Politecnico
di Torino

Politecnico Di Torino

DAD

Department of Architecture and Design

Master of Science

Architecture for the Sustainable Design

International Velux Award
For the Students of Architecture
2022

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Project Name: MaxLight

Special Thanks by:

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Contents

VELUX AWARDS

About Velux Competition

Every second year since 2004, the VELUX Group has invited students of architecture to participate in the International VELUX Award. The award seeks to challenge the students to explore the role of daylight in architecture and inspire new thinking. The aim of the award is to engage with students of architecture about how to use sunlight and daylight as main sources of energy and light and how to ensure health and well-being of the people who live and work in buildings.

The award is global and open to any registered student of architecture backed by a teacher from a school of architecture. The total prize money is up to 30,000 Euro. The jury, comprising internationally renowned architects, will award a number of prize winners and honourable mentions.

The International VELUX Award is a competition for students of architecture that runs every second year. Since the launch in 2004, it has grown into the largest competition of its kind with students from 800 schools, from 130 countries of all continents, submitting more than 6,000 projects on the award theme “Light of Tomorrow”.

Velux Award 2022

International VELUX Award 2022 is arranged in close collaboration with the International Union of Architects (UIA) and acknowledged by the following educational organizations: The European Association for Architectural Education, The American Institute of Architecture Students, the Architectural Research Centers Consortium, and the Association of Collegiate Schools of Architecture.

The Award

The International VELUX Award 2022 for Students of Architecture wants to encourage and challenge students of architecture to explore the theme of daylight – and to create a deeper understanding of this specific and ever-relevant source of energy, light and life.

The award celebrates and promotes excellence in completed study works. These works can be made as works complying with the prize scope of rethinking the values of conscious daylighting design with focus on people’s health in living and working environments.

The award encourages projects that celebrate the privilege of being a student; with curiosity and with the willingness to think “out of the box” – as well as consider the social, sociological and environmental dimension of light.

The award wants to acknowledge not only the students but their teachers as well. Therefore, teachers of the projects are also awarded.

Theme

“Light of Tomorrow” is the overall theme of the International VELUX Award. The award seeks to challenge the future of daylight in the built environment with an open-minded and experimental approach. Therefore, the award seeks to widen the boundaries of daylight in architecture, including aesthetics, functionality, sustainability, and the interaction between buildings and environment.

1. Daylight in buildings
Projects that demonstrate applicable principles for providing daylight and sunlight into buildings – including the effects of building construction and context of the site, shape and dimensions, window openings, screens, shadings, interior divisions, materials and external conditions. Specific focus on architecture for health and well-being and projects that address challenges faced by cities, communities and modern societies, and where daylight and architecture can help create change through better and healthier living environments.

2. Daylight investigations
Projects that look at the physical properties of light, basics of optics and materials, as well as technological developments, new materials, storage or transportation of daylight.
The use of daylight in public space for functional, recreational, cultural or spiritual use and the effect of daylight on state of mind, health and well-being as well as the dynamics and temporal quality of daylight and its effects on behaviour and spaces over time and seasons.

ABSTRACT

MaxLight has worked on a building in Bologna, Italy. Nowadays, using sustainable and recycled materials getting increasing every day. Plastic and light tube inspired us to create this product. Plastic is one of the most accessible and cheap materials around the world. In addition, recycling plastic is not expensive, and also can help the environment. These benefits of plastic can help to solve problems. Always some areas in buildings cannot access daylight and need to use artificial light. Also, some products direct daylight inside the building but have limitations on height and length. Besides, the power of light transmission and efficiency get decreased and low. Polymethyl methacrylate (PMMA) belongs to the family of synthetic polymers is the solution. It is a very transparent, rigid material, with excellent resistance to ultraviolet rays and air. This material is capable of laser cutting, shaping, sanding, piercing, bending, etc. PMMA is used in the light industry and has become a suitable material for implementing some ideas. Synthetic polymers are the main part of optical fibres and is used to manufacture special lights. PMMA is used in many cases because of its unique features. Almost the light conductivity feature is the most significant feature of this material. Conventional PMMA transmits up to 93% of light, which is more than other materials such as glass or plastic. This remarkable feature has led to its use in the manufacture of many pieces of equipment for lighting. Hardness levels of surfaces of this material show good resistance against scratches and such damages. This feature will be handy and suitable in cases where visual beauty is of special importance to us in the long run. It is UV resistant because used for outdoor equipment. This material can be used in such spaces for a long time without changing the colour. In comparison with glass, it is not fragile and has unique properties that can be combined with other polymeric materials to increase its performance properties. Usually, these changes in its composition are made to improve the properties of this polymer for special applications. Examples of features that can be adjusted in this way include impact resistance, chemical resistance, flame retardant, light scattering, UV filter, light effects, and... MaxLight product is designed in three main parts, the first one is the head of the product with a circular shape installed on the roof that collects light and sends it to the inside of the building. The second part is the tube of product that transfers light to dark places. The last part is a light valve to distribute light in the room. This product is designed with a semi-circular shape that inside includes several PMMA rods (light rods), which is supported by some plans. This semi-circular is covered by transparent plastic. There are some advantages to using this product in a building use on more than two floors without losing the efficiency of light. Also, it is a flexible material that can turn in several angles to fit with all the plans of buildings and use as a part of interior design because of the shape and product design this material used inside the building. On the other hand, the price of this material is economical for customers.

INTRODUCTION

Daylight

There are many articles to explain daylight, and here only a summary introduction is provided. To consider the daylight strategies and architectural design strategies are inspirable.

Replace natural light with artificial light can reduce energy uses also, influence both heating and cooling loads. Therefore, various specialities and professionals involve and try for innovative lighting systems that redirect light.

Strategies of daylight depend on different factors like climate, the geography of the location and the skyline of the building, e.g., the presence of obstructions.

Daylight strategies are affected by climate, and it shows seasonal changing identifying prevailing climate conditions, ambient specific temperatures, and per cent of sunshine in a day. The perception of daylight in the building facade is the first step in design because natural light is directly related to health.

Poor housing is an important determinant of poor health. One key aspect of housing quality is lighting. Light is important for visual performance and safety and plays a vital role in regulating human physiological functions.

Most designers aim to maximize daylight penetration in a building in a geographic location that has the limitation of natural light. Redirect daylight into buildings from the brightest regions of the sky contrast with the tropics where daylight levels are high throughout the year design, emphasis is usually on preventing overheating by daylight entering a building.

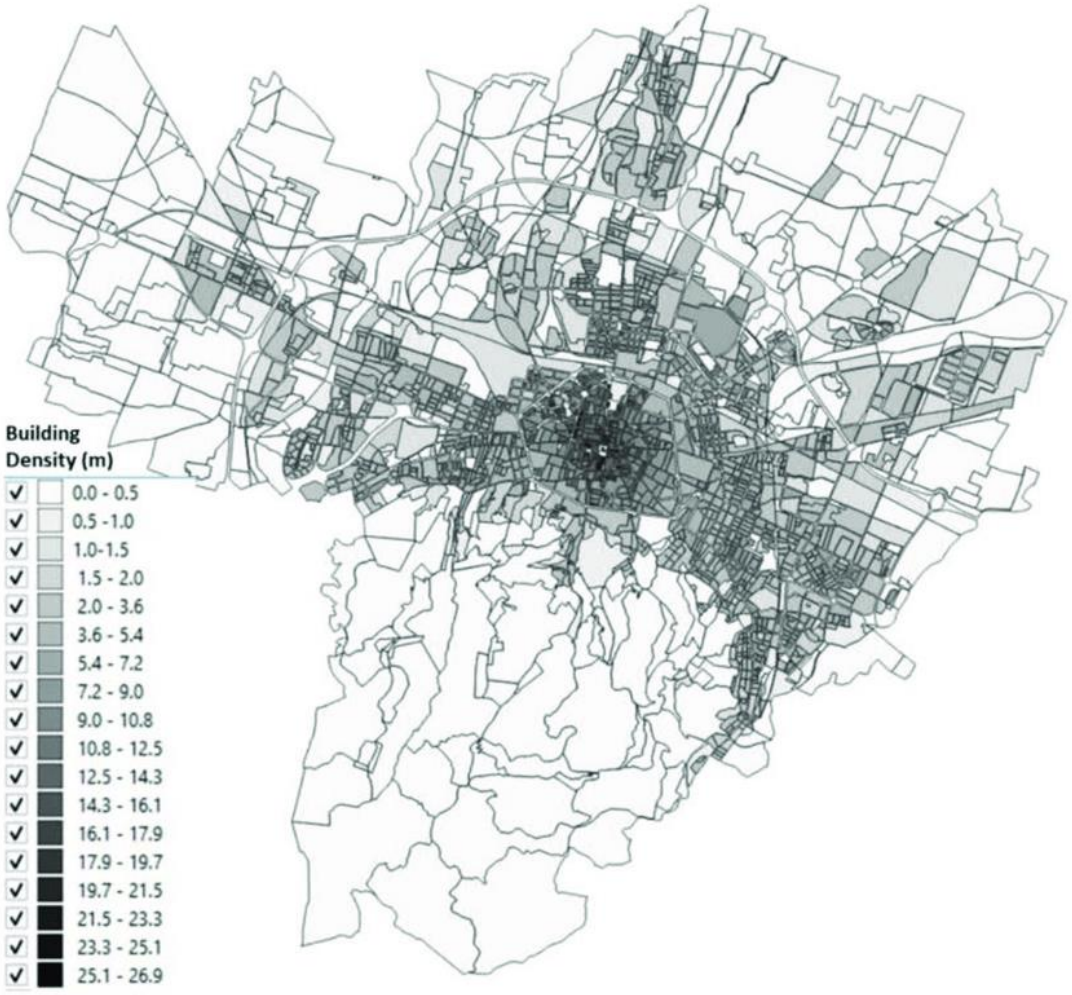
BOLOGNA

The Municipality of Bologna

Capital of the Metropolitan city and of the Emilia Romagna Region (Italy), Bologna (445,075 N; 113,514 E) is located between the mountains of the Tuscan-Emilian Apennines and the heart of the Po Valley. A meeting point between North and South, between East and West, the Adriatic Riviera as well as Venice, Florence, Milan and Rome can be easily reached from the city. Bologna has a warm and temperate climate, and there is significant rainfall throughout the Metropolitan territory. The average annual temperature in Bologna is 14.0 ◦C, and the average annual rainfall is 774 mm (ARPAe Emilia Romagna, Idro-MeteoClima Service). The urban resident population is about 400,000 citizens.

Building Density of Bologna

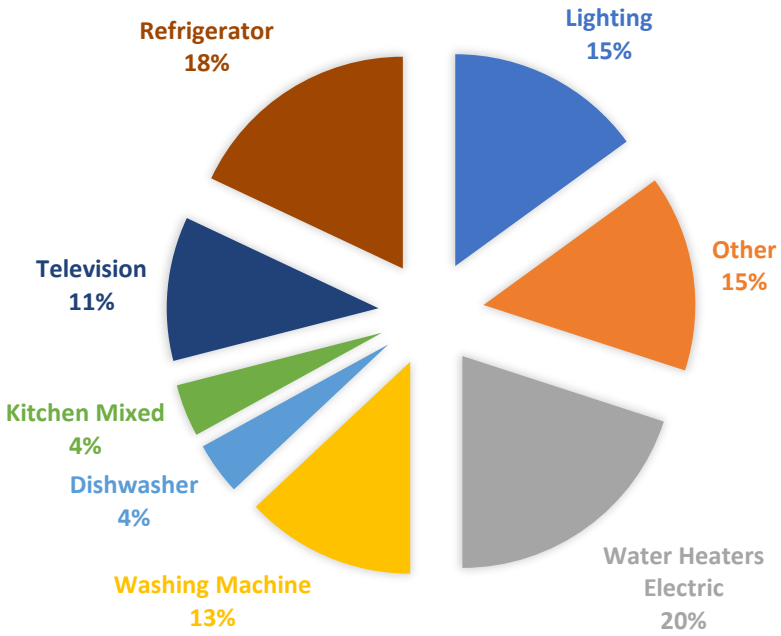
The picture shows the building density for each block of the Bologna Municipality.



ENERGY

Energy Consumption of Home in Italy

The average consumption of an Italian family is about 3000 kW / h and is determined by lighting, water heating and household appliances. The figure shows the domestic energy consumption in a pie chart [Source ENEA]:

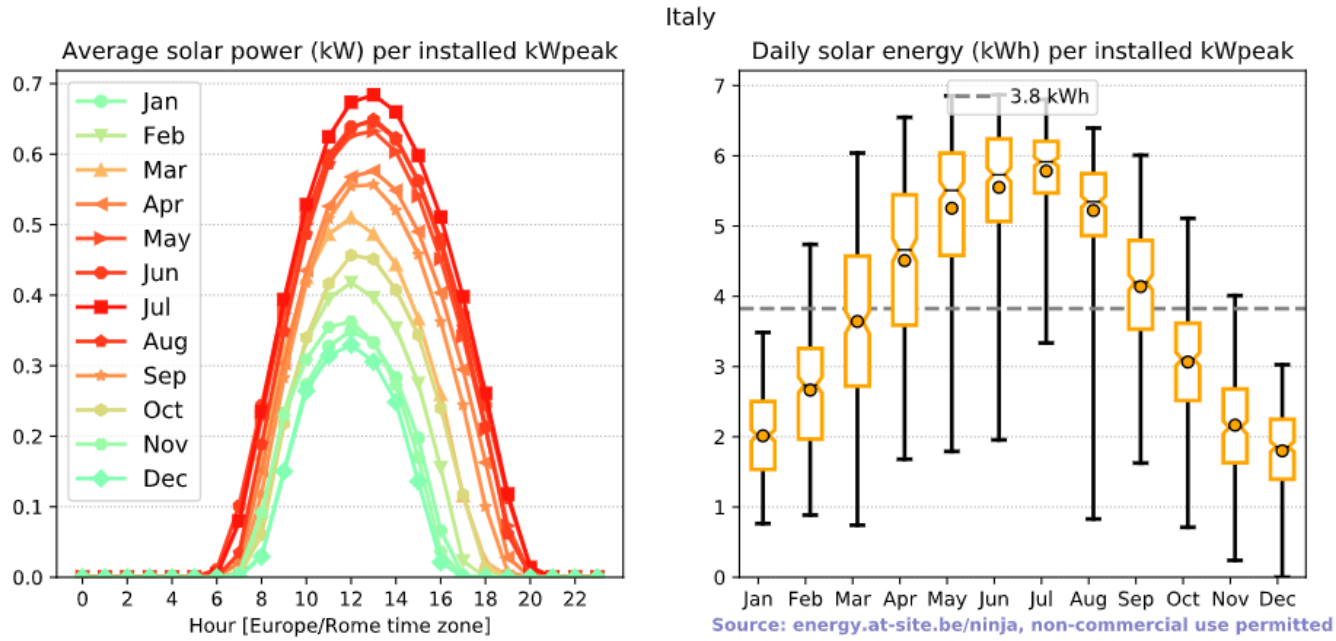


Taking into account that in the path from the production of electricity to its use for individual domestic users, more than 60% of it is lost, it is clear that for each kW/h consumed, pollution is produced for 3 kW/h.

Solar, Wind, Heating and Cooling

Reanalysis models are quickly gaining popularity for simulating solar, wind, heating and cooling power output due to their convenience and global coverage. However, they should only be trusted once thoroughly proven. These analyses can help to understand better, how can control the internal temperature of the building. Especially, in the sustainable design analysis of climate is the main factor to design. According to the climate-sensitive interactions between buildings and the environment, perception of the parameter affects the design of the building energy performance under specific climate environments, which is crucial for the sustainable development of green buildings. Here only collected some statistics about average power and daily energy.

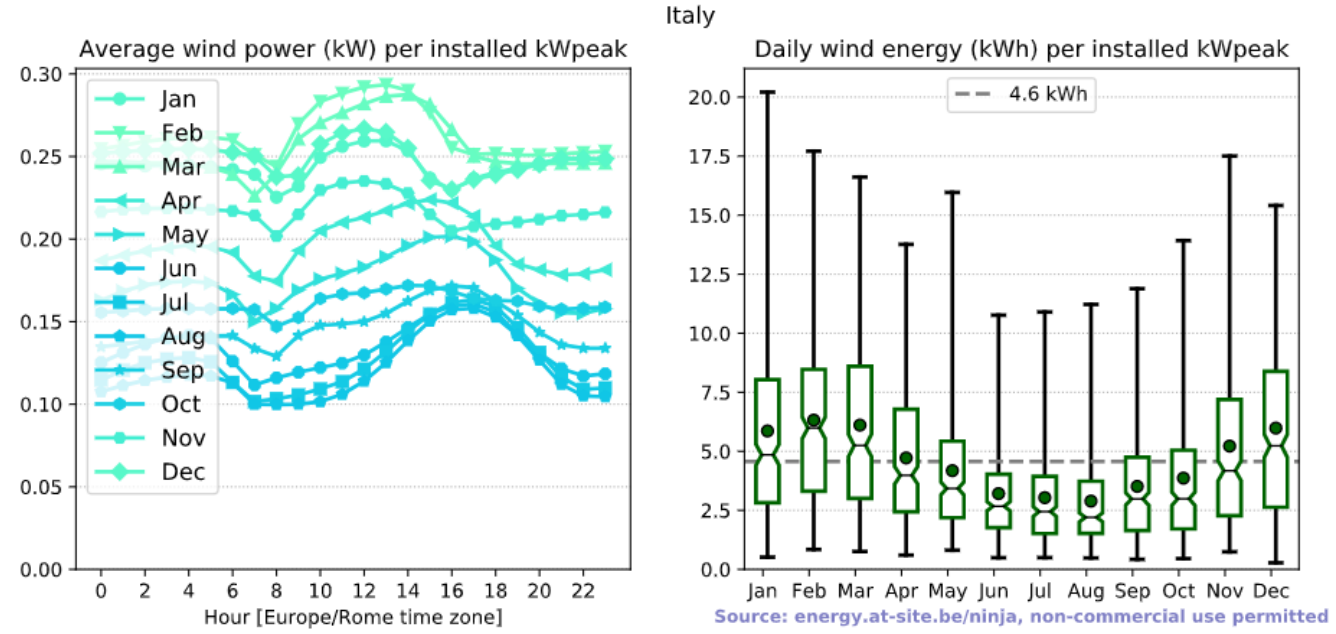
Solar



Data source: renewables.ninja CC BY-NC 4.0, doi: 10.2016/j.energy.2016.08.060
CM-SAF SARAH solar model, years 2005-2015

Figure 2.1 Italy daily solar energy plot.

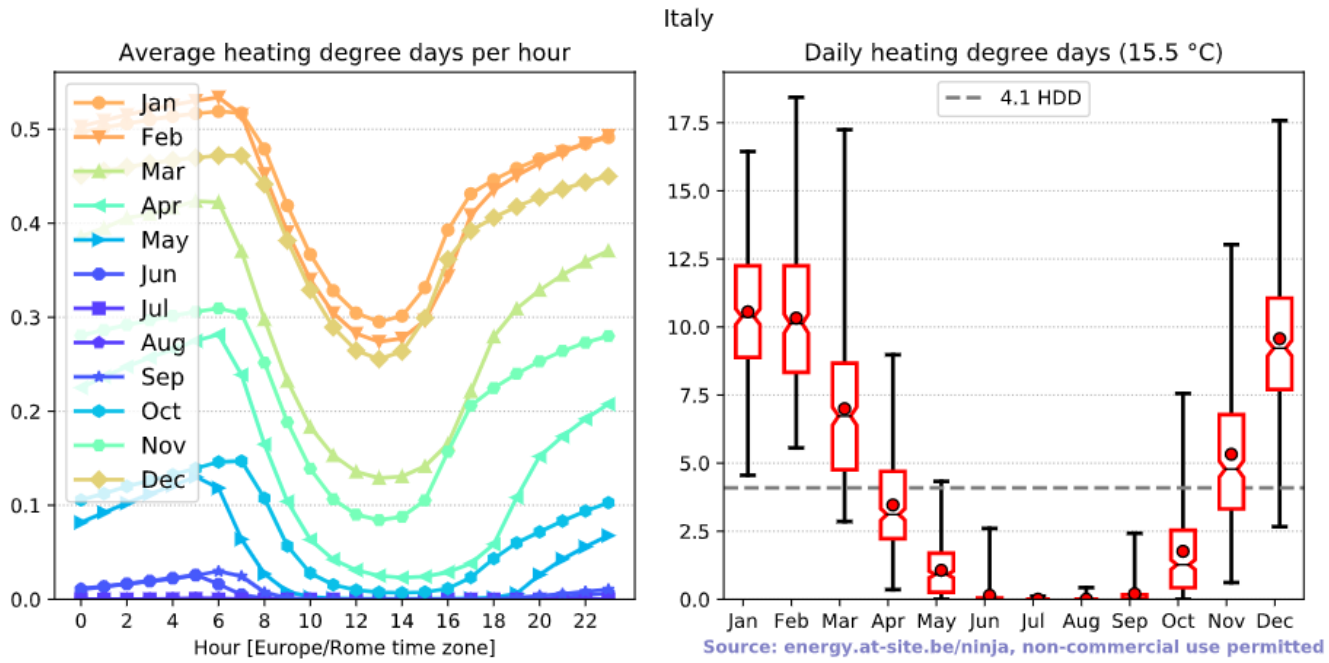
Wind



Data source: renewables.ninja CC BY-NC 4.0, doi: 10.2016/j.energy.2016.08.068
2016 wind fleet, years2005-2015

Figure 2.2 Italy daily wind energy plot.

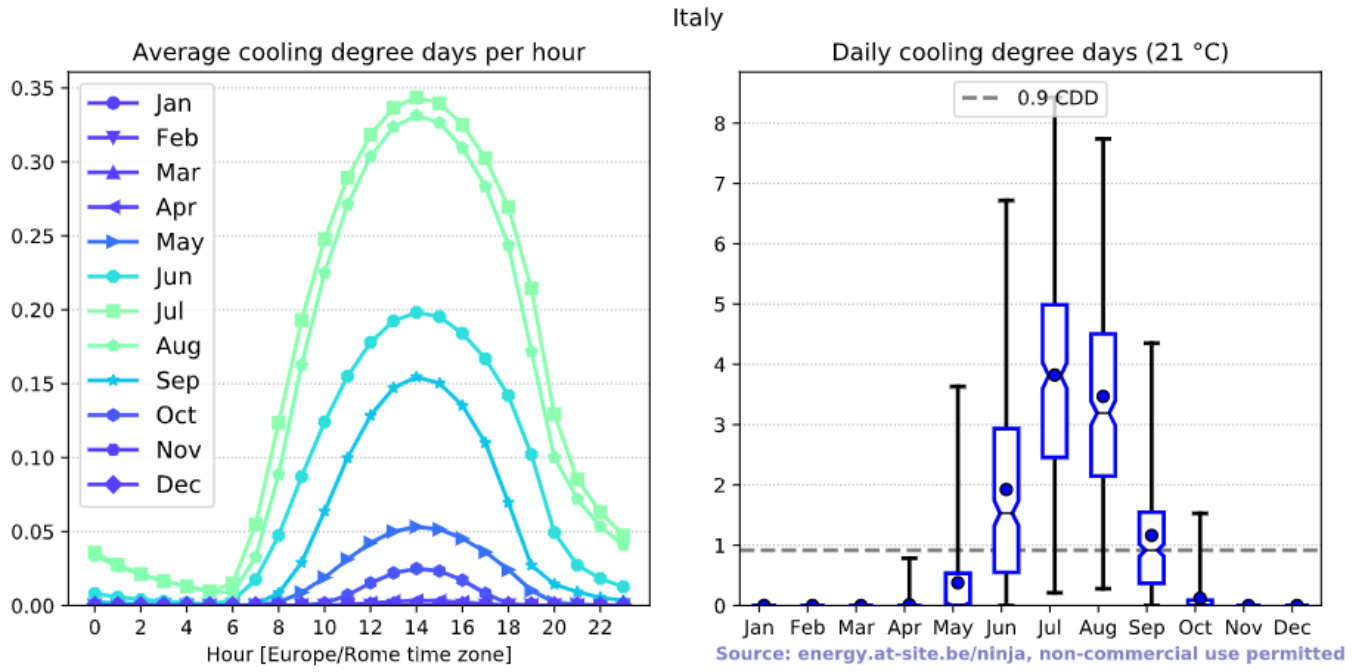
Heating



Data source: renewables.ninja CC BY-NC 4.0, NASA MERRA-2 population weighted temperature model, years 2005-2015

Figure 2.3 Italy daily heating degree days plot.

Cooling



Data source: renewables.ninja CC BY-NC 4.0, NASA MERRA-2 population weighted temperature model, years 2005-2015

Figure 2.4 Italy daily cooling degree days plot.

METHODOLOGY

Analysis of sunlight during the day and year in each hour of the day created some results that helped product design and put in correct locations. In this analysis Grasshopper, Ladybug and Honeybee software that used for analysing walls, roofs and interior areas. Sunlight was the main factor to design this product, the analysis of sunlight and daylight include, daylight autonomy (DLA), Useful daylight illuminance (UDI) and Continuous Daylight Autonomy (CDA) parameters simulated for a type of plan was a method to analyse as a case study.

Daylight Autonomy (DLA)

Daylight autonomy (DLA), is the percentage of the time during the active occupancy hours that the test point receives more daylight than the illuminance threshold. Dynamic daylighting metric is called daylight autonomy. DLA metrics on time series are illuminances base, that are based on yearly solar radiation data for the building site (Reinhart, Mardaljevic, & Rogers, 2006). The principal privilege of dynamic daylight efficiency metrics over static metrics is that they consider the content and features of daily variations of daylight together with atypical meteorological events (Reinhart, Mardaljevic, & Rogers, 2006).

Useful Daylight Illuminance (UDLI)

Useful daylight illuminance (UDLI) is the ratio of the number of hours in the year when illuminance provided by daylighting is within a useful range to the total number of occupied hours in a year (Nabil & Mardaljevic, 2005). UDLI goals to define the daylighting level that is neither too dark nor too bright (Reinhart, Mardaljevic, & Rogers, 2006). UDLI is usually presented by three metrics: UDLI <100 lux, UDLI 100-200 lux, and UDLI >2000 lux. The illuminance range that is considered useful is between 100 lux to 2000 lux. Illuminance below 100 lux is considered too dark, and illuminance above 2000 lux is considered too bright.

Continuous Daylight Autonomy (CDA)

Continuous Daylight Autonomy (CDA) is Similar to Daylight Autonomy except that the point receives an illuminance level/illuminance threshold for hours the illuminance level is less than the threshold. For example, the minimum illuminance requirement of a space is 300 lux, and at a certain time step, the illuminance is 150 lux. DA would give it 0 credit, while CDA would give it 0.5 credit.

Shadows Analysis

During a particular time of year, analysing the shadow can help identify which areas of the drawing will receive less sunlight or remain hidden. Using multiple directional light sources that represent different times of day, we create an overlapping range of shadows that show how long a specific area spends in the shade.

Sunlight Analysis

By analysing solar light, we can determine the impact of proposed new developments on the occupants of the new development as well as those in adjacent buildings.

Taking full advantage of passive solar design features and increasing the energy efficiency, comfort, and financial value of a building can be achieved by analysing the impact of the sun on a site, along with the building's location, spatial arrangement, orientation, window placement, and daylight access.

Wind Direction

According to global climate conditions, most locations have a predominant wind direction during the different seasons and times of the year. The truth is that this isn't true everywhere and varies from place to place. Considering wind direction when designing a climatically responsive house is extremely important if the designer intends to channel it through interiors. The size & placement of openings will be influenced by this

CASE STUDY

Around the site, there is a university and an open area of the university is the side of the alley that can help to decrease the density of buildings in that area. Also, a square is near the site location and two main streets surround the location. This map shows two high residences that are almost near the site but they did not affect sunlight or shadow analysis.

With the big backyard and another open area of the neighbour's building, there was ample space and the light could easily enter the flat. A narrow alley there is on the east side of the building, it means blocks are too near to each other, and light comes into the rooms hardly.

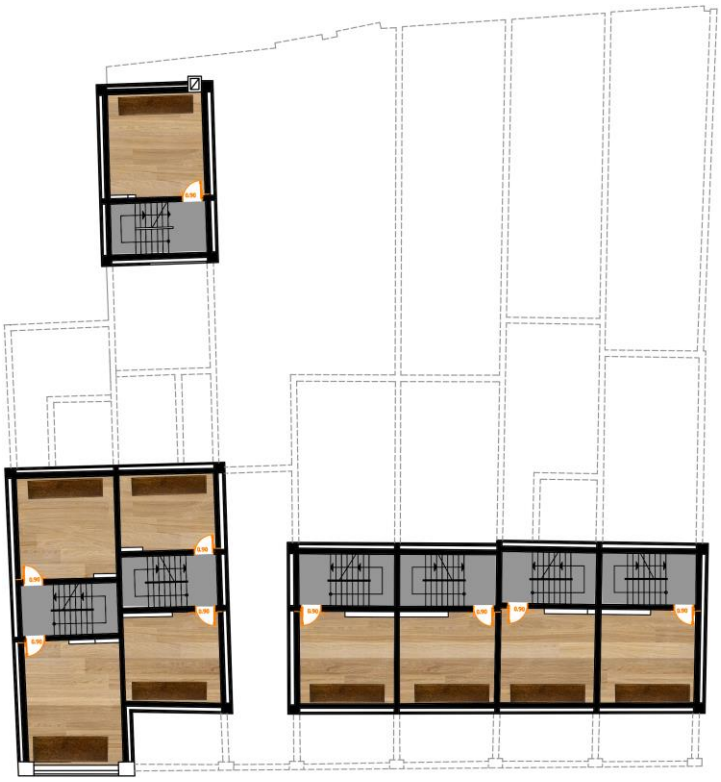
- Site
- University area
- Square
- Main street

Site Location and Building Analysis

Site area shows is more density of buildings in location, also streets and alley are narrow that is why buildings in front of each other are near and it has an effect on sunlight and avoid the light to enter inside the building. But roof is free to use for sunlight and there is no obstacle around the building.

Plans

The building includes four floors with a basement. Units designed for student suites between 20 to 45 m². Also, there is a shared bathroom on the first and second floors. There is no parking but the basement is store and unites started from ground floor. Three typical plans designed in this building with several dimension.



Basement Plan

Ground Floor

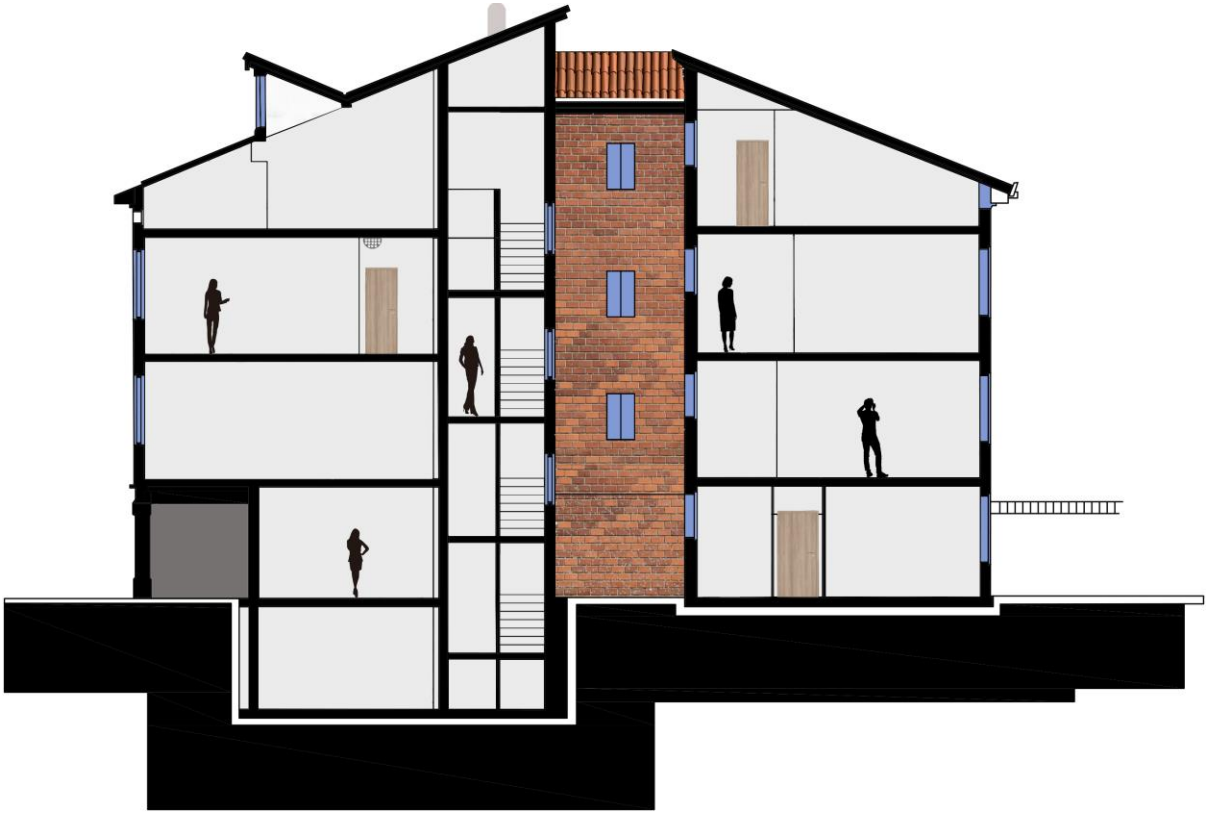
First Floor Plan

Second Floor Plan

Section A_A

Section B_B

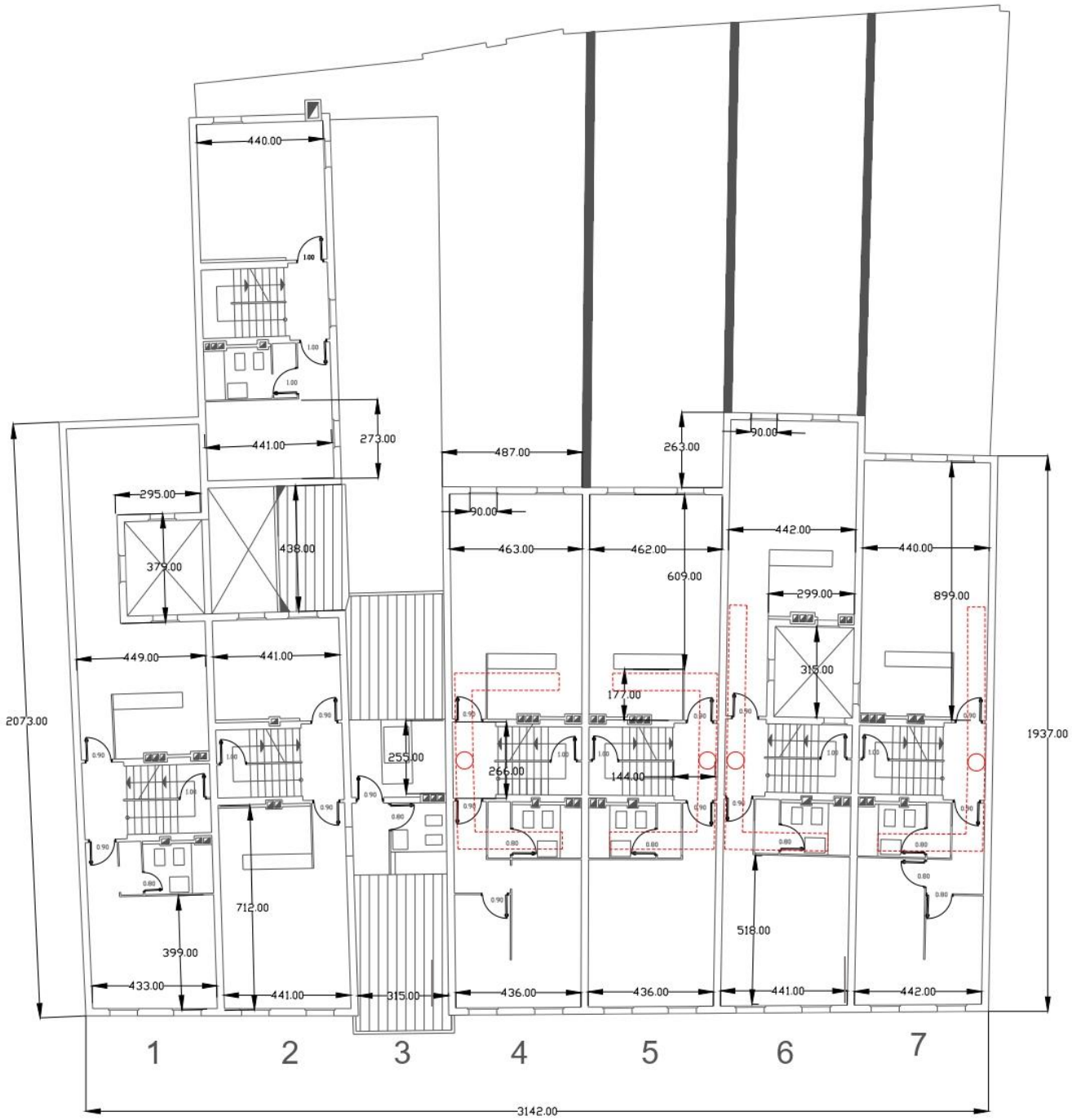
Section C_C



Section D_D

Elevation West

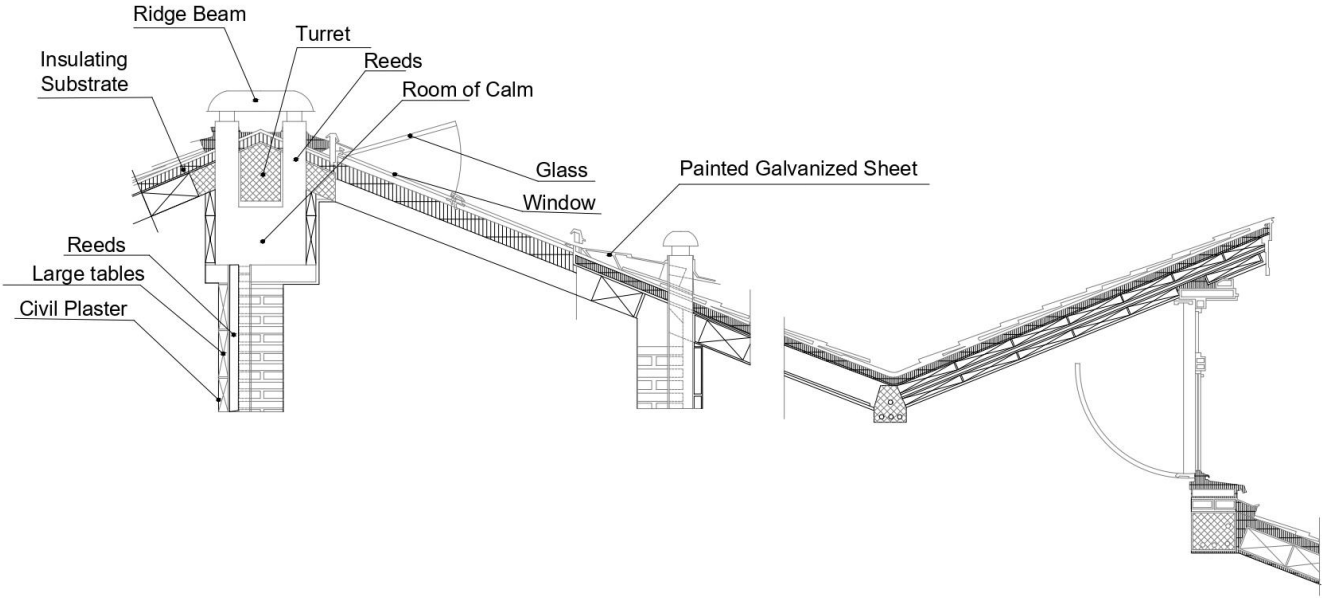
Elevation East

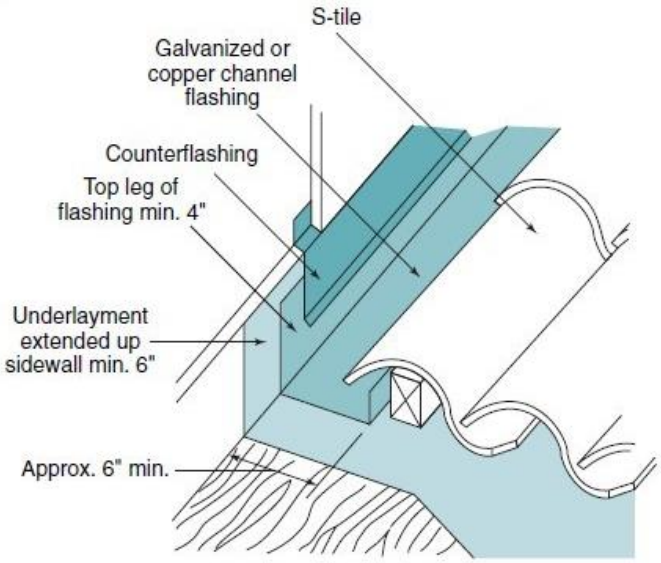


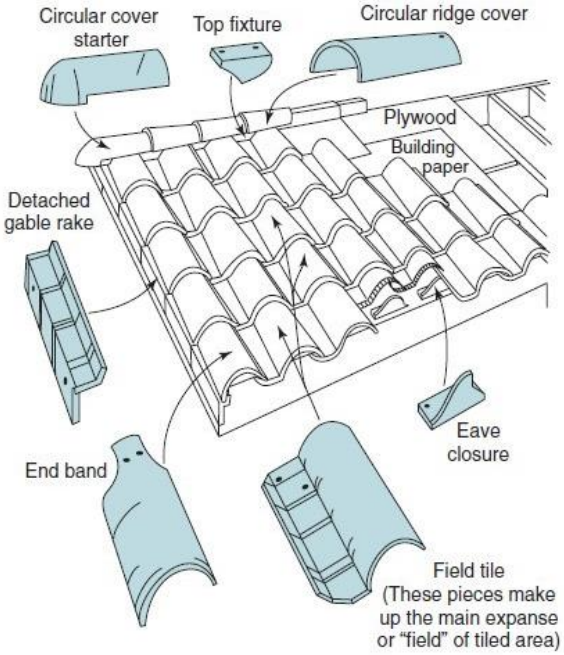
Dimensional Plan

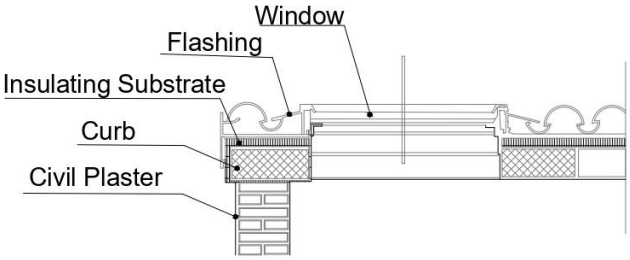
_ _ _ _ _ PMMA Line

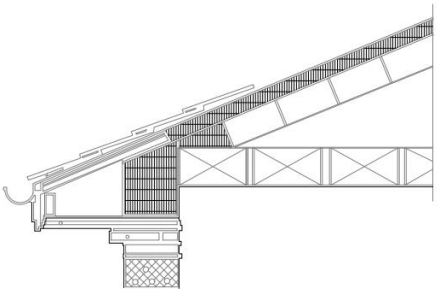
Details of Roof



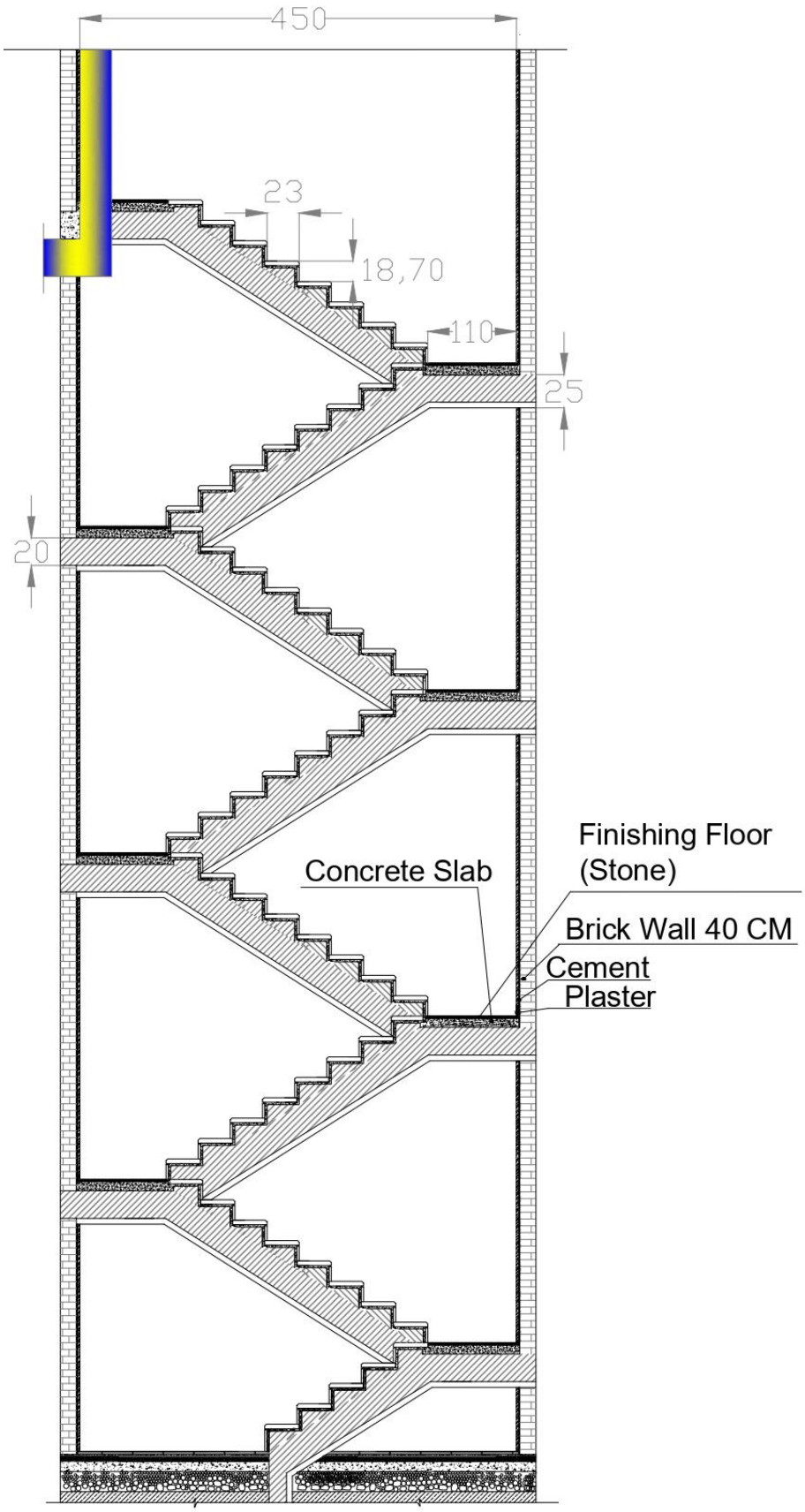




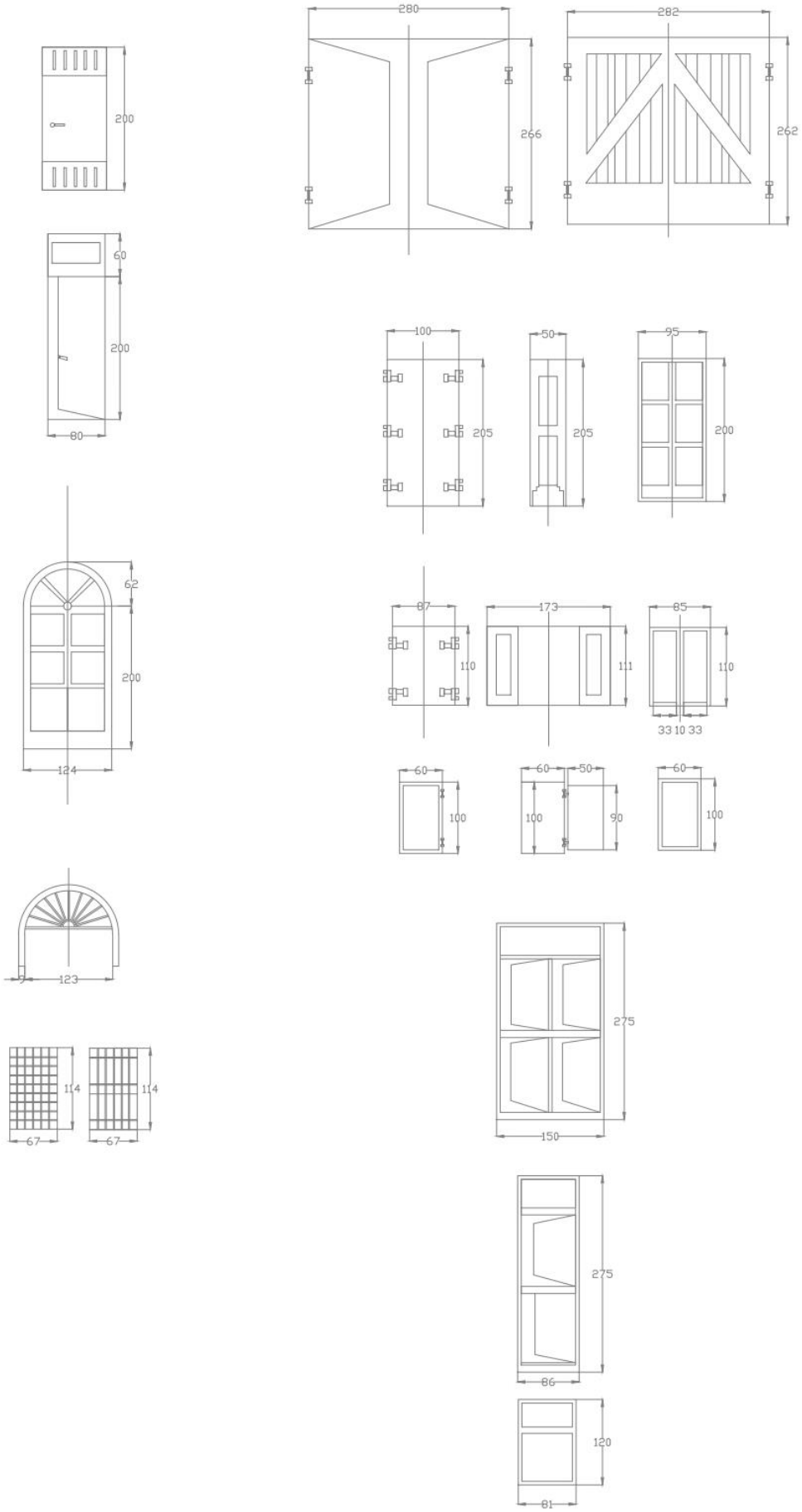




Stair Section

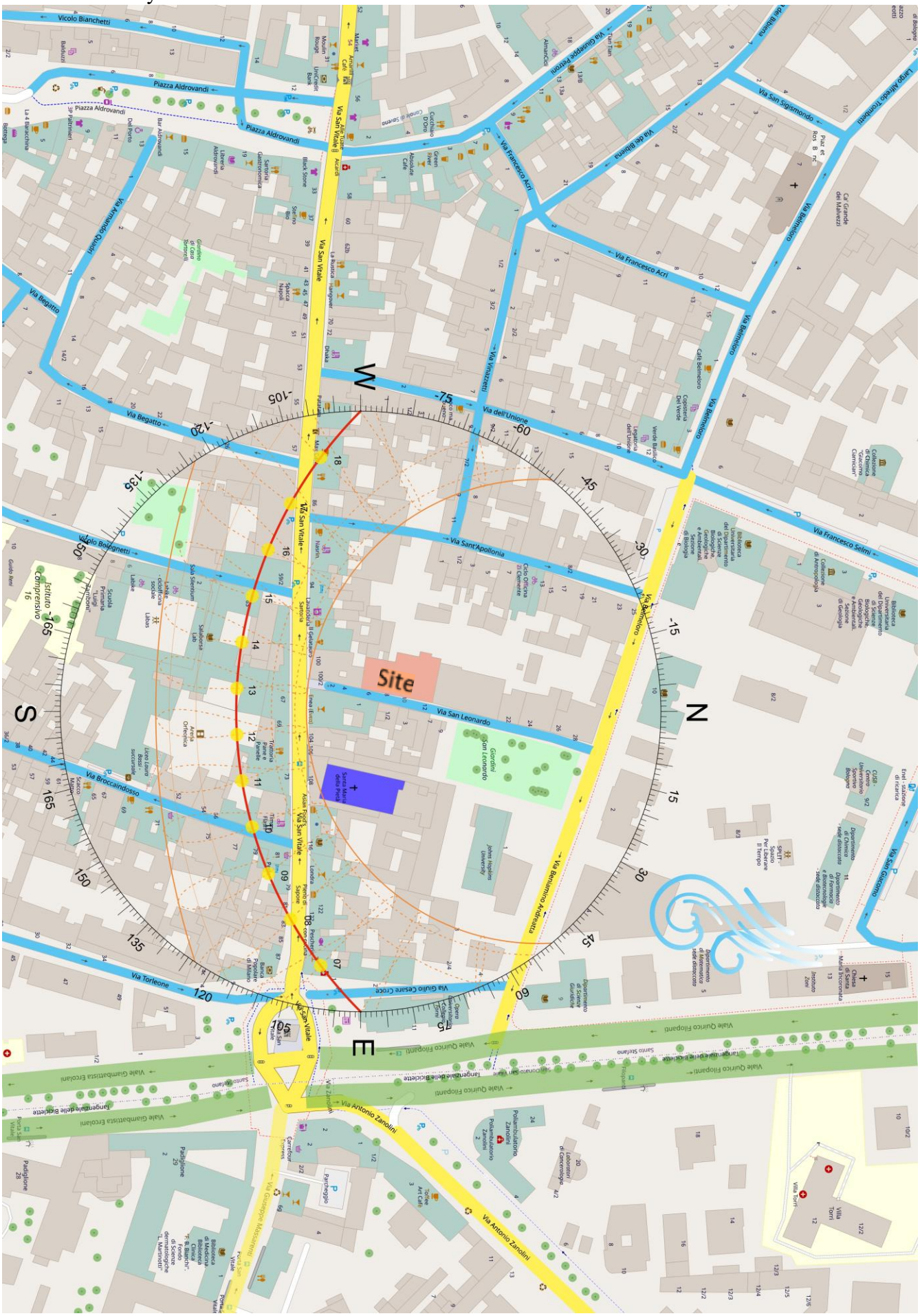


Doors And Windows



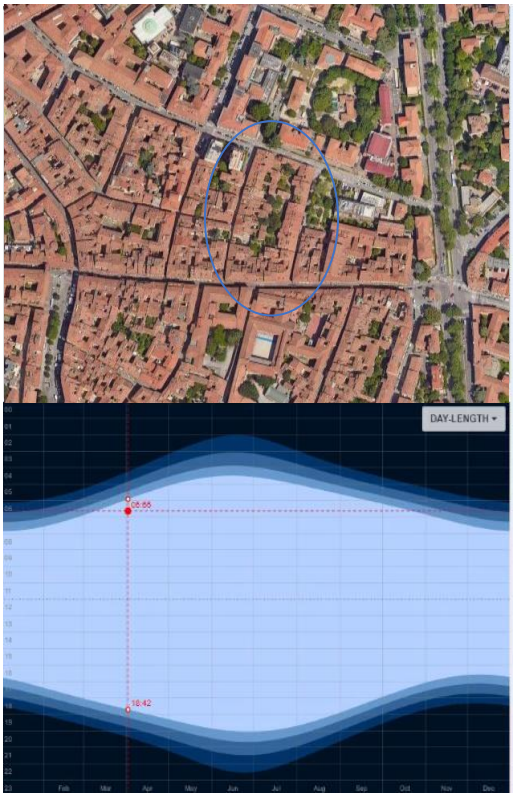
SITE ANALYSIS

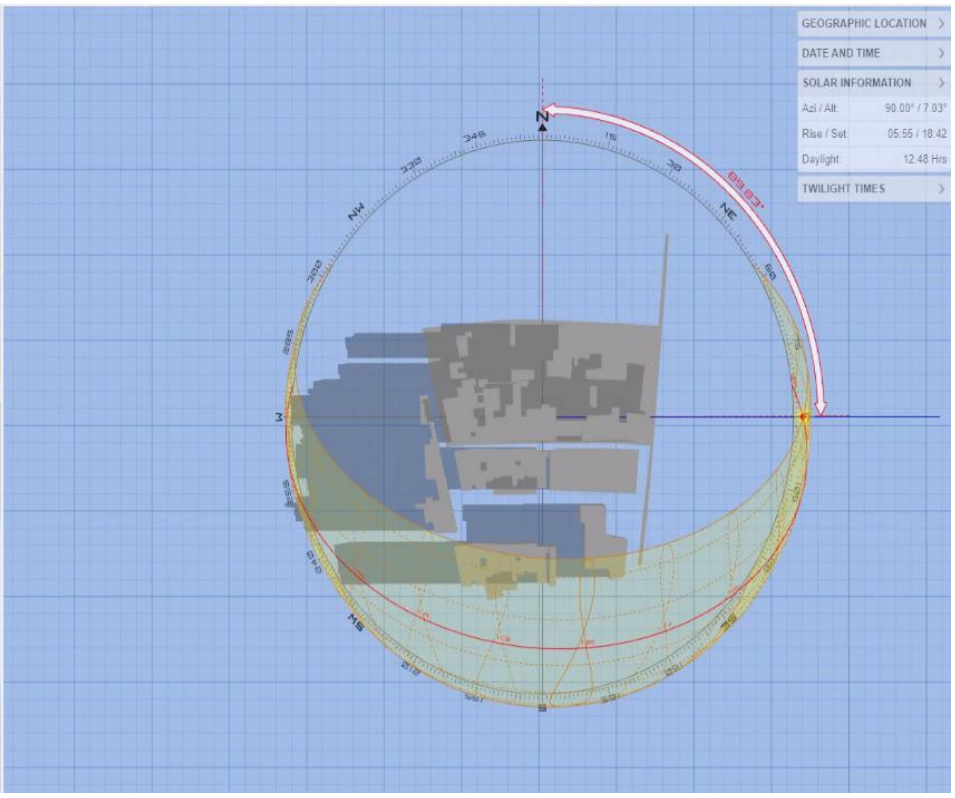
Urban Site Analysis

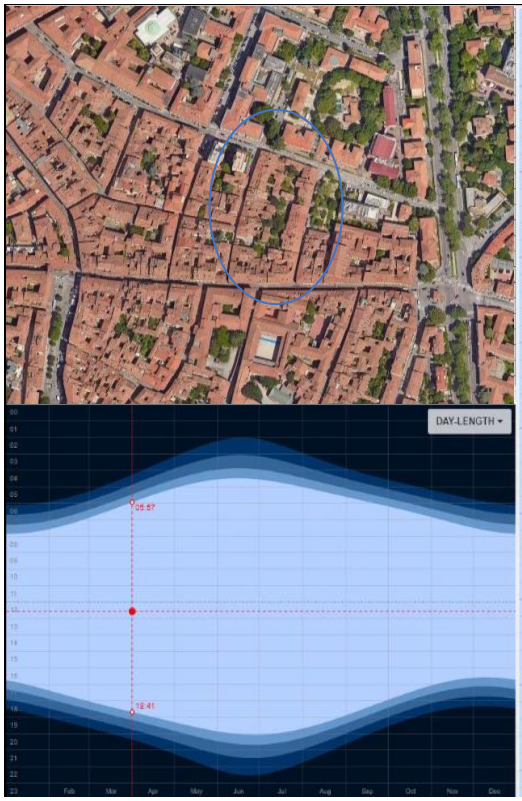


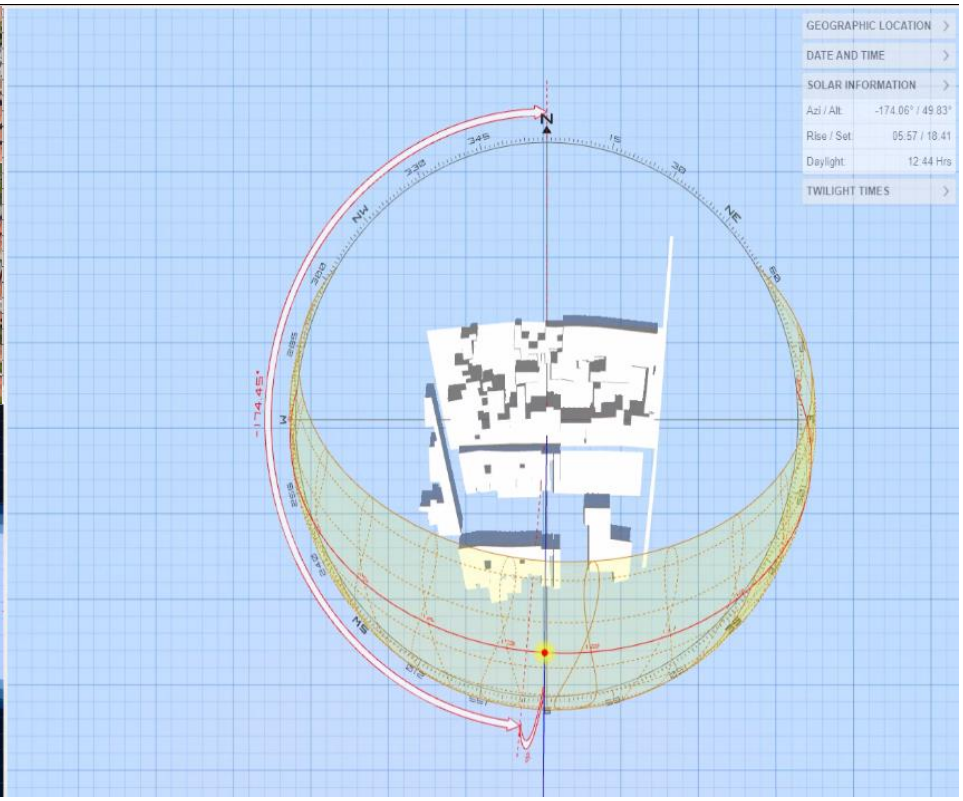
Shadow

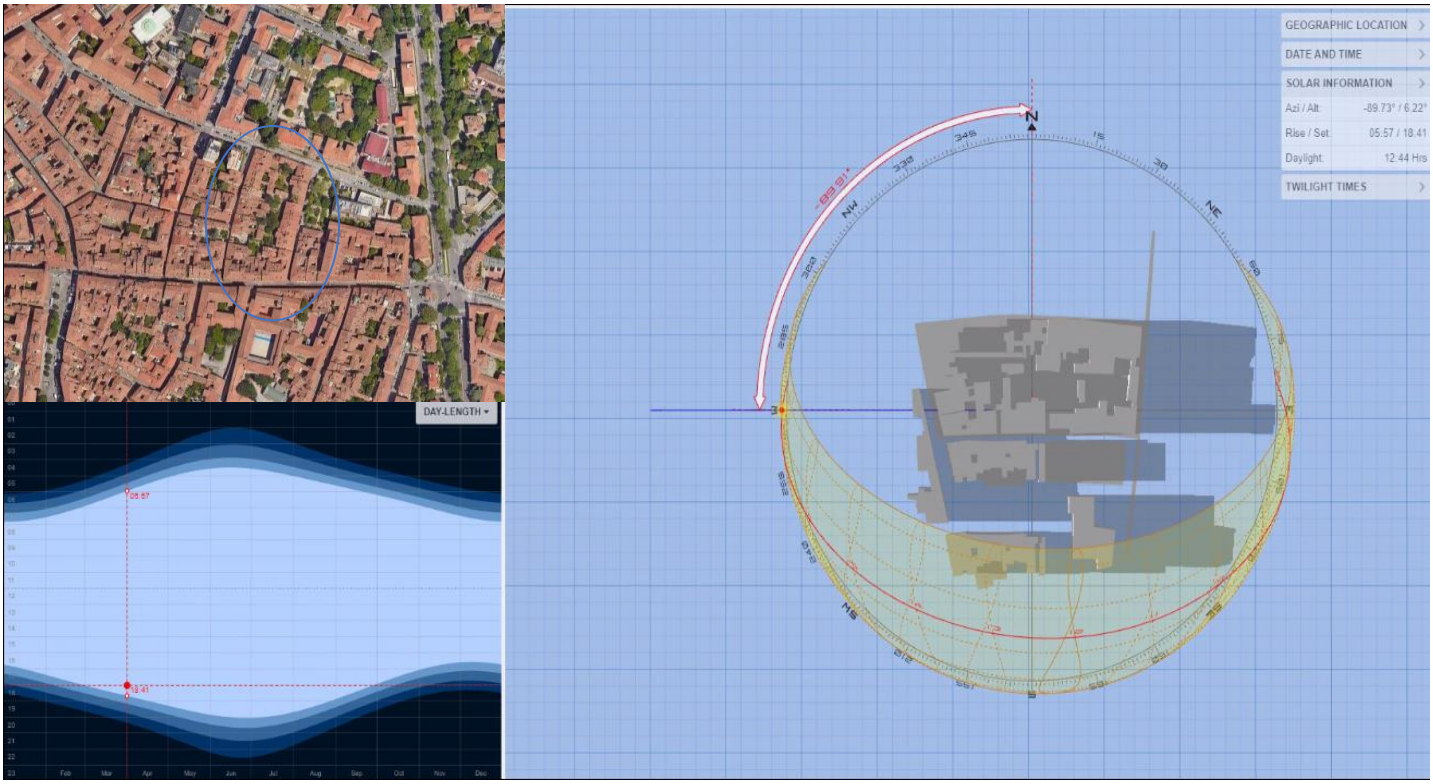
Shadow Analysis in site zone









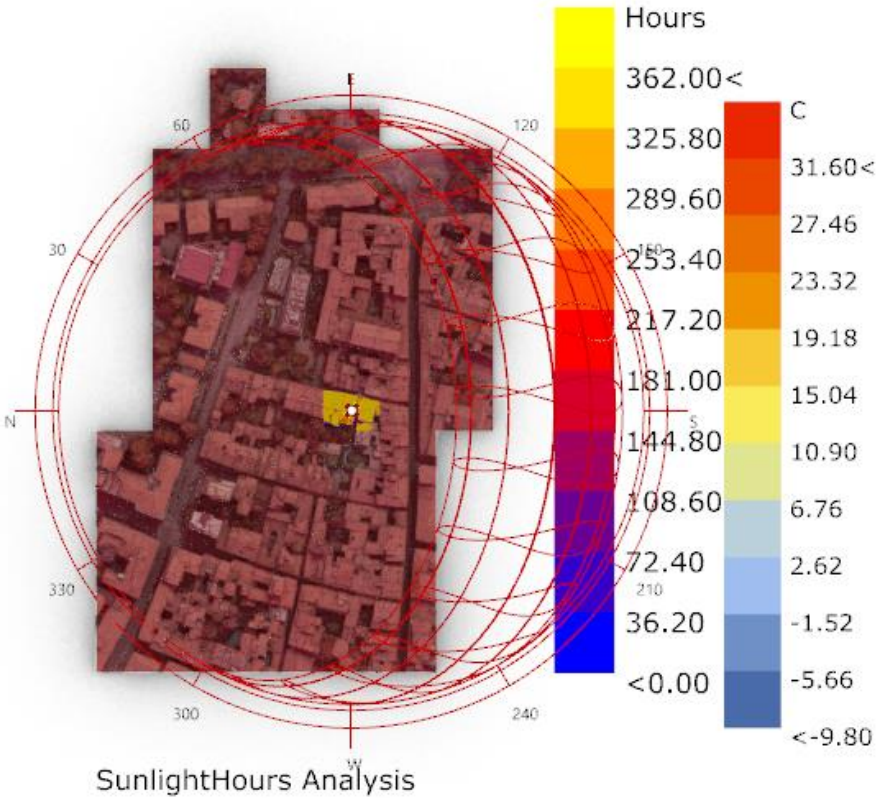


Shadow analysis is the most essential part of this project to better understand how to use the product of light to use the most efficient daylight. That is the reason for the analysis of shadow in several scales and several sessions used and attention.

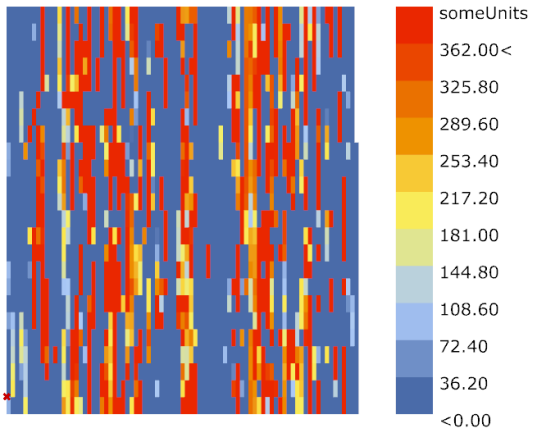
Here in the site zone, there are three images of analysis at different times of the day. As an example, the date of the study is the first of April.

Sunlight Analysis

Roof and wall analysis



SunlightHours Analysis



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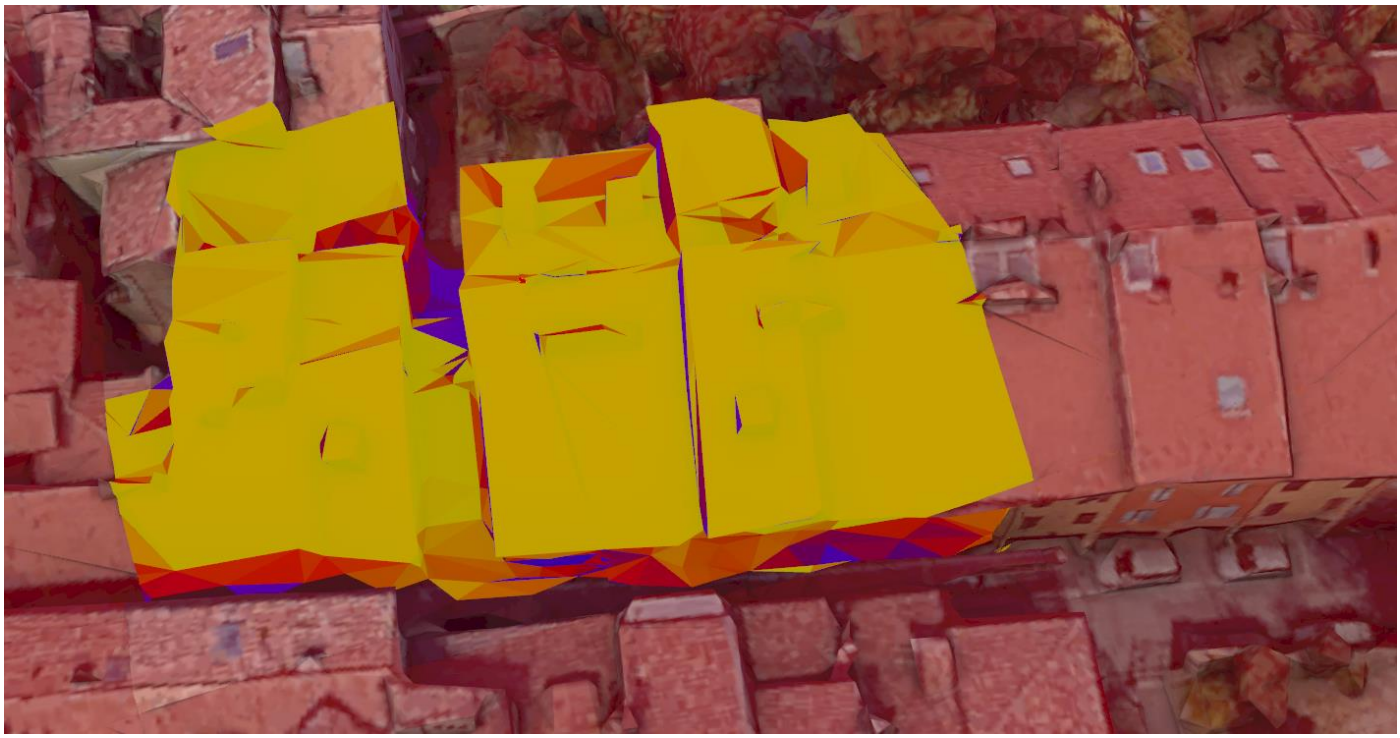

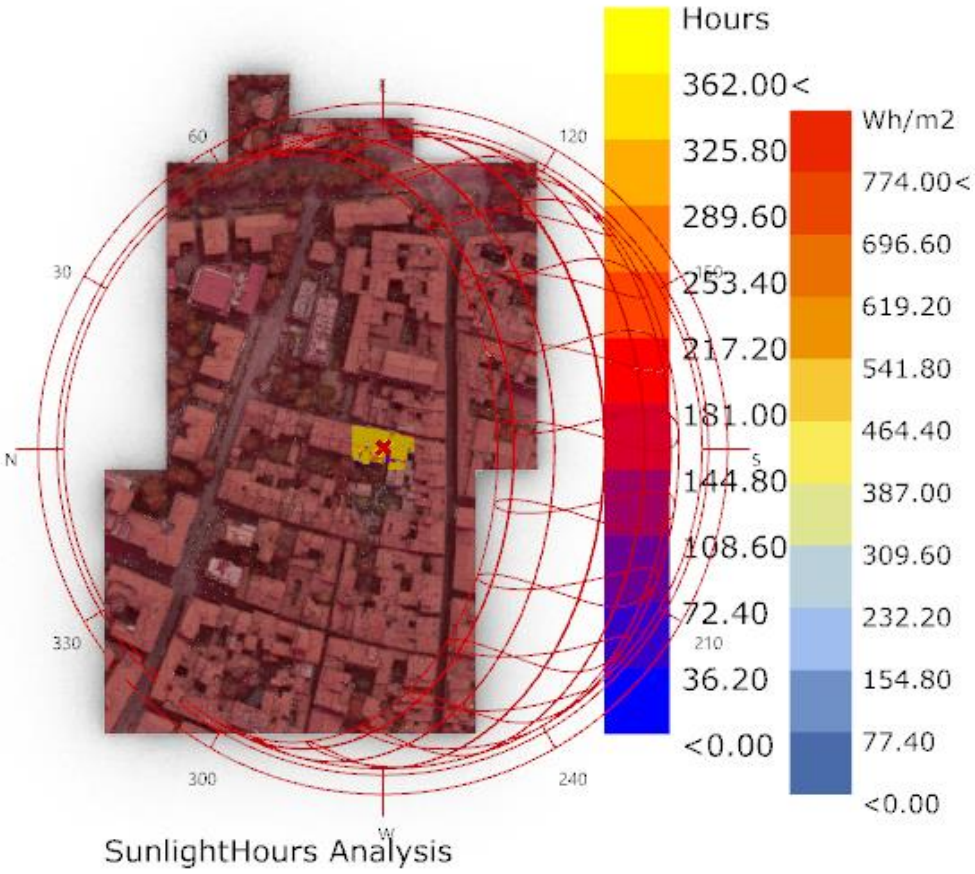
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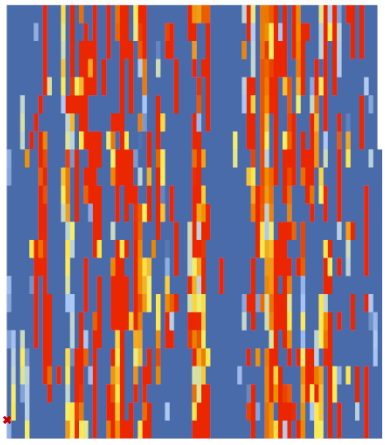
SunlightHours Analysis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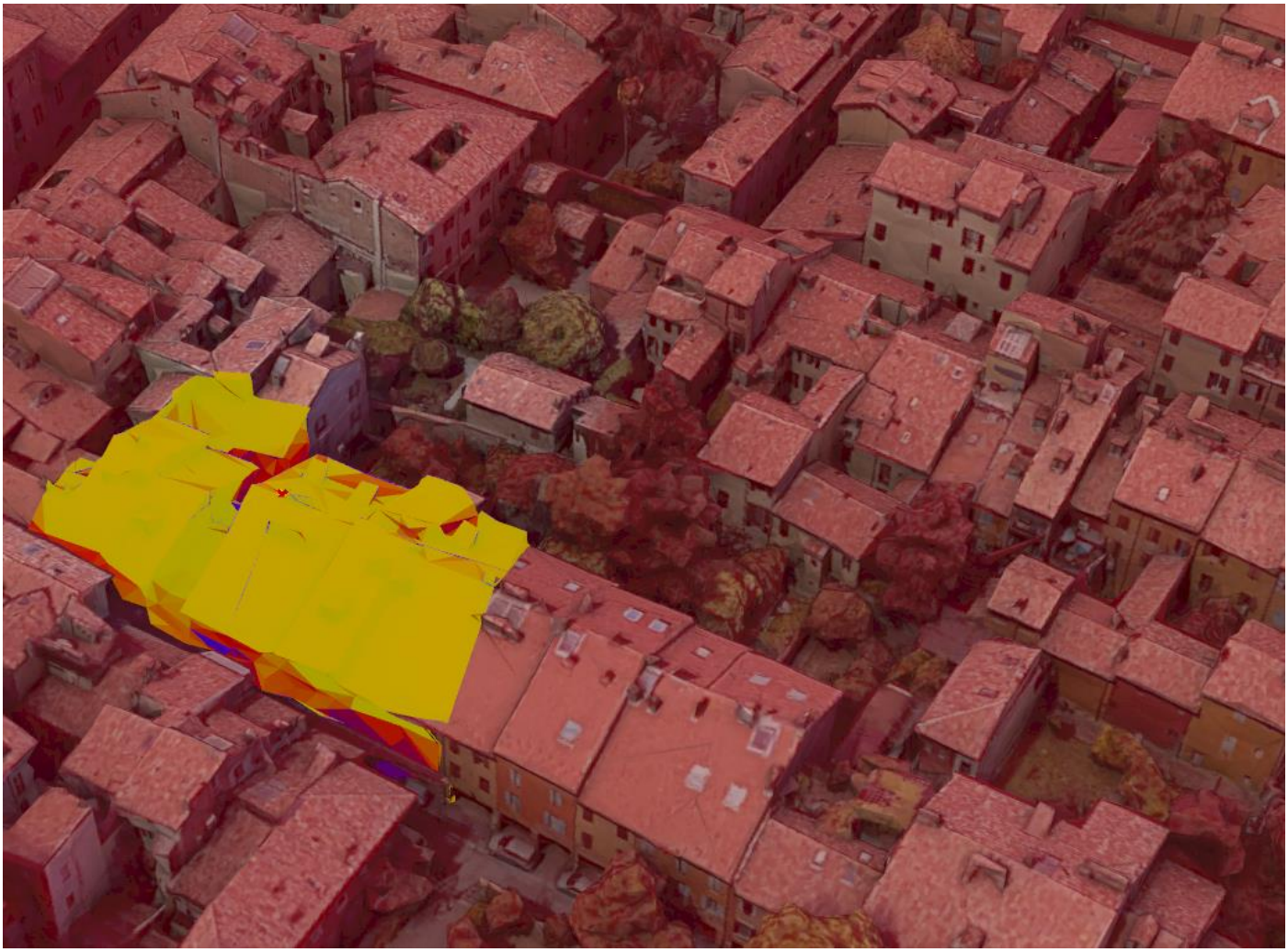

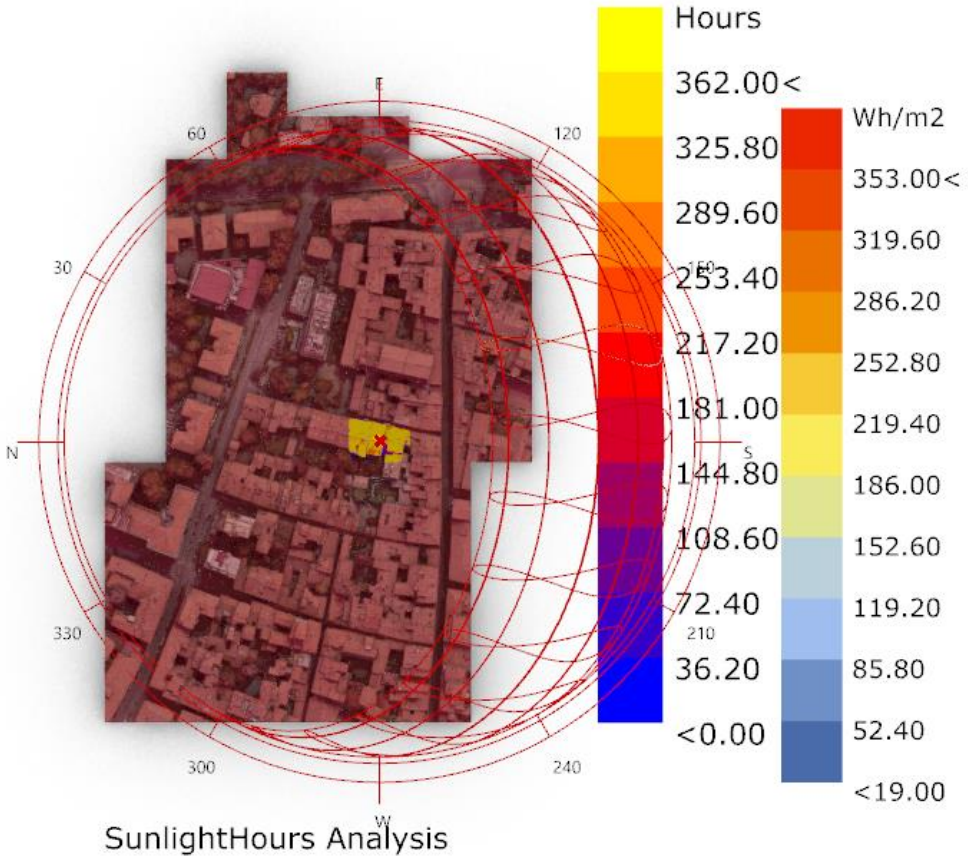
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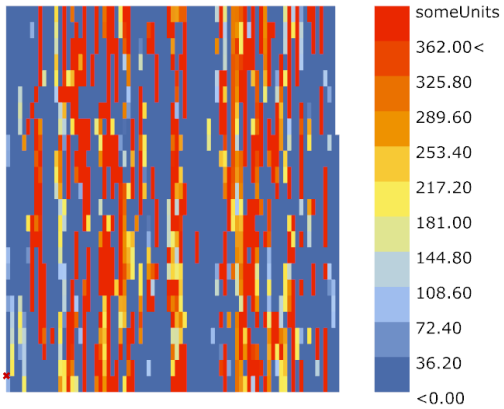
SunlightHours Analysis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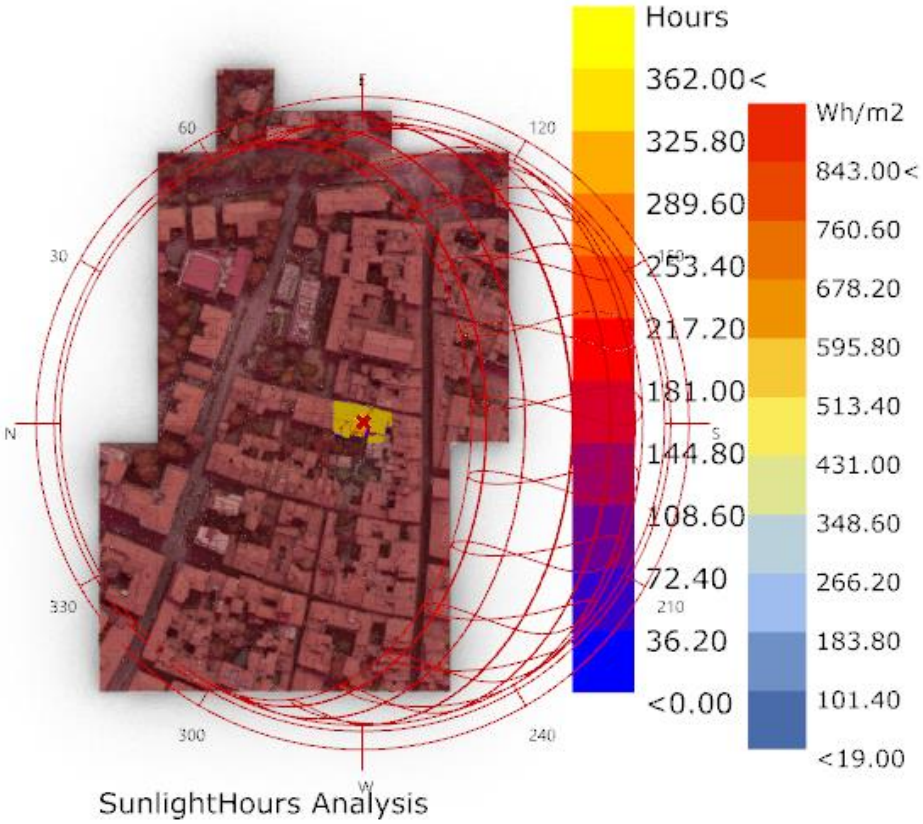
somewhere
1 JAN 1:00 - 31 DEC 24:00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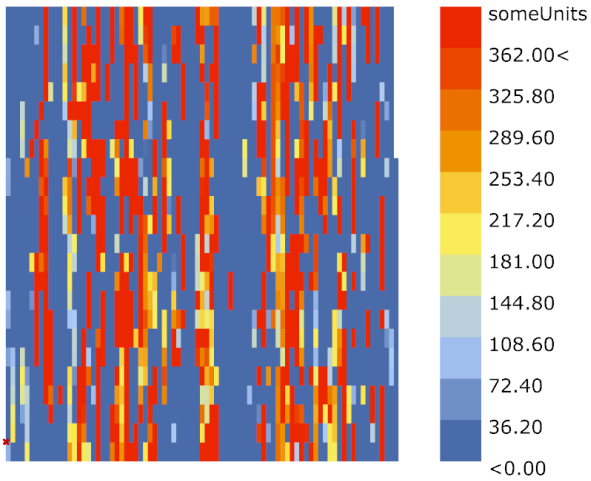
SunlightHours Analysis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72.40
36.20
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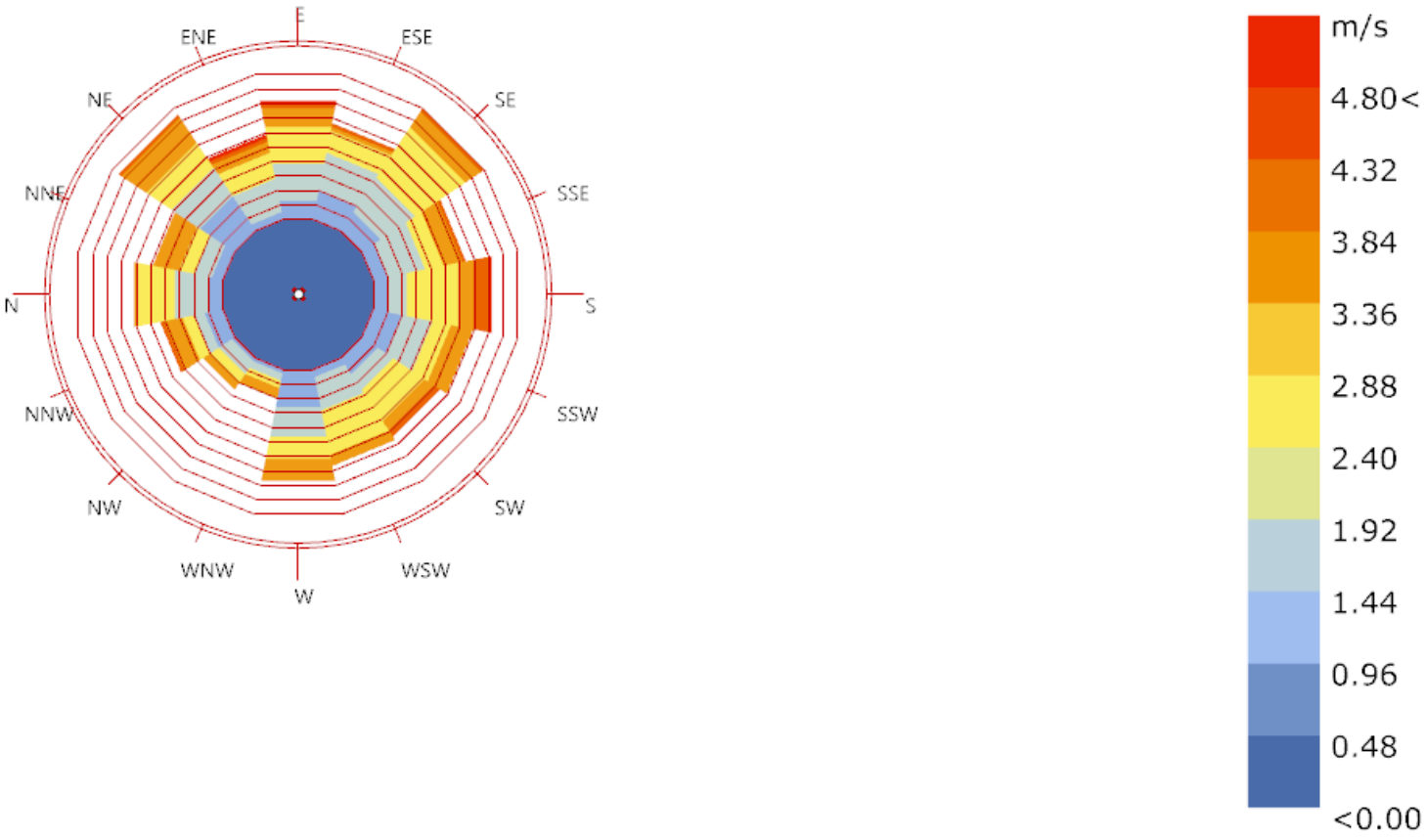
someData (someUnits) - someTimeStep
somewhere
1 JAN 1:00 - 31 DEC 24:00

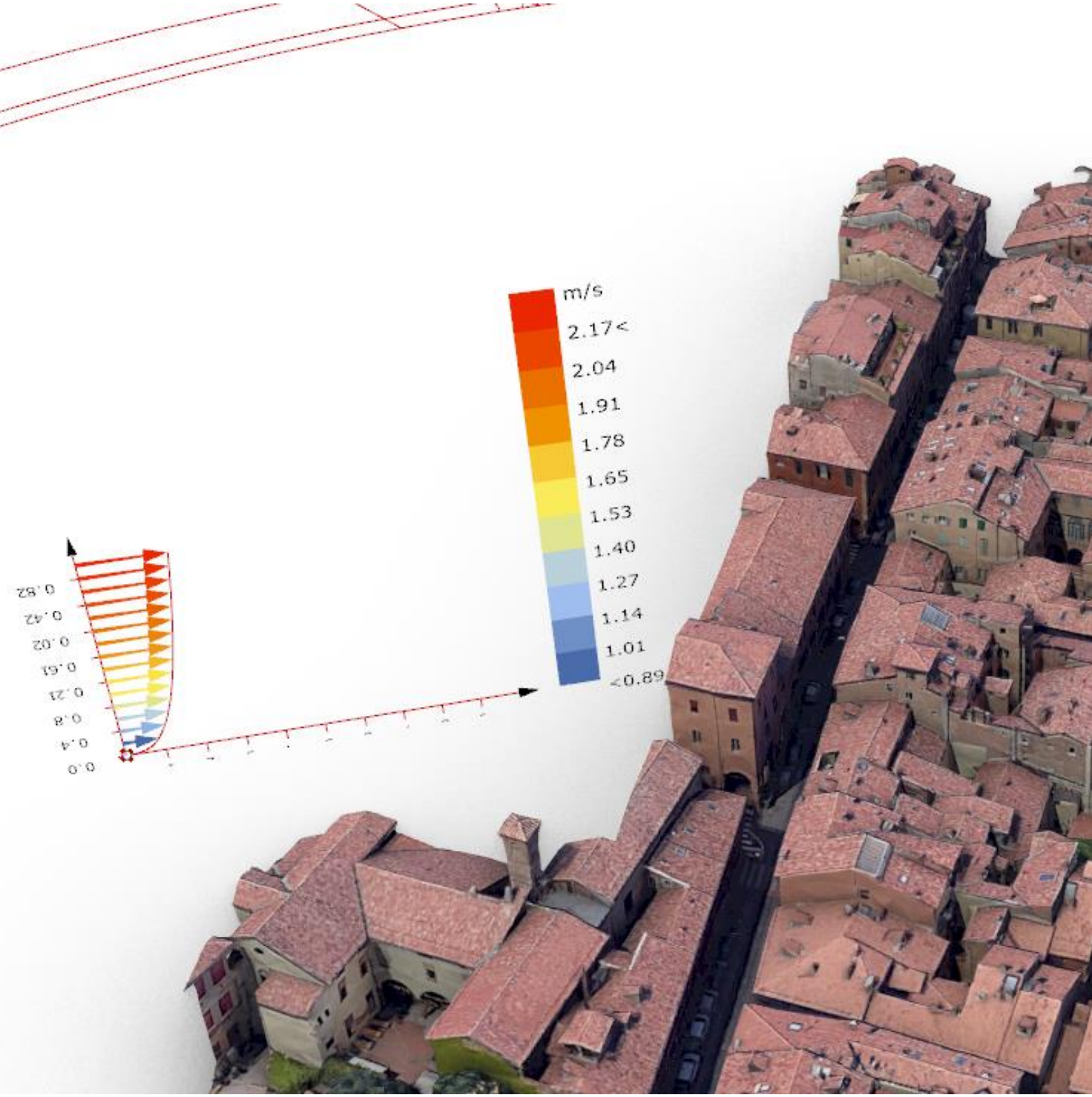
Wind Rose

In wind roses, the speed and direction of winds at a place are visualized graphically. Wind blows from a specific direction for a defined period of time, as indicated by the length of each "spoke" around the circle. Wind speed categories are indicated by colours along the spokes.



Wind-Rose
Bologna-Borgo Panigale_ITA
1 JAN 11:00 - 28 DEC 12:00
Hourly Data: Wind Speed (m/s)
Calm for 3.74% of the time = 324 hours.
Each closed polyline shows frequency of 0.0%. = 3 hours.

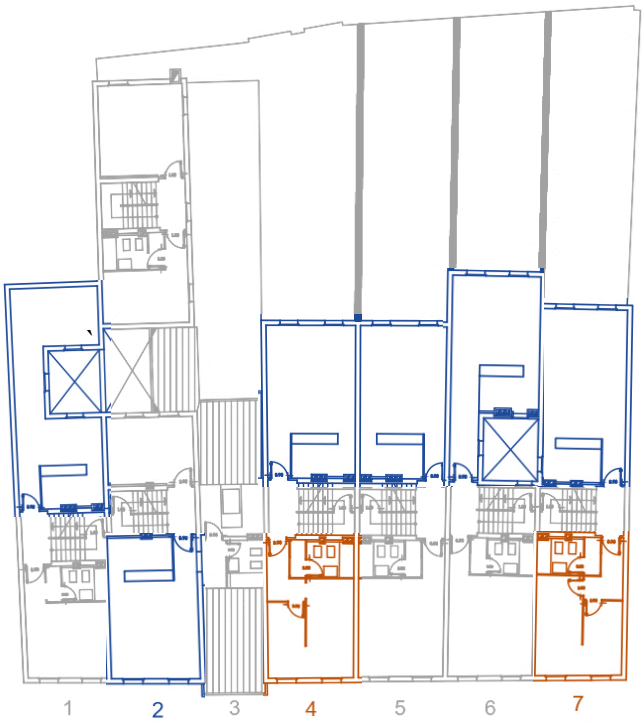
Wind Level

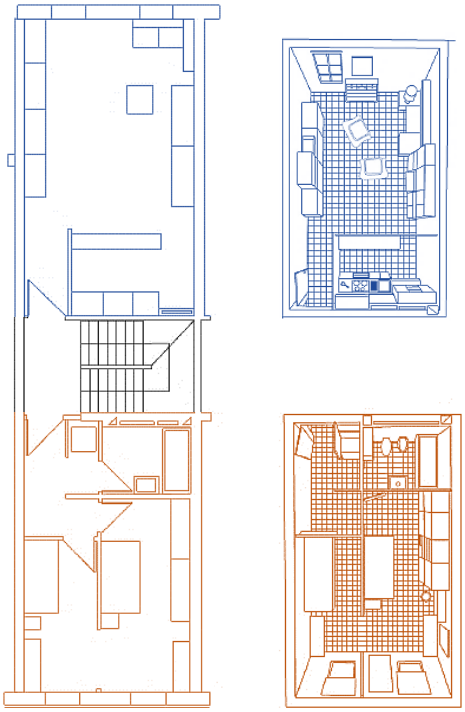


ANALYSIS THE PLAN

Typical Plan

Typical floors with decoration in second floor





Sunlight Analysis

First typical plan

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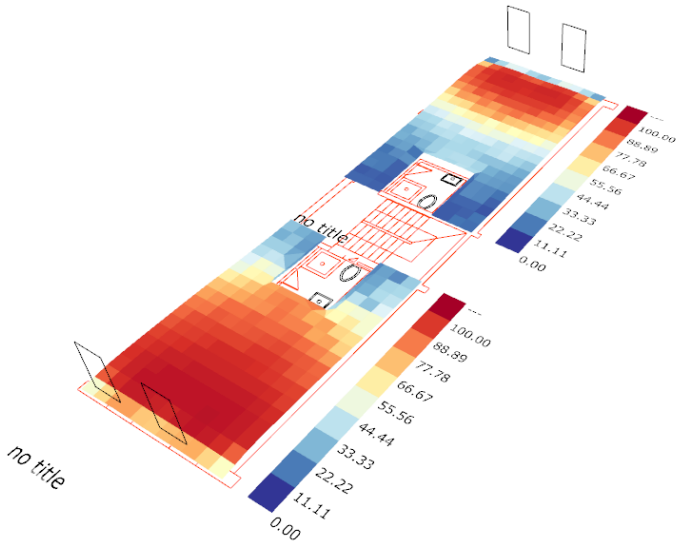

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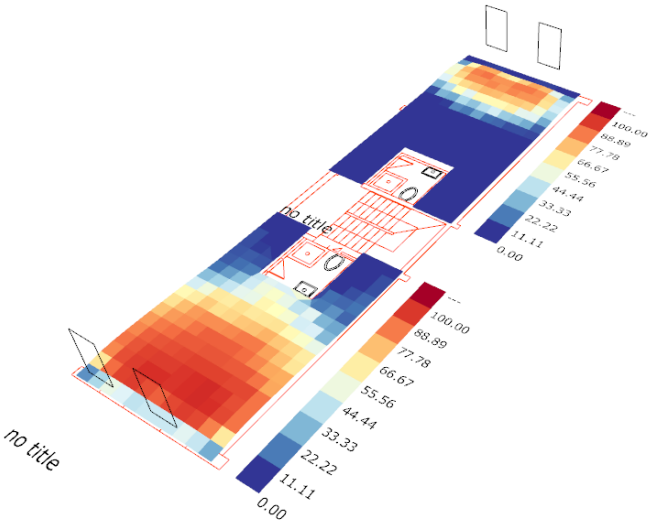

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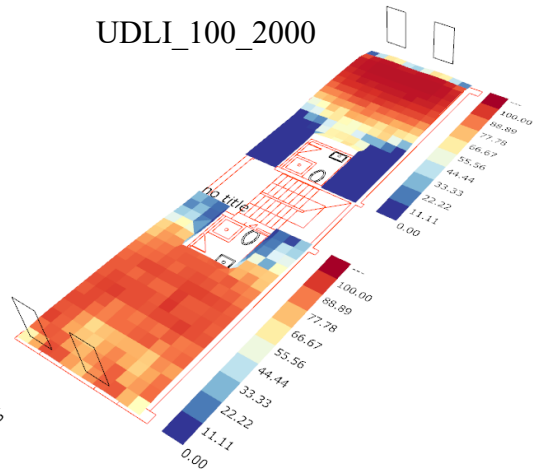

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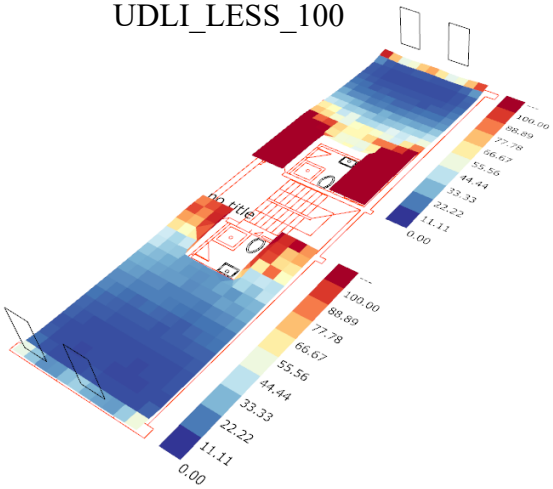

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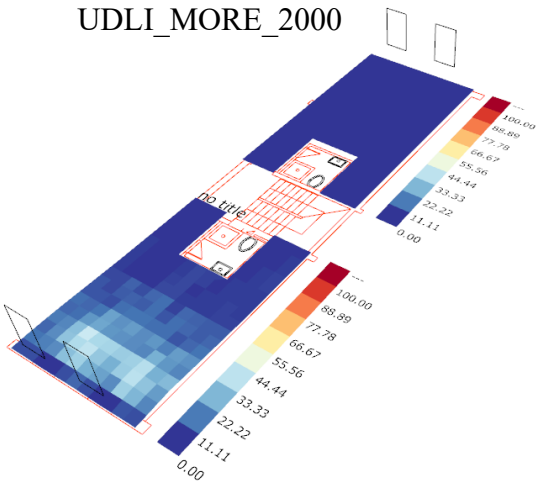
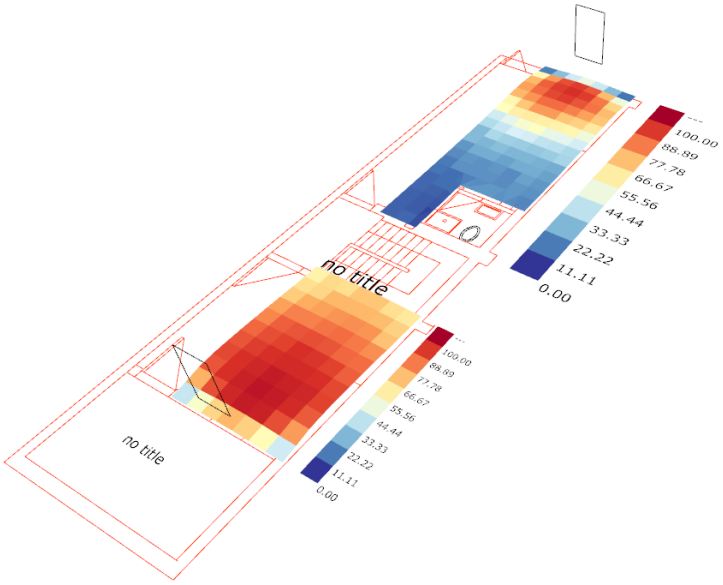


Second typical Plan

CDA



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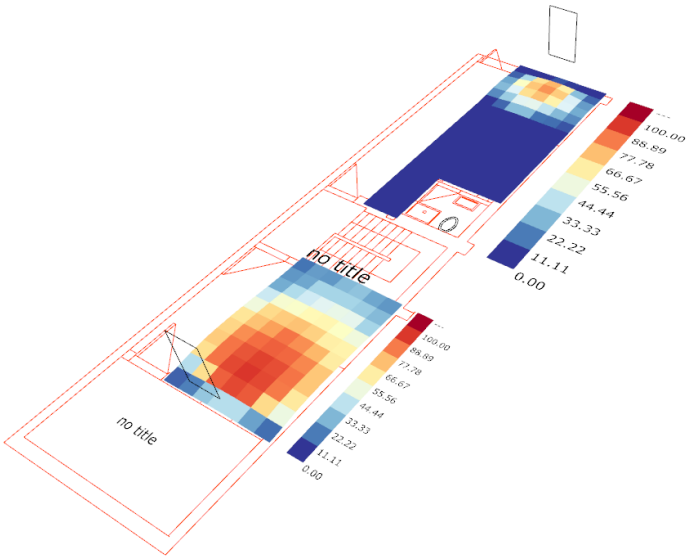

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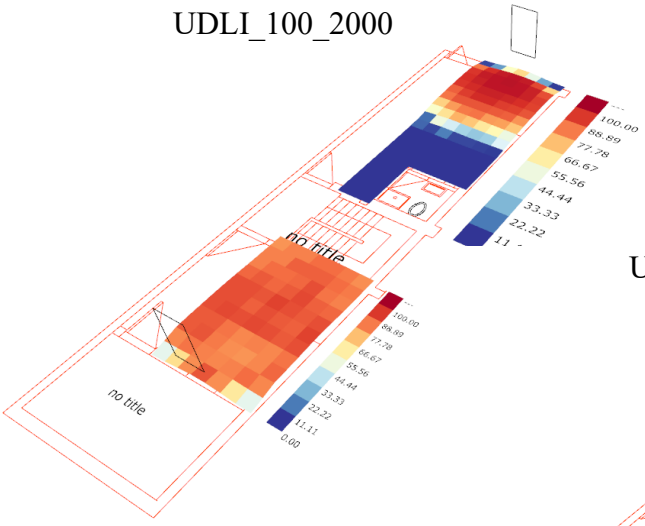

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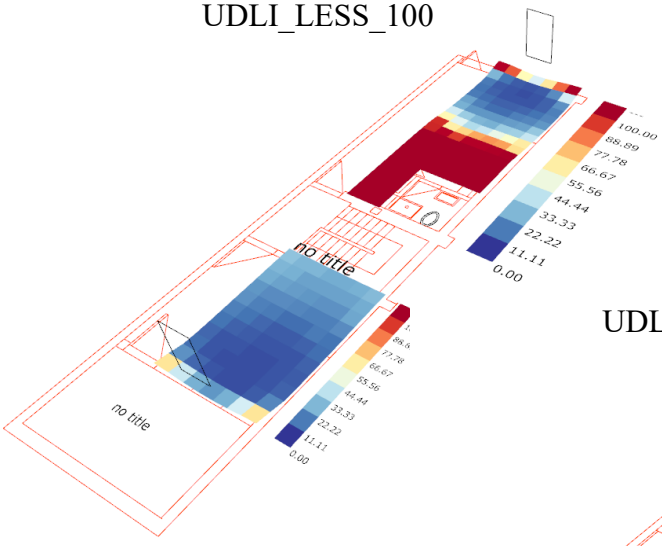

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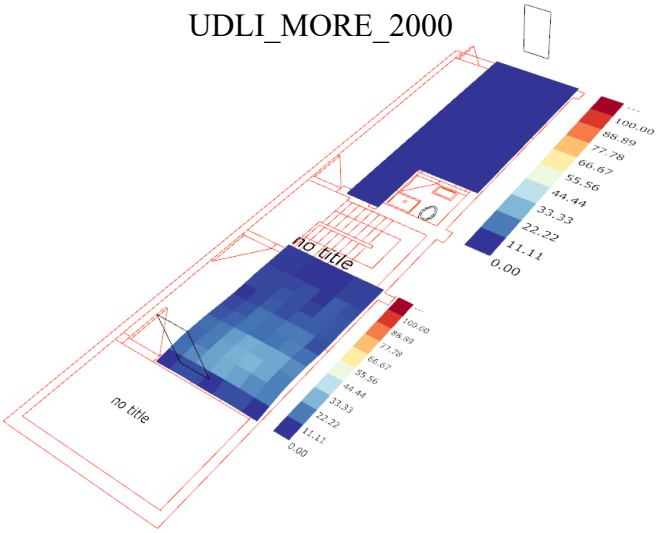
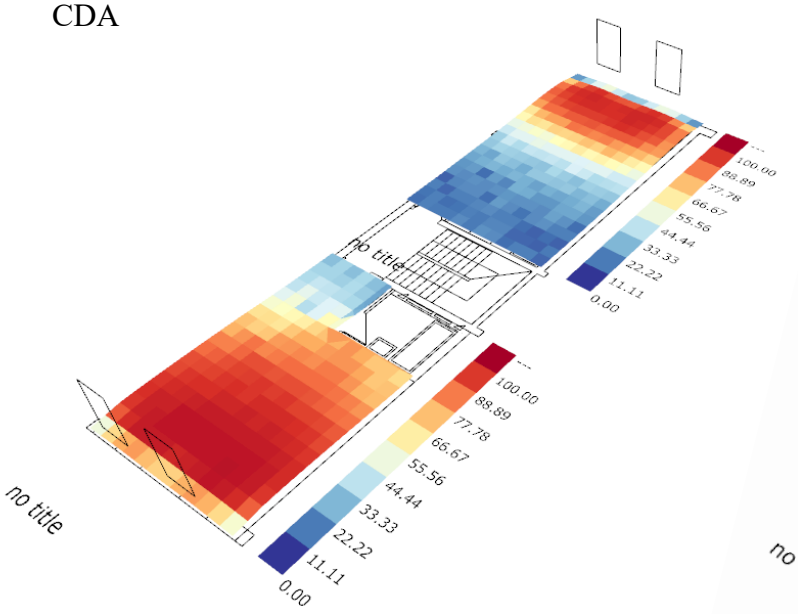


Third typical Plan (Study case)

CDA



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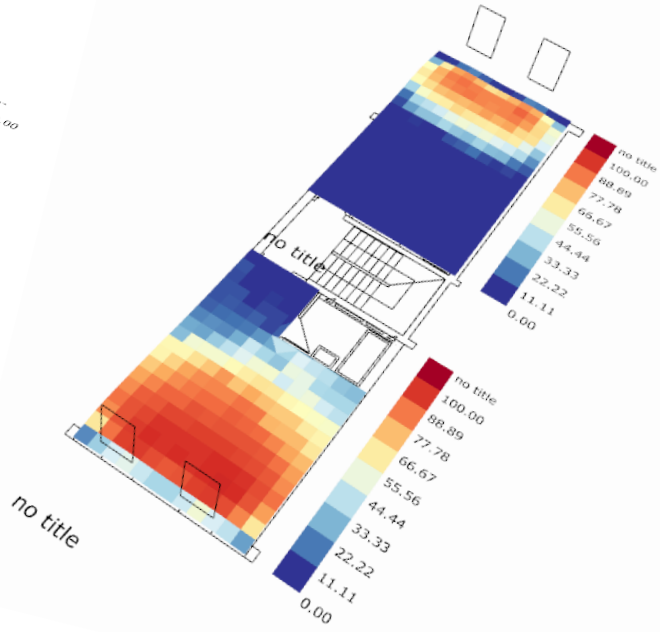

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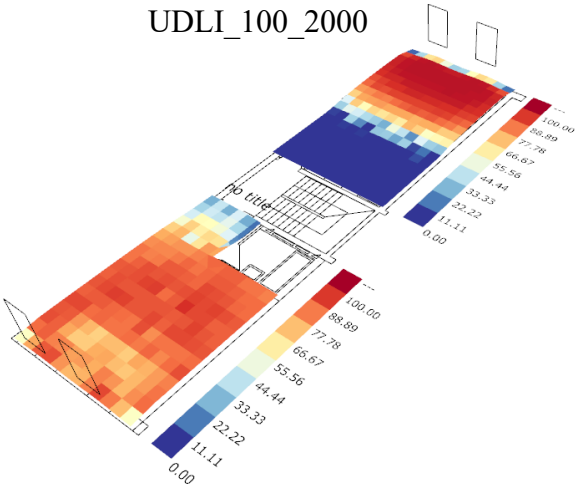

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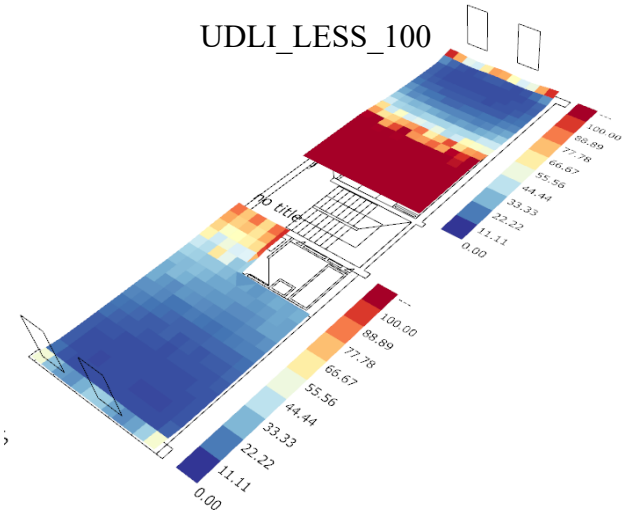

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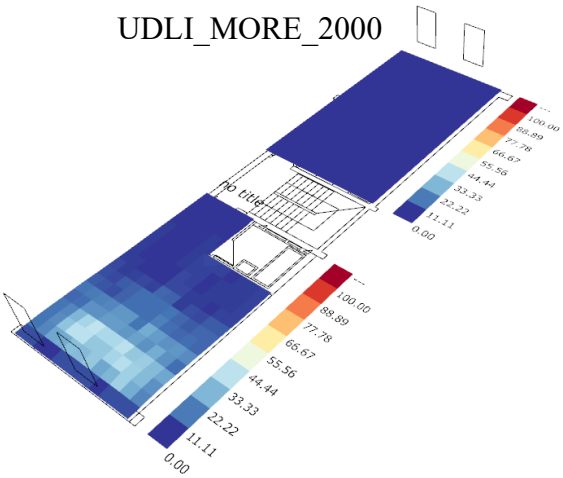
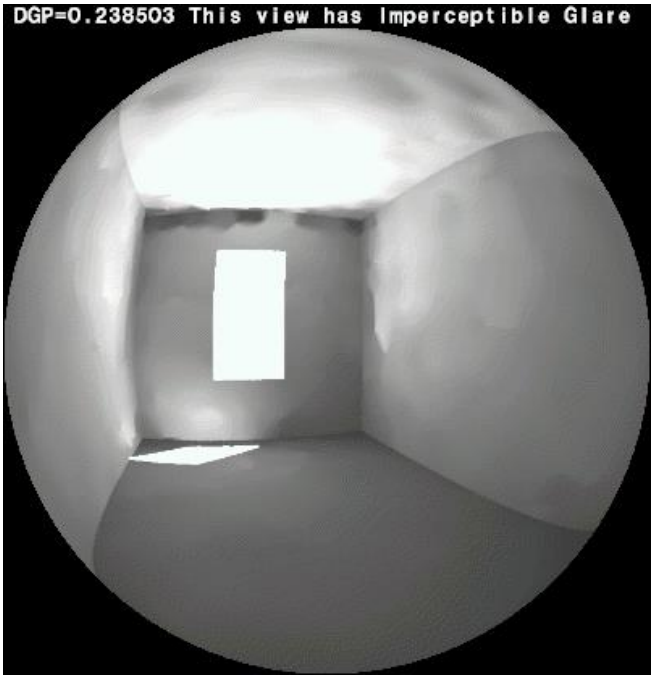


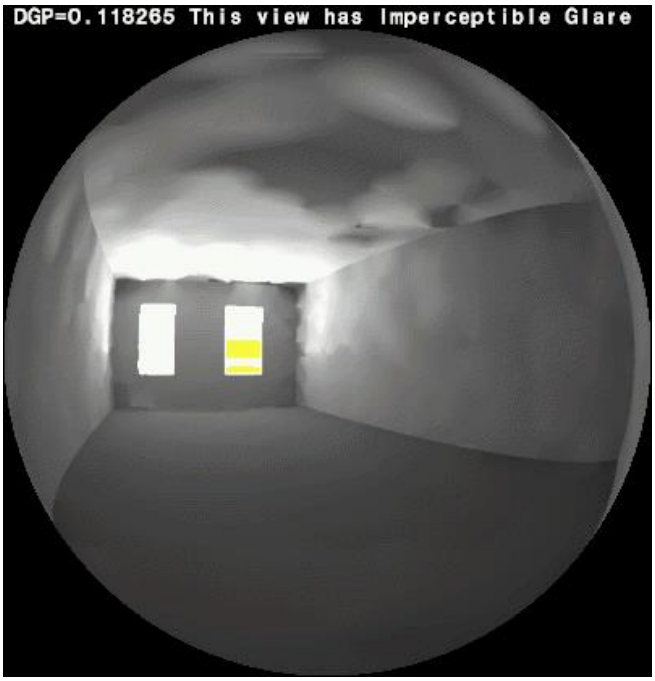
Imperceptible Glare

A variety of buildings have incorporated daylighting in order to conserve electrical energy and enhance occupant comfort. In order to evaluate daylighting design performance before construction, designers have access to many tools and metrics. By introducing natural light into a building through transparent building envelopes, excessive sunlight can cause discomfort glare for occupants. We have also developed validated metrics to accurately assess and quantify perceived levels of visual discomfort in a similar manner to daylighting tools and metrics. There are currently sophisticated and complex glare metrics and tools that can analyse discomfort glare very thoroughly, but they only report the results based on the glare categories, without providing much information to the user about the reasons for the discomfort.


DGP=0.238503 This view has Imperceptible Glare

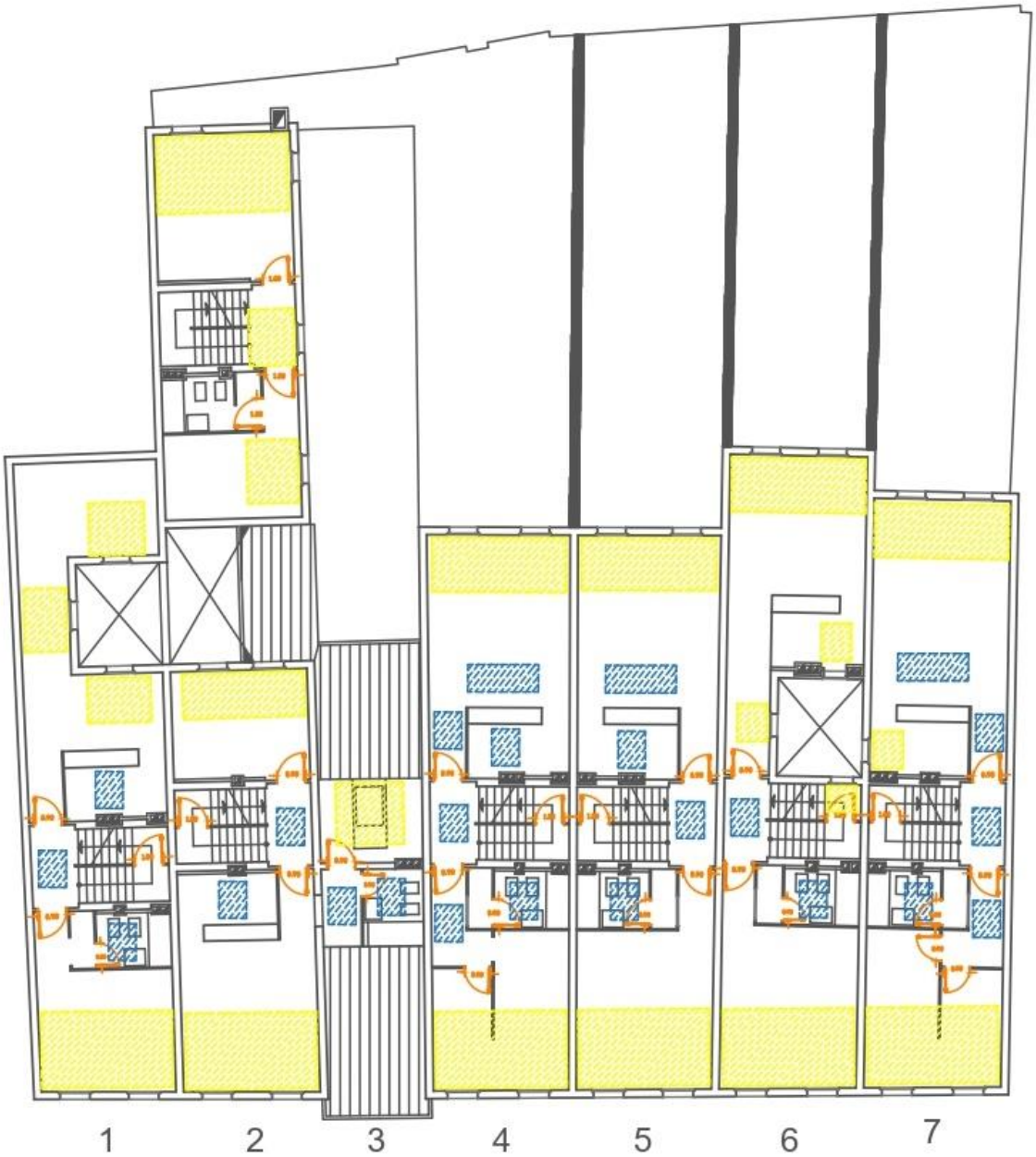

DGP=0.021948 This view has Imperceptible Glare


DGP=0.238094 This view has Imperceptible Glare


DGP=0.118265 This view has Imperceptible Glare

Problem of Daylight in Building

According to this plan, blue and yellow marks show which parts of the plan could access or not access daylight. The problem is that centre of the plan needs artificial light. But the quality of daylight and energy spending is not compatible with natural light. Also, sometimes creating windows in the façade is not a suitable solution because of interior design, façade design and isolation.



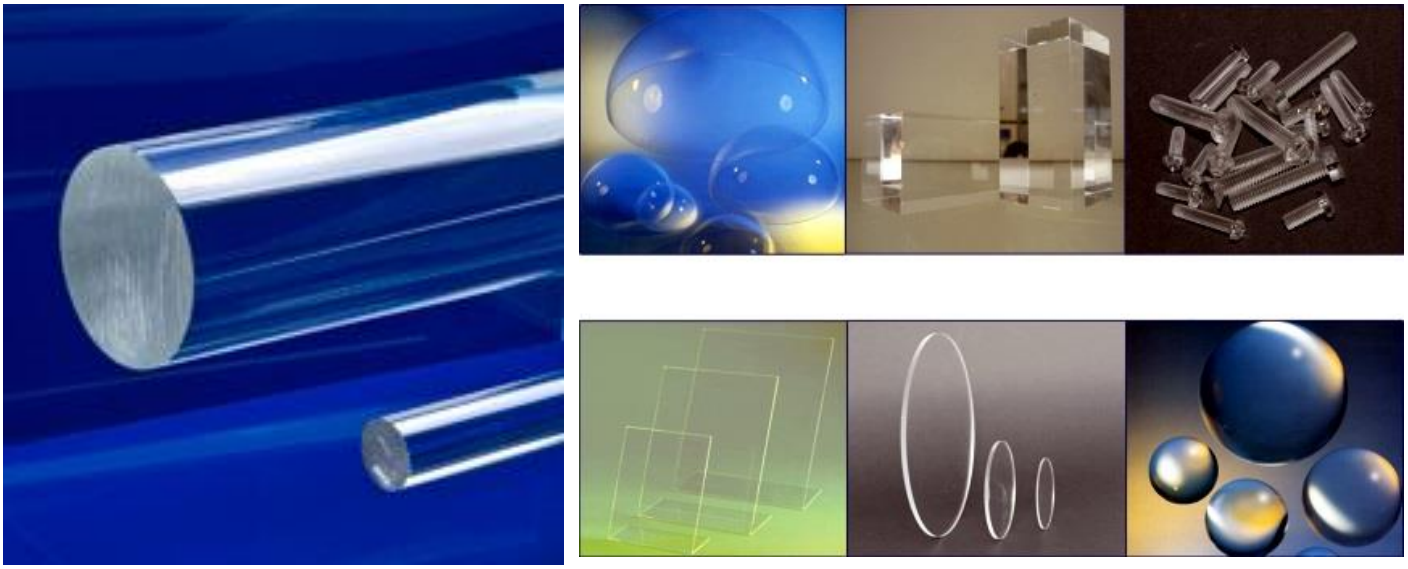
Light area

Dark area

POLYMETHYL METHACRYLATE (PMMA)

In science, Poly (methyl methacrylate) is the name given to acrylic, acrylic glass, and plexiglass, which are synthetic polymers. Amounts of light can be transmitted through it when not modified, although it is brittle, transparent, and lightweight when unmodified. After it is modified, it can take on a wide variety of colour casting options, textures, and shapes. The Plexiglas product was first introduced to the market by Otto Rohm in 1993 as a product that was first discovered in 1893 by a French chemist.

This material with the features that were discussed and will be discussed below, in the lighting and lighting industry has been able to become a suitable material for the implementation of some ideas. This material is the main part of optical fibres and is also used in the manufacture of special lights.



Physical Properties	Value
Density	**1.15 - 1.19 g/cm3**
Water Absorption	**0.3 – 2 %**
Moisture Absorption at Equilibrium	**0.3 - 0.33 %**
Linear Mould Shrinkage	**0.003 - 0.0065 cm/cm**
Melt Flow	**0.9 – 27 g/10 min**

PMMA is used in many cases because of its unique features. Almost the light conductivity feature is the most significant feature of this material. Conventional PMMA transmits up to 93% of light, which is more than other materials such as glass or plastic. This remarkable feature has led to its use in the manufacture of many lightings' equipment.

Physical Properties

Hardness levels, the surfaces of this material show good resistance against scratches and such damages. This feature will be very useful and suitable in cases where visual beauty is of special importance to us in the long run.

Due to the orientation effect, it exhibits significantly different strengths during injection molding in longitudinal and transverse directions. PMMA's mechanical properties change as the temperature increases, just as they do with other thermoplastics. It is incompatible with multiple dynamic loads due to its creeping behaviour. In terms of direct sunlight exposure, PMMA is one of the most resilient polymers. As well as in the presence of ozone, its strength characteristics display relatively small variations. A product intended for long-term outdoor use can benefit from PMMA's properties.

Mechanical Properties	Value
Hardness, Rockwell M	**63 - 97**
Tensile Strength, Ultimate	**47 - 79 MPa**
Elongation at Break	**1 - 30 %**
Tensile Modulus	**2.2 - 3.8 GPa**
Flexural Modulus	**3 - 3.5 GPa**
Izod Impact, Notched	**1.2 – 20k J/m2**
Izod Impact, Unnotched	**11kJ/m2**
Tensile Creep Modulus, 1 h	**1800 - 2700 MPa**
Tensile Creep Modulus, 1000 h	**1200 - 1800 MPa**

UV Resistance

Because it is UV resistant, it is used for outdoor equipment. In fact, this material can be used in such spaces for a long time without changing the colour.

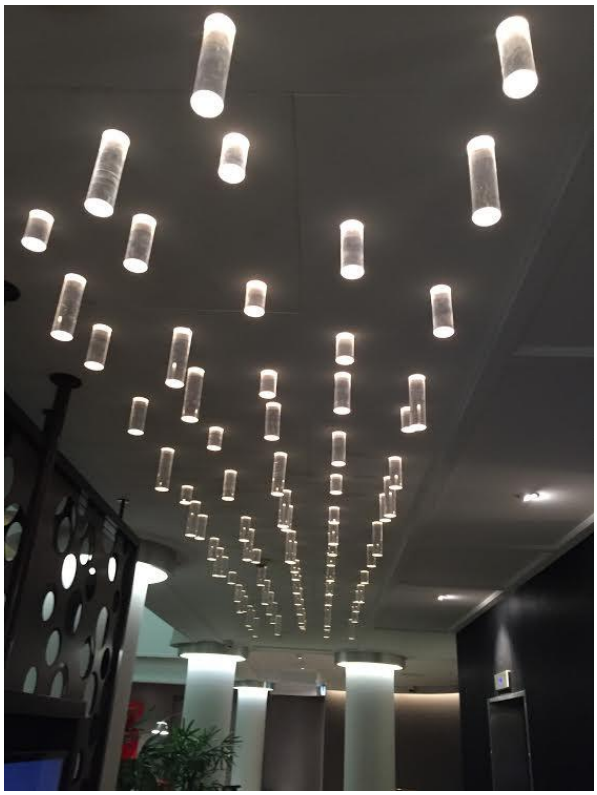
Unique Propities for Unique Performance

In contrast, breaking this material is a suitable alternative to glass. It can also be improved by combining with other substances that enhance its properties. These changes in its composition are usually made to improve the properties of this polymer for special applications. Examples of features that can be adjusted in this way include impact resistance, chemical resistance, flame retardant, light scattering, UV filter, or light effects, and so on.

Applications

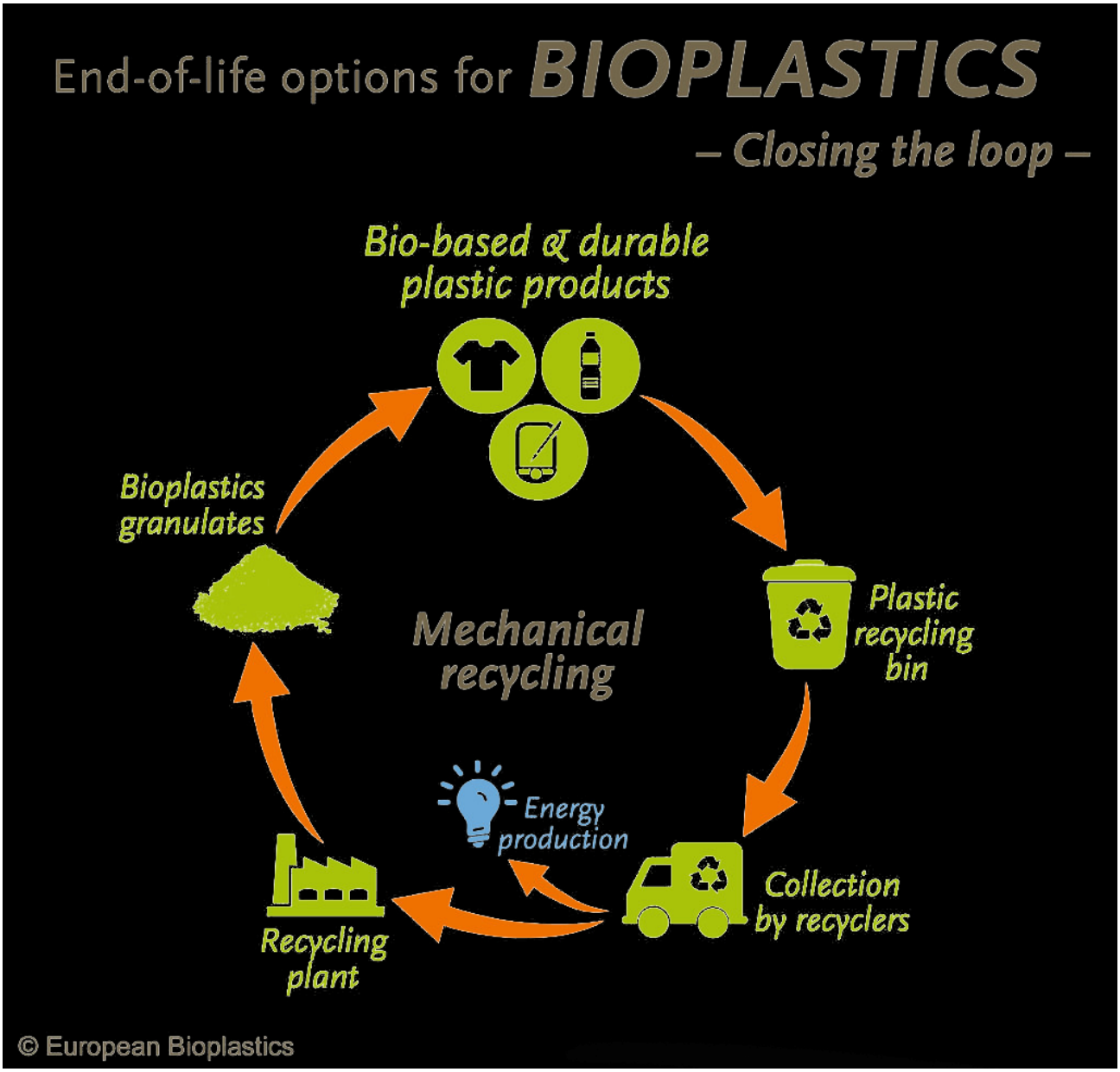
PMMA is a cost-effective, all-purpose polymer with several uses. Extruded and/or cast materials are available in sheet, rod, and tube forms, as well as in bespoke profiles. There are several different varieties of acrylics used in many different industries and purposes, including:

- **Optical products**, such as dust covers for audio equipment, sunglasses, watch glasses, lenses, and magnifying glasses;
- **Vehicles**: such as rear lights, indicators, tachometer covers, and caution triangles;
- **Electrical engineering:** supplies include lamp covers, switch parts, dials, and control buttons;
- **office supplies**: include pens and writing and drawing implements;
- **Medicine**: Containers for tablets, capsules, suppositories, urine, and sterilisable equipment;
- **Other**: Leaflet dispensers, shower cubicles, transparent pipelines, lit signs, and toys.



Sustainability of PMMA

The topic of the current study is the efficient use of plastics made from electronic trash. In this study, two different polymers were used to create PVC/PMMA recycled blends using mechanical recycling techniques at various compositions. Poly (vinyl chloride) (PVC) was recovered from data cables and Poly (methyl methacrylate) (PMMA) was recovered from liquid crystal display (LCD) panels used in computers. The blends were evaluated for various morphological, thermal, physicomechanical, and processability investigations. For recycled blends including a higher weight % of recycled PVC, improved impact strength and elongation at break were noted. Recycled PMMA (r-PMMA): Recycled PVC (70:30 wt ratio) in recycled blend demonstrated superior impact strength and elongation at break compared to the other blends. The recycled materials' thermal deterioration.



PRODUCT DESIGN

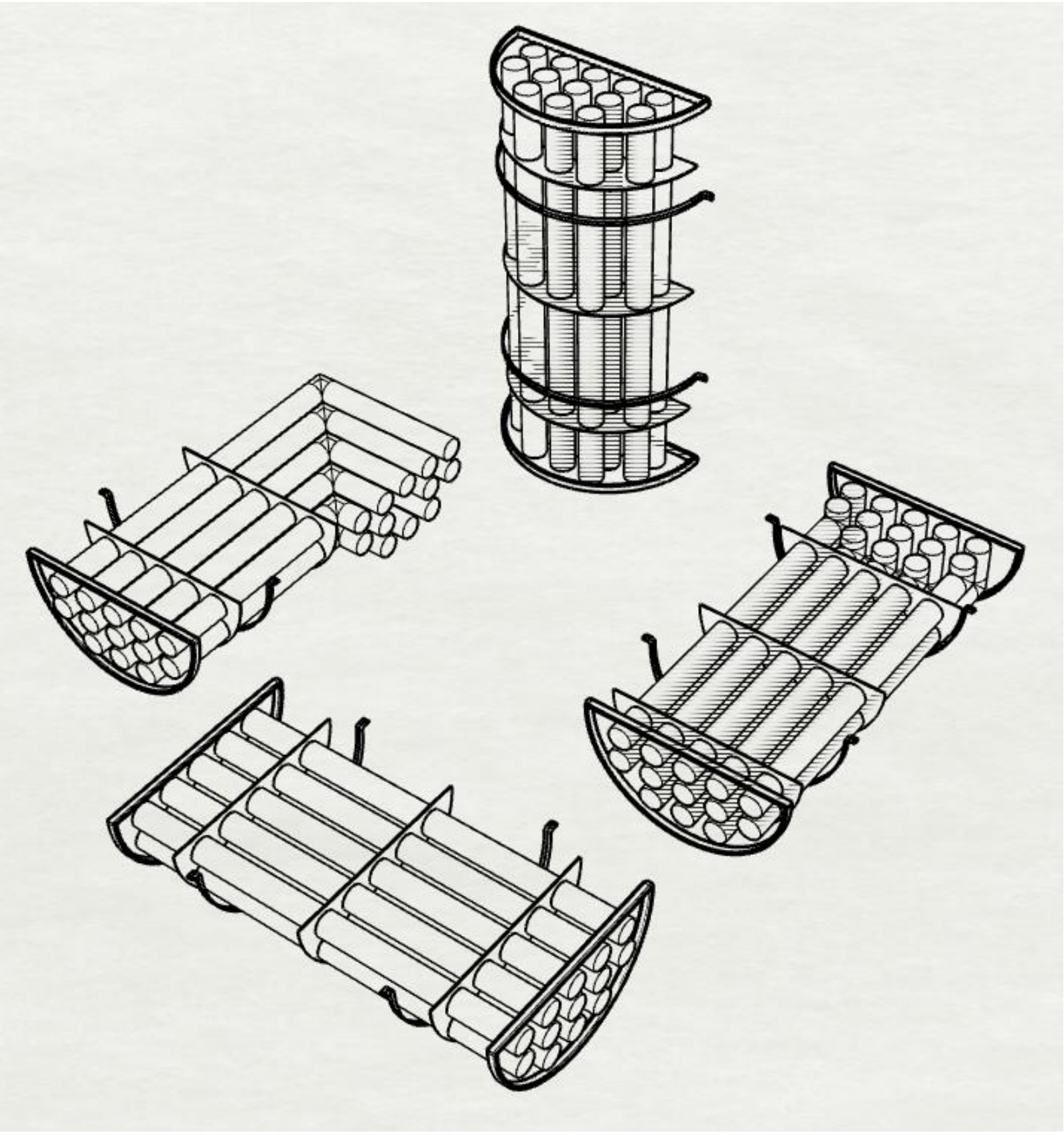
This product is designed in three main parts, the first part which is the head of the product with a circular shape, install on the roof that collects light and sends it to the inside of the building. The second part is the tube of product that transfers light to dark places. The last part is a light valve to distribute light in the room.

Finally, this product will be seen semi-circular shape that inside includes several PMMA rods (light rods), which are supported by some supporters. This semi-circular can be covered by transparent plastic as an option. This product is flexible to design and implement, and also compatible with interior design, even in some designer use PMMA pipe for interior design as artificial light. The shape dimension and number of pipes to use in this product depend on how much light wants for inside the room. Making angle and return is possible to do inside the building by heating the pipe and changing the line way during the plan, fixing and instal the product can be accessible by just heating and without any connection can be possible. The only needs to be put on support to stay under the cell and there is no need to use some electrical things inside the product, it does not need to ruin the wall or ceiling, only needs punch supports to keep pipes. The cap of the tube is covered by a semi-circle and it is gone out of the roof around 50 cm. The pillar of the line is a cylinder shape and the beam is a semi-circle shape.

There are some advantages to using this product in building like use on more than two floors without losing efficiency of light. Also, it is a flexible material that can turn in several angles to fit with all the plans of buildings and use as a part of interior design because of shape and product design this material using inside the building. On the other hand, the price of this material is too cheap, which can be economic for customers.

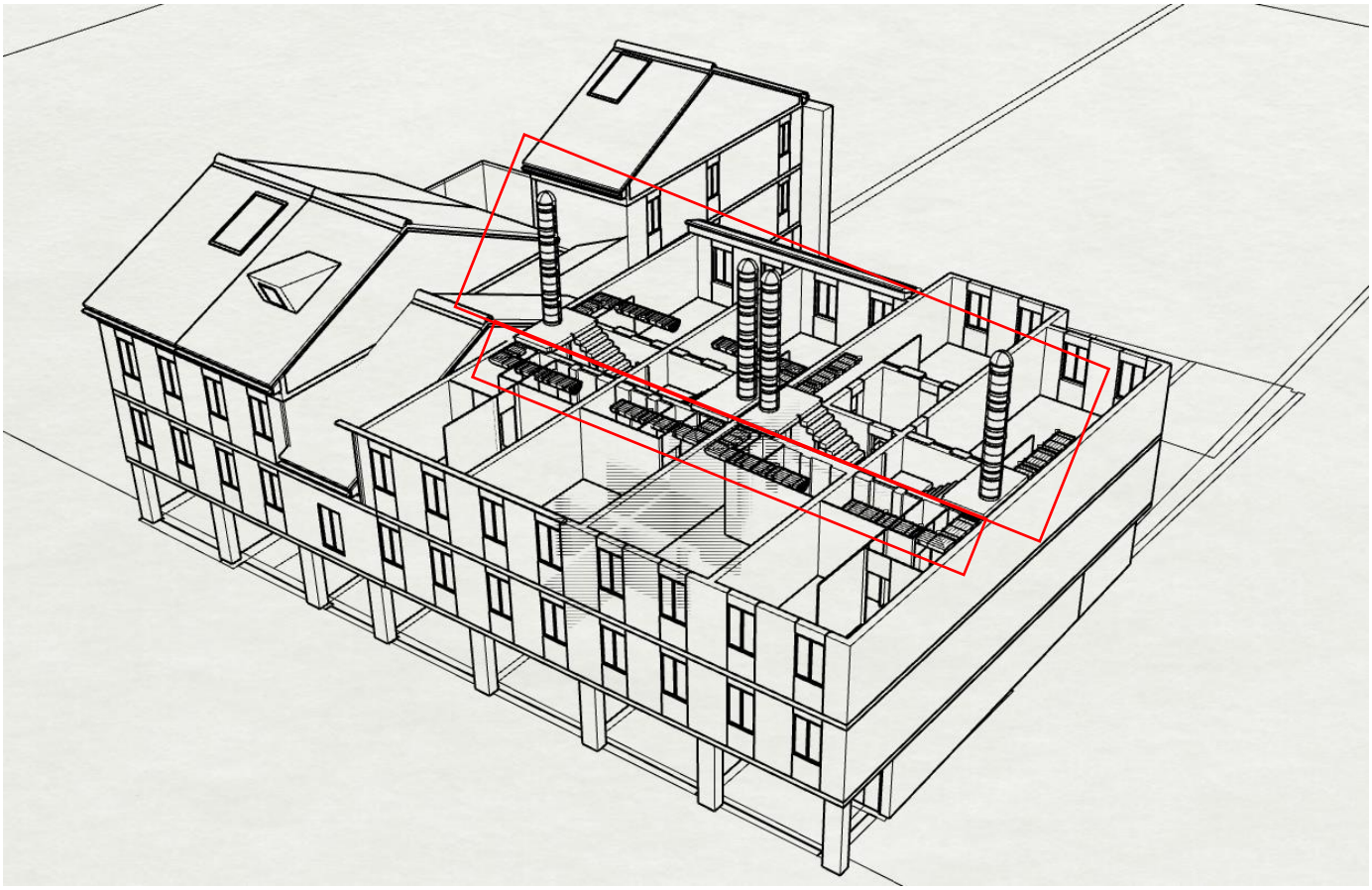
Product Detail

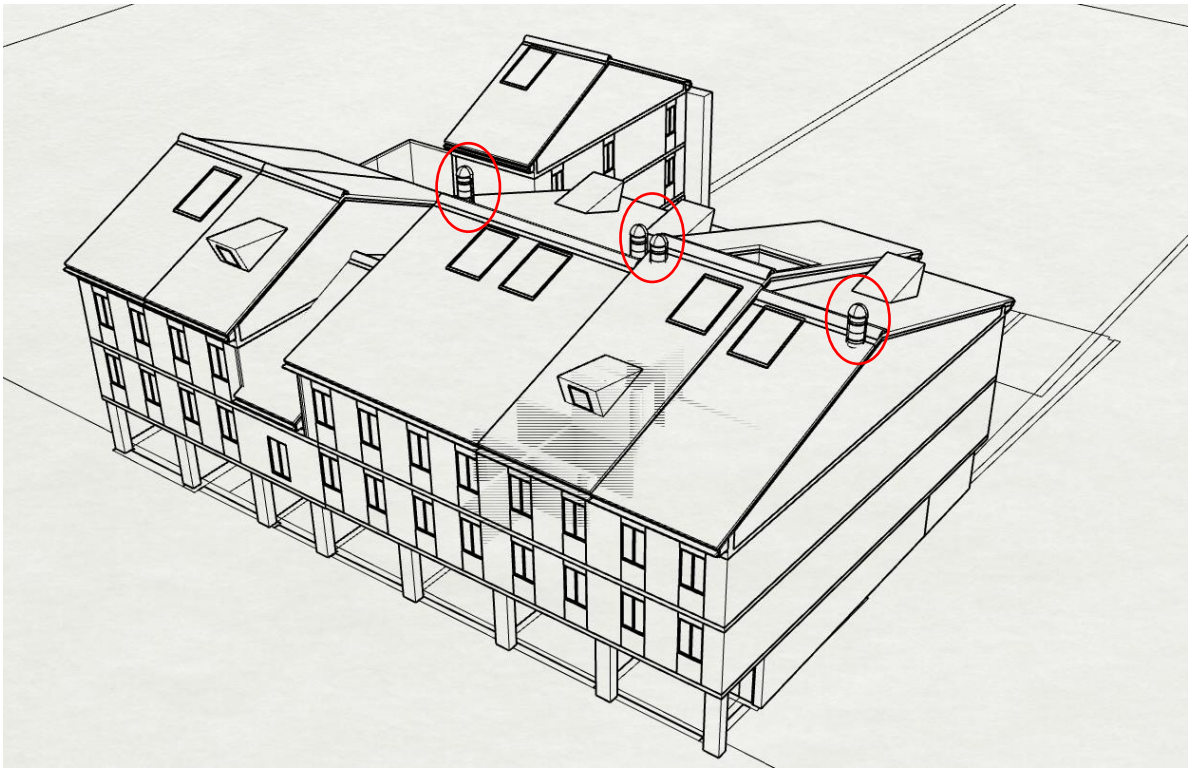
All the dimensions and details can be changed and modify depend on interior design and amount of the light required. Also, number of pipes possible to change.



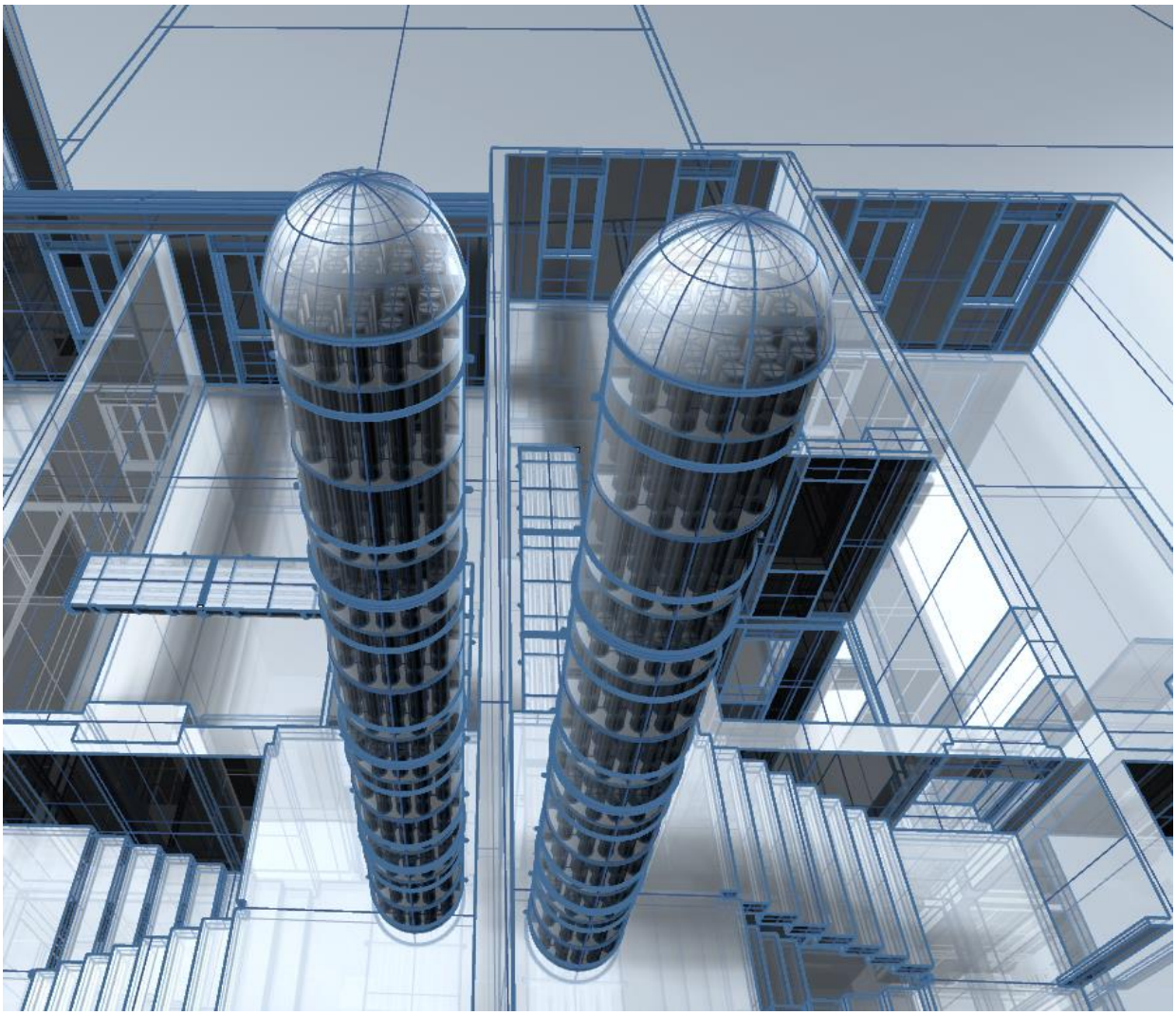
Isometric Plan

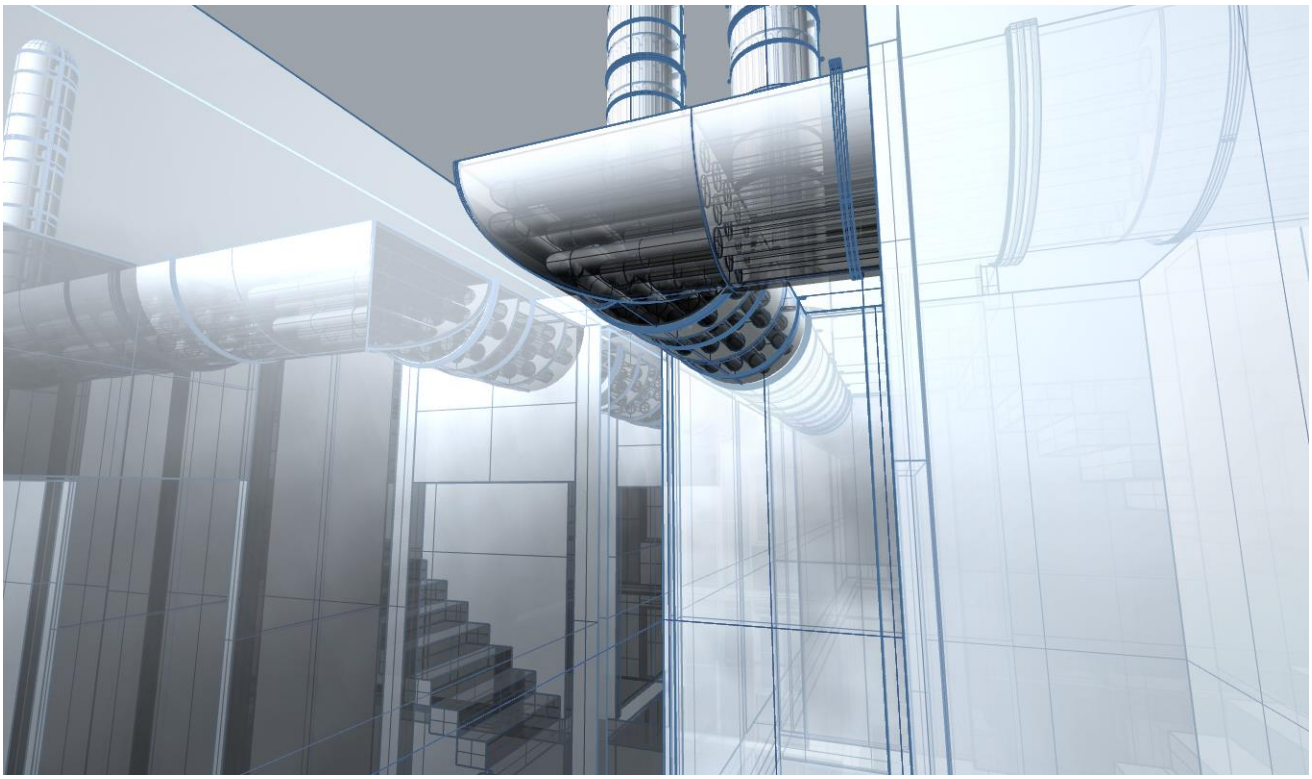
The models show the pleases of the tube, their ways and how are passed inside the building and the position of them how should be. As the model shows, with a small area open on the roof this system can be applied, without destroying and changing some parts of the building.





3D Model

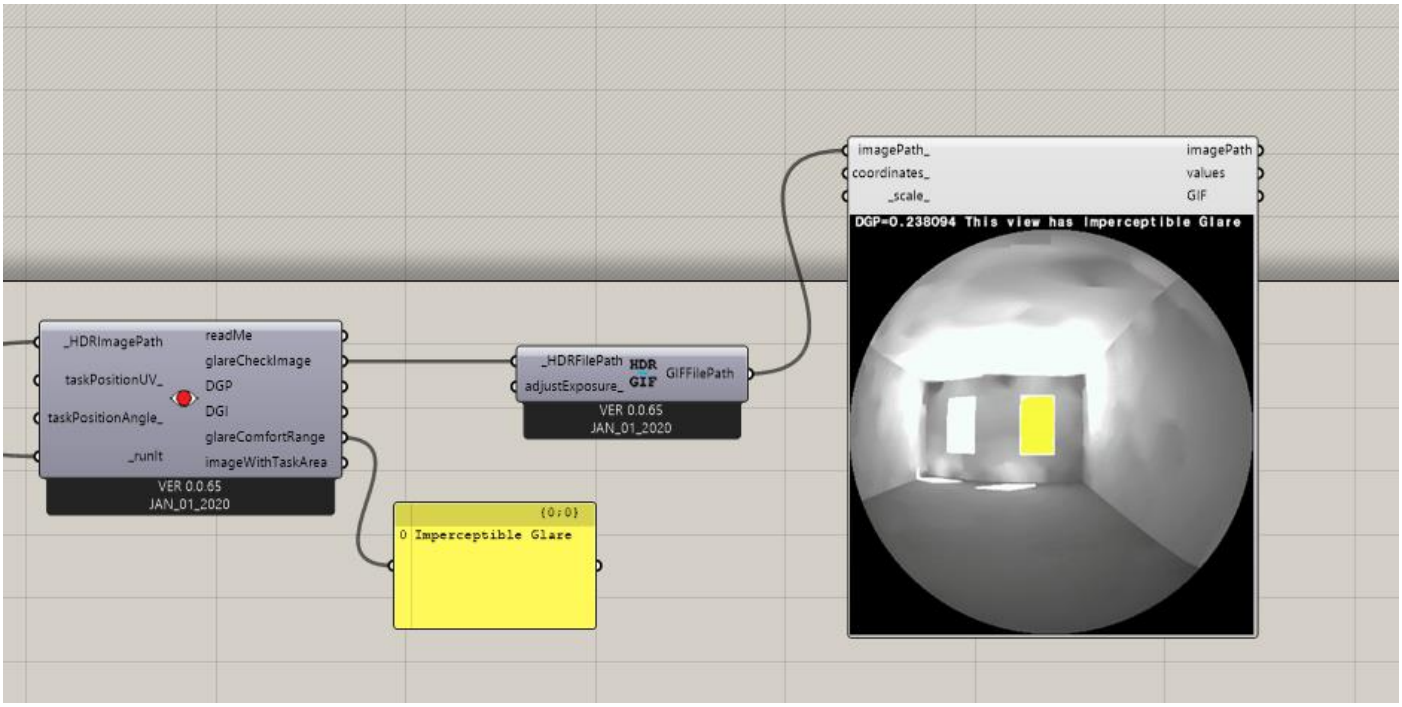


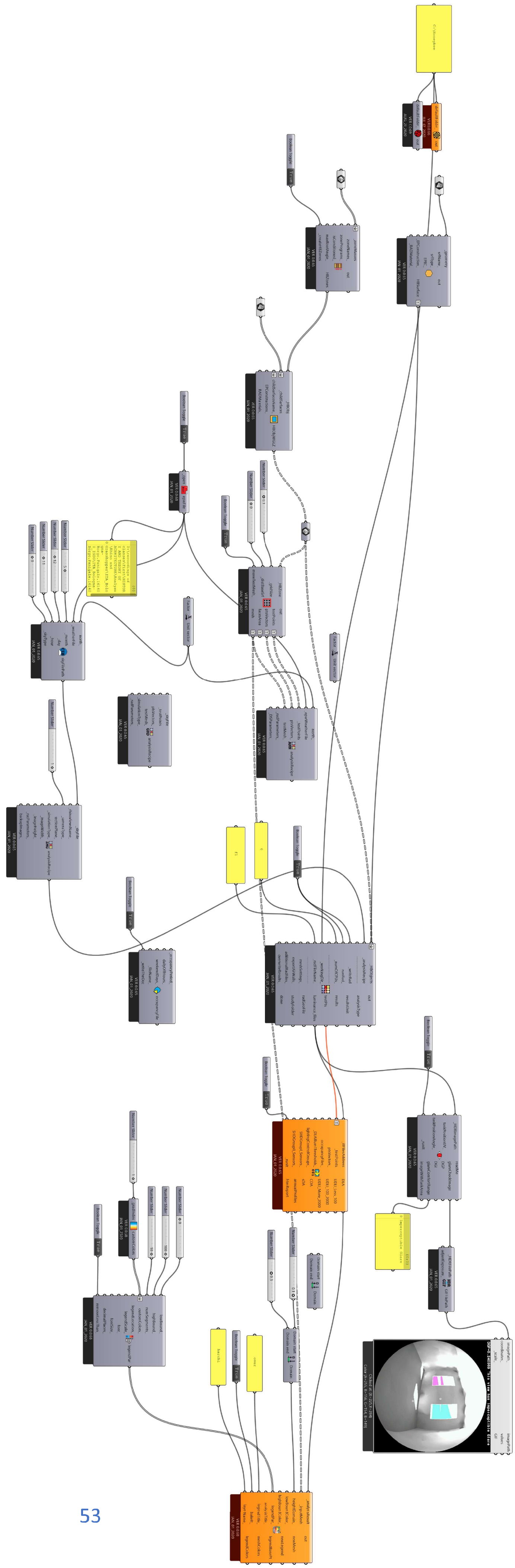


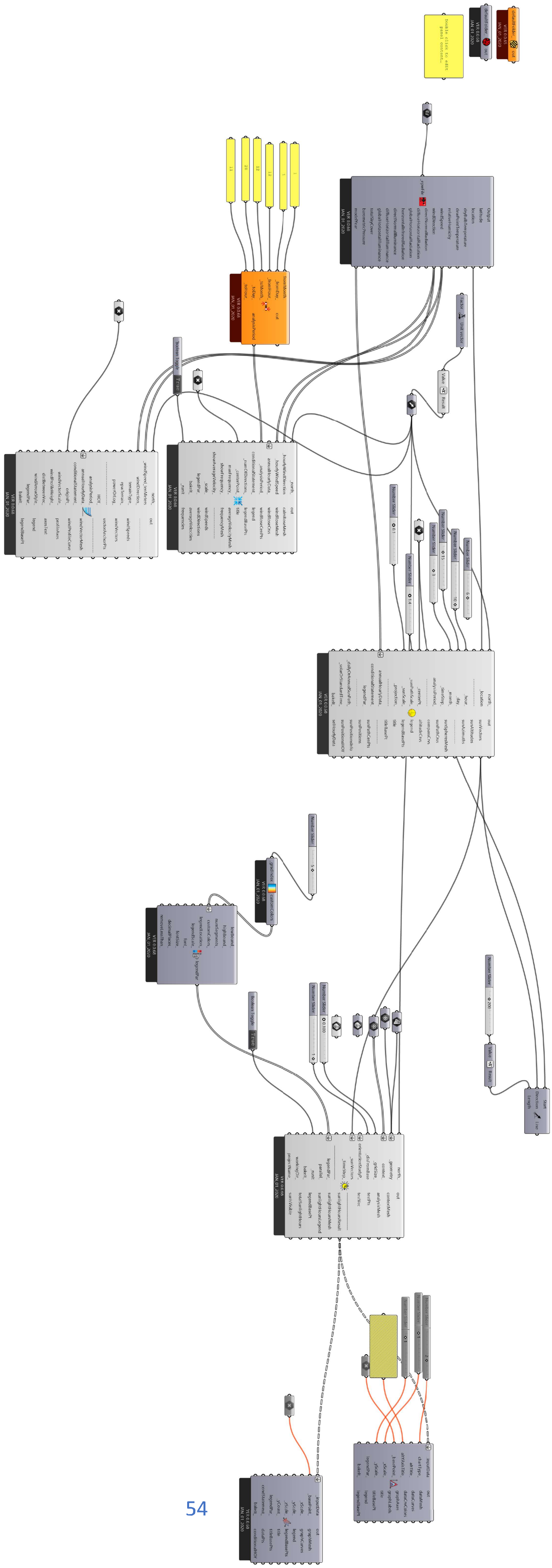
CODING

These two pages codes use in analysis for environment to understand better behaviour of the building in face of sun, shadow, wind and ….

A part of imperceptible glare code example







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Read All the Hourly Results from Annual Daylight Study - Honeybee - Component for Grasshopper | Grasshopper Docs

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