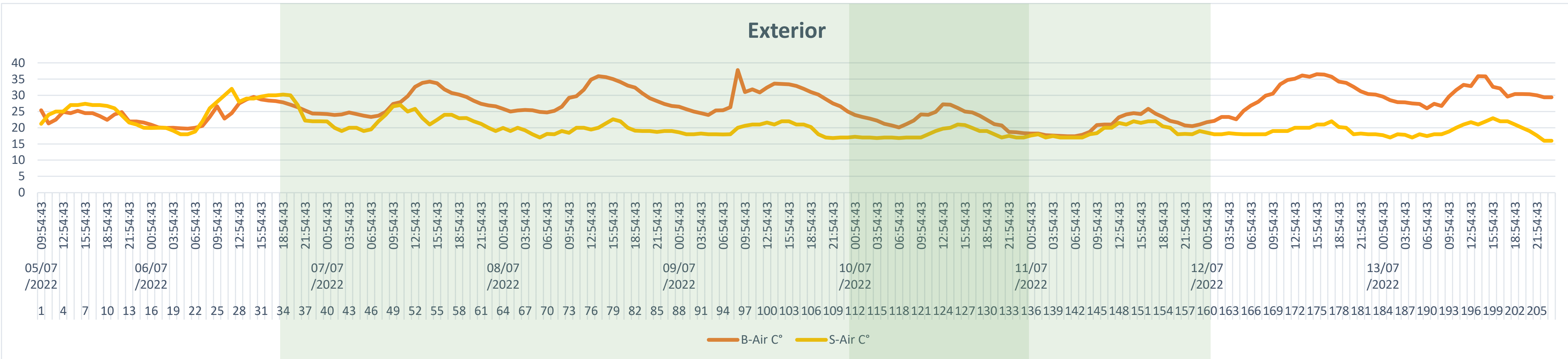
	Exterior		B-Air C°	B-RH%	S-Air C°	S-RH%
113	10/07/2022	01:54:43	23.3	61.8	17	94
114		02:54:43	22.8	64.7	17	94
115		03:54:43	22.2	70.4	16.8	94
116		04:54:43	21.2	78.2	17	94
117		05:54:43	20.7	83.2	17	94
118		06:54:43	20.1	86.7	16.8	95
119		07:54:43	21.1	82.8	17	94
120		08:54:43	22.2	77.8	17	94
121		09:54:43	24.1	69.1	17	95
122		10:54:43	24	68.3	18	88
123		11:54:43	24.9	64.4	19	83
124		12:54:43	27.2	56.5	19.7	79
125		13:54:43	27.1	55	20	78
126		14:54:43	26.1	58.3	21	73
127		15:54:43	25	59.8	20.8	76
128		16:54:43	24.7	57.6	19.9	81
129		17:54:43	23.7	59.6	19	86
130		18:54:43	22.4	66.2	19	86
131		19:54:43	21.1	69.2	18	88
132		20:54:43	20.7	71.9	17	94
133		21:54:43	18.7	78.8	17.5	93
134		22:54:43	18.6	79.4	17	94
135		23:54:43	18.3	79	17	94
136	11/07/2022	00:54:43	18.2	78.8	17.6	90
137		01:54:43	18.2	77.7	18	88
138		02:54:43	17.7	78.6	17	94
139		03:54:43	17.6	79.5	17.4	93
140		04:54:43	17.5	81	17	94
141		05:54:43	17.4	81.6	17	94
142		06:54:43	17.4	82.1	17	94
143		07:54:43	17.8	81.5	17	94
144		08:54:43	18.7	78.6	18	88
145		09:54:43	20.8	69.7	18.3	94
146		10:54:43	21	69.1	20	83
147		11:54:43	21	68.5	20	78
148		12:54:43	23.2	62.1	21.5	75
149		13:54:43	24.1	61.5	21	78
150		14:54:43	24.5	59.1	22	73
151		15:54:43	24.2	60.4	21.5	76
152		16:54:43	25.8	55.3	22	73
153		17:54:43	24.3	63.1	22	73
154		18:54:43	23.3	64.9	20.4	79
155		19:54:43	22.1	67.1	20	83
156		20:54:43	21.6	69.5	18	88
157		21:54:43	20.7	73.6	18.1	89
158		22:54:43	20.5	74.7	18	88
159		23:54:43	21	75.4	19	88
160	12/07/2022	00:54:43	21.7	74.4	18.5	89
161		01:54:43	22.1	75.1	18	88
162		02:54:43	23.3	70.8	18	88
163		03:54:43	23.3	71.2	18.3	89
164		04:54:43	22.6	75.2	18.1	91
165		05:54:43	25.2	53.8	18	94
166		06:54:43	26.8	45.3	18	92
167		07:54:43	28	38.8	18	94
168		08:54:43	29.9	36.6	18	94

	Exterior		B-Air C°	B-RH%	S-Air C°	S-RH%
169	12/07/2022	09:54:43	30.5	46.1	19	87
170		10:54:43	33.4	29.5	19	88
171		11:54:43	34.7	31.6	19	88
172		12:54:43	35.1	32.3	20	83
173		13:54:43	36.1	32.1	20	83
174		14:54:43	35.7	31.6	20	83
175		15:54:43	36.5	29.4	21	77
176		16:54:43	36.4	25.9	21	73
177		17:54:43	35.7	25.8	22	73
178		18:54:43	34.2	29.1	20.2	78
179		19:54:43	33.8	30.7	20	78
180		20:54:43	32.6	30.3	18	88
181		21:54:43	31.2	31.2	18.2	86
182		22:54:43	30.4	30.2	18	88
183		23:54:43	30.2	30.7	18	88
184	13/07/2022	00:54:43	29.6	35.1	17.7	90
185		01:54:43	28.5	41.1	17	94
186		02:54:43	27.9	42.4	18	88
187		03:54:43	27.8	41.3	17.8	90
188		04:54:43	27.5	43.2	17	94
189		05:54:43	27.3	45.3	18	88
190		06:54:43	26	53.5	17.4	91
191		07:54:43	27.4	50.3	18	88
192		08:54:43	26.7	52.8	18	94
193		09:54:43	29.6	45.7	18.8	89
194		10:54:43	31.6	32.5	20	83
195		11:54:43	33.2	27	21	73
196		12:54:43	32.8	24.9	21.7	66
197		13:54:43	35.9	26.3	21	73
198		14:54:43	35.8	26.1	21.9	59
199		15:54:43	32.6	29.8	22.9	53
200		16:54:43	32.1	33.4	22	64
201		17:54:43	29.6	40.2	22	64
202		18:54:43	30.4	35.7	21	69
203		19:54:43	30.4	32.4	20	73
204		20:54:43	30.3	28.8	19	78
205		21:54:43	30	31.8	17.6	83
206		22:54:43	29.4	39.6	16	88
207		23:54:43	29.4	41.1	16	88

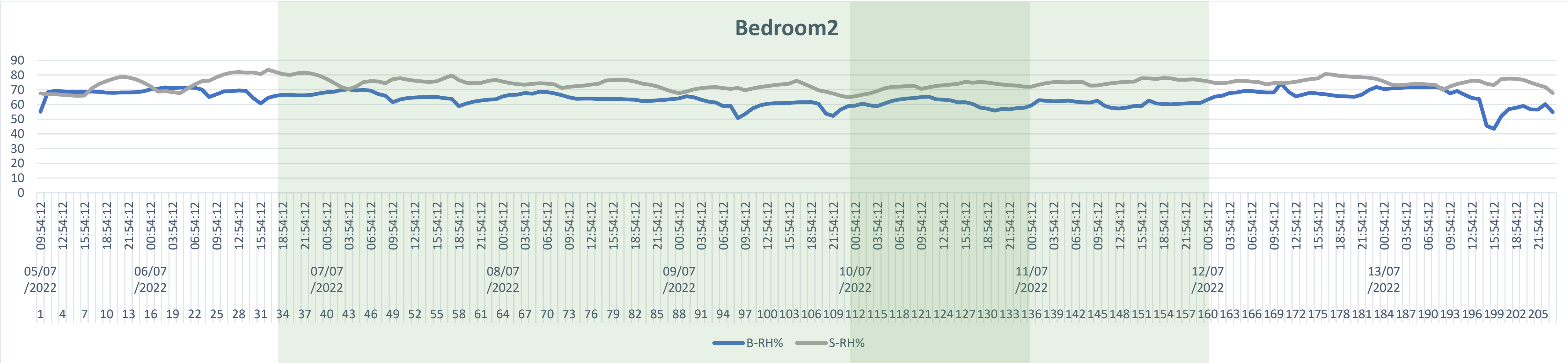
8.5 Comparison graph of collected and simulated data- Air Temperature C°

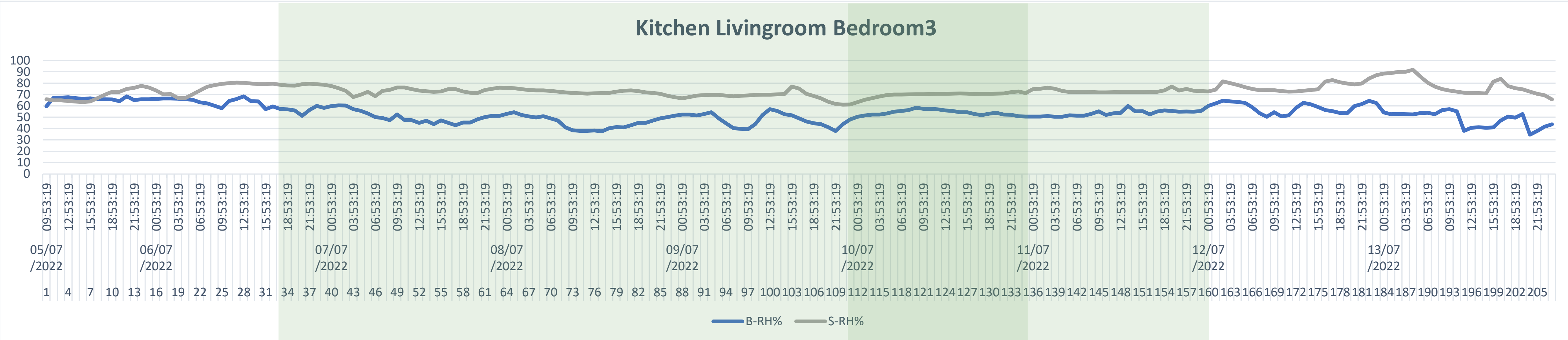


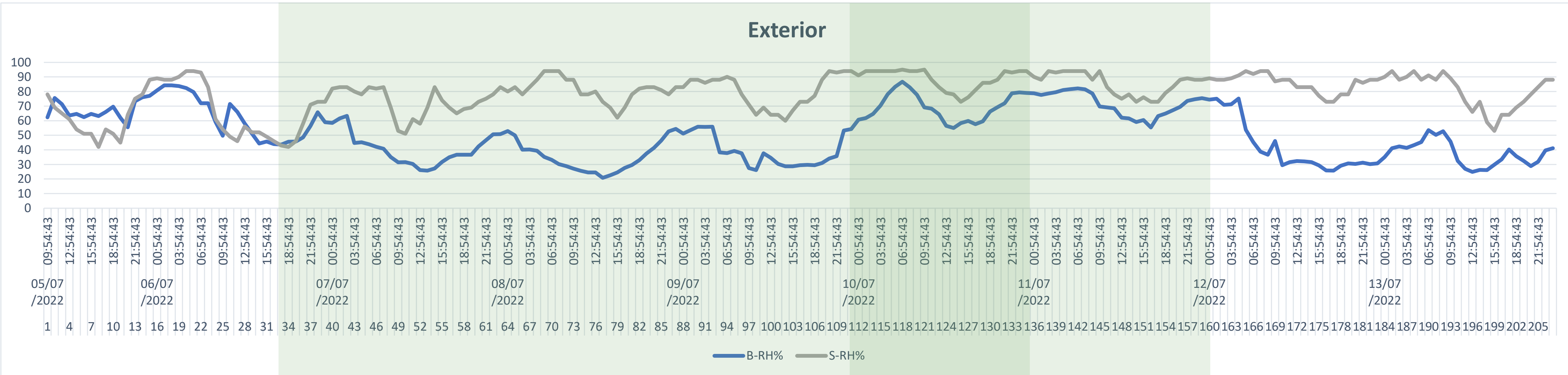




8.6 Comparison graph of collected and simulated data- Relative humidity %







8.7 Comparison of simulated data from the different variations - Daylight Autonomy

	1_1	1_2	1_3	1_4	2_1	2_2	2_3	2_4	3_1	3_2	3_3	3_4	4_1
Existent	15.6%	27.6%	25.0%	24.4%	13.0%	20.8%	29.2%	20.2%	81.5%	57.8%	82.7%	62.7%	14.8%
Rotation 90	16.7%	30.7%	30.2%	24.4%	15.6%	25.5%	27.6%	22.6%	81.5%	58.9%	82.7%	64.3%	14.1%
	1.1%	3.1%	5.2%	0.0%	2.6%	4.7%	-1.6%	2.4%	0.0%	1.1%	0.0%	1.6%	-0.7%

4_2	4_3	4_4	5_1	5_2	5_3	5_4	6_1	6_2	6_3	6_4	7_1	7_2
20.8%	55.7%	27.4%	6.8%	21.4%	21.4%	18.5%	15.6%	28.1%	44.3%	35.1%	6.3%	18.8%
20.8%	53.1%	26.2%	6.2%	26.0%	23.4%	19.6%	17.2%	27.1%	41.7%	31.0%	5.7%	16.1%
0.0%	-2.6%	-1.2%	-0.6%	4.6%	2.0%	1.1%	1.6%	-1.0%	-2.6%	-4.1%	-0.6%	-2.7%

7_3	7_4	8_1	8_2	8_3
20.8%	17.3%	52.1%	43.2%	42.2%
20.3%	17.9%	51.6%	43.2%	41.1%
-0.5%	0.6%	-0.5%	0.0%	-1.1%

	1_1	1_2	1_3	1_4	2_1	2_2	2_3	2_4	3_1	3_2	3_3	3_4	4_1
Existent	15.6%	27.6%	25.0%	24.4%	13.0%	20.8%	29.2%	20.2%	81.5%	57.8%	82.7%	62.7%	14.8%
Rotation 174	16.7%	25.5%	27.1%	30.4%	15.1%	25.5%	29.7%	24.4%	81.2%	56.6%	84.2%	63.1%	16.4%
	1.1%	-2.1%	2.1%	6.0%	2.1%	4.7%	0.5%	4.2%	-0.3%	-1.2%	1.5%	0.4%	1.6%

4_2	4_3	4_4	5_1	5_2	5_3	5_4	6_1	6_2	6_3	6_4	7_1	7_2
20.8%	55.7%	27.4%	6.8%	21.4%	21.4%	18.5%	15.6%	28.1%	44.3%	35.1%	6.3%	18.8%
19.3%	57.8%	32.7%	6.2%	25.5%	22.9%	23.2%	17.2%	32.3%	45.8%	44.0%	6.3%	22.4%
-1.5%	2.1%	5.3%	-0.6%	4.1%	1.5%	4.7%	1.6%	4.2%	1.5%	8.9%	0.0%	3.6%

7_3	7_4	8_1	8_2	8_3
20.8%	17.3%	52.1%	43.2%	42.2%
24.5%	20.2%	50.5%	48.4%	36.5%
3.7%	2.9%	-1.6%	5.2%	-5.7%

	1_1	1_2	1_3	1_4	2_1	2_2	2_3	2_4	3_1	3_2	3_3	3_4	4_1
Existent	15.6%	27.6%	25.0%	24.4%	13.0%	20.8%	29.2%	20.2%	81.5%	57.8%	82.7%	62.7%	14.8%
Rotation 219	14.6%	27.1%	27.1%	26.8%	13.0%	25.0%	30.7%	23.2%	81.2%	56.0%	85.6%	63.1%	15.6%
	-1.0%	-0.5%	2.1%	2.4%	0.0%	4.2%	1.5%	3.0%	-0.3%	-1.8%	2.9%	0.4%	0.8%

4_2	4_3	4_4	5_1	5_2	5_3	5_4	6_1	6_2	6_3	6_4	7_1	7_2
20.8%	55.7%	27.4%	6.8%	21.4%	21.4%	18.5%	15.6%	28.1%	44.3%	35.1%	6.3%	18.8%
18.7%	56.3%	33.3%	6.8%	24.5%	23.4%	22.0%	17.2%	31.8%	45.3%	41.7%	5.7%	23.4%
-2.1%	0.6%	5.9%	0.0%	3.1%	2.0%	3.5%	1.6%	3.7%	1.0%	6.6%	-0.6%	4.6%

7_3	7_4	8_1	8_2	8_3
20.8%	17.3%	52.1%	43.2%	42.2%
26.6%	23.8%	45.8%	47.9%	39.1%
5.8%	6.5%	-6.3%	4.7%	-3.1%

	1_1	1_2	1_3	1_4	2_1	2_2	2_3	2_4	3_1	3_2	3_3	3_4	4_1
Existent	15.6%	27.6%	25.0%	24.4%	13.0%	20.8%	29.2%	20.2%	81.5%	57.8%	82.7%	62.7%	14.8%
Removing Stairs	15.6%	27.6%	25.0%	24.4%	16.7%	25.5%	29.2%	20.2%	81.5%	57.8%	82.7%	62.7%	14.8%
	0.0%	0.0%	0.0%	0.0%	3.7%	4.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

	4_2	4_3	4_4	5_1	5_2	5_3	5_4	6_1	6_2	6_3	6_4	7_1	7_2
Existent	20.8%	55.7%	27.4%	6.8%	21.4%	21.4%	18.5%	15.6%	28.1%	44.3%	35.1%	6.3%	18.8%
Removing Stairs	20.8%	55.7%	27.4%	8.9%	27.1%	21.4%	18.5%	15.6%	28.1%	44.3%	35.1%	6.3%	18.8%
	0.0%	0.0%	0.0%	2.1%	5.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

	7_3	7_4	8_1	8_2	8_3
Existent	20.8%	17.3%	52.1%	43.2%	42.2%
Removing Stairs	20.8%	17.3%	52.1%	43.2%	42.2%
	0.0%	0.0%	0.0%	0.0%	0.0%

	1_1	1_2	1_3	1_4	2_1	2_2	2_3	2_4	3_1	3_2	3_3	3_4	4_1
Existent	15.6%	27.6%	25.0%	24.4%	13.0%	20.8%	29.2%	20.2%	81.5%	57.8%	82.7%	62.7%	14.8%
Bigger Windows	16.7%	27.6%	46.9%	54.2%	16.1%	29.2%	42.2%	54.2%	81.5%	58.1%	83.3%	63.5%	14.8%
	1.1%	0.0%	21.9%	29.8%	3.1%	8.4%	13.0%	34.0%	0.0%	0.3%	0.6%	0.8%	0.0%

	4_2	4_3	4_4	5_1	5_2	5_3	5_4	6_1	6_2	6_3	6_4	7_1	7_2
Existent	20.8%	55.7%	27.4%	6.8%	21.4%	21.4%	18.5%	15.6%	28.1%	44.3%	35.1%	6.3%	18.8%
Bigger Windows	21.4%	55.7%	53.6%	7.8%	29.7%	40.6%	36.9%	17.2%	33.9%	44.8%	64.3%	6.3%	18.8%
	0.6%	0.0%	26.2%	1.0%	8.3%	19.2%	18.4%	1.6%	5.8%	0.5%	29.2%	0.0%	0.0%

	7_3	7_4	8_1	8_2	8_3
Existent	20.8%	17.3%	52.1%	43.2%	42.2%
Bigger Windows	30.7%	38.7%	52.1%	43.2%	54.3%
	9.9%	21.4%	0.0%	0.0%	12.1%

	1_1	1_2	1_3	1_4	2_1	2_2	2_3	2_4	3_1	3_2	3_3	3_4	4_1
Existent	15.6%	27.6%	25.0%	24.4%	13.0%	20.8%	29.2%	20.2%	81.5%	57.8%	82.7%	62.7%	14.8%
Sunroom 3°floor	15.6%	27.6%	31.8%	24.4%	13.0%	20.8%	35.4%	20.2%	81.5%	57.8%	82.7%	62.7%	14.8%
	0.0%	0.0%	6.8%	0.0%	0.0%	0.0%	6.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

	4_2	4_3	4_4	5_1	5_2	5_3	5_4	6_1	6_2	6_3	6_4	7_1	7_2
Existent	20.8%	55.7%	27.4%	6.8%	21.4%	21.4%	18.5%	15.6%	28.1%	44.3%	35.1%	6.3%	18.8%
Sunroom 3°floor	20.8%	40.6%	27.4%	6.8%	21.4%	27.6%	18.5%	15.6%	28.1%	52.1%	35.1%	6.3%	18.8%
	0.0%	-15.1%	0.0%	0.0%	0.0%	6.2%	0.0%	0.0%	0.0%	7.8%	0.0%	0.0%	0.0%

	7_3	7_4	8_1	8_2	8_3
Existent	20.8%	17.3%	52.1%	43.2%	42.2%
Sunroom 3°floor	30.7%	17.3%	52.1%	43.2%	42.2%
	9.9%	0.0%	0.0%	0.0%	0.0%

	1_1	1_2	1_3	1_4	2_1	2_2	2_3	2_4	3_1	3_2	3_3	3_4	4_1
Existent	15.6%	27.6%	25.0%	24.4%	13.0%	20.8%	29.2%	20.2%	81.5%	57.8%	82.7%	62.7%	14.8%
Remmoving trees	16.7%	32.8%	25.0%	24.4%	13.0%	20.8%	29.2%	20.2%	81.5%	61.3%	82.7%	62.7%	18.0%
	1.1%	5.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	3.5%	0.0%	0.0%	3.2%

4_2	4_3	4_4	5_1	5_2	5_3	5_4	6_1	6_2	6_3	6_4	7_1	7_2
20.8%	55.7%	27.4%	6.8%	21.4%	21.4%	18.5%	15.6%	28.1%	44.3%	35.1%	6.3%	18.8%
20.8%	57.8%	34.5%	16.1%	31.3%	28.1%	27.4%	18.7%	30.7%	46.4%	38.7%	13.0%	21.4%
0.0%	2.1%	7.1%	9.3%	9.9%	6.7%	8.9%	3.1%	2.6%	2.1%	3.6%	6.7%	2.6%

7_3	7_4	8_1	8_2	8_3
20.8%	17.3%	52.1%	43.2%	42.2%
27.6%	22.6%	52.1%	43.2%	42.2%
6.8%	5.3%	0.0%	0.0%	0.0%

	1_1	1_2	1_3	1_4	2_1	2_2	2_3	2_4	3_1	3_2	3_3	3_4	4_1
Existent	15.6%	27.6%	25.0%	24.4%	13.0%	20.8%	29.2%	20.2%	81.5%	57.8%	82.7%	62.7%	14.8%
Changing Circulation	14.6%	24.5%	25.5%	28.0%	14.6%	21.9%	21.9%	21.4%	81.5%	58.7%	83.0%	63.5%	14.8%
	-1.0%	-3.1%	0.5%	3.6%	1.6%	1.1%	-7.3%	1.2%	0.0%	0.9%	0.3%	0.8%	0.0%

4_2	4_3	4_4	5_1	5_2	5_3	5_4	6_1	6_2	6_3	6_4	7_1	7_2
20.8%	55.7%	27.4%	6.8%	21.4%	21.4%	18.5%	15.6%	28.1%	44.3%	35.1%	6.3%	18.8%
21.9%	54.7%	29.8%	7.3%	22.9%	20.3%	19.6%	16.4%	26.6%	41.1%	36.3%	6.3%	15.6%
1.1%	-1.0%	2.4%	0.5%	1.5%	-1.1%	1.1%	0.8%	-1.5%	-3.2%	1.2%	0.0%	-3.2%

7_3	7_4	8_1	8_2	8_3
20.8%	17.3%	52.1%	43.2%	42.2%
19.8%	18.5%	52.1%	42.2%	41.7%
-1.0%	1.2%	0.0%	-1.0%	-0.5%

8.8 Comparison of DBT(C°) and RH(%) to obtain theThermal Comfort Levels

Existent

Unit1	1_F1	2_F1	3_F1	4_F1	5+6_F2	7_F2	5+6_F3	2_F3	7__F3	4_F4	3_F4	2_F4	1_F4
DBT (C°)	19.76	18.32	19.14	18.33	20.54	19.58	19.50	18.57	18.54	19.60	20.63	19.72	20.75
RH %	55.18	59.47	62.69	63.19	56.62	59.75	53.67	53.78	57.38	54.97	58.15	54.55	52.02
Comfort%	0%	0%	0%	0%	33%	0%	100%	67%	0%	0%	0%	67%	0%

Variation 1

Unit1	1_F1	2_F1	3_F1	4_F1	5+6_F2	7_F2	5+6_F3	2_F3	7__F3	4_F4	3_F4	2_F4	1_F4
DBT (C°)	18.27	18.81	19.31	20.94	21.60	19.30	21.19	20.78	20.79	20.28	20.75	19.91	20.55
RH %	63.44	58.57	62.21	52.15	53.46	60.65	55.06	51.62	55.16	52.94	57.88	54.03	52.64
Comfort%	0%	33%	0%	0%	100%	0%	100%	67%	0%	0%	0%	67%	0%

Variation 2

Unit1	1_F1	2_F1	3_F1	4_F1	5+6_F2	7_F2	5+6_F3	2_F3	7__F3	4_F4	3_F4	2_F4	1_F4
DBT (C°)	18.28	18.02	18.31	18.96	19.78	19.64	21.95	19.61	19.61	19.16	20.52	19.46	20.71
RH %	63.43	60.59	65.28	58.08	59.58	59.62	53.04	55.93	59.27	56.83	58.56	55.38	52.17
Comfort%	0%	0%	0%	0%	0%	67%	100%	0%	33%	0%	33%	0%	0%

Variation 3

Unit1	1_F1	2_F1	3_F1	4_F1	5+6_F2	7_F2	5+6_F3	2_F3	7__F3	4_F4	3_F4	2_F4	1_F4
DBT (C°)	18.34	18.57	19.08	19.43	20.21	19.72	21.94	19.75	19.74	19.16	19.34	19.59	20.78
RH %	63.10	58.87	62.91	56.44	58.02	59.46	52.93	55.42	58.63	56.83	55.98	54.95	51.80
Comfort%	0%	0%	0%	0%	33%	0%	100%	67%	0%	0%	0%	33%	0%

Variation 4

Unit1	1_F1	2_F1	3_F1	4_F1	5+6_F2	7_F2	5+6_F3	2_F3	7__F3	4_F4	3_F4	2_F4	1_F4
DBT (C°)	18.29	18.14	18.41	19.70	20.54	19.60	21.72	20.19	20.25	19.67	20.64	19.73	20.76
RH %	63.28	60.19	64.88	55.33	56.69	59.71	53.63	53.66	56.71	54.72	58.04	54.41	51.97
Comfort%	0%	0%	0%	0%	33%	0%	100%	67%	0%	0%	0%	33%	0%

Variation 5

Unit1	1_F1	2_F1	3_F1	4_F1	5+6_F2	7_F2	5+6_F3	2_F3	7__F3	4_F4	3_F4	2_F4	1_F4
DBT (C°)	17.34	16.38	18.42	18.03	18.47	17.53	18.63	18.66	18.72	18.47	19.44	18.38	18.91
RH %	66.77	66.63	64.90	61.12	62.90	66.23	62.31	58.98	61.62	58.83	61.47	59.26	57.38
Comfort%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Variation 6

Unit1	1_F1	2_F1	3_F1	4_F1	5+6_F2	7_F2	5+6_F3	2_F3	7__F3	4_F4	3_F4	2_F4	1_F4
DBT (C°)	18.33	18.32	19.14	19.76	20.54	19.58	18.57	19.50	18.54	19.60	20.63	19.72	20.75
RH %	63.19	59.47	62.69	55.18	56.62	59.75	62.65	59.56	62.46	54.97	58.15	54.55	52.02
Comfort%	0%	0%	0%	0%	33%	0%	33%	0%	0%	0%	0%	67%	0%

Variation 7

Unit1	1_F1	2_F1	3_F1	4_F1	5+6_F2	7_F2	5+6_F3	2_F3	7__F3	4_F4	3_F4	2_F4	1_F4
DBT (C°)	18.29	18.14	18.41	19.70	20.54	19.60	21.72	20.19	20.25	19.67	20.64	19.73	20.76
RH %	63.28	60.19	64.88	55.33	56.69	59.71	53.63	53.66	56.71	54.72	58.04	54.41	51.97
Comfort%	0%	0%	0%	0%	33%	0%	100%	67%	0%	0%	0%	67%	0%

Variation 8

Unit1	1_F1	2_F1	3_F1	4_F1	5+6_F2	7_F2	5+6_F3	2_F3	7__F3	4_F4	3_F4	2_F4	1_F4
DBT (C°)	17.32	16.19	18.42	18.01	18.46	17.54	18.63	18.38	18.72	18.47	19.44	18.38	18.91
RH %	66.87	67.49	64.92	61.20	62.93	66.20	62.30	59.27	61.62	58.83	61.48	59.27	57.38
Comfort%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

	Existent												
Unit2	1_F1	2_F1	3_F1	4_F1	5+6_F2	7_F2	5+6_F3	2_F3	7__F3	4_F4	3_F4	2_F4	1_F4
DBT (C°)	19.99	18.60	17.47	19.93	21.60	20.25	20.57	20.24	18.54	19.98	20.45	19.56	18.99
RH %	57.19	59.43	67.67	55.31	53.76	57.04	56.39	53.27	57.38	54.07	58.51	54.84	60.56
Comfort%	0%	0%	0%	0%	100%	0%	67%	67%	0%	0%	0%	33%	0%

	Variation 1												
Unit2	1_F1	2_F1	3_F1	4_F1	5+6_F2	7_F2	5+6_F3	2_F3	7__F3	4_F4	3_F4	2_F4	1_F4
DBT (C°)	18.70	18.64	18.57	20.68	21.22	20.84	21.10	19.88	20.79	19.54	20.19	19.03	19.90
RH %	61.67	58.90	64.29	53.23	54.99	55.57	54.91	54.60	55.16	55.61	59.34	56.60	58.25
Comfort%	0%	0%	0%	0%	100%	0%	67%	67%	0%	0%	0%	33%	0%

	Variation 2												
Unit2	1_F1	2_F1	3_F1	4_F1	5+6_F2	7_F2	5+6_F3	2_F3	7__F3	4_F4	3_F4	2_F4	1_F4
DBT (C°)	18.70	18.64	18.57	20.68	21.22	20.84	21.10	19.88	19.61	19.54	20.19	19.03	19.90
RH %	61.67	58.90	64.29	53.23	54.99	55.57	54.91	54.60	59.27	55.61	59.34	56.60	58.25
Comfort%	0%	0%	0%	0%	100%	0%	67%	67%	0%	0%	0%	33%	0%

	Variation 3												
Unit2	1_F1	2_F1	3_F1	4_F1	5+6_F2	7_F2	5+6_F3	2_F3	7__F3	4_F4	3_F4	2_F4	1_F4
DBT (C°)	18.25	17.51	18.55	21.24	22.15	19.74	20.20	20.23	19.74	19.91	20.07	19.06	18.81
RH %	63.53	63.30	64.42	51.24	52.40	59.01	58.11	53.30	58.63	54.21	59.70	56.77	61.62
Comfort%	0%	0%	0%	0%	100%	0%	67%	67%	0%	0%	0%	33%	0%

	Variation 4												
Unit2	1_F1	2_F1	3_F1	4_F1	5+6_F2	7_F2	5+6_F3	2_F3	7__F3	4_F4	3_F4	2_F4	1_F4
DBT (C°)	18.99	18.60	17.47	20.33	21.59	20.25	20.57	20.24	20.25	19.98	20.45	19.56	19.99
RH %	60.56	59.43	67.67	53.25	53.91	57.04	56.39	53.27	56.71	54.07	58.51	54.84	57.19
Comfort%	0%	0%	0%	0%	100%	0%	67%	67%	0%	0%	0%	33%	0%

	Variation 5												
Unit2	1_F1	2_F1	3_F1	4_F1	5+6_F2	7_F2	5+6_F3	2_F3	7__F3	4_F4	3_F4	2_F4	1_F4
DBT (C°)	19.55	20.49	16.29	19.19	20.43	20.28	20.74	22.77	18.72	17.97	20.00	20.28	18.37
RH %	59.58	53.16	68.11	56.27	56.28	59.19	58.79	48.53	61.62	61.11	57.90	53.53	62.82
Comfort%	0%	67%	0%	0%	100%	0%	100%	67%	0%	0%	0%	67%	0%

	Variation 6												
Unit2	1_F1	2_F1	3_F1	4_F1	5+6_F2	7_F2	5+6_F3	2_F3	7__F3	4_F4	3_F4	2_F4	1_F4
DBT (C°)	19.99	18.60	17.47	19.93	21.60	19.32	20.58	20.10	18.54	19.98	20.45	19.56	18.99
RH %	57.19	59.43	67.67	55.31	53.76	60.38	59.44	53.79	62.46	54.07	58.51	54.84	60.56
Comfort%	0%	0%	0%	0%	100%	0%	67%	67%	0%	0%	0%	33%	0%

	Variation 7												
Unit2	1_F1	2_F1	3_F1	4_F1	5+6_F2	7_F2	5+6_F3	2_F3	7__F3	4_F4	3_F4	2_F4	1_F4
DBT (C°)	18.99	18.60	17.47	19.93	21.59	20.25	20.57	20.24	20.25	19.98	20.45	19.56	19.99
RH %	60.56	59.43	67.67	55.31	53.91	57.04	56.39	53.27	56.71	54.07	58.51	54.84	57.19
Comfort%	0%	0%	0%	0%	100%	0%	67%	67%	0%	0%	0%	33%	0%

	Variation 8												
Unit2	1_F1	2_F1	3_F1	4_F1	5+6_F2	7_F2	5+6_F3	2_F3	7__F3	4_F4	3_F4	2_F4	1_F4
DBT (C°)	18.92	18.38	17.45	19.21	21.36	20.17	20.51	20.15	18.72	19.95	20.40	19.51	19.95
RH %	60.83	60.09	67.77	57.00	54.57	57.29	56.61	53.57	61.62	54.21	58.68	55.05	57.37
Comfort%	0%	0%	0%	0%	33%	0%	67%	67%	0%	0%	0%	33%	0%

	Existent				
Unit3	OFF1	OFF2	OFF3	3_F1	3_F2
DBT (C°)	18.78	18.93	18.02	18.11	20.01
RH %	60.08	60.26	62.48	63.68	61.03
Comfort%	33%	33%	0%	0%	0%

	Variation 1				
Unit3	OFF1	OFF2	OFF3	3_F1	3_F2
DBT (C°)	18.62	19.25	19.23	17.83	19.96
RH %	60.56	59.09	58.54	64.56	61.24
Comfort%	0%	33%	33%	0%	0%

	Variation 2				
Unit3	OFF1	OFF2	OFF3	3_F1	3_F2
DBT (C°)	18.75	19.18	17.78	18.33	19.99
RH %	60.38	59.54	63.33	62.98	61.09
Comfort%	0%	33%	0%	0%	0%

	Variation 3				
Unit3	OFF1	OFF2	OFF3	3_F1	3_F2
DBT (C°)	18.38	19.44	19.11	18.26	19.70
RH %	61.56	58.14	59.03	62.83	61.91
Comfort%	0%	33%	33%	0%	0%

	Variation 4				
Unit3	OFF1	OFF2	OFF3	3_F1	3_F2
DBT (C°)	18.78	18.93	18.02	18.11	20.01
RH %	60.08	60.26	62.48	63.68	61.03
Comfort%	33%	33%	0%	0%	0%

	Variation 5				
Unit3	OFF1	OFF2	OFF3	3_F1	3_F2
DBT (C°)	19.42	19.92	19.65	18.53	20.91
RH %	58.00	57.00	57.21	62.39	58.87
Comfort%	33%	67%	33%	0%	67%

	Variation 6				
Unit3	OFF1	OFF2	OFF3	3_F1	3_F2
DBT (C°)	18.78	18.93	18.02	18.11	20.01
RH %	60.08	60.26	62.48	63.68	61.03
Comfort%	33%	33%	0%	0%	0%

	Variation 7				
Unit3	OFF1	OFF2	OFF3	3_F1	3_F2
DBT (C°)	18.78	18.93	18.02	18.11	20.01
RH %	60.08	60.26	62.48	63.68	61.03
Comfort%	33%	33%	0%	0%	0%

	Variation 8				
Unit3	OFF1	OFF2	OFF3	3_F1	3_F2
DBT (C°)	18.78	18.93	18.02	18.11	20.01
RH %	60.08	60.26	62.48	63.68	61.03
Comfort%	33%	67%	0%	0%	67%

	Existent											
Unit4	1_F1	3_F1	2_F1	7_F3	1_F4	2_F4	3_F4	6+5_F3	2_F3	4_F4	6+5_F2	7_F3
DBT (C°)	17.77	17.80	16.04	20.78	19.51	19.62	20.54	21.57	22.13	19.96	19.53	20.63
RH %	65.55	66.72	68.35	55.21	55.26	54.88	58.37	54.09	54.49	54.53	58.69	60.37
Comfort%	0%	0%	0%	67%	0%	100%	100%	0%	0%	0%	33%	0%

	Variation 1											
Unit4	1_F1	3_F1	2_F1	7_F3	1_F4	2_F4	3_F4	6+5_F3	2_F3	4_F4	6+5_F2	7_F3
DBT (C°)	17.65	17.84	16.49	20.57	20.22	19.80	20.65	21.02	20.54	20.76	20.83	19.09
RH %	66.13	66.65	68.08	55.93	53.21	54.50	58.22	55.62	52.39	52.06	55.92	61.43
Comfort%	0%	0%	0%	67%	0%	67%	67%	0%	0%	0%	67%	0%

	Variation 2											
Unit4	1_F1	3_F1	2_F1	7_F3	1_F4	2_F4	3_F4	6+5_F3	2_F3	4_F4	6+5_F2	7_F3
DBT (C°)	16.79	16.83	16.38	20.82	19.08	19.44	20.51	21.97	19.51	19.38	19.40	19.92
RH %	69.00	70.68	67.03	55.21	57.12	55.47	58.62	53.05	56.27	56.75	60.88	59.14
Comfort%	0%	0%	0%	33%	0%	100%	33%	0%	0%	0%	33%	0%

	Variation 3											
Unit4	1_F1	3_F1	2_F1	7_F3	1_F4	2_F4	3_F4	6+5_F3	2_F3	4_F4	6+5_F2	7_F3
DBT (C°)	17.79	18.00	16.38	20.82	19.24	19.49	20.48	21.81	19.56	19.52	19.62	19.59
RH %	65.48	66.17	67.66	55.07	56.32	55.27	58.55	53.33	56.13	55.98	60.08	60.00
Comfort%	0%	0%	0%	67%	0%	100%	67%	0%	0%	0%	33%	0%

	Variation 4											
Unit4	1_F1	3_F1	2_F1	7_F3	1_F4	2_F4	3_F4	6+5_F3	2_F3	4_F4	6+5_F2	7_F3
DBT (C°)	16.79	16.54	16.50	20.86	19.57	19.69	20.61	21.71	20.07	19.96	20.08	19.86
RH %	69.09	71.60	66.66	54.99	55.09	54.63	58.21	53.72	54.14	54.23	58.22	59.35
Comfort%	0%	0%	0%	67%	0%	100%	100%	0%	0%	0%	33%	0%

	Variation 5											
Unit4	1_F1	3_F1	2_F1	7_F3	1_F4	2_F4	3_F4	6+5_F3	2_F3	4_F4	6+5_F2	7_F3
DBT (C°)	16.77	16.54	16.53	21.41	19.87	19.96	20.88	21.86	20.23	20.16	20.26	19.92
RH %	69.14	71.60	66.59	53.89	54.41	53.94	57.64	53.29	53.58	53.66	57.68	59.16
Comfort%	0%	0%	0%	67%	0%	100%	67%	0%	0%	0%	67%	0%

	Variation 6											
Unit4	1_F1	3_F1	2_F1	7_F3	1_F4	2_F4	3_F4	6+5_F3	2_F3	4_F4	6+5_F2	7_F3
DBT (C°)	17.77	17.80	16.04	20.78	19.51	19.62	20.54	20.35	18.57	19.71	19.53	20.63
RH %	65.55	66.72	#REF!	55.21	55.26	54.88	58.37	60.46	61.10	59.76	58.69	60.37
Comfort%	0%	0%	0%	67%	0%	67%	67%	0%	0%	0%	33%	0%

	Variation 7											
Unit4	1_F1	3_F1	2_F1	7_F3	1_F4	2_F4	3_F4	6+5_F3	2_F3	4_F4	6+5_F2	7_F3
DBT (C°)	16.79	16.50	16.54	20.08	19.86	21.71	20.07	20.86	19.96	20.61	19.69	19.57
RH %	69.09	66.66	71.60	58.22	59.35	53.72	54.14	54.99	54.23	58.21	54.63	55.09
Comfort%	0%	0%	0%	67%	0%	100%	100%	0%	0%	0%	33%	0%

	Variation 8											
Unit4	1_F1	3_F1	2_F1	7_F3	1_F4	2_F4	3_F4	6+5_F3	2_F3	4_F4	6+5_F2	7_F3
DBT (C°)	17.79	16.04	17.74	19.82	19.42	21.52	19.87	20.75	19.80	20.50	19.57	19.47
RH %	65.45	68.80	66.91	59.04	60.44	54.22	54.74	68.49	54.72	58.47	55.02	55.39
Comfort%	0%	0%	0%	67%	100%	100%	67%	0%	0%	33%	33%	100%

	Existent												
Unit5	1_F1	2_F1	3_F1	4_F1	5+6_F2	7_F2	5+6_F3	2_F3	7__F3	4_F4	3_F4	2_F4	1_F4
DBT (C°)	18.74	18.84	17.43	19.49	20.03	19.09	20.89	19.15	19.49	19.19	19.88	18.72	20.18
RH %	61.70	58.00	67.86	55.93	58.16	61.48	60.85	56.32	58.99	56.28	60.02	57.49	57.68
Comfort%	0%	33%	0%	0%	67%	0%	67%	33%	0%	0%	0%	0%	0%

	Variation 1												
Unit5	1_F1	2_F1	3_F1	4_F1	5+6_F2	7_F2	5+6_F3	2_F3	7__F3	4_F4	3_F4	2_F4	1_F4
DBT (C°)	18.63	19.22	17.40	20.57	20.67	18.79	20.38	19.79	20.26	19.86	19.97	18.86	19.79
RH %	62.13	57.18	68.00	53.10	56.65	62.58	57.34	54.28	56.80	54.29	59.84	57.01	58.91
Comfort%	0%	33%	0%	0%	67%	0%	67%	67%	0%	0%	0%	33%	0%

	Variation 2												
Unit5	1_F1	2_F1	3_F1	4_F1	5+6_F2	7_F2	5+6_F3	2_F3	7__F3	4_F4	3_F4	2_F4	1_F4
DBT (C°)	19.08	18.36	19.25	18.90	21.52	19.46	21.44	18.83	19.11	18.83	20.09	19.08	20.27
RH %	60.32	59.23	62.24	57.85	54.13	59.91	54.21	57.60	60.25	57.48	59.58	56.45	56.57
Comfort%	0%	33%	0%	0%	100%	0%	100%	33%	0%	0%	0%	33%	0%

	Variation 3												
Unit5	1_F1	2_F1	3_F1	4_F1	5+6_F2	7_F2	5+6_F3	2_F3	7__F3	4_F4	3_F4	2_F4	1_F4
DBT (C°)	18.76	19.00	17.43	19.20	21.31	19.24	21.17	18.60	19.34	18.97	19.86	18.65	20.26
RH %	61.48	57.60	67.86	57.06	54.77	61.03	55.03	58.59	59.65	57.19	60.13	57.87	57.11
Comfort%	0%	33%	0%	0%	100%	0%	100%	0%	0%	0%	0%	0%	0%

	Variation 4												
Unit5	1_F1	2_F1	3_F1	4_F1	5+6_F2	7_F2	5+6_F3	2_F3	7__F3	4_F4	3_F4	2_F4	1_F4
DBT (C°)	19.07	18.43	19.33	20.23	21.28	19.39	21.13	19.33	19.61	19.30	20.15	19.24	20.27
RH %	60.32	58.83	61.91	55.38	54.70	60.19	55.03	55.49	58.48	55.71	59.22	55.89	56.73
Comfort%	0%	33%	0%	0%	67%	0%	67%	33%	0%	0%	0%	0%	0%

	Variation 5												
Unit5	1_F1	2_F1	3_F1	4_F1	5+6_F2	7_F2	5+6_F3	2_F3	7__F3	4_F4	3_F4	2_F4	1_F4
DBT (C°)	19.09	18.45	19.37	19.67	20.31	19.42	21.20	19.43	20.66	19.60	20.34	19.41	21.10
RH %	60.25	58.76	61.79	55.16	57.06	60.12	54.81	55.18	58.67	55.14	58.72	55.23	54.90
Comfort%	0%	0%	0%	0%	67%	0%	100%	33%	0%	0%	0%	33%	0%

	Variation 6												
Unit5	1_F1	2_F1	3_F1	4_F1	5+6_F2	7_F2	5+6_F3	2_F3	7__F3	4_F4	3_F4	2_F4	1_F4
DBT (C°)	18.74	18.84	17.43	19.49	20.03	19.09	20.25	18.83	19.11	19.19	19.88	18.72	20.18
RH %	61.70	58.00	67.86	55.93	58.16	61.48	59.87	57.60	60.25	56.28	60.02	57.49	57.68
Comfort%	0%	33%	0%	0%	67%	0%	67%	33%	0%	0%	0%	0%	0%

	Variation 7												
Unit5	1_F1	2_F1	3_F1	4_F1	5+6_F2	7_F2	5+6_F3	2_F3	7__F3	4_F4	3_F4	2_F4	1_F4
DBT (C°)	19.07	18.43	19.33	19.59	21.28	19.39	21.13	19.33	19.61	19.30	20.15	19.24	20.27
RH %	60.32	58.83	61.91	55.38	54.70	60.19	55.03	55.49	58.48	55.71	59.22	55.89	56.73
Comfort%	0%	33%	0%	0%	100%	0%	100%	33%	0%	0%	0%	33%	0%

	Variation 8												
Unit5	1_F1	2_F1	3_F1	4_F1	5+6_F2	7_F2	5+6_F3	2_F3	7__F3	4_F4	3_F4	2_F4	1_F4
DBT (C°)	18.74	18.84	17.43	19.49	21.08	19.09	20.89	19.15	19.49	19.19	19.88	18.72	20.18
RH %	61.70	58.00	67.86	55.93	55.48	61.48	55.93	56.32	58.99	56.28	60.02	57.49	57.68
Comfort%	100%	33%	0%	0%	67%	100%	67%	33%	0%	0%	0%	0%	0%

	Existent											
Unit6	1_F1	2_F1	3_F1	5+6_F2	7_F2	5+6_F3	2_F3	7__F3	4_F4	3_F4	2_F4	1_F4
DBT	18.90	17.99	17.99	21.23	21.10	21.72	21.46	22.35	20.95	22.14	21.20	22.76
RH	60.38	60.60	65.35	54.57	52.44	53.47	55.42	50.70	57.74	54.16	50.06	50.58
Cft %	0%	0%	0%	100%	0%	100%	67%	0%	33%	0%	33%	33%

	Variation 1											
Unit6	1_F1	2_F1	3_F1	5+6_F2	7_F2	5+6_F3	2_F3	7__F3	4_F4	3_F4	2_F4	1_F4
DBT	18.99	18.37	18.13	20.82	21.46	22.33	21.52	22.05	21.44	22.18	21.32	22.39
RH	60.34	59.79	65.27	55.85	51.92	51.81	55.42	51.12	57.09	54.40	49.97	51.67
Cft %	0%	0%	0%	67%	0%	100%	33%	33%	0%	0%	100%	33%

	Variation 2											
Unit6	1_F1	2_F1	3_F1	5+6_F2	7_F2	5+6_F3	2_F3	7__F3	4_F4	3_F4	2_F4	1_F4
DBT	17.53	17.67	18.93	19.43	17.91	19.42	19.37	20.37	20.11	19.96	19.01	19.16
RH	66.46	62.67	63.96	59.17	64.93	60.34	56.06	56.30	53.62	60.09	56.95	59.91
Cft %	0%	0%	0%	33%	0%	33%	33%	0%	0%	0%	33%	0%

	Variation 3											
Unit6	1_F1	2_F1	3_F1	5+6_F2	7_F2	5+6_F3	2_F3	7__F3	4_F4	3_F4	2_F4	1_F4
DBT	17.54	17.65	18.96	19.47	18.16	19.79	19.63	20.50	20.21	20.07	19.16	19.52
RH	66.32	62.61	63.86	58.69	64.02	59.30	55.09	56.03	53.25	59.68	56.20	58.93
Cft %	0%	0%	0%	0%	0%	33%	67%	0%	0%	0%	33%	0%

	Variation 4											
Unit6	1_F1	2_F1	3_F1	5+6_F2	7_F2	5+6_F3	2_F3	7__F3	4_F4	3_F4	2_F4	1_F4
DBT	17.69	18.01	19.11	19.41	18.36	19.99	19.50	20.43	20.17	20.11	19.20	19.71
RH	65.36	60.72	63.17	59.06	63.38	58.22	55.42	56.42	53.62	59.42	56.03	58.13
Cft %	0%	0%	0%	100%	0%	100%	67%	0%	33%	0%	33%	33%

	Variation 5											
Unit6	1_F1	2_F1	3_F1	5+6_F2	7_F2	5+6_F3	2_F3	7__F3	4_F4	3_F4	2_F4	1_F4
DBT	17.65	17.94	19.04	18.95	18.34	19.99	19.51	20.35	20.54	20.17	19.28	19.81
RH	65.55	61.06	63.50	60.11	63.44	58.23	55.38	56.62	52.90	59.26	55.78	57.98
Cft %	0%	0%	0%	67%	0%	0%	0%	0%	33%	0%	33%	0%

	Variation 6											
Unit6	1_F1	2_F1	3_F1	5+6_F2	7_F2	5+6_F3	2_F3	7__F3	4_F4	3_F4	2_F4	1_F4
DBT	18.90	17.99	17.99	21.23	21.10	17.89	21.46	19.93	20.95	22.14	18.79	22.76
RH	60.38	60.60	65.35	54.57	52.44	65.82	55.42	57.76	57.74	54.16	58.14	50.58
Cft %	0%	0%	0%	100%	0%	67%	67%	0%	33%	0%	33%	33%

	Variation 7											
Unit6	1_F1	2_F1	3_F1	5+6_F2	7_F2	5+6_F3	2_F3	7__F3	4_F4	3_F4	2_F4	1_F4
DBT	17.69	18.01	19.11	19.41	18.36	19.99	19.50	20.43	20.17	19.20	20.11	19.71
RH	65.36	60.72	63.17	59.06	63.38	58.22	55.42	56.42	53.62	56.03	59.42	58.13
Cft %	0%	0%	0%	100%	0%	100%	67%	0%	33%	0%	33%	33%

	Variation 8											
Unit6	1_F1	2_F1	3_F1	5+6_F2	7_F2	5+6_F3	2_F3	7__F3	4_F4	3_F4	2_F4	1_F4
DBT	17.69	18.01	19.11	19.41	18.36	19.99	19.50	20.43	20.17	19.20	20.11	19.71
RH	65.36	60.72	63.17	59.06	63.38	58.22	55.42	56.42	53.62	56.03	59.42	58.13
Cft %	0%	0%	0%	33%	0%	67%	67%	33%	0%	0%	0%	0%

Existent

Unit7	1_F1	2_F1	3_F1	5+6_F2	7_F2	5+6_F3	2_F3	7__F3	4_F4	3_F4	2_F4	1_F4
DBT (C°)	20.04	19.72	20.19	20.96	21.69	21.78	21.74	22.76	22.17	21.25	21.02	18.71
RH %	57.42	55.34	59.66	57.89	51.56	53.20	49.63	50.76	50.86	55.85	50.62	61.96
Comfort%	0%	33%	0%	67%	0%	100%	100%	33%	0%	0%	67%	33%

Variation 1

Unit7	1_F1	2_F1	3_F1	5+6_F2	7_F2	5+6_F3	2_F3	7__F3	4_F4	3_F4	2_F4	1_F4
DBT (C°)	18.06	17.47	18.70	20.73	19.13	21.07	20.43	20.59	20.39	20.61	19.73	20.18
RH %	64.27	63.27	63.95	56.41	61.08	55.08	53.00	56.14	52.75	58.22	54.52	53.57
Comfort%	0%	0%	0%	67%	0%	67%	67%	0%	0%	0%	67%	0%

Variation 2

Unit7	1_F1	2_F1	3_F1	5+6_F2	7_F2	5+6_F3	2_F3	7__F3	4_F4	3_F4	2_F4	1_F4
DBT (C°)	17.34	16.49	18.72	21.42	18.05	19.76	20.26	20.86	19.47	20.38	19.40	20.45
RH %	66.89	67.25	63.96	54.78	64.40	59.49	53.43	55.13	56.07	59.06	55.65	52.89
Comfort%	0%	0%	0%	100%	0%	67%	67%	0%	0%	0%	33%	0%

Variation 3

Unit7	1_F1	2_F1	3_F1	5+6_F2	7_F2	5+6_F3	2_F3	7__F3	4_F4	3_F4	2_F4	1_F4
DBT (C°)	16.70	18.41	17.37	21.56	18.43	20.00	20.53	21.30	18.59	20.15	19.19	20.55
RH %	69.17	60.38	68.27	54.05	63.36	58.91	52.72	54.05	59.12	59.59	56.50	52.49
Comfort%	0%	0%	0%	100%	0%	67%	67%	0%	0%	0%	33%	0%

Variation 4

Unit7	1_F1	2_F1	3_F1	5+6_F2	7_F2	5+6_F3	2_F3	7__F3	4_F4	3_F4	2_F4	1_F4
DBT (C°)	16.81	18.69	17.43	21.35	18.65	20.17	20.31	21.18	18.87	20.18	19.17	20.47
RH %	68.61	58.95	68.00	54.68	62.56	57.98	53.19	54.49	58.04	59.46	56.50	52.93
Comfort%	0%	33%	0%	67%	0%	100%	100%	33%	0%	0%	67%	33%

Variation 5

Unit7	1_F1	2_F1	3_F1	5+6_F2	7_F2	5+6_F3	2_F3	7__F3	4_F4	3_F4	2_F4	1_F4
DBT (C°)	20.04	19.72	20.19	20.96	21.69	21.78	21.74	22.76	22.17	21.25	21.02	18.71
RH %	58.71	68.59	67.94	53.21	58.98	54.14	55.91	58.99	58.56	56.90	62.40	49.71
Comfort%	0%	33%	0%	100%	0%	100%	100%	67%	0%	0%	100%	33%

Variation 6

Unit7	1_F1	2_F1	3_F1	5+6_F2	7_F2	5+6_F3	2_F3	7__F3	4_F4	3_F4	2_F4	1_F4
DBT (C°)	20.04	19.72	20.19	20.96	21.69	20.52	20.31	21.33	22.17	21.25	21.02	18.71
RH %	57.42	55.34	59.66	57.89	51.56	59.94	53.37	53.95	50.86	55.85	50.62	61.96
Comfort%	0%	33%	0%	67%	0%	67%	67%	0%	0%	0%	67%	33%

Variation 7

Unit7	1_F1	2_F1	3_F1	5+6_F2	7_F2	5+6_F3	2_F3	7__F3	4_F4	3_F4	2_F4	1_F4
DBT (C°)	16.81	18.69	17.43	21.35	18.65	20.17	20.31	21.18	18.87	20.18	19.17	20.47
RH %	68.61	58.95	68.00	54.68	62.56	57.98	53.19	54.49	58.04	59.46	56.50	52.93
Comfort%	0%	33%	0%	100%	0%	100%	100%	33%	0%	0%	67%	33%

Variation 8

Unit7	1_F1	2_F1	3_F1	5+6_F2	7_F2	5+6_F3	2_F3	7__F3	4_F4	3_F4	2_F4	1_F4
DBT (C°)	17.67	17.04	18.75	21.30	18.52	20.32	20.38	20.90	19.86	20.51	19.61	20.48
RH %	65.58	64.82	63.87	54.88	62.88	57.50	52.89	55.27	54.43	58.53	54.88	52.88
Comfort%	0%	0%	0%	100%	0%	67%	0%	0%	0%	0%	33%	0%

	Existent											
Unit7	1_F1	2_F1	3_F1	5+6_F2	7_F2	5+6_F3	2_F3	7__F3	4_F4	3_F4	2_F4	1_F4
DBT (C°)	20.04	19.72	20.19	20.96	21.69	21.78	21.74	22.76	22.17	21.25	21.02	18.71
RH %	57.42	55.34	59.66	57.89	51.56	53.20	49.63	50.76	50.86	55.85	50.62	61.96
Comfort%	0%	33%	0%	67%	0%	100%	100%	33%	0%	0%	67%	33%

	Variation 1											
Unit7	1_F1	2_F1	3_F1	5+6_F2	7_F2	5+6_F3	2_F3	7__F3	4_F4	3_F4	2_F4	1_F4
DBT (C°)	18.06	17.47	18.70	20.73	19.13	21.07	20.43	20.59	20.39	20.61	19.73	20.18
RH %	64.27	63.27	63.95	56.41	61.08	55.08	53.00	56.14	52.75	58.22	54.52	53.57
Comfort%	0%	0%	0%	67%	0%	67%	67%	0%	0%	0%	67%	0%

	Variation 2											
Unit7	1_F1	2_F1	3_F1	5+6_F2	7_F2	5+6_F3	2_F3	7__F3	4_F4	3_F4	2_F4	1_F4
DBT (C°)	17.34	16.49	18.72	21.42	18.05	19.76	20.26	20.86	19.47	20.38	19.40	20.45
RH %	66.89	67.25	63.96	54.78	64.40	59.49	53.43	55.13	56.07	59.06	55.65	52.89
Comfort%	0%	0%	0%	100%	0%	67%	67%	0%	0%	0%	33%	0%

	Variation 3											
Unit7	1_F1	2_F1	3_F1	5+6_F2	7_F2	5+6_F3	2_F3	7__F3	4_F4	3_F4	2_F4	1_F4
DBT (C°)	16.70	18.41	17.37	21.56	18.43	20.00	20.53	21.30	18.59	20.15	19.19	20.55
RH %	69.17	60.38	68.27	54.05	63.36	58.91	52.72	54.05	59.12	59.59	56.50	52.49
Comfort%	0%	0%	0%	100%	0%	67%	67%	0%	0%	0%	33%	0%

	Variation 4											
Unit7	1_F1	2_F1	3_F1	5+6_F2	7_F2	5+6_F3	2_F3	7__F3	4_F4	3_F4	2_F4	1_F4
DBT (C°)	16.81	18.69	17.43	21.35	18.65	20.17	20.31	21.18	18.87	20.18	19.17	20.47
RH %	68.61	58.95	68.00	54.68	62.56	57.98	53.19	54.49	58.04	59.46	56.50	52.93
Comfort%	0%	33%	0%	67%	0%	100%	100%	33%	0%	0%	67%	33%

	Variation 5											
Unit7	1_F1	2_F1	3_F1	5+6_F2	7_F2	5+6_F3	2_F3	7__F3	4_F4	3_F4	2_F4	1_F4
DBT (C°)	20.04	19.72	20.19	20.96	21.69	21.78	21.74	22.76	22.17	21.25	21.02	18.71
RH %	58.71	68.59	67.94	53.21	58.98	54.14	55.91	58.99	58.56	56.90	62.40	49.71
Comfort%	0%	33%	0%	100%	0%	100%	100%	67%	0%	0%	100%	33%

	Variation 6											
Unit7	1_F1	2_F1	3_F1	5+6_F2	7_F2	5+6_F3	2_F3	7__F3	4_F4	3_F4	2_F4	1_F4
DBT (C°)	20.04	19.72	20.19	20.96	21.69	20.52	20.31	21.33	22.17	21.25	21.02	18.71
RH %	57.42	55.34	59.66	57.89	51.56	59.94	53.37	53.95	50.86	55.85	50.62	61.96
Comfort%	0%	33%	0%	67%	0%	67%	67%	0%	0%	0%	67%	33%

	Variation 7											
Unit7	1_F1	2_F1	3_F1	5+6_F2	7_F2	5+6_F3	2_F3	7__F3	4_F4	3_F4	2_F4	1_F4
DBT (C°)	16.81	18.69	17.43	21.35	18.65	20.17	20.31	21.18	18.87	20.18	19.17	20.47
RH %	68.61	58.95	68.00	54.68	62.56	57.98	53.19	54.49	58.04	59.46	56.50	52.93
Comfort%	0%	33%	0%	100%	0%	100%	100%	33%	0%	0%	67%	33%

	Variation 8											
Unit7	1_F1	2_F1	3_F1	5+6_F2	7_F2	5+6_F3	2_F3	7__F3	4_F4	3_F4	2_F4	1_F4
DBT (C°)	17.67	17.04	18.75	21.30	18.52	20.32	20.38	20.90	19.86	20.51	19.61	20.48
RH %	65.58	64.82	63.87	54.88	62.88	57.50	52.89	55.27	54.43	58.53	54.88	52.88
Comfort%	0%	0%	0%	100%	0%	67%	0%	0%	0%	0%	33%	0%

8.9 Comparison of simulated data from the different variations - Thermal Comfort Level

	Unit 1												
	1_F1	2_F1	3_F1	4_F1	5+6_F2	7_F2	5+6_F3	2_F3	7__F3	4_F4	3_F4	2_F4	1_F4
Existent	0%	0%	0%	0%	33%	0%	100%	67%	0%	0%	0%	67%	0%
Variation1	0%	33%	0%	0%	100%	0%	100%	67%	0%	0%	0%	67%	0%
Variation2	0%	0%	0%	0%	33%	0%	100%	67%	0%	0%	0%	33%	0%
Variation3	0%	0%	0%	0%	33%	0%	100%	67%	0%	0%	0%	33%	0%
Variation4	0%	0%	0%	0%	33%	0%	100%	67%	0%	0%	0%	67%	0%
Variation5	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Variation6	0%	0%	0%	0%	33%	0%	33%	0%	0%	0%	0%	67%	0%
Variation7	0%	0%	0%	0%	33%	0%	100%	67%	0%	0%	0%	67%	0%
Variation8	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

	Unit 2												
	1_F1	2_F1	3_F1	4_F1	5+6_F2	7_F2	5+6_F3	2_F3	7__F3	4_F4	3_F4	2_F4	1_F4
Existent	0%	0%	0%	0%	100%	0%	67%	67%	0%	0%	0%	33%	0%
Variation1	0%	0%	0%	0%	100%	0%	67%	67%	0%	0%	0%	33%	0%
Variation2	0%	0%	0%	0%	100%	0%	67%	67%	0%	0%	0%	33%	0%
Variation3	0%	0%	0%	0%	100%	0%	67%	67%	0%	0%	0%	33%	0%
Variation4	0%	0%	0%	0%	100%	0%	67%	67%	0%	0%	0%	33%	0%
Variation5	0%	67%	0%	0%	100%	0%	100%	67%	0%	0%	0%	67%	0%
Variation6	0%	0%	0%	0%	100%	0%	67%	67%	0%	0%	0%	33%	0%
Variation7	0%	0%	0%	0%	100%	0%	67%	67%	0%	0%	0%	33%	0%
Variation8	0%	0%	0%	0%	33%	0%	67%	67%	0%	0%	0%	33%	0%

	Unit 3				
	OFF1	OFF2	OFF3	3_F1	3_F2
Existent	33%	33%	0%	0%	0%
Variation1	0%	33%	33%	0%	0%
Variation2	0%	33%	0%	0%	0%
Variation3	0%	33%	33%	0%	0%
Variation4	33%	33%	0%	0%	0%
Variation5	33%	67%	33%	0%	67%
Variation6	33%	33%	0%	0%	0%
Variation7	33%	33%	0%	0%	0%
Variation8	33%	67%	0%	0%	67%

	Unit 4											
	1_F1	3_F1	2_F1	7_F3	1_F4	2_F4	3_F4	6+5_F3	2_F3	4_F4	6+5_F2	7_F3
Existent	0%	0%	0%	67%	0%	100%	100%	0%	0%	0%	33%	0%
Variation1	0%	0%	0%	67%	0%	67%	67%	0%	0%	0%	67%	0%
Variation2	0%	0%	0%	33%	0%	100%	33%	0%	0%	0%	33%	0%
Variation3	0%	0%	0%	67%	0%	100%	67%	0%	0%	0%	33%	0%
Variation4	0%	0%	0%	67%	0%	100%	100%	0%	0%	0%	33%	0%
Variation5	0%	0%	0%	67%	0%	100%	67%	0%	0%	0%	67%	0%
Variation6	0%	0%	0%	67%	0%	67%	67%	0%	0%	0%	33%	0%
Variation7	0%	0%	0%	67%	0%	100%	100%	0%	0%	0%	33%	0%
Variation8	0%	0%	0%	67%	100%	100%	67%	0%	0%	33%	33%	100%

	Unit 5												
	1_F1	2_F1	3_F1	4_F1	5+6_F2	7_F2	5+6_F3	2_F3	7__F3	4_F4	3_F4	2_F4	1_F4
Existent	0%	33%	0%	0%	67%	0%	67%	33%	0%	0%	0%	0%	0%
Variation1	0%	33%	0%	0%	67%	0%	67%	67%	0%	0%	0%	33%	0%
Variation2	0%	33%	0%	0%	100%	0%	100%	33%	0%	0%	0%	33%	0%
Variation3	0%	33%	0%	0%	100%	0%	100%	0%	0%	0%	0%	0%	0%
Variation4	0%	33%	0%	0%	67%	0%	67%	33%	0%	0%	0%	0%	0%
Variation5	0%	0%	0%	0%	67%	0%	100%	33%	0%	0%	0%	33%	0%
Variation6	0%	33%	0%	0%	67%	0%	67%	33%	0%	0%	0%	0%	0%
Variation7	0%	33%	0%	0%	100%	0%	100%	33%	0%	0%	0%	33%	0%
Variation8	100%	33%	0%	0%	67%	100%	67%	33%	0%	0%	0%	0%	0%

	Unit 6											
	1_F1	3_F1	2_F1	7_F3	1_F4	2_F4	3_F4	6+5_F3	2_F3	4_F4	6+5_F2	7_F3
Existent	0%	0%	0%	100%	0%	100%	67%	0%	33%	0%	33%	33%
Variation1	0%	0%	0%	67%	0%	100%	33%	33%	0%	0%	100%	33%
Variation2	0%	0%	0%	33%	0%	33%	33%	0%	0%	0%	33%	0%
Variation3	0%	0%	0%	0%	0%	33%	67%	0%	0%	0%	33%	0%
Variation4	0%	0%	0%	100%	0%	100%	67%	0%	33%	0%	33%	33%
Variation5	0%	0%	0%	67%	0%	0%	0%	0%	33%	0%	33%	0%
Variation6	0%	0%	0%	100%	0%	67%	67%	0%	33%	0%	33%	33%
Variation7	0%	0%	0%	100%	0%	100%	67%	0%	33%	0%	33%	33%
Variation8	0%	0%	0%	33%	0%	67%	67%	33%	0%	0%	0%	0%

	Unit 7											
	1_F1	3_F1	2_F1	7_F3	1_F4	2_F4	3_F4	6+5_F3	2_F3	4_F4	6+5_F2	7_F3
Existent	0%	33%	0%	67%	0%	100%	100%	33%	0%	0%	67%	33%
Variation1	0%	0%	0%	67%	0%	67%	67%	0%	0%	0%	67%	0%
Variation2	0%	0%	0%	100%	0%	67%	67%	0%	0%	0%	33%	0%
Variation3	0%	0%	0%	100%	0%	67%	67%	0%	0%	0%	33%	0%
Variation4	0%	33%	0%	67%	0%	100%	100%	33%	0%	0%	67%	33%
Variation5	0%	33%	0%	100%	0%	100%	100%	67%	0%	0%	100%	33%
Variation6	0%	33%	0%	67%	0%	67%	67%	0%	0%	0%	67%	33%
Variation7	0%	33%	0%	100%	0%	100%	100%	33%	0%	0%	67%	33%
Variation8	0%	0%	0%	100%	0%	67%	0%	0%	0%	0%	33%	0%

	Unit 8								
	Store_F1	3_F1	6+5_F2	2_F2	7_Fl2	4_F3	3_F3	2_F3	4_F3
Existent	0%	0%	33%	0%	0%	0%	0%	33%	0%
Variation1	0%	0%	33%	33%	0%	0%	0%	0%	0%
Variation2	0%	0%	33%	33%	0%	0%	0%	0%	0%
Variation3	0%	0%	33%	33%	0%	0%	0%	33%	0%
Variation4	0%	0%	33%	0%	0%	0%	0%	33%	0%
Variation5	0%	0%	33%	0%	0%	0%	0%	0%	0%
Variation6	0%	0%	33%	0%	0%	0%	0%	33%	0%
Variation7	0%	0%	33%	0%	0%	0%	0%	33%	0%
Variation8	100%	0%	33%	0%	0%	0%	0%	0%	0%

	Unit 1												
Existent vs Variation1	0%	33%	0%	0%	67%	0%	0%	0%	0%	0%	0%	0%	0%
Existent vs Variation2	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	-33%	0%
Existent vs Variation3	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	-33%	0%
Existent vs Variation4	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Existent vs Variation5	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Existent vs Variation6	0%	0%	0%	0%	-33%	0%	-100%	-67%	0%	0%	0%	-67%	0%
Existent vs Variation7	0%	0%	0%	0%	0%	0%	-67%	-67%	0%	0%	0%	0%	0%
Existent vs Variation8	0%	0%	0%	0%	-33%	0%	-100%	-67%	0%	0%	0%	-67%	0%

	Unit 2												
Existent vs Variation1	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Existent vs Variation2	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Existent vs Variation3	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Existent vs Variation4	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Existent vs Variation5	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Existent vs Variation6	0%	67%	0%	0%	0%	0%	33%	0%	0%	0%	0%	33%	0%
Existent vs Variation7	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Existent vs Variation8	0%	0%	0%	0%	-67%	0%	0%	0%	0%	0%	0%	0%	0%

	Unit 3				
Existent vs Variation1	-33%	0%	33%	0%	0%
Existent vs Variation2	-33%	0%	0%	0%	0%
Existent vs Variation3	-33%	0%	33%	0%	0%
Existent vs Variation4	0%	0%	0%	0%	0%
Existent vs Variation5	0%	0%	0%	0%	0%
Existent vs Variation6	0%	33%	33%	0%	67%
Existent vs Variation7	0%	0%	0%	0%	0%
Existent vs Variation8	0%	33%	0%	0%	67%

	Unit 4											
Existent vs Variation1	0%	0%	0%	0%	0%	-33%	-33%	0%	0%	0%	33%	0%
Existent vs Variation2	0%	0%	0%	-33%	0%	0%	-67%	0%	0%	0%	0%	0%
Existent vs Variation3	0%	0%	0%	0%	0%	0%	-33%	0%	0%	0%	0%	0%
Existent vs Variation4	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Existent vs Variation5	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Existent vs Variation6	0%	0%	0%	0%	0%	0%	-33%	0%	0%	0%	33%	0%
Existent vs Variation7	0%	0%	0%	0%	0%	-33%	-33%	0%	0%	0%	0%	0%
Existent vs Variation8	0%	0%	0%	0%	100%	0%	-33%	0%	0%	33%	0%	100%

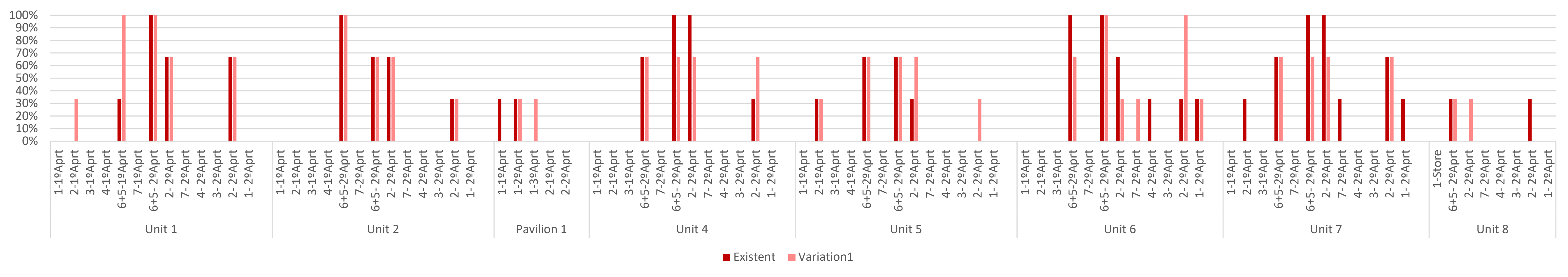
	Unit 5												
Existent vs Variation1	0%	0%	0%	0%	0%	0%	0%	33%	0%	0%	0%	33%	0%
Existent vs Variation2	0%	0%	0%	0%	33%	0%	33%	0%	0%	0%	0%	33%	0%
Existent vs Variation3	0%	0%	0%	0%	33%	0%	33%	-33%	0%	0%	0%	0%	0%
Existent vs Variation4	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Existent vs Variation5	0%	0%	0%	0%	33%	0%	33%	0%	0%	0%	0%	33%	0%
Existent vs Variation6	0%	-33%	0%	0%	0%	0%	33%	0%	0%	0%	0%	33%	0%
Existent vs Variation7	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Existent vs Variation8	100%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%

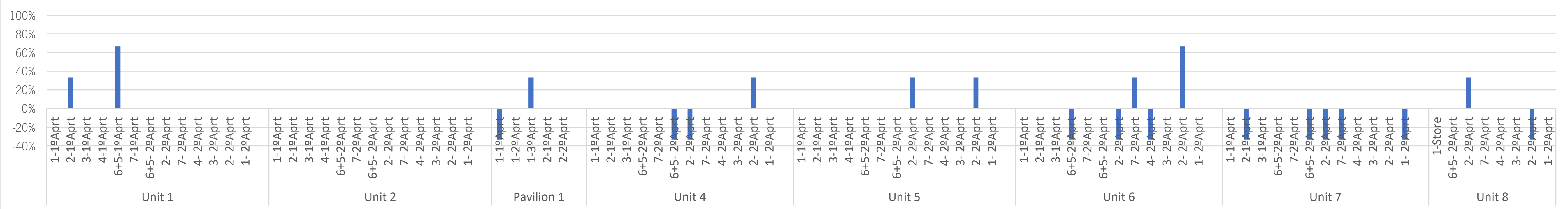
	Unit 6											
Existent vs Variation1	0%	0%	0%	-33%	0%	0%	-33%	33%	-33%	0%	67%	0%
Existent vs Variation2	0%	0%	0%	-67%	0%	-67%	-33%	0%	-33%	0%	0%	-33%
Existent vs Variation3	0%	0%	0%	-100%	0%	-67%	0%	0%	-33%	0%	0%	-33%
Existent vs Variation4	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Existent vs Variation5	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Existent vs Variation6	0%	0%	0%	-33%	0%	-100%	-67%	0%	0%	0%	0%	-33%
Existent vs Variation7	0%	0%	0%	0%	0%	-33%	0%	0%	0%	0%	0%	0%
Existent vs Variation8	0%	0%	0%	-67%	0%	-33%	0%	33%	-33%	0%	-33%	-33%

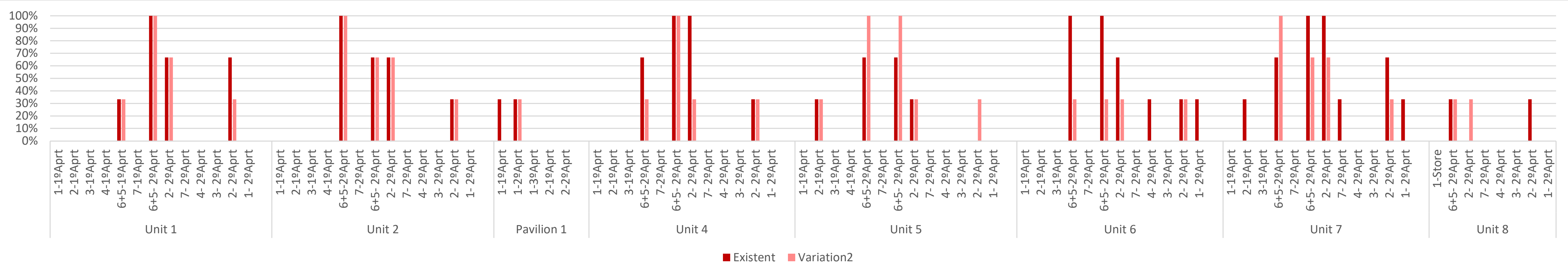
	Unit 7											
Existent vs Variation1	0%	-33%	0%	0%	0%	-33%	-33%	-33%	0%	0%	0%	-33%
Existent vs Variation2	0%	-33%	0%	33%	0%	-33%	-33%	-33%	0%	0%	-33%	-33%
Existent vs Variation3	0%	-33%	0%	33%	0%	-33%	-33%	-33%	0%	0%	-33%	-33%
Existent vs Variation4	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Existent vs Variation5	0%	0%	0%	33%	0%	0%	0%	0%	0%	0%	0%	0%
Existent vs Variation6	0%	0%	0%	33%	0%	0%	0%	33%	0%	0%	33%	0%
Existent vs Variation7	0%	0%	0%	0%	0%	-33%	-33%	-33%	0%	0%	0%	0%
Existent vs Variation8	0%	-33%	0%	33%	0%	-33%	-100%	-33%	0%	0%	-33%	-33%

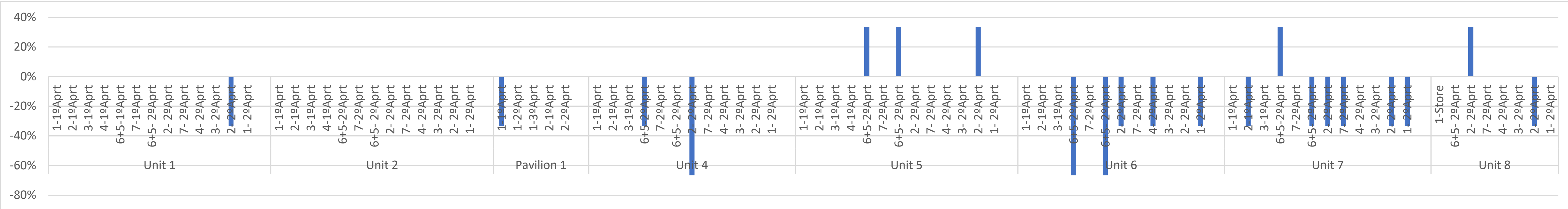
	Unit 8							
Existent vs Variation1	0%	0%	33%	0%	0%	0%	-33%	0%
Existent vs Variation2	0%	0%	33%	0%	0%	0%	-33%	0%
Existent vs Variation3	0%	0%	33%	0%	0%	0%	0%	0%
Existent vs Variation4	0%	0%	0%	0%	0%	0%	0%	0%
Existent vs Variation5	0%	0%	0%	0%	0%	0%	0%	0%
Existent vs Variation6	0%	0%	0%	0%	0%	0%	-33%	0%
Existent vs Variation7	0%	0%	0%	0%	0%	0%	0%	0%
Existent vs Variation8	100%	0%	0%	0%	0%	0%	-33%	0%

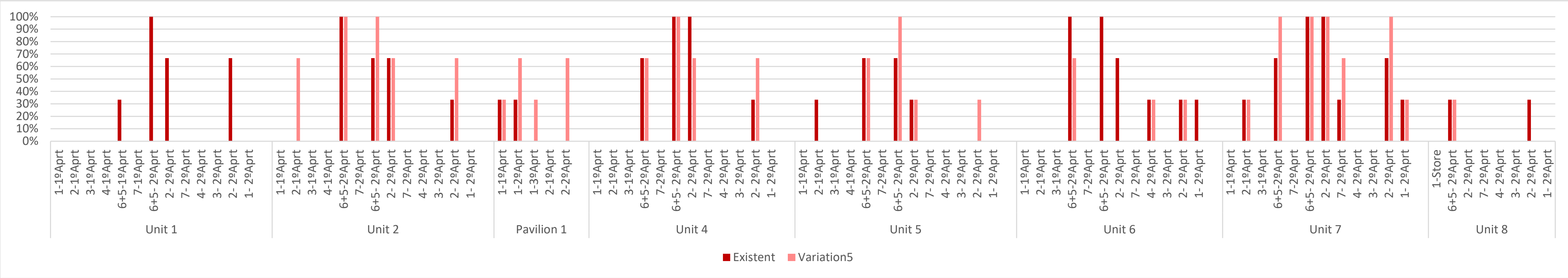
8.10 Comparison graph of the simulated data of the different variations- Thermal comfort level

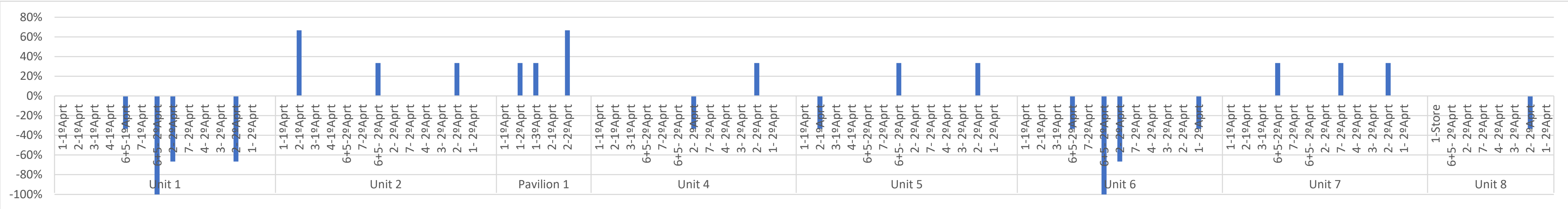


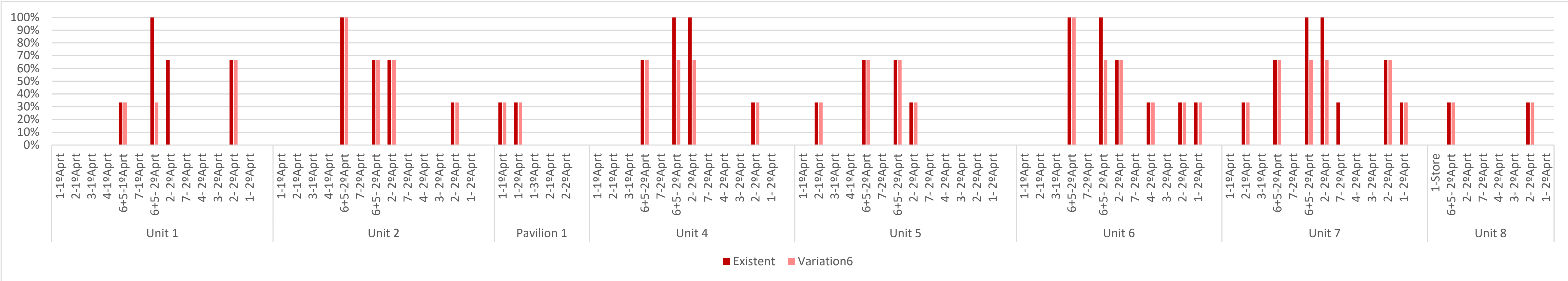


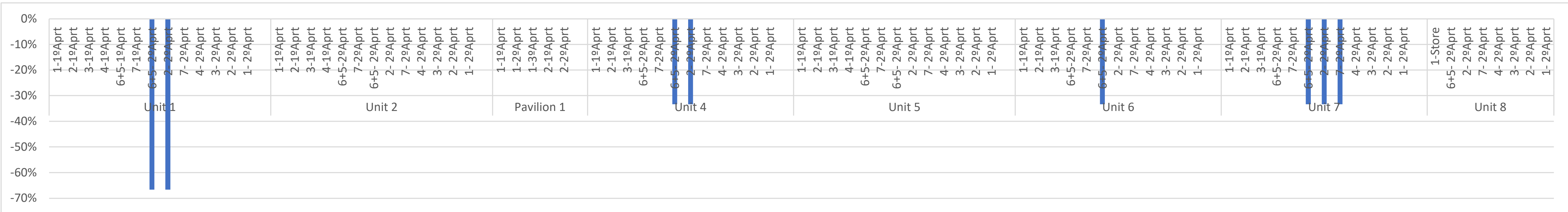


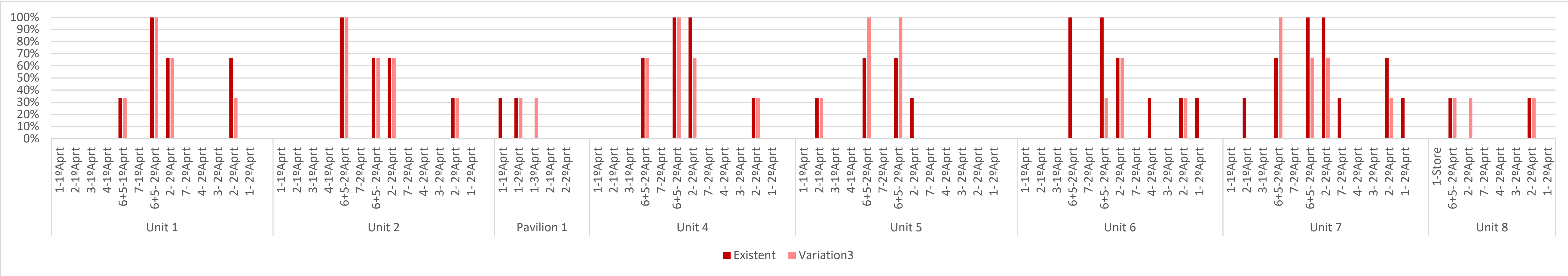


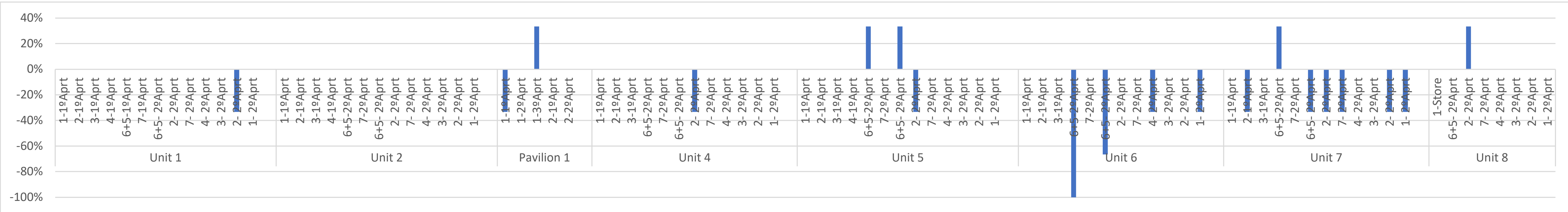

100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Unit 1
Unit 2
Pavilion 1
Unit 4
Unit 5
Unit 6
Unit 7
Unit 8
Existent
Variation5

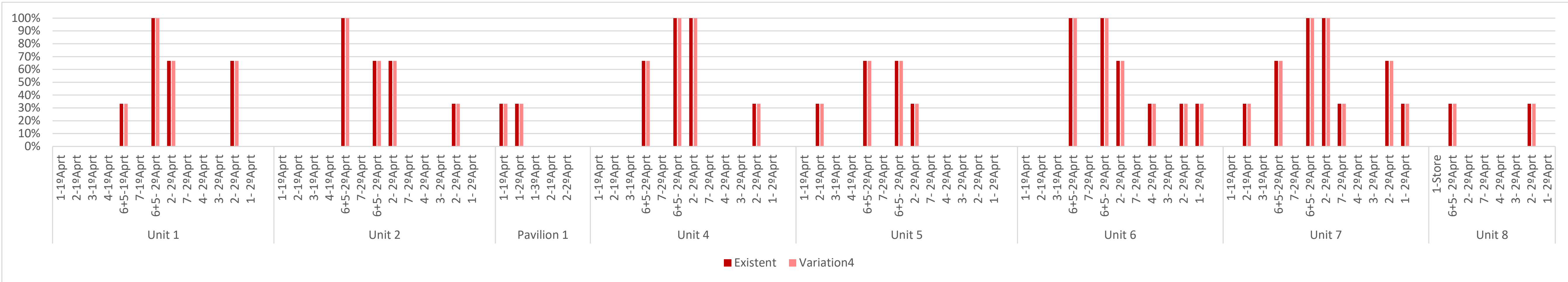

80%
60%
40%
20%
0%
-20%
-40%
-60%
-80%
-100%
Unit 1
Unit 2
Pavilion 1
Unit 4
Unit 5
Unit 6
Unit 7
Unit 8

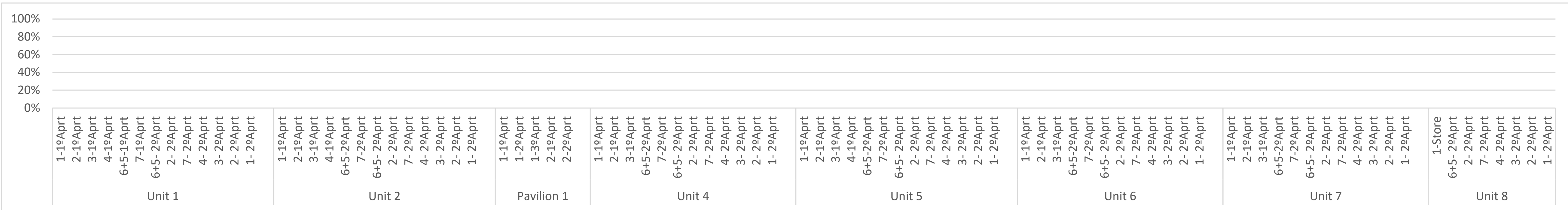

100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Unit 1
Unit 2
Pavilion 1
Unit 4
Unit 5
Unit 6
Unit 7
Unit 8
Existent
Variation6


0%
-10%
-20%
-30%
-40%
-50%
-60%
-70%
Unit 1
Unit 2
Pavilion 1
Unit 4
Unit 5
Unit 6
Unit 7
Unit 8

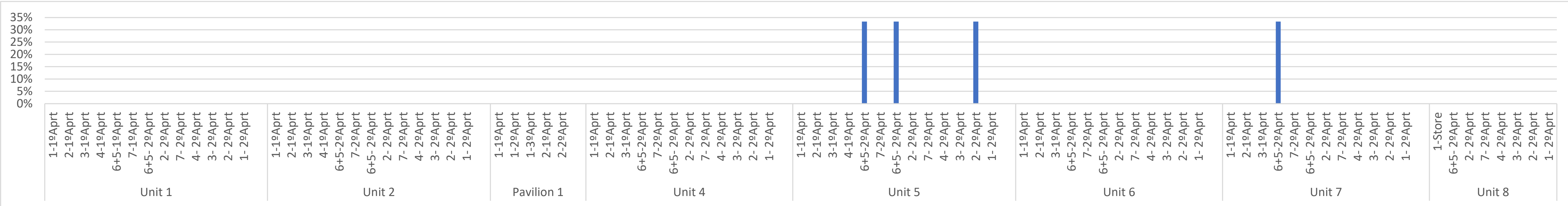

100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Unit 1
Unit 2
Pavilion 1
Unit 4
Unit 5
Unit 6
Unit 7
Unit 8
Existent
Variation3

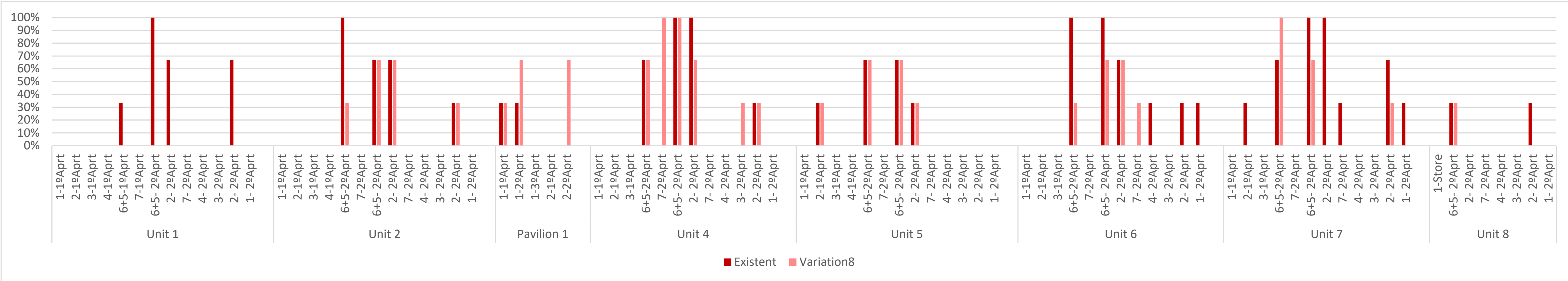

40%
20%
0%
-20%
-40%
-60%
-80%
-100%
Unit 1
Unit 2
Pavilion 1
Unit 4
Unit 5
Unit 6
Unit 7
Unit 8

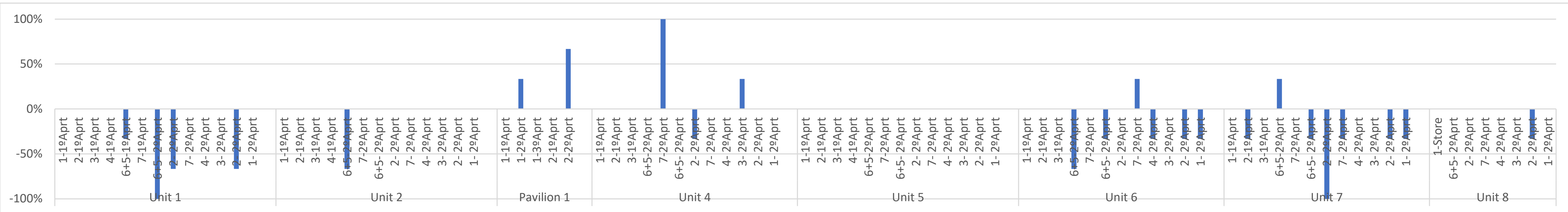

100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Unit 1
Unit 2
Pavilion 1
Unit 4
Unit 5
Unit 6
Unit 7
Unit 8
Existent
Variation4


100%
80%
60%
40%
20%
0%
Unit 1
Unit 2
Pavilion 1
Unit 4
Unit 5
Unit 6
Unit 7
Unit 8


100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Unit 1
Unit 2
Pavilion 1
Unit 4
Unit 5
Unit 6
Unit 7
Unit 8
Existent
Variation7


35%
30%
25%
20%
15%
10%
5%
0%
Unit 1
Unit 2
Pavilion 1
Unit 4
Unit 5
Unit 6
Unit 7
Unit 8


100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Unit 1
Unit 2
Pavilion 1
Unit 4
Unit 5
Unit 6
Unit 7
Unit 8
Existent
Variation8


100%
50%
0%
-50%
-100%
Unit 1
Unit 2
Pavilion 1
Unit 4
Unit 5
Unit 6
Unit 7
Unit 8

8.11 Improvement comparison data of the different variations

	Existent vs Variation1									
	1	2	3	4	5	6	7	8	Total	Average
Daylight Autonomy	9.4%	8.1%	2.7%	-4.5%	7.1%	-6.1%	-3.2%	-1.6%	11.9%	1.5%
Thermal confort	7.7%	0.0%	0.0%	-2.6%	5.1%	0.0%	-12.8%	0.0%	-2.6%	-0.3%

	Existent vs Variation2									
	1	2	3	4	5	6	7	8	Total	Average
Daylight Autonomy	7.1%	11.5%	0.4%	7.5%	9.7%	16.2%	10.2%	-2.1%	60.5%	7.6%
Thermal confort	-2.6%	0.0%	-2.6%	-7.7%	7.7%	-17.9%	-12.8%	0.0%	-35.9%	-4.5%

	Existent vs Variation3									
	1	2	3	4	5	6	7	8	Total	Average
Daylight Autonomy	3.0%	8.7%	1.2%	5.2%	8.6%	12.9%	16.3%	-4.7%	51.2%	6.4%
Thermal confort	-2.6%	0.0%	0.0%	-2.6%	2.6%	-17.9%	-12.8%	2.6%	-30.8%	-3.8%

	Existent vs Variation4									
	1	2	3	4	5	6	7	8	Total	Average
Daylight Autonomy	0.0%	8.4%	0.0%	0.0%	7.8%	0.0%	0.0%	0.0%	16.2%	2.0%
Thermal confort	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

	Existent vs Variation5									
	1	2	3	4	5	6	7	8	Total	Average
Daylight Autonomy	6.3%	0.0%	3.5%	12.4%	34.8%	11.4%	21.4%	0.0%	89.8%	11.2%
Thermal confort	0.0%	0.0%	0.0%	0.0%	7.7%	0.0%	2.6%	0.0%	10.3%	1.3%

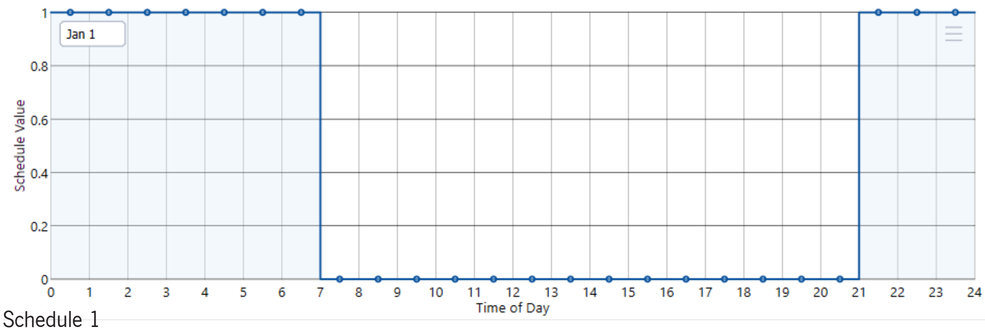
	Existent vs Variation6									
	1	2	3	4	5	6	7	8	Total	Average
Daylight Autonomy	52.8%	58.5%	1.7%	26.8%	46.9%	37.1%	31.3%	12.1%	267.2%	33.4%
Thermal confort	-1.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-1.6%	-0.2%

	Existent vs Variation7									
	1	2	3	4	5	6	7	8	Total	Average
Daylight Autonomy	6.8%	6.2%	0.0%	-15.1%	6.2%	7.8%	9.9%	0.0%	21.8%	2.7%
Thermal confort	-0.8%	0.0%	0.0%	-0.4%	0.0%	-2.6%	-7.7%	0.0%	-11.4%	-1.4%

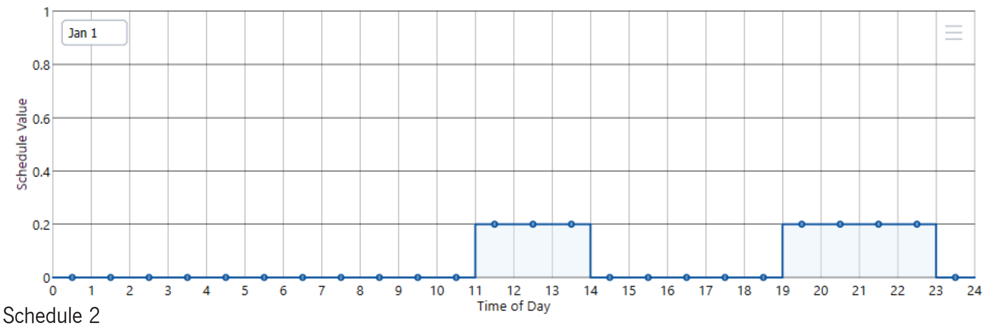
	Existent vs Variation8									
	1	2	3	4	5	6	7	8	Total	Average
Daylight Autonomy	0.0%	2.3%	2.0%	-2.7%	2.0%	-2.7%	-3.0%	-1.5%	-3.6%	-0.4%
Thermal confort	-1.6%	-5.1%	7.7%	1.2%	15.4%	-12.8%	-17.9%	5.1%	-8.1%	-1.0%

8.12 Input data from the different areas for thermal simulation

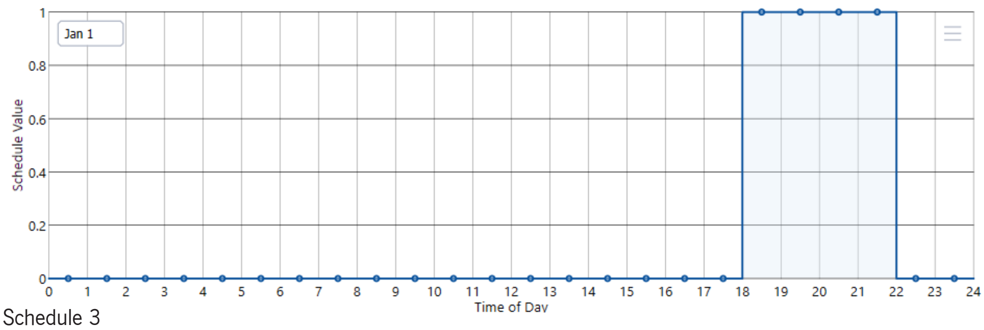
		Zone						
		1	2	3	4	5	6	7
People	On/Off	On	On	On	On	On	On	On
	People Density [P/m²]	0.025	___	0.6	0.025	___	0.075	0.025
	Metabolic Rate [met]	0.8	1.7	1.2	0.8	1.7	1.7	0.8
	Occupancy Shedule	1	___	5	1	7	7	1
	Clothing [clo]	Dynamic Clothing Model ASHRAE55						
Equipment	On/Off	On	___	On	On	___	On	On
	Equipment Power Density [W/m²]	Defaut	___	Defaut	Defaut	___	Defaut	Defaut
	Equipment Availability Shedule	2	___	5	2	___	8	2
Lighting	On/Off	On	___	On	On	___	On	On
	Lighting Power Dendity [W/m²]	Defaut	___	Defaut	Defaut	___	Defaut	Defaut
	Lights Availability Shedule	3	___	5	3	___	9	3
	Illuminace Target [lux]	200	___	200	200	___	200	200
	Dimming Type	Off	___	Off	Off	___	Off	Off
Hot Water	On/Off	Off	___	On	Off	___	On	Off
	COP [unitless]	___	___	Defaut	___	___	Defaut	___
	Inlet Water Temperatture [C°]	___	___	Defaut	___	___	Defaut	___
	Water Supply Temperatture [C°]	___	___	Defaut	___	___	Defaut	___
	Water Schedule	___	___	5	___	___	10	___
	Flow Rate Per Person [m³/h/P]	___	___	Defaut	___	___	Defaut	___
	Heating	Off	___	Off	Off	___	Off	Off
	Cooling	Off	___	Off	Off	___	Off	Off
	Humidity Control	Off	___	Off	Off	___	Off	Off
Mechanical Ventilation	On/Off	Off	___	On	Off	___	Off	Off
	Min Fresh Air Person [L/s/p]	___	___	Defaut	___	___	___	___
	Min Fresh Air Area [L/s/m²]	___	___	Defaut	___	___	___	___
	MechVentSchedule [Schedule name]	___	___	5	___	___	___	___
	Heat Recovery Type [enum]	___	___	Sensible	___	___	___	___
	Heat Recovery Efficiency Sensible [0-1]	___	___	Defaut	___	___	___	___
	Heat Recovery Efficiency Latent [0-1]	___	___	Defaut	___	___	___	___
	Economizer Type [enum]	___	___	NoEconomizer	___	___	___	___
	Fan Pressure Rise [Pa]	___	___	Defaut	___	___	___	___
Natural Ventilation Scheduled	On/Off	On	___	Off	On	On	On	On
	Schedule Ventilation SetPoint [C°]	18	___	___	18	18	18	18
	Schedule Ventilation Airchange [ACH]	0.6	___	___	0.6	0.6	0.6	0.6
	Schedule Ventilation Availability	4	___	___	4	6	6	4
Constructions	Roof	EE (Roof)						
	Façade	EE (Paint/Tiles)						
	Partition	Partition (Paint | Paint,Tiles | Paint, Tiles | Tiles)						
	Slab	EWTR (Slab-Corck, Slab-Tiles)						
	Ground Slab	EWTR (Slab-Corck, Slab-Tiles)						
Infiltration	On/Off	On	On	On	On	On	On	On
	Schedule Ventilation Airchange [ACH]	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	Other Parameters	Defaut	Defaut	Defaut	Defaut	Defaut	Defaut	Defaut
	Other Parameters	Defaut	Defaut	Defaut	Defaut	Defaut	Defaut	Defaut



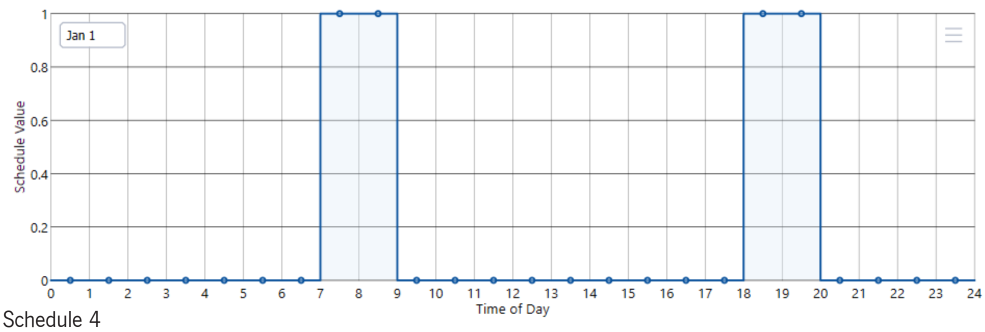
Schedule 1



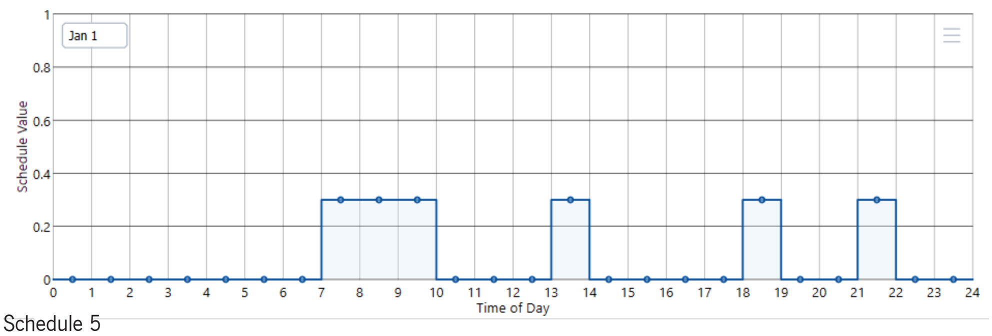
Schedule 2



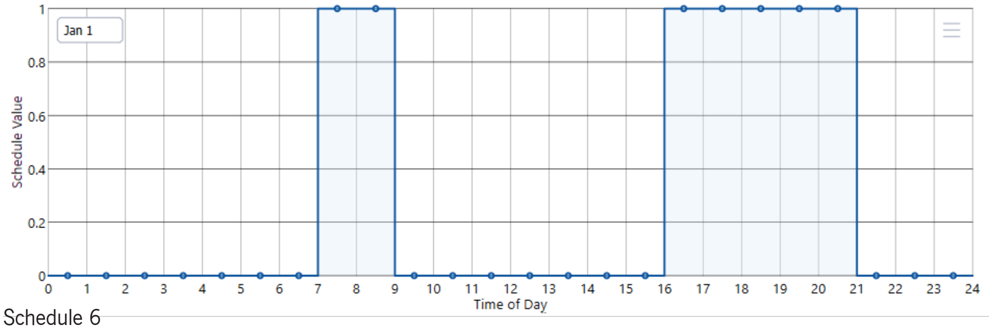
Schedule 3



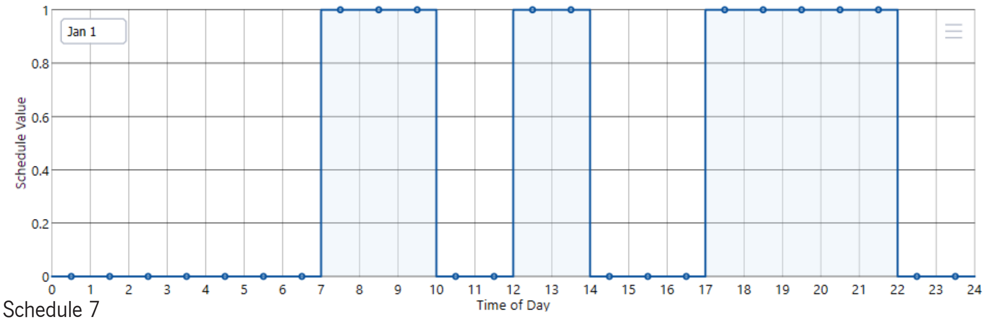
Schedule 4



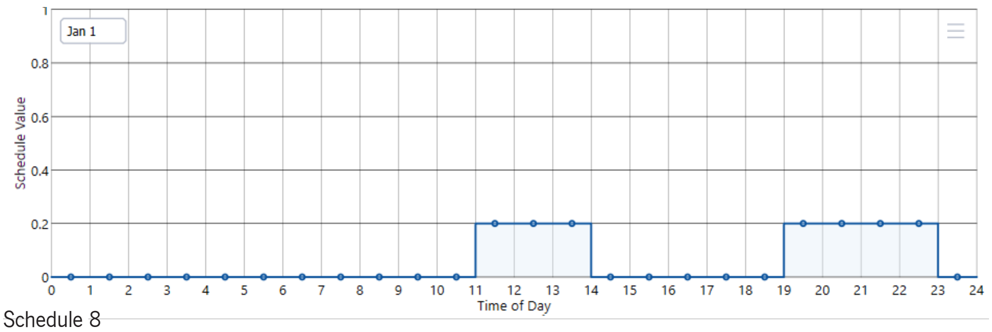
Schedule 5



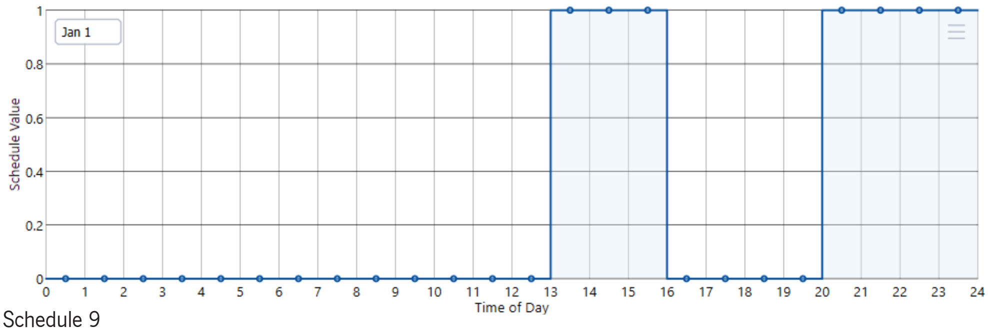
Schedule 6



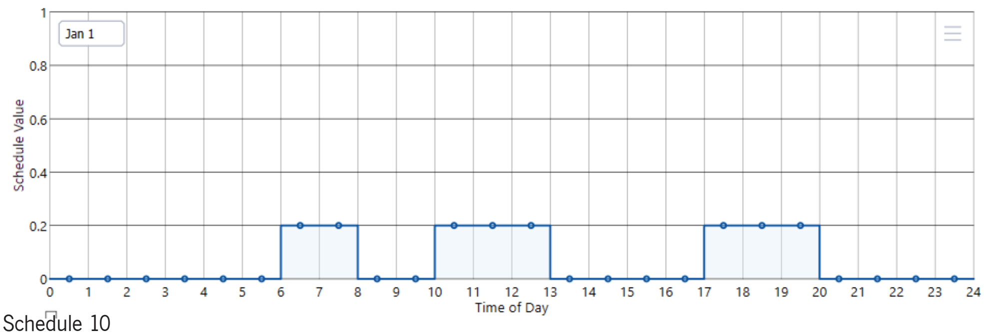
Schedule 7



Schedule 8



Schedule 9



Schedule 10

8.13 Data collected on site- Routine of the inhabitants

Collected Information

- Is there mechanical ventilation equipment in the housign unit? **Yes X** No____
  - What type of equipment is used?

    Mecanical ventilation that works in the bathrooms of all the buildings in morning and night.

- Is there heating equipment in the housign unit? **Yes X** No____
  - What type of equipment is used?

    Just oil heaters

- Is there cooling equipment in the housign unit? Yes____ **No X**
  - What type of equipment is used?

    (It dosent need because is one of the down housign units)

	Bedroom 1	Kitchen&Living	Closed Balcony	Bedroom 2	Bedroom 3	Toilet	Bathroom	Circulation
Equipment (WashingMachine,Coffee Machine...)	________	Cooker, Fridge, Television, Dishwasher	Washing machine, water heater	________	________	________	________	________
Cooling	________	________	________	________	________	________	________	________
Heating	Oil heater	________	________	Oil heater	________	________	________	________
Mechanical Ventilation	________	Kitchen Exhaust Hood	________	________	________	Collective ventilation in the morning and evening	________	________
Glass type	Simple	Simple	Simple	Simple	Simple	Simple	Simple	Simple
Number for Lamps/Type	LED table lamp- 2 Round LED wall lamp-1	Strait LED lamp- 1 Round LED wall lamp– 2	Round LED wall lamp-1	Round LED wall lamp-1	LED table lamp– 1 Round LED wall lamp-2	Round LED wall lamp-1	Round LED wall lamp-1	Round LED wall lamp-3
Hot Water	________	X	________	________	________	________	X	X

ZONE: Living Room

Date	Schedule	N° People	Activity	Hot Water(on/off)		Equipment(on/off)		Window (Open/Close)	Lights (on/off)	
04/05/2022	1°__18:50h-22:00h	1°__4	Cooking+ Dinner	X		Stove		W3+W2+W1	X	
	2°__22:00h-24:00h	2°__1	TV		X		X	W3+W2	X	
05/05/2022	1°__00:00h-00:30h	1°__2	TV		X		X	W3+W2	X	
	2°__08:45h-12:25h	2°__2	Working		X		X	W3+W2+W1	X	
	3°__12:25h-14:00h	3°__2	Lunch		X		X	W3+W2+W1	X	
	4°__14:00h-17:20h	4°__2	Working		X		X	W3+W2+W1	X	
	5°__17:20h-22:00h	5°__3	Cooking+Dinner	X		Stove+Oven		W3+W2+W1	X	
	6°__22:00h-24:00h	6°__1	TV		X		X	W3+W2	X	
06/05/2022	1°__24:00h-01:00h	1°__1	TV		X	Stove+Oven		W3+W2	X	
	2°__07:30h-08:40h	2°__3	Cooking+Breakfast	X			X	W3+W2+W1	X	
	3°__18:50h-22:45h	3°__6	Cooking+Jantar	X		Stove				
07/05/2022	1°__08:25h-10:10h	1°__3	Breakfast		X		X	W3+W2+W1	X	
	2°__13:00-15:00h	2°__3	Cooking+Lunch	X		Stove		W3+W2+W1	X	
08/05/2022	1°__09:00h-12:00h	1°__3	Cooking+Lunch	X		Stove		W3+W2+W1	X	
09/05/2022	1°__07:30h-08:40h	1°__3	Breakfast		X		X	W3+W2+W1	X	
	2°__18:00h-24:00h	2°__3	Cooking+Dinner+Tv	X		Stove		W3+W2+W1	X	
10/05/2022	1°__00:00h-00:30h	1°__1	TV		X		X	W3+W2	X	
	2°__07:40h-09:30h	2°__3	Breakfast		X		X	W3+W2	X	
05/07/2022	1°__13:00h-15:00h	1°__1	Lunch		X		X	W3+W2+W1	X	
	2°__20:00h-24:00h	2°__1	Cooking Dinner+ TV		X	Stove		W3+W2+W1	X	
06/07/2022	1°__20:35h-24:00h	1°__1	Cooking Dinner+ TV		X	Stove		W3+W2+W1	X	
07/07/2022	1°__13:00h-14:00h	1°__1	Lunch		X		X	W3+W2+W1	X	
08/07/2022										
09/07/2022	1°__08:30h-09:30h	1°__1	Breakfast		X		X	W2		X
	2°__13:00h-14:30h	2°__1	Cooking+Lunch		X	Stove				
10/07/2022	1°__08:40h-09:30h	1°__1	Breakfast		X		X	W3+W2+W1		X
	2°__09:30h-13:00h	2°__2	Lunch		X		X	W3+W2+W1		X
	3°__13:00h-21:00h	3°__2	Cooking+Dinner	X		Stove				
11/07/2022	1°__12:20h-14:00h	1°__2	Lunch		X		X	W3+W2+W1		X
	2°__14:00h-18:20h	2°__3	TV		X		X	W3+W2+W1		X
12/07/2022	1°__07:35h-09:30h	1°__3	Breakfast		X		X			X
	2°__09:30h-13:00h	2°__2	Cooking+Lunch		X	Stove				X
	3°__13:00h-21:00h	3°__3	Cooking+Dinner	X		Stove				X
13/07/2022	1°__08:25h-10:00h	1°__3	Breakfast		X		X	W3+W2+W1		X
	2°__17:25h-22:10	2°__6	Lunch	X			X	W3+W2+W1		X

ZONE: BeedRoom

Date	Schedule	N° People	Activity	Hot Water(on/off)		Equipment(on/off)		Window (Open/Close)		Lights (on/off)	
04/05/2022	1°__23:30h-24:00h	1°__2	Sleep		X		X		X		X
05/05/2022	1°__00:00h-07:40h	1°__2	Sleep		X		X		X		X
	2°__07:40h-08:45h	2°__0	Ventilation		X		X	X			X
	3°__17:25h-23:35h	3°__0	Ventilation		X		X	X			X
	4°__23:35h-24:00h	4°__2	Sleep		X		X		X		X
06/05/2022	1°__00:00h-08:15h	1°__2	Sleep		X		X	X			X
	2°__08:15h-09:35h	2°__0	Ventilation		X		X	X			X
	3°__23:10h-24:00h	3°__0	Ventilation		X		X	x			X
07/05/2022	1°__00:00h-08:35h	1°__2	Sleep		X		X		X		X
	2°__08:35h-12:00h	2°__0	Ventilation		X		X	X			X
	3°__23:00h-24:00h	3°__2	Sleep		X		X		X		X
08/05/2022	1°__00:00h-08:35h	1°__2	Sleep		X		X		X		X
	2°__08:35h-12:00h	2°__0	Ventilation		X		X	X			X
	3°__23:00h-24:00h	3°__2	Sleep		X		X		X		X
09/05/2022	1°__00:00h-07:25h	1°__2	Sleep		X		X		X		X
	2°__18:00h-18:50h	2°__0	Ventilation		X		X	X			X
	3°__23:00h-24:00h	3°__2	Sleep		X		X		X		X
10/05/2022	1°__00:00h-09:35h	1°__2	Sleep		X		X		X		X
05/07/2022	1°__19:10h-22:40h	1°__0	Ventilation		X		X	X			X
06/07/2022	1°__00:30h-08:00h	1°__1	Sleep		X		X		X		X
	2°__08:00h-09:15h	2°__0	Ventilation		X		X	X			X
	3°__20:50h-24:00h	3°__0	Ventilation		X		X	X			X
07/07/2022	1°__00:15h-08:15h	1°__1	Sleep		X		X		X		X
	2°__08:15h-11:50h	2°__0	Ventilation		X		X	X			X
08/07/2022	1°__00:00h-05:30h	1°__1	Sleep		X		X		X		X
09/07/2022	1°__01:25h-08:40h	1°__1	Sleep		X		X		X		X
	2°__08:40h-09:30h	2°__0	Ventilation		X		X	X			X
10/07/2022	1°__00:30h-08:10h	1°__1	Sleep		X		X	X			X
	2°__08:10h-09:30h	2°__0	Ventilation		X		X	X			X
	3°__22:25h-24:00	3°__1	Sleep		X		X	X			X
11/07/2022	1°__00:00h-07:00h	1°__1	Sleep		X		X		X		X
	2°__09:00h-10:45h	2°__0	Ventilation		X		X	X			X
12/07/2022	1°__00:10h-07:35h	1°__1	Sleep		X		X		X		X
13/07/2022	1°__00:00h-08:20h	1°__2	Sleep		X		X		X		X