Politecnico Di Torino

Daylight and natural ventilation analysis for residential buildings in two different climates; Cairo and Turin

Politecnico di Torino

Master of Science Thesis

Architecture for the Sustainable Design

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Abstract

Daylight and natural ventilation are the most important two factors to provide inner comfort, it doesn't only affect the inner comfort but also the energy consumption. There is a rapid growth in the population in Cairo since 1950 as it was 2.5 million and in 2022 Cairo reached 21.8 million, while Turin during 1950 was 1 million and in 2022 the population is 1.8 million. The heigh population in Cairo affects the energy consumption, especially that the residential sector consumes a large portion of electrical energy generated in Egypt, also most of the energy consumed in Cairo is on the light and air conditioners, which can be solved with daylight and natural ventilation planning.

Cairo and Turin have different climate conditions. The variation in temperature between Cairo and Turin is due to the fact that they lie in different latitude and longitude. Egypt lies in the hot dry climate zone, part of Sahara Desert in north Africa. Turin is Located in north west Italy, it features a humid subtropical climate, due to its hot summers as does most of Northern Italy, Winters are moderately cold and dry, summers are mild in the hills and quite hot in the plains.

To understand more about the built environment in Cairo a comparison between the materials that normally used in Egypt and some proposed and suggested materials by Mansoura University and materials that were used during the Islamic era in Egypt, the comparison gives more understanding of the U-value, thermal resistance and time lag for the wall's material. There is another comparison carried out for different materials that were suggested by Egyptian codes to improve energy efficiency in residential buildings ECP 306-2005, and the daylight factor, illuminance, useful daylight illuminance UDIA, spatial daylight autonomy SDA and the amount of time where the blinds used of each type of glass effect on the building.

A complex of 148 residential buildings, lies on 0.133 Km² varying from town house to twin house to stand-alone villa which is in the construction stage in Cairo, Egypt was used as the case study. The same case study was used in different climate condition in Turin to understand how the climate will affect the inner comfort, In Turin the complex was built with 40 cm wall thickness and double glass, with respect to Italian building regulations as SHGC, T_{vis}, U-value.

There are two proposed cases one in Cairo and the other one in Turin, In the case of Turin a 55 cm wall glass was used to decrease the U-value of glass to comply with the new Italian requirements, and low emissive type of glass was selected instead of selective glass, but the thicker wall gives small inner area and less daylight. The case is then modified after studying the building regulations in Egypt and Italy and compare between them to understand more how to improve the building functionality. In Cairo a proposed case with horizontal and vertical shading device in the south façade and a vertical shading device on the east and west façade, and different glass type with higher thermal transmittance to offer more open blinds hours, as the main concept of the complex is to provide more of the view of the pyramids, with the old case in Cairo the blinds was closed more hours which provide less view of the pyramids.

Aim of the thesis

1- To compare the different climate conditions in Cairo and Turin with different latitude as the climate have a great effect on the built environment.

2- Compare the daylight availability and natural ventilation in the two cases and presenting the different regulations in Cairo and Turin, and compare them to LEED V4.1 regulations to understand how to improve the cases.

3- Compare the different materials in Egypt to understand more about the Egyptian built environment and introduce a case study in Egypt.

4- The same case study is proposed in Italy with using standard Italian materials and compare the two cases to show the effect of different climate condition on the urban context.

5- Propose two cases in Cairo and Turin to improve the daylight in the original cases

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Introduction

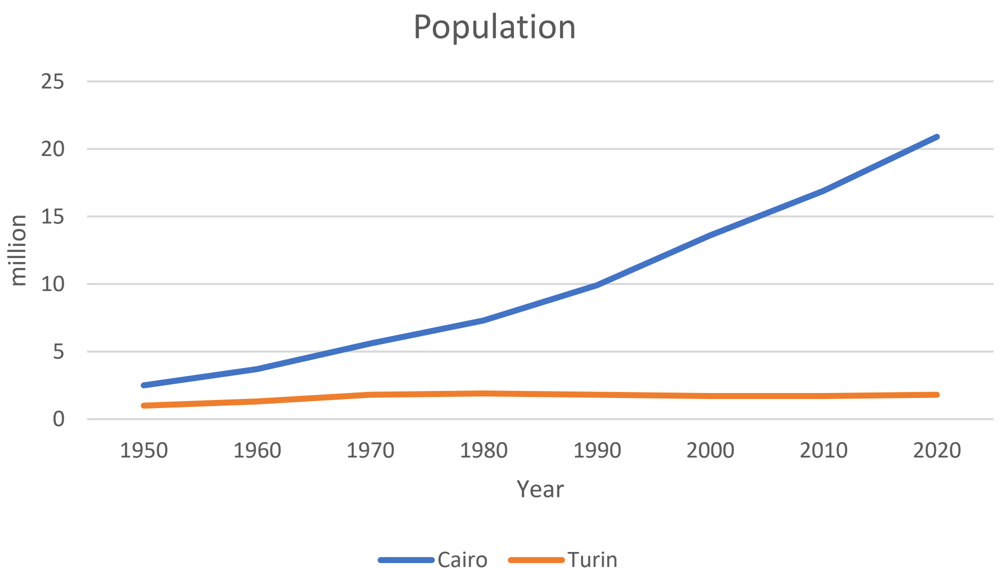
Daylight and natural ventilation

Daylight and natural ventilation are two of the most important factors affecting the indoor thermal indoor quality. Indoor air quality is defined as the air quality inside the building and around the building and structure which directly affects the inhabitant's health, comfort and ability to work, there are several factors that affect the indoor air quality as ventilation rates. The thermal comfort is defined as the condition of mind which expresses satisfaction with the thermal environment, it is affected by the air temperature and humidity. Daylight is more preferred for the inhabitants to use not only for energy saving but also it gives sense of satisfaction, it gives more concentration on the tasks and helps the human visual system.

By providing natural ventilation and daylight there is less energy consumption by reducing the usage of mechanical ventilation systems and artificial light. In Cairo more energy is consumed in air conditioners in summer the inverse is in Turin as more energy is consumed on the heating systems.

Population growth

Cairo is the largest city in Egypt and the capital of Egypt, Cairo is the highest population city in Africa and middle east, and is considered highly populated city when compared to Turin which is the old capital of Italy in 1800 and is the administrative capital. There is a rapid growth in the population in Cairo since 1950 as it was 2.5 million and in 2022 Cairo reached 21.8 million, while Turin during 1950 was 1 million and in 2022 the population is 1.8 million. Cairo population keeps growing while the population in Turin keeps increasing and decreasing through the time. Great Cairo includes three governments Cairo, Giza and Qalyubia.



Fig(1): Graph represent the growth of population in Cairo and Turin from 1950 to 2020

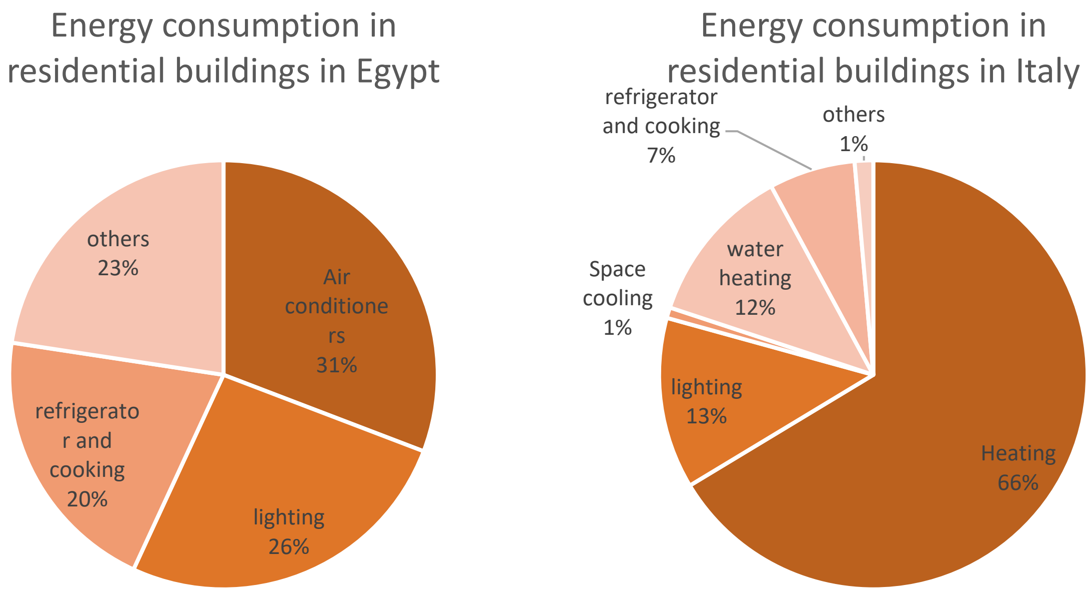
"Cairo Population 2022." Cairo Population 2022 (Demographics, Maps, Graphs), https://worldpopulationreview.com/world-cities/cairo-population.

The population growth is reflected on the building heritage, In Cairo the growth rate is 2% which doubled the urban population in the past 20 years, when comparing the building heritage in Cairo through history it shows how the building envelope changes through time from street view, complex houses with inner court, building materials, wall thickness and cross ventilation all those sustainable elements that were used to be considered during the Islamic era are now not considered due to the rapid growth in the population rate. Due to the growth in the building and construction sector in Egypt to cope with the population growth, and the new building materials that were used in Egypt, the government issued rules and regulations to assure the inner comfort for the users, which was released in 2005 Building energy efficiency codes by housing and building national research center under the supervision of the ministry of housing, utilities and urban communities.

El-Shakhs, Salah. "National Factors in the Development of Cairo." Town Planning Review, vol. 42, no. 3, 1971, p. 233., https://doi.org/10.3828/tpr.42.3.c573893735683216.

Energy consumption

The main sources of energy used in Egypt are natural gas and petroleum products. The electricity can be generated from the high energy planning, the situation could have adverse impacts on the national economy through the increased energy demand. A previous study by Cairo University and OEP 2000 showed that electrical energy is the most widely used energy in Cairo. The share of air conditioning in the residential sector represents about 30.8%, lighting 26.1%, refrigerator and cooking about 20.5 and others about 12.7%. From that study, it's clear that Cairo's heating demand is very low and barely exists. The residential sector in Egypt is responsible for consuming nearly 41.5% (61542 GW/H total sold energy on all voltages classified according to usage) of the total energy in Egypt. According to the Ministry of Electricity and renewable energy report in 2019/2020, the number of residential subscribers reach 85.7% while the commercial reach 10.9%, Industrial and agriculture each 0.3% which is reasonable as the population reached nearly 102.3 million in 2020.



Fig(2): Pie chart for the energy consumption in residential buildings in Cairo and Turin

In Italy the percentage of the residential sector energy consumption is less than in Egypt, as according to ODYSSEE-MURE the residential sector reach 29% of the total energy consumption which is nearly equal to the transportation sector, then comes the industrial sector with 21%, despite that there are different sources of energy from gas to oil to petroleum to renewable waste and other sources, the energy consumption according to different types of end-use in 2019 is divides as following the highest consumption is the space heating 66.3%, lighting 12.9%, water heating 12%, cooking 6.5%, space cooling 0.8% others 1.4%.

In comparing the Energy consumption in Egypt and Italy, The Energy consumption in residential sector in Egypt is 41.5% of the total energy consumption and in Italy is 29% of the total energy consumption in Italy. In Egypt the highest consumption end-use is the light and cooling systems, while in Italy the space heating systems.

Egyptian Electricity Holding Company Annual Report 2020/2021. Ministery of Electricity & Renewable Energy
"Statistics Explained." Statistics Explained, https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Energy_consumption_in_households#Energy_consumption_in_households_by_type_of_end-use.

Cairo and Turin:

Cairo and Turin have different climate conditions, as the climate has a major effect on the performance of the building and energy consumption. The variation in temperature between Cairo and Turin is due to the fact that they lie in different latitude and longitude. Egypt lies in the hot dry climate zone, part of Sahara Desert in north Africa. This made Egypt have extremely high temperature with nearly no rains over the year, but Cairo has a low humidity percentage due the Nile River, the summer season starts from June to September. Turin is Located in north west Italy, it features a humid subtropical climate, due to its hot summers as does most of Northern Italy, Winters are moderately cold and dry, summers are mild in the hills and quite hot in the plains. Rain falls mostly during spring and autumn; during the hottest months, otherwise, rains are less frequent but heavier, the average humidity rate in Turin can reach 70%, while in Cairo the average is 55%.

	Latitude	*Longitude*
Cairo	30.13˚North	31.4˚East
Turin	45.22˚North	7.65˚East

Table (1): Cairo and Turin latitude and longitude

To simulate the climate comparison between Cairo and Turin Climate Consultant 6.0 is used with ASHARE standard 55 and current handbook of fundamentals model is used as a comfort model to measure the thermal comfort, in this software various parameters are analysed considering the hourly, daily and monthly data.

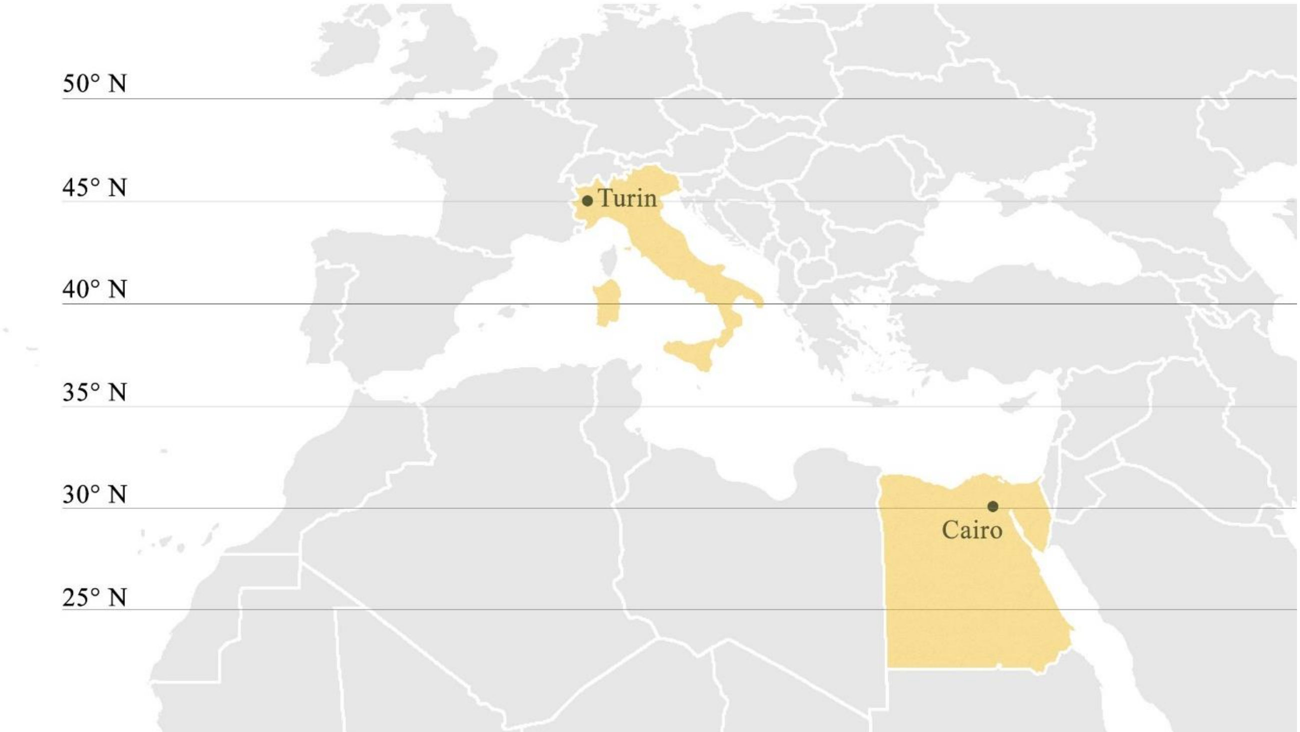


Fig (3): Cairo and Turin locations

“Weather Data by Location.” EnergyPlus, https://energyplus.net/weatherlocation/africa_wmo_region_1/EGY//EGY_Cairo.623660_IWEC.
“Weather Data by Location.” EnergyPlus https://energyplus.net/weatherlocation/europe_wmo_region_6/ITA//ITA_Torino.160590_IWEC.

CDD and HDD

The heating degree days HDD and cooling degree days CDD are methods used to calculate the amount of energy demand for heating and cooling the buildings to reach the thermal comfort. This database from Euro-Mediterranean center for climate change CMCC and King Abdullah petroleum studies and research center KAPSARC is used to compare between 147 countries to understand the energy consumption and is used by traders and economist for analysing the market. The database is also used to understand the raise awareness on the effect of climate change, as it is analysing the period from 1949 to 2013.

According to CMCC-KAPSARC "the data series employed were actual values and reanalysis of geo-located climate parameters: air temperature at two meters altitude, relative humidity, solar radiation available at a four-time intra-day frequency ranging from 1949 through 2013. These parameters were used to calculate global thermal comfort indices within grids determined by latitude and longitude at a spatial resolution of 1.8°x1.8°. The value of a decimal degree 1° of longitude fluctuates between 40 Km and 112 Km, depending on the location distance from the equator. One degree of latitude remains 112 KM regardless of location."

CDD	*Temp 15.6*°C	*Temp 18.3*°C	*Temp 21.1°C*
Egypt	2387	1725	1166
Italy	617	352	172
HDD	*Temp 15.6*°C	*Temp 18.3*°C	*Temp 21.1°C*
Egypt	531	855	1318
Italy	2101	2822	3665

Table (2): Cairo and Turin CDD and HDD

"A Global Degree Days Database for Energy-Related Applications by Tarek Atalla, Silvio Gualdi, Alessandro Lanza :: SSRN." Search ELibrary :: SSRN, https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2586960.

Temperature range

The chart shows the temperature in degree Celsius °C those values are calculated for each month and for the whole (annual), the comfort zone is presented with gray colour in winter (from 21°C to 24°C) and in summer is presented with light gray (from 24°C to 27°C), The average temperature is presented in the middle of the bar between the average high and average low which is presented in yellow and the design high and design low temperature presented in green. Monthly variation in fig (4) shows the temperature range in Cairo, and it shows that the highest temperature recorded is 43°C and the lowest is 7°C, the average temperature in winter (from November to March) is less than the comfort degree with 6°C, while in summer (from June to September) is more with 4°C. In Turin the highest temperature recorded is 31°C and the lowest -6°C, the average temperature in winter (from November to March) is less than the thermal comfort by 16°C, while in summer is less than the thermal comfort with 2°C.

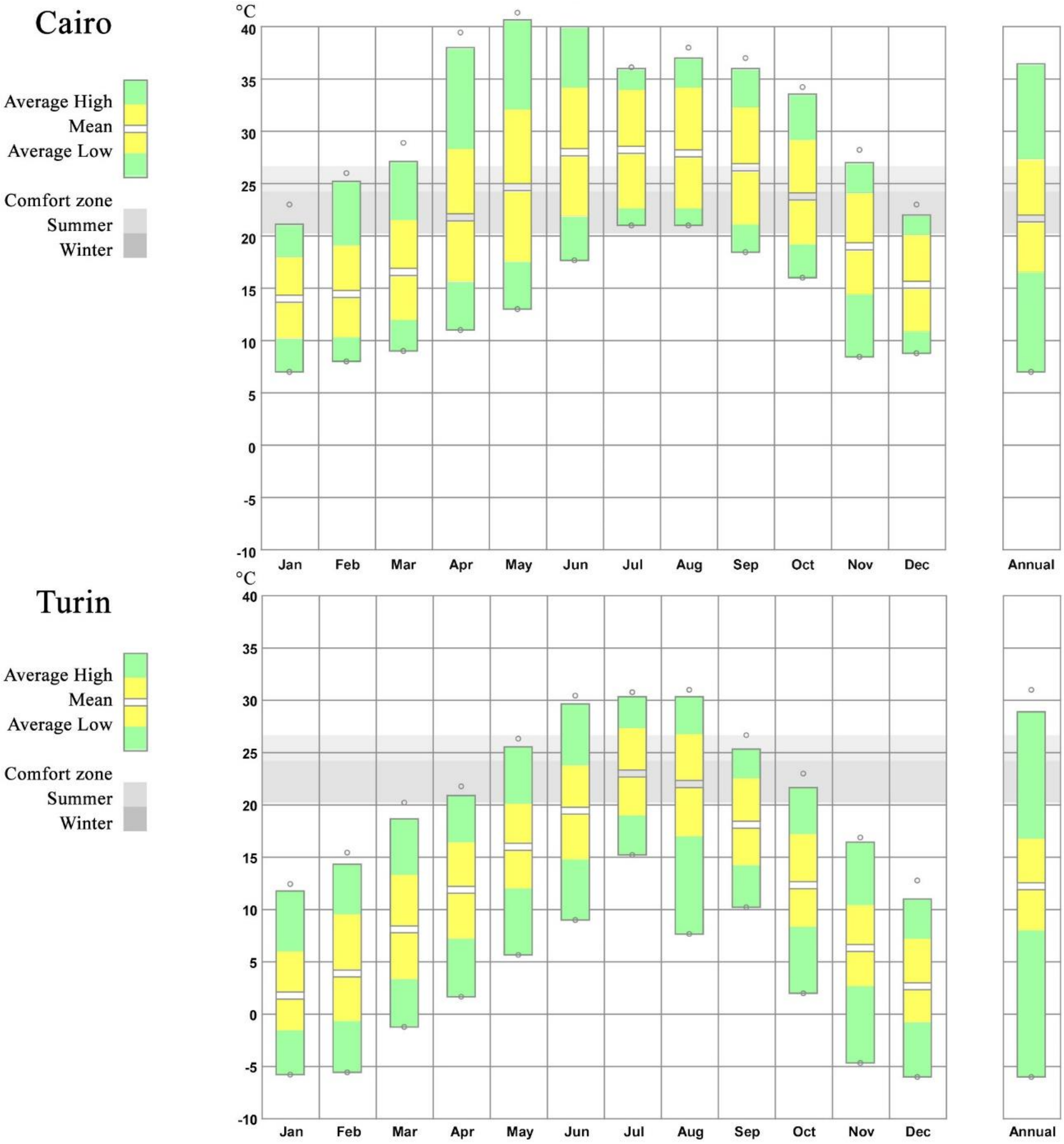


Fig (4): The monthly temperature range for Cairo and Turin, this graph is a result of climate consultant study.

R. Liggett, and Rashed Alshaali. CLIMATE CONSULTANT 3.0: A TOOL FOR VISUALIZING BUILDING ENERGY IMPLICATIONS OF CLIMATES. 2016.

Radiation range

This chart Fig (5) shows the average monthly radiation in yellow, green and orange which are the direct, global and total radiation (Wh/sq.m per hour) respectively. The radiation range is an important aspect for in urban scale and building scale, so for the urban scale it has a big influence for the heat island effect, For the building scale the global and the total radiation plays an important role in the urban canyon and building daylight factor. The direct radiation range in Cairo average is 400 Wh/sq.m per hour, which can be considered as nearly the double of the radiation in Turin 250 Wh/sq.m per hour.

The global radiation is the total amount of shortwave radiation received from above by a surface horizontal to the ground. In Cairo the GHI average is 420 Wh/sq.m per hour but it is lower in Turin with average 250 Wh/sq.m per hour. The average total radiation in Cairo is 420 Wh/sq.m per hour while in Turin around 270 Wh/sq.m per hour.

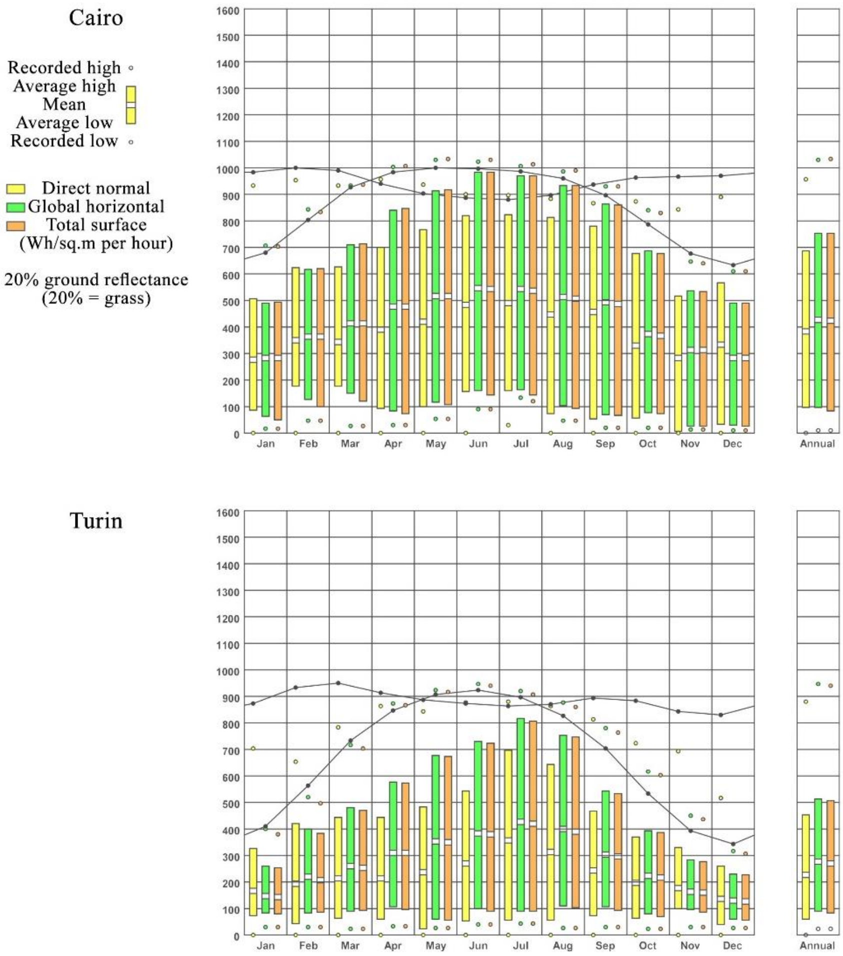


Fig (5): The radiation range for Cairo and Turin, this graph is a result of climate consultant study.

Sky cover

Sky cover in Fig (6) is the cloud amount and the cloud cover within the field of view. The sky cover is measured in percentage from zero to hundred, hundred percent means that no clear sky is visible while zero percent means that the sky is clear. In Cairo the average sky cover range is from 0-25%, while in Turin the range is from 25-50%. This comparison means that in Turin there is less clear sky than in Cairo

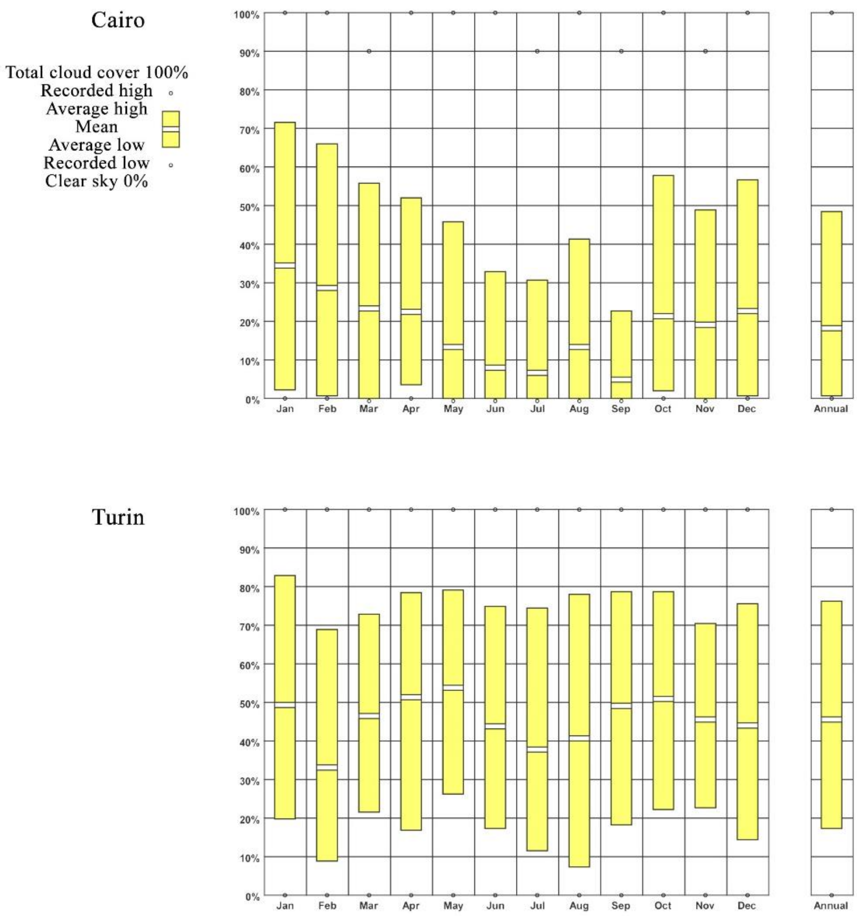


Fig (6): for the Sky cover percentage in Cairo and Turin, this graph is a result of climate consultant study.

Wind wheel

The wind wheel in fig (7) shows multiple elements as the direction and the velocity of the wind, temperature and humidity range. In Cairo the yearly wind direction is north, north east and north west, with average velocity of 7 m/s that occurs 5% of the hours per day. In Turin yearly there is no specific direction of the wind with average velocity of 3 m/s that occurs 3% of hours per day but there is wind that occurs 13% of hours per day from north. In April which is considered as the first month of spring season, In Cairo fig (8) the Strongest wind direction is north east with velocity that reach 26 m/s and temperature ranges from 0 to 38 °C which can occur 3% of the time only in the month of March, In Turin fig (8) The strongest wind can occur in March only 10% of the month with speed can reach 16 m/s. In Cairo during June and December there is no specific wind direction with average wind speed of 4 m/s and temperature between 24 and 38 °C in June, and In December the average wind speed is 3 m/s and temperature between 0 and 20°C. In September the wind temperature average is between 24 and 38 °C, there is no wind from west and south the main wind is from north east at nearly 20% of the hours and wind speed average 6 m/s. In Turin the average wind speed is 2 m/s in March and the dominant wind is 8 m/s up to 30% of the hours, In June there is no specific wind direction and wind temperature between 0 and 24 °C and humidity between 30 and 70% and the wind can only be 10% of the hours. In September the dominant wind direction is north which and it can occur 30% of the hours and wind temperature between 0 and 24 °C. In December there is no specific wind direction the dominant wind is north at 20% of the hours, the average wind speed is 6 m/s and the strongest wind can reach 12 m/s, the wind temperature is between 0 and 20 °C and relative humidity between 30 and 70%.

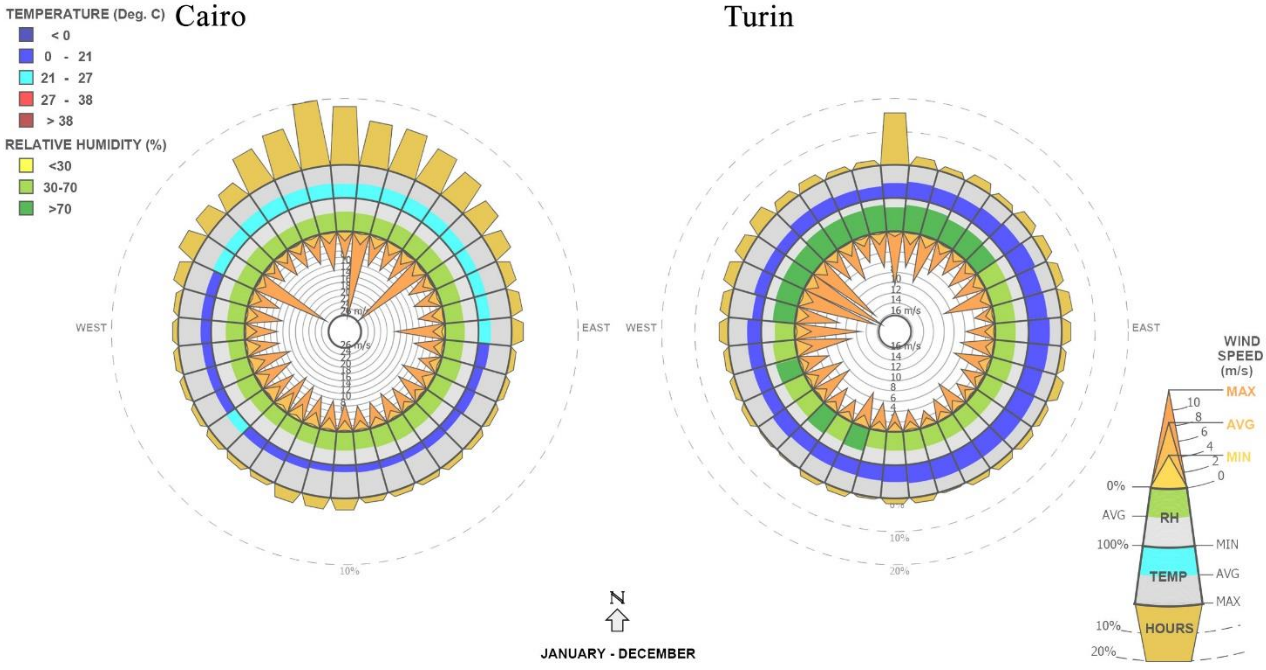


Fig (7): The wind wheel in Cairo and Turin chart through the whole year

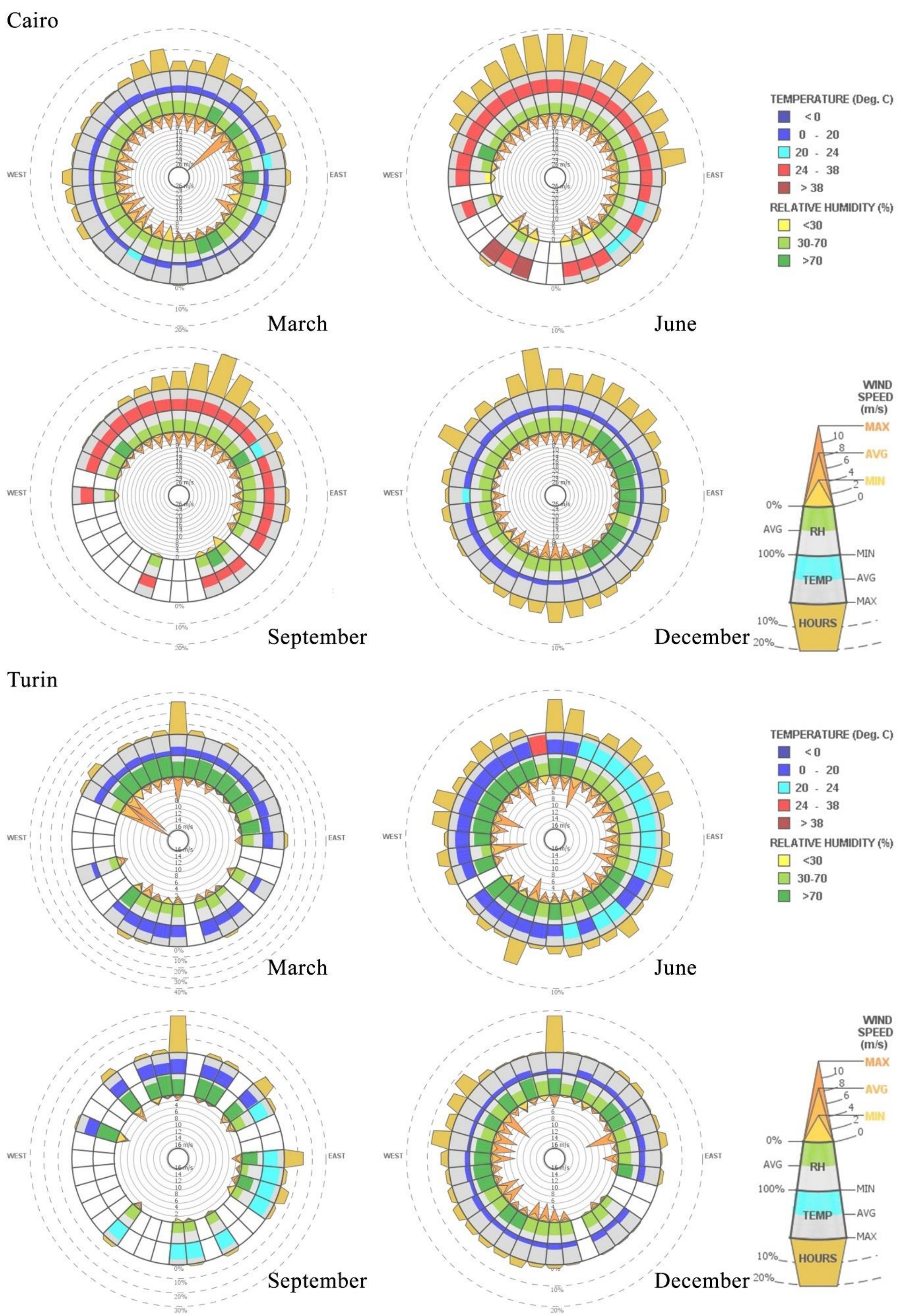


Fig (8): The wind wheel in Cairo and Turin in March, June, September and December respectively.

Wind velocity

Is defined as by two parameters distance in meters and time in seconds. As shown in fig(9), In Cairo during the year the minimum wind velocity is 1 m/s un November, December and January, and maximum of nearly 8 m/s in April, while the annual average velocity is 3 m/s. In Turin the wind velocity is lower than in Cairo, the minimum wind velocity is 0 m/s which means that some times of the days in January, February, March, July, August, September, October, November and December there is no wind, while the maximum wind velocity can reach 5 m/s in June, and the annual mean velocity is 1 m/s.

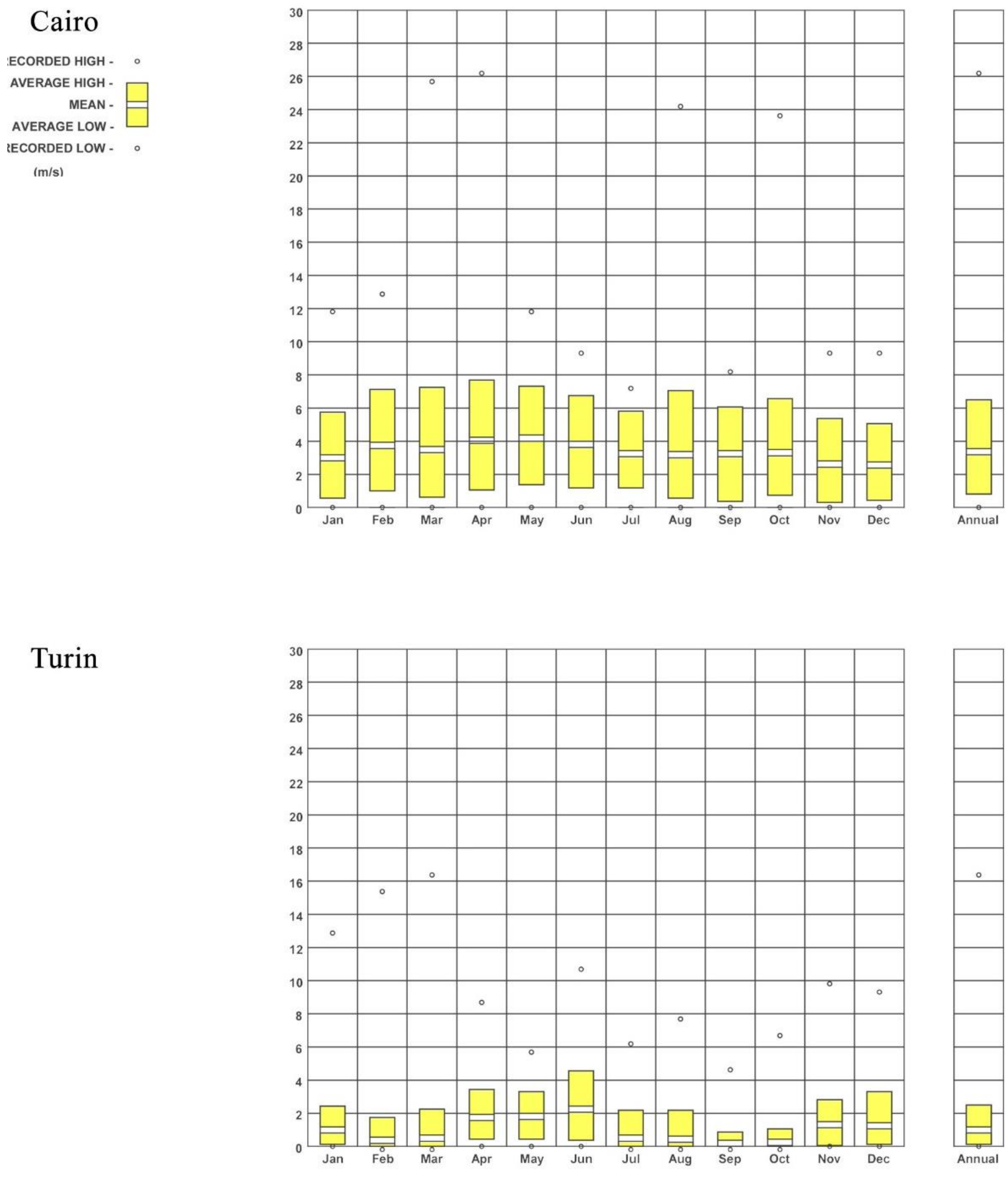


Fig (9): The wind velocity in Cairo and Turin, this graph is a result of climate consultant study.

Climate comparison
Dry bulb and relative humidity

Dry bulb fig (10) is defined as the air temperature measured with thermometer without considering the radiation and moisture, while the relative humidity is measured in percentage the 100% means that the air is completely saturated with water vapour. The graph represents both the dry bulb in yellow dots while the relative humidity is represented in green dots, the comfort zone is represented in light green for summer and dark grey for winter. In Cairo the maximum humidity is 85% while the minimum humidity 30% with average humidity during summer of 50% and in winter 70%. In Turin the maximum humidity 95% and minimum of 55% and in summer the average is 80% and in winter 85%.

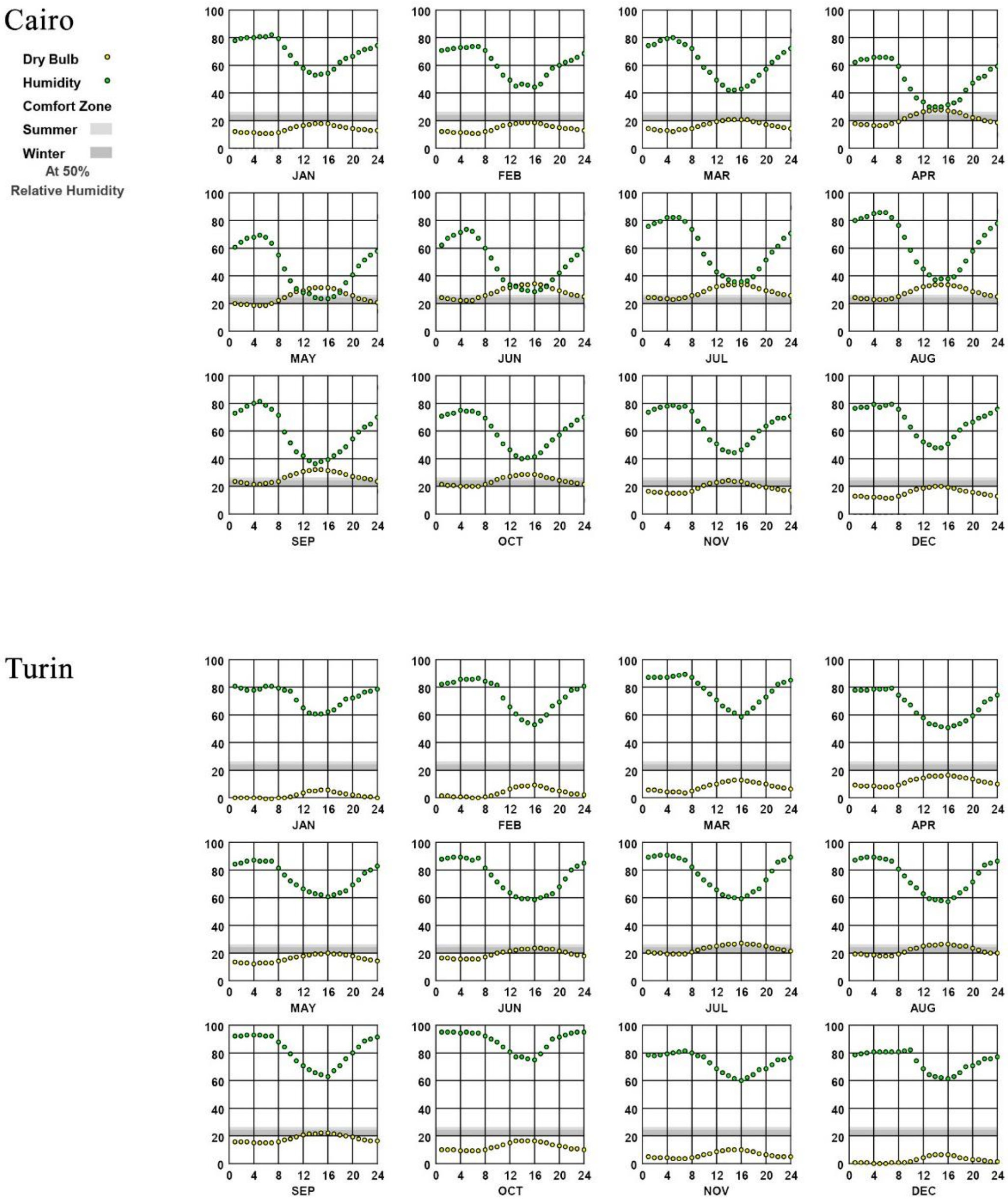


Fig (10): The dry bulb and relative humidity in Cairo and Turin, this graph is a result of climate consultant study.

Sun shading chart

The chart is showing two parameters the altitude in the vertical axis in summer and fall fig (11) from 21 of June to 21 of December and winter and spring fig (12) from 21 of December to 21 of June, and the orientation in the horizontal axis so south in 0 degrees and east and west are in 90 degrees (which can be considered as the azimuth angles), Beside the hours of exposure which are coloured in red, yellow and blue that represents hot, comfort and cold simultaneously. In table 1 a window without any shading device is studied while facing the south from east to west to know the numbers of hours of exposure and shading and the. In table 2 the altitude of four months of the year are considered April, June, August and December.

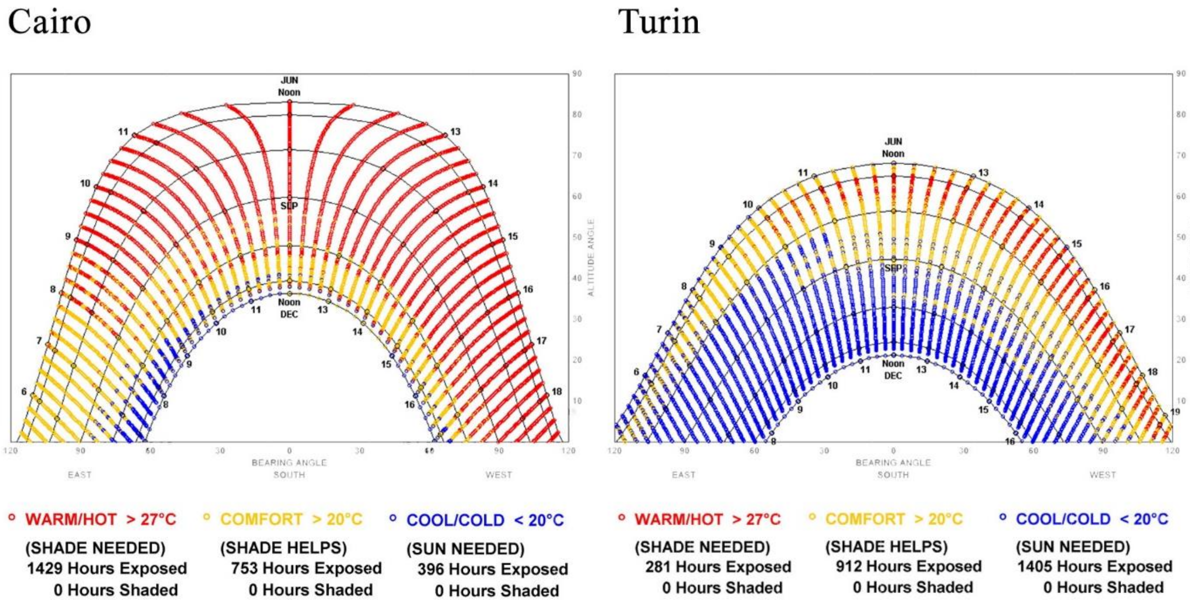


Fig (11): The sun shading in summer and fall in Cairo and Turin

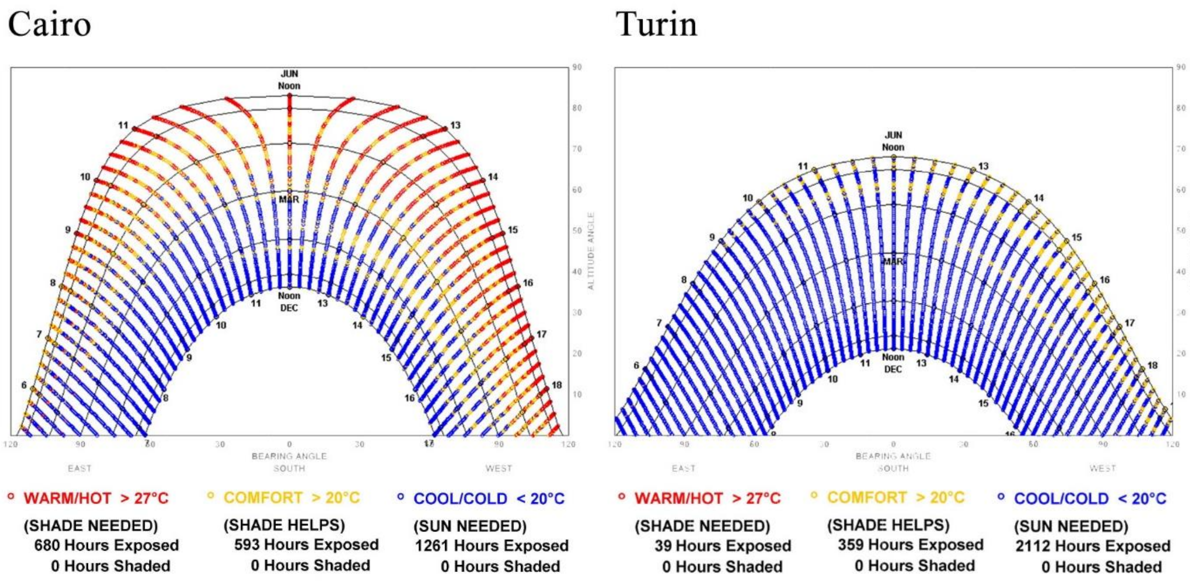


Fig (12): The sun shading in winter and spring in Cairo and Turin

	City	Hot hours	Comfort hours	Cold hours
21 Dec To 21 June	Cairo	422 exposed 258 shaded	420 exposed 173 shaded	1160 exposed 101 shaded
	Turin	26 exposed 13 shaded	264 exposed 95 shaded	1769 exposed 343 shaded
21 June To 21 Dec	Cairo	1034 exposed 395 shaded	533 exposed 220 shaded	359 exposed 1 shaded
	Turin	207 exposed 74 shaded	692 exposed 220 shaded	1185 exposed 220 shaded

Table (3): Exposure hours done by the author using climate consultant data

	21 April	*21 June*	*21 August*	*21 Dec*
Cairo	71°	83°	71°	35°
Turin	57°	68°	57°	21°

Table (4): Altitude angle done by the author using climate consultant data

Methodology

To understand how the location and the weather effects on the inner comfort, there are different aspects that should be studied as the selection of the materials, U-value and thermal resistance, glazing type SHGC, T_{vis} and U-value of glass, building orientation, wind speed and direction, solar radiation, window to wall ratio, and shading devices all of those factors should change and should be considered from one climatic location and another. In this thesis there are many tools that were used to simulate and give results to understand more about this difference from urban scale to building scale.

Tools and software

Firstly, Climate Studio was used to give a brief about the major difference between Cairo and Turin, which gave me a guideline of the climatic major problems between each city. Revit was used to create a BIM model for both complex urban level and building level. Ladybug and Butterfly are two plugins modified through Rhino grasshopper to analyse both wind analysis and solar radiation analysis, through the urban complex. The next tool is design builder to simulate and understand more about the inner ventilation and material selection. Lastly used software is Climate Studio Solemma which is used for the indoor daylight factor using the actual materials that were used in the real case study and adapted materials as the ones that are used in Turin

Climate consultant

Climate consultant is a program that is used to give climate data, whether it is an hourly, monthly or annually data. There are different climatic results as temperature, humidity, solar radiation, wind speed, wind rose and cloud cover, all of those data can help the designer to understand more about the climate, and gives the architect guideline for his work. Through the usage of the climate consultant, it gave a brief and primary understanding of the climate difference between Cairo and Turin.

Revit 2020

Is a BIM software developed by Autodesk in both 2D and 3D views that is used to create shapes, geometries and structure systems with an easy parametric method, Revit is also used to create schedules, documentations, 3D views, plans, elevations and sections. Revit is used in thesis as an easy software to create the case studies in details, and the complex urban with the 148 building units.

Rhino Grasshopper

Grasshopper is a building algorithm that is used as modelling software through dragging components into the canvas to create parametric architecture with light performance analysis and eco-friendly architecture studies. The analysis in the thesis is processed using Rhino, grasshopper and the plugin ladybug and Butterfly which are used to analyse and visualize the weather data through using an EPW files.

Ladybug and Butterfly

Ladybug uses energyplus weather files EPW files to give more 2D and 3D weather data and climatic analysis graphs as it provides solar radiation, sun path, wind rose, and sunlight hours graphics. Ladybug was used in the thesis to compare the solar radiation difference between Cairo and Turin in both summer and winter in different urban elevations.

Butterfly is a grasshopper plugin that is used to calculate computational fluid dynamics CFD the simulation is running through OpenFOAM. Butterfly is used in the thesis to simulate and run airflow through the urban complex to understand more how the wind is distributed through the urban design with different wind speed and directions to understand more the ventilation efficiency.

Design builder

Design builder is an energy simulation tool, the software used to simulate the thermal simulation, heat gain, energy consumption, heating and cooling systems and whole life cycle cost, using the weather data file and according to Ashare standards simulations occurred in the two different climates and testing different materials to understand more which material suits the climate in Cairo, and comparison between the materials between Cairo and Turin in the heat loss and gains, with an overall comparison with the natural ventilation in different climates.

Climate Studio Solemma

Climate Studio is an advanced simulation rhino plugin for architecture, engineering and construction AEC sectors, that is used to analyse the building energy performance, daylight, visual, sun path, shadow analysis and thermal comfort. Climate Studio is used to design with eco friendly and sustainable design. The software is used in the thesis to calculate the daylight factors in both climates and illuminance, through setting the location and the used materials in both cases.

Rules and regulations

Egyptian codes to improve energy efficiency in residential buildings ECP 306-2005

The Egyptian regulations focus on the window to wall ratio, solar heat gain coefficient and shaded glass ratio according to window orientation and the location the requirements of building envelope divided Egypt to eight different regions according to different climate conditions. The illuminance range was divided according to the function of the space bedroom, living, bathroom and kitchen each space have minimum and maximum illuminance.
There are other requirements for the ventilation according to the activity inside the building to control the air flow inside the building.

Italian regulations
In Italy the main regulation related to the daylight is Ministerial Decree 07/05/1975 which state that "All housing rooms except those used as toilets, lobbies, corridors, stairs and closets, must enjoy direct natural lighting, appropriate to the intended use. For each room the width of the window must be proportioned to ensure an average daylight factor value of not less than 2% and in any case the opened surface of windows must be not less than 1/8 of the floor surface. For public housing it is recommended on the basis of the above provisions and of the results of experimental trials, to adopt standardized dimensions of window and their fixtures"

LEED V4.1

According to LEED V4.1 regulations the SDA must exceed 300 Lux for 50% of the working hours per day, the SDA should not be less than 40% for one point and 50% for two points, and the annual sunlight exposure ASE must not exceed 10% if it exceeds 10% it means that the space addresses glare which means that the space need shading device to decrease the glare, a balance between the SDA and ASE should be achieved to prevent glare.
There is another requirement for the daylight simulation according to LEED V4.1 that the illuminance level should be between 300 lux and 3000 lux for 9 am and 3 pm on a clear sky in equinox day, if the illuminance exceeds 3000 the space is facing glare which need to be solved using shading system.

MODIFICAZIONI ALLE ISTRUZIONI MINISTERIALI 20 GIUGNO 1896 RELATIVAMENTE ALL'ALTEZZA MINIMA ED AI REQUISITI IGIENICO SANITARI PRINCIPALI DEI LOCALI D'ABITAZIONE. DECRETO MINISTERIALE , 1975.

Each country have regulations for the daylight availability Egyptian regulations focus on window to wall ratio, illuminance, shaded glass ratio and solar heat gain coefficient, Italian regulations focus on window to floor ratio and daylight factor. The Egyptian regulations focus on the shading glass ratio due to the climate in Egypt and the solar radiation. So In order to proceed in this comparison the LEED V4.1 is considered as an international regulation.

Case study comparison

The comparison is between four cases two in Cairo and two in Turin. In Cairo a simulation run on the original case as it is built in Cairo with the same materials that is used. Then the same case was simulated in different climate condition in Turin and with materials as the materials used in the Italian buildings. The second case is a proposal in Cairo and Turin to improve the original case after studding the comparison between the first cases in Cairo and Turin and the effect of the building materials on the daylight availability.

"Daylight Credit – LEED v4." ArchEcology, 15 Mar. 2017, https://www.archecology.com/2017/03/15/daylight-credit-leed-v4/#:~:text=Annual%20Sunlight%20Exposure%20(ASE)%3A&text=For%20LEED%20v4%2C%20no%20more,glare%20such%20as%20shading%20devices.

Introduction to case study

In the recent years Egypt is facing a huge growth in the construction and infrastructure sector due to the growth in population, Both the private and governmental sectors investing in the residential market. The case study is developed by a private real estate developer. The case study is located in Cairo and the same case study is used in Turin to study how the different climate conditions as air temperature, wind direction, wind speed and solar radiation reflects on the sun path, solar radiation, wind rose to analyse the interior radiation analysis, shadow studies, view analysis, material usage and shading system.

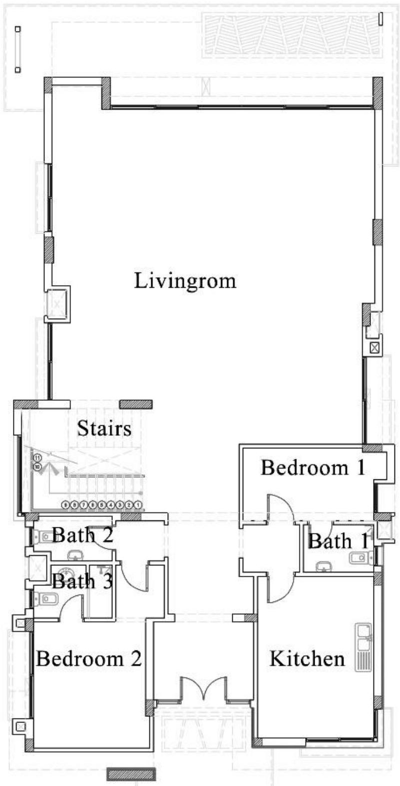
The residential complex is originally located in 6th of October city in the west of Cairo near the main axis with the pyramids view Fig(13) which is considered as the main silling factor of the complex the pyramids view, and the complex is considered as a luxuries complex with different services as swimming pools, green area, mall, restaurant, cafes and gym. The complex lies on 0.133 Km², with 148 units varying from town house to twin house to stand-alone villa.

There are five different prototypes selected in different locations and orientations Fig (14). The stand-alone villa is for one big family with floor area of 220 m² for each of the two floors and roof built up area of 85 m² consists of living room, kitchen, guest bedroom and maid room in the ground floor, in the first floor there are 4 bedrooms each of them is attached to a bathroom, living room and a kitchen, the roof consists of bedroom, living, bathroom and kitchenette. The Twin house is two attached villas that are interiorly separated for two families, each of them consist of two floors 270 m² for each floor, each of them consist of Kitchen, maid room and living room in the first floor, three bedrooms each attached to a bathroom, kitchen and living room in the first floor. The Town house consists of five, six or eight units, each of them is 105 m² for two floors the ground floor consists of living room, Kitchen, bathroom and maid room, the first floor consists of three bedrooms and two bathrooms.

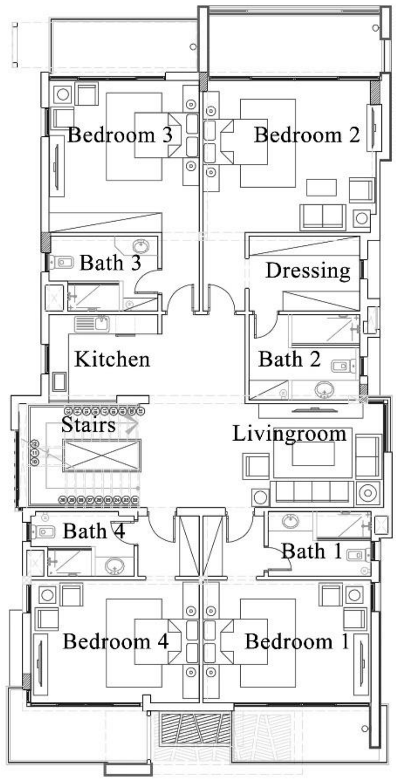
Fig (13): Rendered view of the complex with a view for the pyramids

Fig (14): Layout of the residential complex and the selected case studies

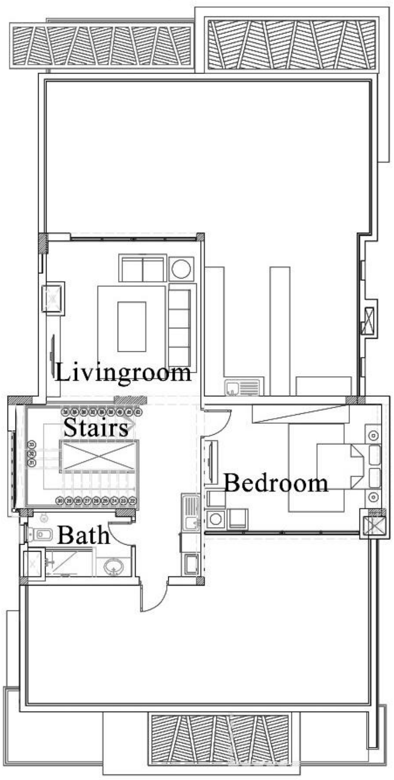
Stand alone Villa



Ground floor 1:200



First floor 1:200

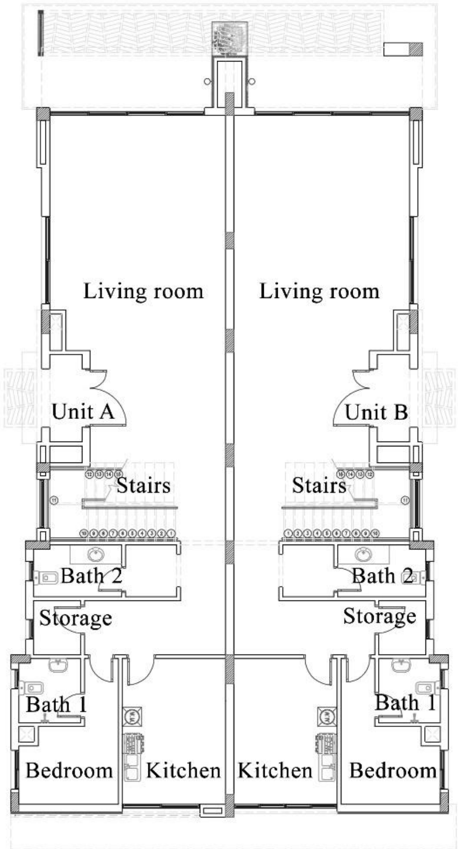


Second floor 1:200

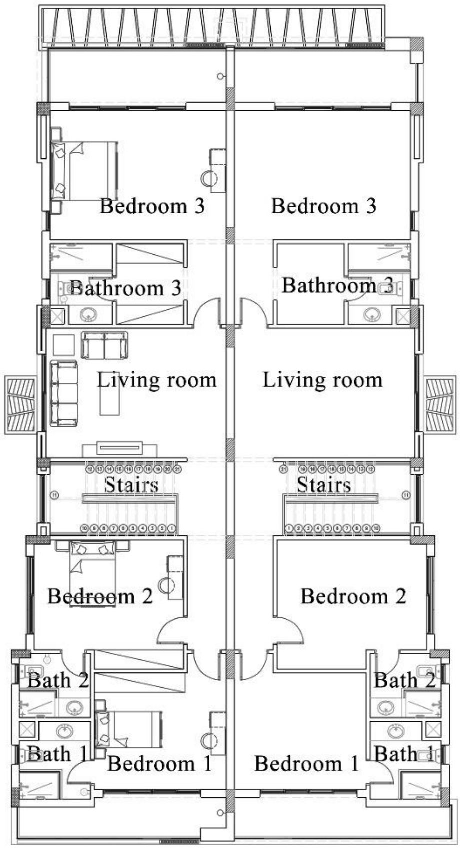
	window area (m²)	Floor area (m²)	WWR%	WFR%
	Stand alone Villa			
	Ground floor			
Kitchen	7.04	18	23%	39%
Bathroom 1	0.72	3.2	15%	23%
Bedroom 1	1.02	9.4	14%	11%
Living room	33.11	104	34%	32%
Stairs	21.24	13	69%	163%
Bathroom 2	0.72	3	23%	24%
Bathroom 3	0.72	3.6	23%	20%
Bedroom 2	5.94	14	21%	42%
	First floor			
Bedroom 1	10.26	20	38%	51%
Bathroom 1	0.72	6.4	12%	11%
Living room	2.88	18	30%	16%
Bathroom 2	0.72	9	9%	8%
Dressing room	0.72	8	10%	9%
Bedroom 2	11.44	25	39%	46%
Bedroom 3	7.92	22	29%	36%
Bathroom 3	0.72	7.2	17%	10%
Kitchen	1.02	12	13%	9%
Bathroom 4	0.72	5.5	24%	13%
Bedroom 4	7.7	20	29%	39%
	Second floor			
Bedroom	10.56	21	26%	50%
Living room	8.58	23	19%	37%
Bathroom	0.72	5.8	4%	12%

Fig(15): Standard standalone villa floor levels, window to floor area and window to floor area

Twin house



Ground floor 1:200

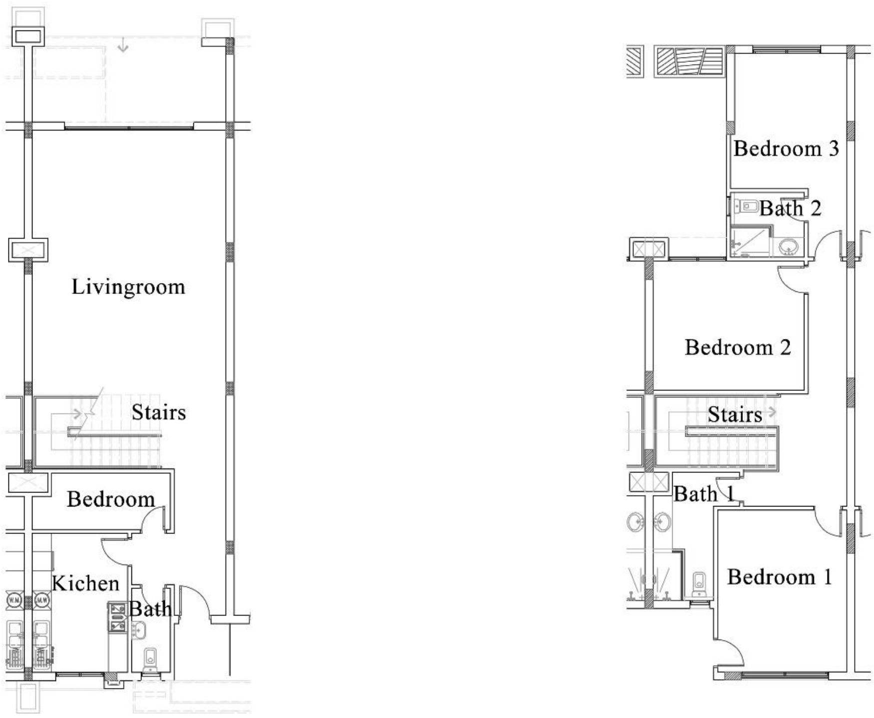


First floor 1:200

	window area (m²)	Floor area (m²)	WWR%	WFR%
		Twin house		
		Ground floor		
Bedroom	1.44	9.3	9%	15%
Bathroom 1	0.72	3.7	13%	19%
Storage	0.72	2.5	13%	29%
Bathroom 2	0.72	4	14%	18%
Stairs	8.1	9.2	55%	88%
Living room	15.42	54	38%	29%
Kitchen	6.82	14.4	67%	47%
		First floor		
Bedroom 1	6.6	15.5	55%	43%
Bthroom 1	0.72	5	6%	14%
Bthroom 2	0.72	4.3	13%	17%
Bedroom 2	3.12	17.3	32%	18%
Living room	3.12	22.3	26%	14%
Bathroom 3	0.72	4.5	13%	16%
Bedroom 3	8.64	22	30%	39%

Fig(16): Standard twin house floor levels, window to floor area and window to floor area

Town house



Ground floor 1:200

First floor 1:200

	window area (m²)	Floor area (m²)	WWR%	WFR%
		Town house		
		Ground floor		
Bathroom	0.72	3.3	19%	22%
Kitchen	3.3	13	34%	25%
Bedroom	0	7	0%	0%
Stairs	0	10	0%	0%
Living room	8.8	49	46%	18%
		First floor		
Bedroom 1	5.22	20	29%	26%
Bathroom 1	0.72	8	13%	9%
Bedroom 2	3.96	19	55%	21%
Bathroom 2	0.72	4.5	12%	16%
Bedroom 3	4.2	20	18%	21%

Fig(17): Standard town house floor levels, window to floor area and window to floor area

According to the Italian regulations the window to floor ratio should not be less than 1/8 which is equal to 12.5%, in the Egyptian regulations there is no codes for the window to floor ration but instead there is regulations for the window to wall ratio according to Egyptian codes to improve energy efficiency in residential buildings ECP 306-2005 section 3 page 19, the maximum WWR allowed for the windows facing north east, north west and south is 30% and windows facing east, west, south east and south west maximum percentage is 20%.

Urban scale analysis

Wind distribution

The pedestrian level wind on urban planning is one of the major concerns in the recent years, the wind comfort is now the concern for the city planners in some cities. There are several factors that directly affect the wind comfort as the width of the street, the building orientation and building height. Cairo and Turin have different wind speed and wind directions, so through running simulations to understand how this can change from city to another. The following simulations run through the computational fluid dynamics through Honeybee a plugin used by Grasshopper Rhino, the simulation states the complete picture of the problem in both climates, there are two main winds the dominant wind which occurs most of the month and the strongest wind in the month, on each of the four months March, June, September and December. The simulation occurred on the pedestrian level exactly 1.5 m from the ground level. All the plan views from fig(18) to fig(28) are directed to the north and the wind direction and speed changes according to the month. The building height in the case study ranges from 6.5 m to 9.8 m and the simulation was carried on the whole urban complex. The following table show both the dominant and strongest wind in Cairo and Turin, in general the wind speed in Cairo range is 7 m/s and the main direction is north direction, while in Turin the dominant wind speed is 3 m/s and the wind direction is north, the strongest wind in Cairo is 23 m/s in march which occurs 3% of the hours in the month of march, in Turin the strongest wind is in March with speed of 13 m/s and north west direction in 8% of the hours of the month.

The urban design helps the wind speed to increase between the buildings especially the standalone villa and the twin house as all the windows lie on the narrow side of the plan, as the distance between the buildings range from 3 m to 8 m, while the main problem is in the town villa as the windows lie in the large side of the building with less wind speed and larger distance between the buildings.

Cairo

	March		June		September		December	
	Direction	speed	Direction	speed	Direction	speed	Direction	speed
Dominant	N	7	N	7	NNE	8	N	7
Strongest	NE	23					S	9

Turin

	March		June		September		December	
	Direction	speed	Direction	speed	Direction	speed	Direction	speed
Dominant	N	6	N	6	N	2	N	4
Strongest	NW	13	W	9	E	3	NW	9

Table (5): The wind distribution through March, June, September and December in Cairo and Turin

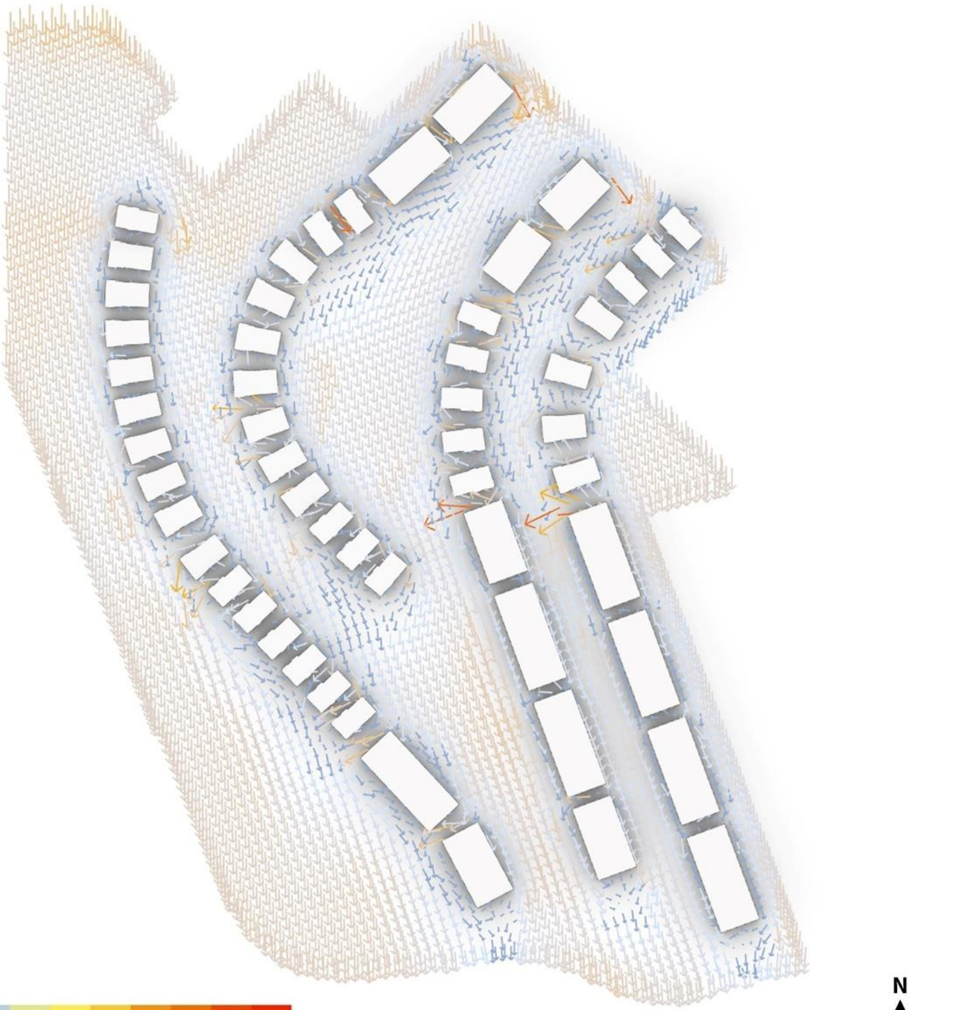
Mohamed Sakr Fadl, and John Karadelis. CFD Simulation for Wind Comfort and Safety in Urban Area: A Case Study of Coventry University Central Campus. Department of Civil Engineering, Architecture and Building, Coventry University, Coventry CV1 5FB, United Kingdom, 2013.

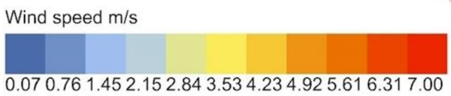
Cairo

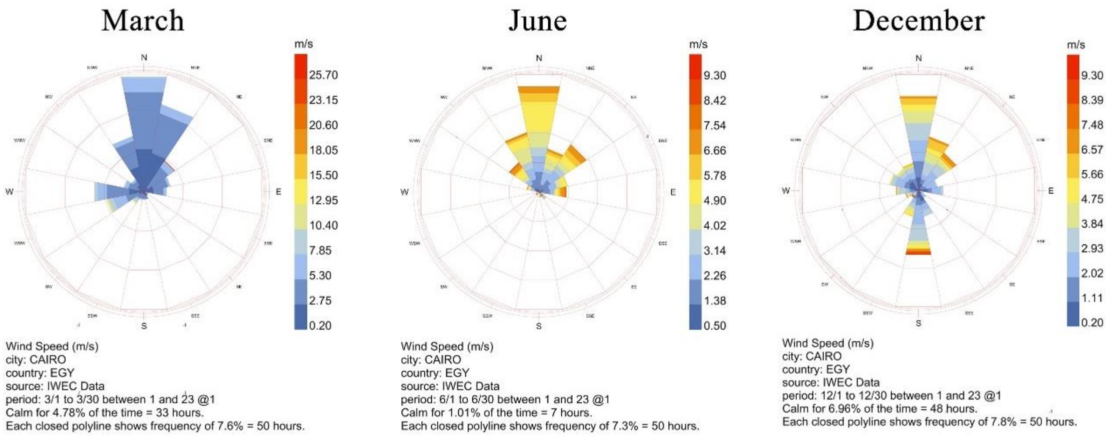
North wind direction

Wind speed 7 m/s

March, June and December







Fig(18): Cairo dominant wind in March, June, December with speed 7 m/s and north direction

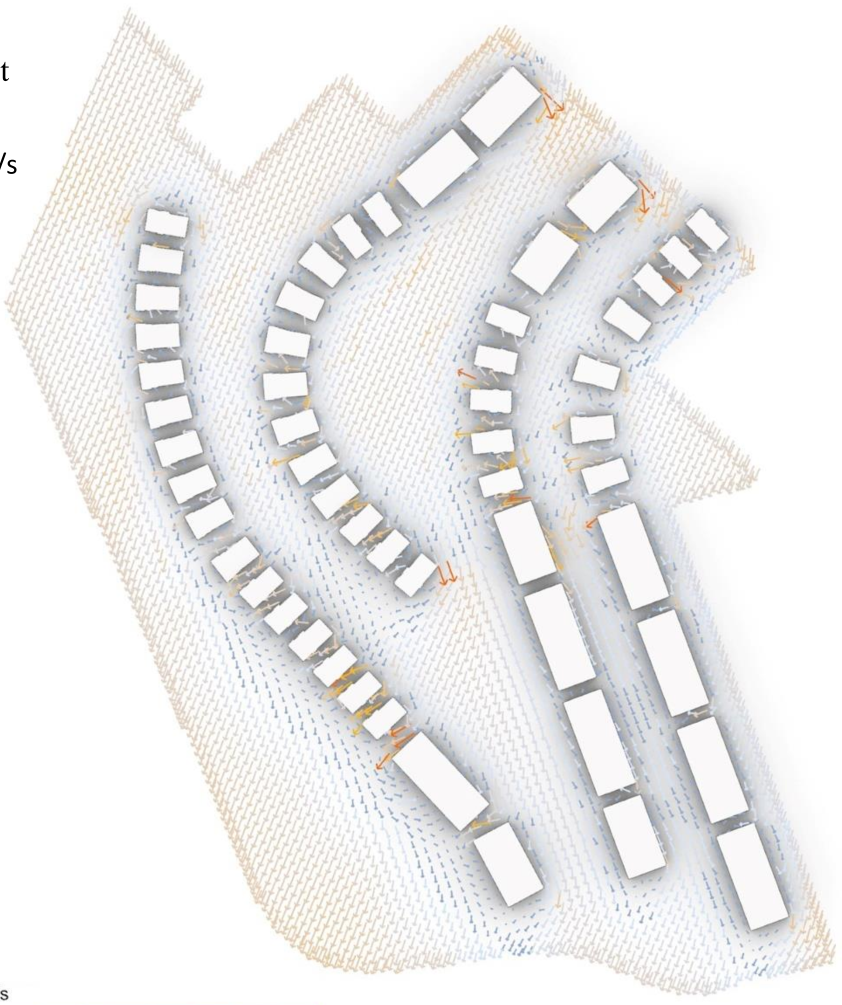
According to the wind rose study in Cairo the dominant wind in March, June and December is from the north direction with speed 7 m/s, as it is shown in the diagram the wind starts with speed of 5 m/s in the north, and as the wind goes in the south direction the speed decrease in the middle and increase again in the south, around the buildings the speed decrease it can reach 1 m/s, in the narrow side between the buildings the speed increase again it can reach 5 m/s.

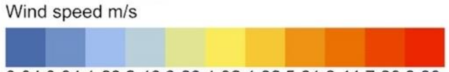
Cairo

North north east wind direction

Wind speed 8 m/s

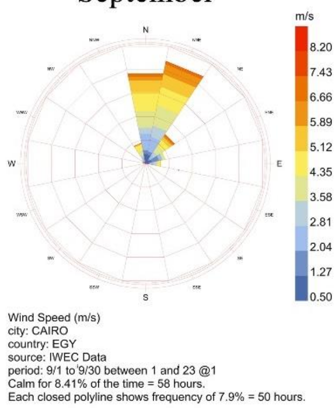
September





Scale1:3000

September



Fig(19): Cairo dominant wind in September with speed 8 m/s and north north east direction

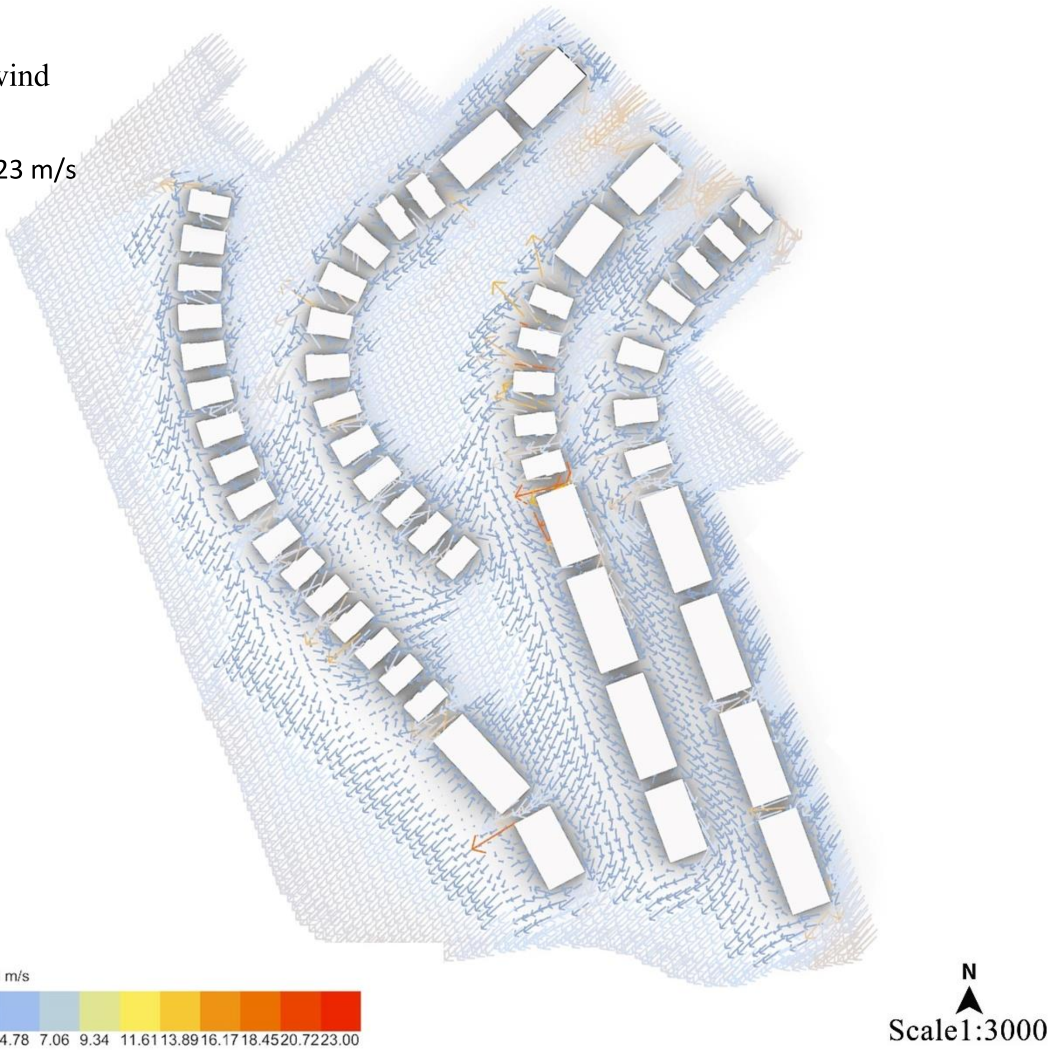
In September in Cairo the dominant wind is from north north east with speed of 8 m/s, the town house is having the main problem as all the windows lies on the longest side with speed reaches 1.5 m/s, the stand alone villas and the town houses windows have wind with speed reach 4 m/s and at some parts it reaches 6 m/s.

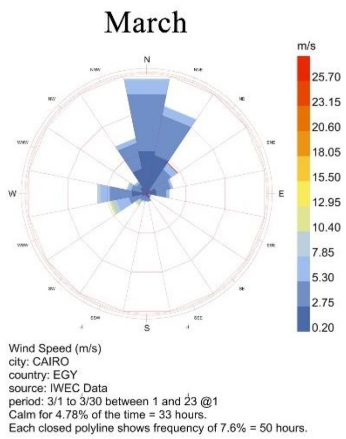
Cairo

North east wind direction

Wind speed 23 m/s

March





Fig(20): Cairo dominant strongest wind in March with speed 23 m/s and north east direction

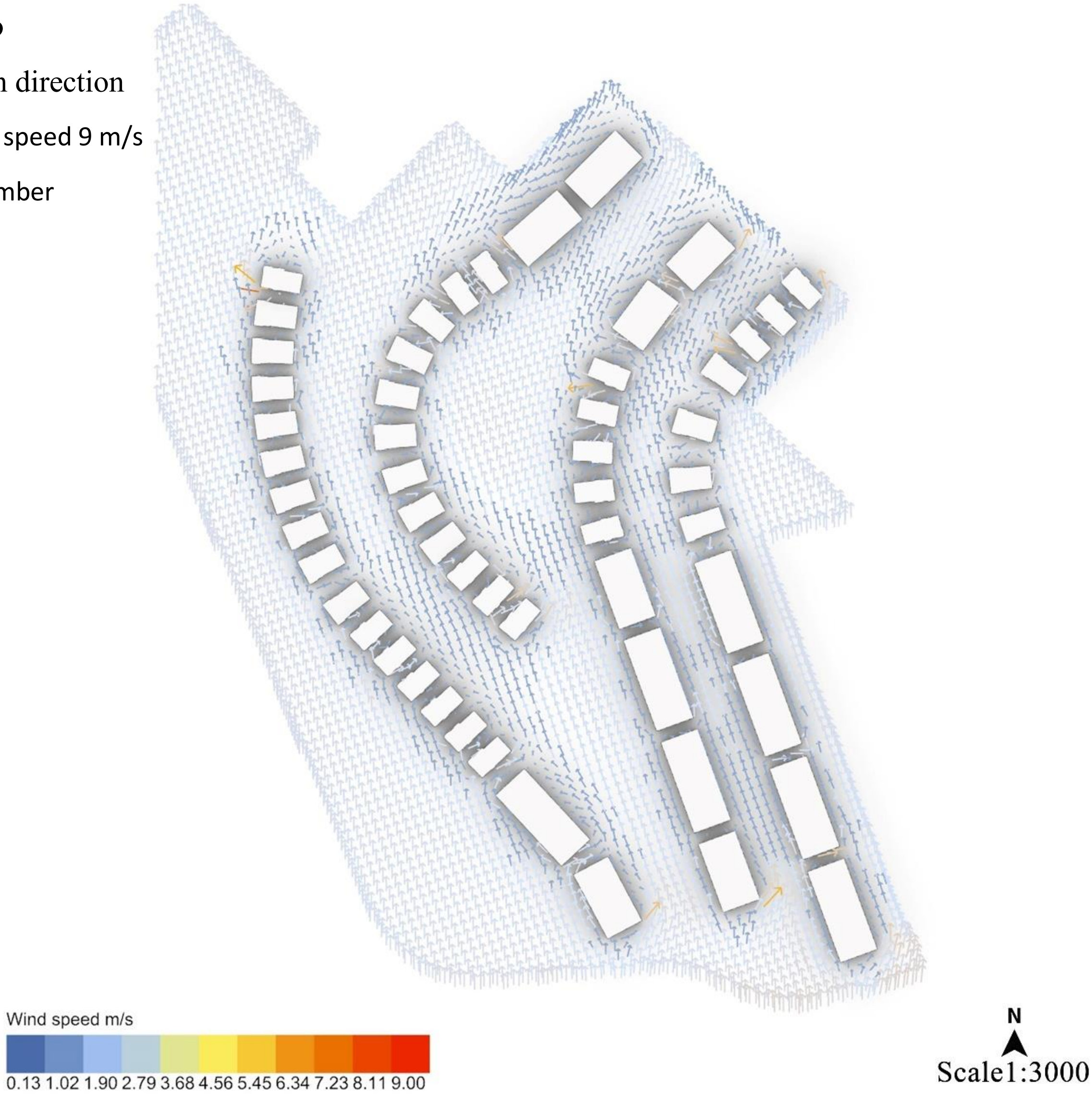
In march the strongest wind can reach 23 m/s but the average speed inside the complex reach 7 m/s, with higher speed in the narrow area between buildings that can reach up to 16 m/s.

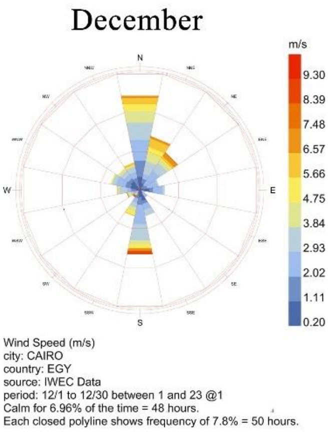
Cairo

South direction

Wind speed 9 m/s

December





Fig(21): Cairo dominant strongest wind in December with speed 9 m/s and south direction

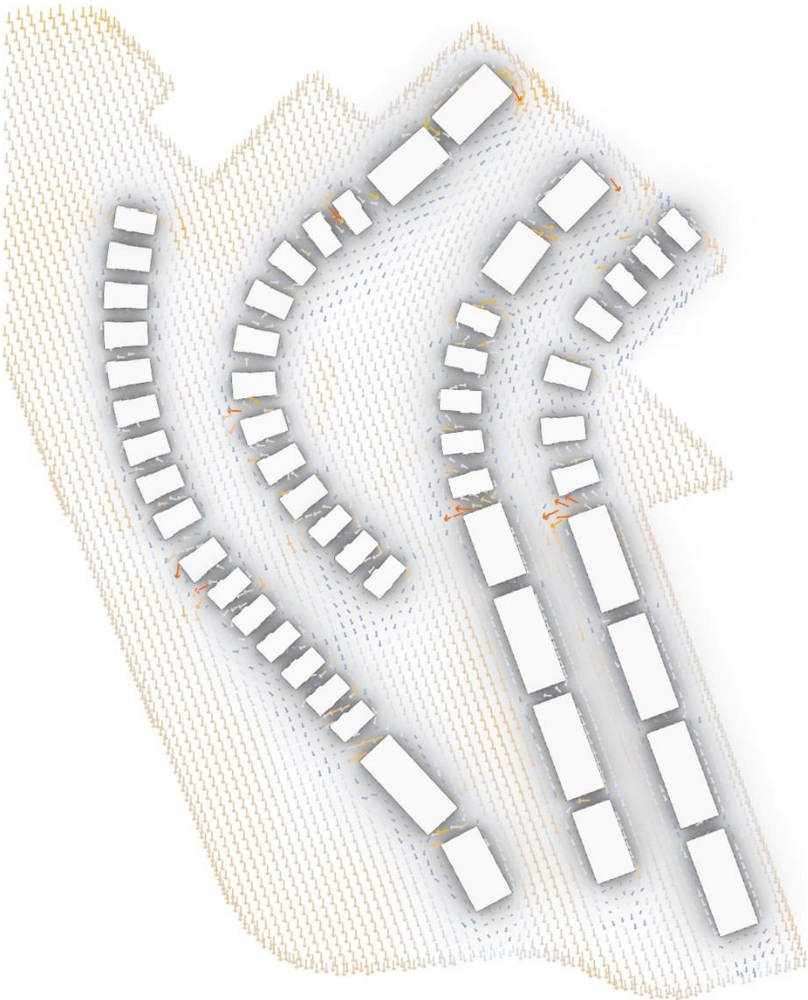
In Cairo the south wind occurs only in December and it is the strongest wind that occurs only 5% of the hours of the month, the distribution of the wind is in 2 m/s in the whole complex with lower speed around the buildings around 1 m/s and higher speed in the narrow side between the buildings from 2 m/s to 5 m/s.

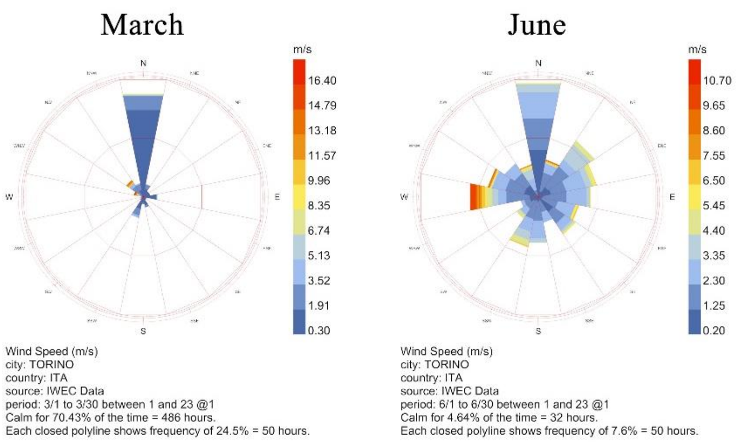
Turin

North direction

Wind speed 6 m/s

March and June





Fig(22): Turin dominant wind in March and June with speed 6 m/s and north direction

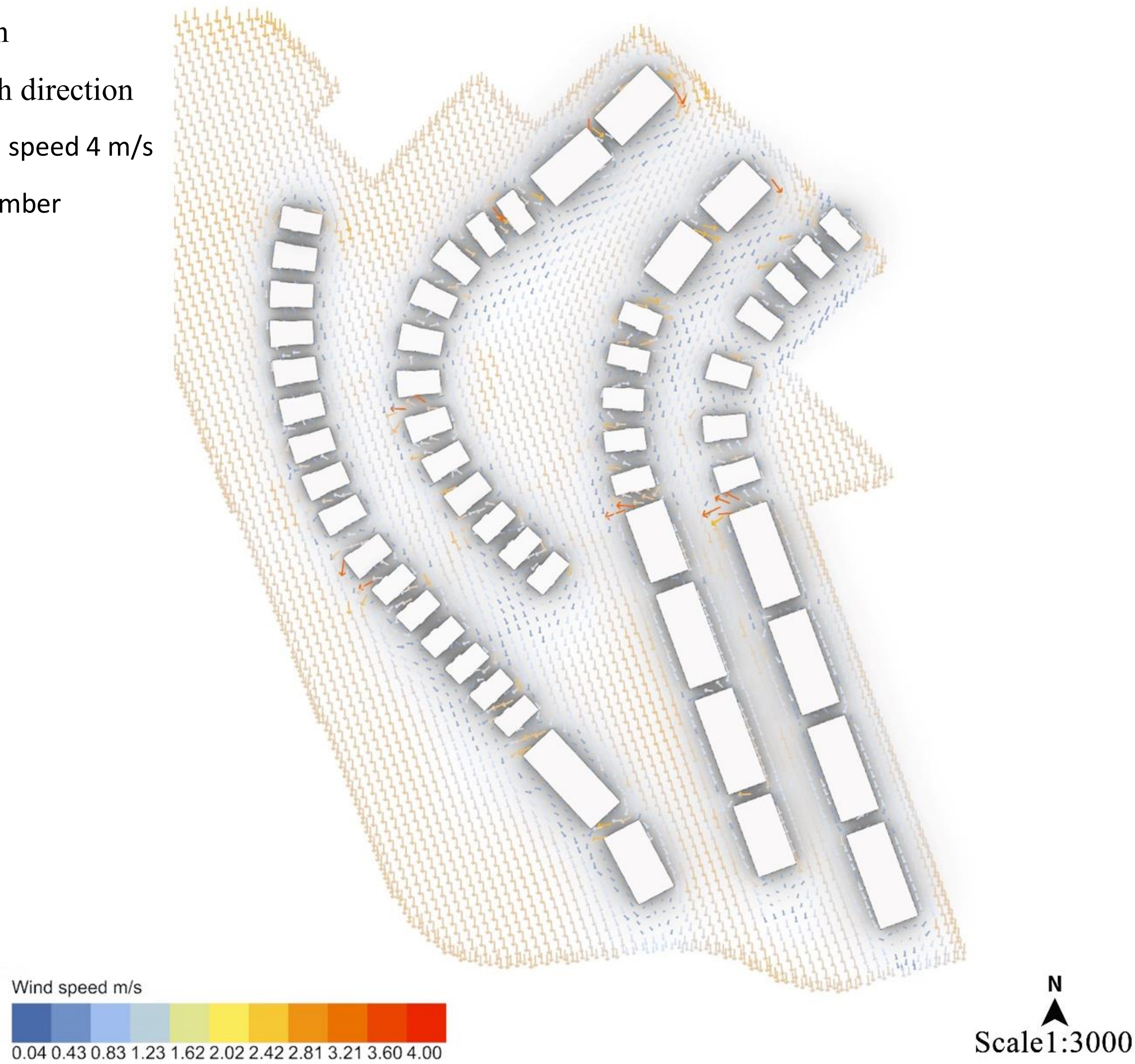
In Turin during the months of March and June the dominant wind is from the north direction with 6 m/s wind speed the wind speed in the urban complex is around 3 m/s with less speed around the building with 1 m/s wind speed, and in the narrow area between the buildings the speed can reach 6 m/s.

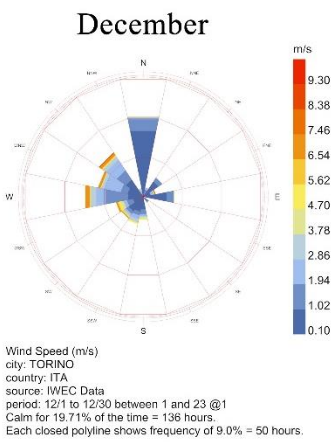
Turin

North direction

Wind speed 4 m/s

December





Fig(23): Turin dominant wind in December with speed 4 m/s and north direction

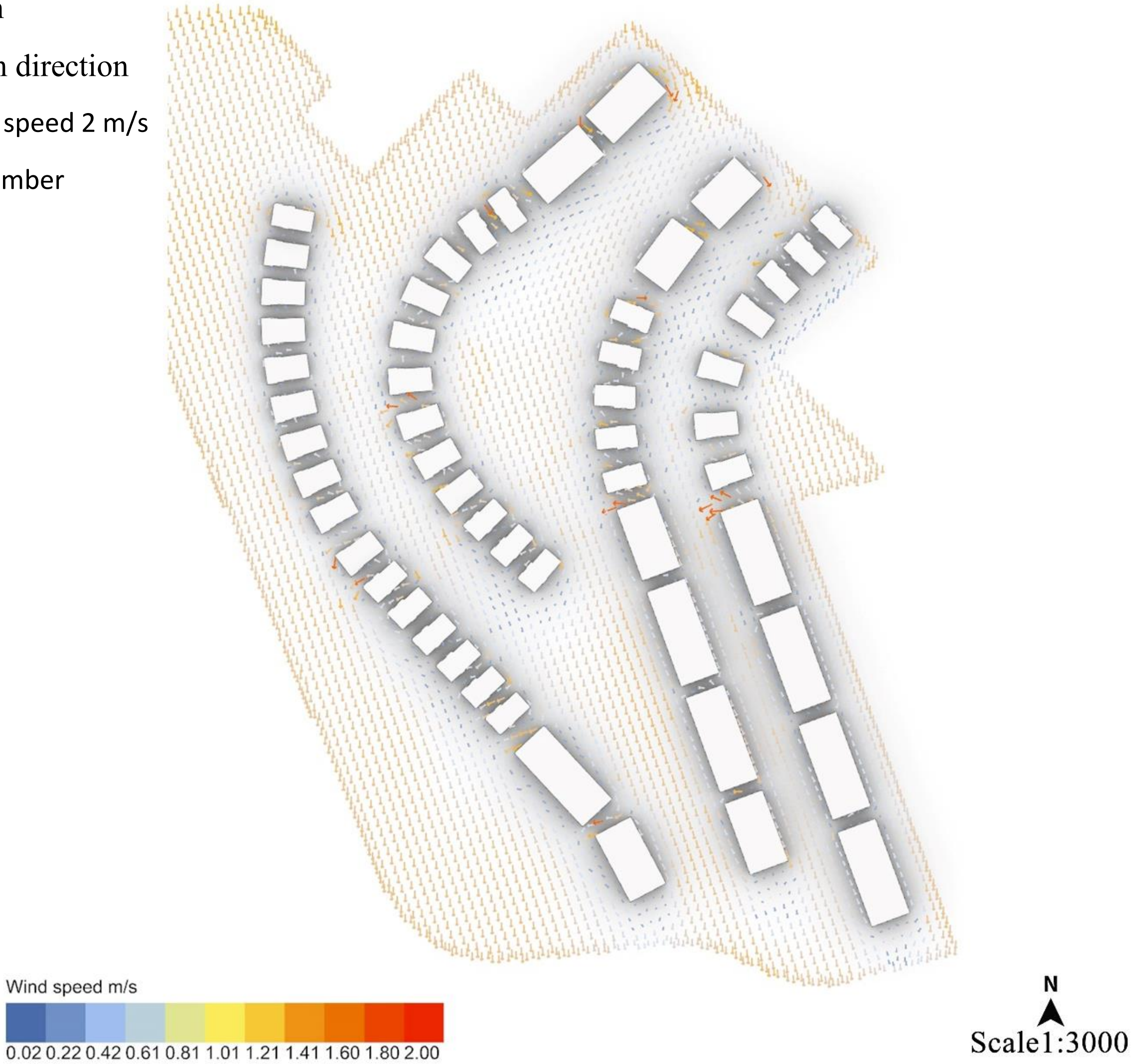
In Turin the dominant wind speed is 4 m/s from the north direction in December, in the urban complex the average speed is 2 m/s, and the speed reach o.5 m/s around the building with higher speed in the narrow side between buildings that speed of the wind can reach 4 m/s in that longer side of the stand alone villa and the twin house.

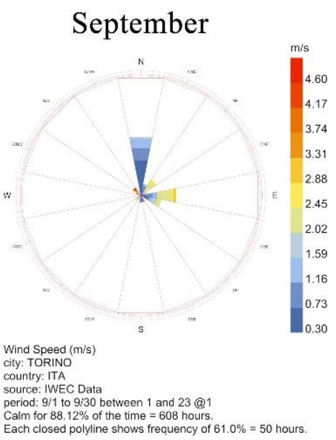
Turin

North direction

Wind speed 2 m/s

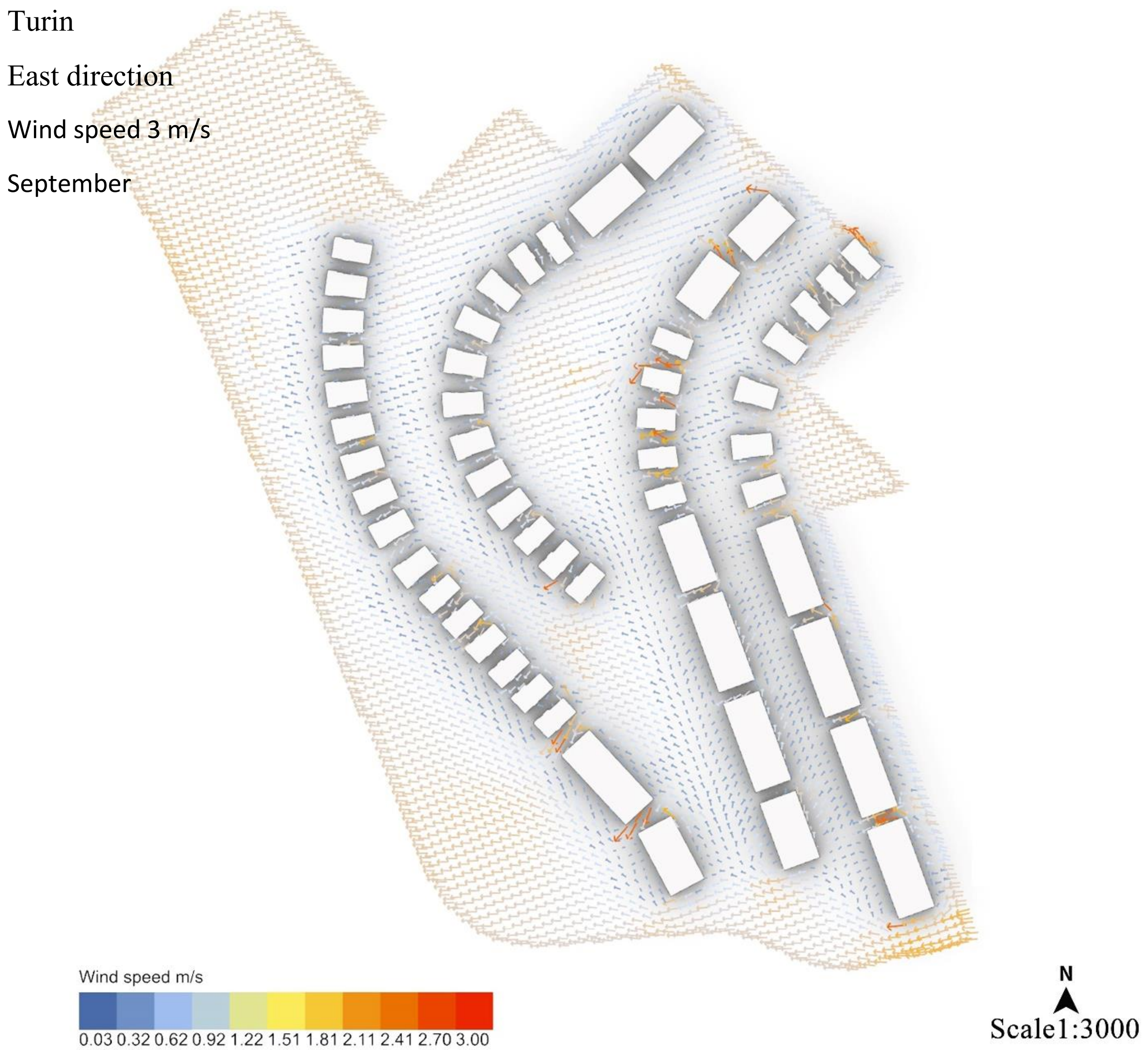
September

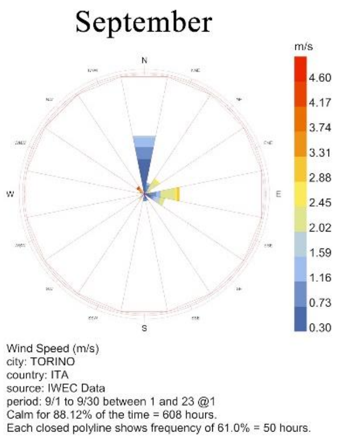




Fig(24): Turin dominant wind in September with speed 2 m/s and north direction

In Turin during September the dominant wind speed is 2 m/s from the north direction which can occur nearly 25% of the hours, the average wind speed in the complex is 1 m/s with less wind speed around the buildings 0.2 m/s.





Fig(25): Turin strongest wind in September with speed 3 m/s and east direction

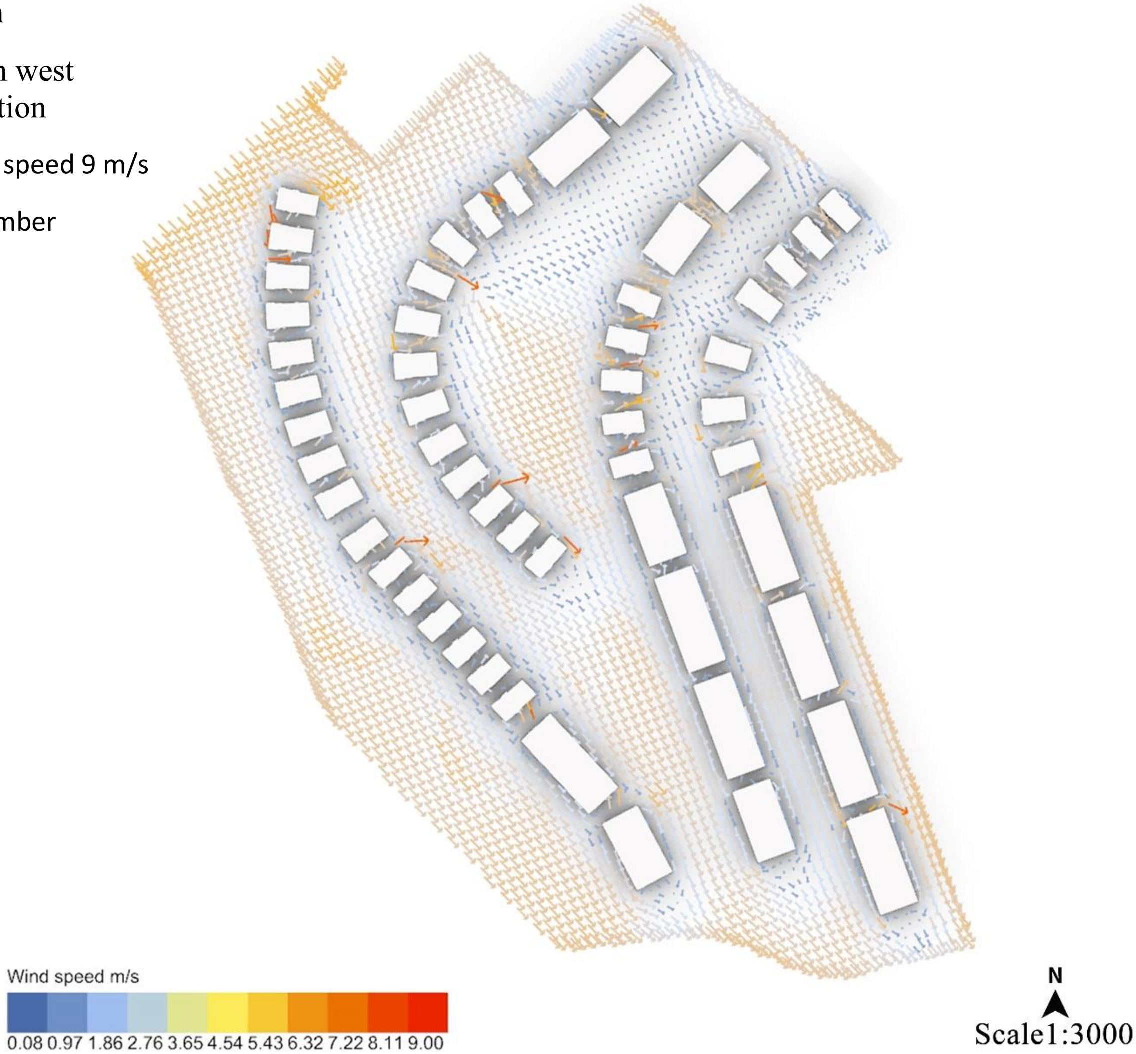
In September in Turin the strongest wind is from the east direction with speed 3 m/s which can occur 13% of the hours of the month, in the centre of the complex the speed is 1.2 m/s and around the buildings the speed is around 0.6 m/s.

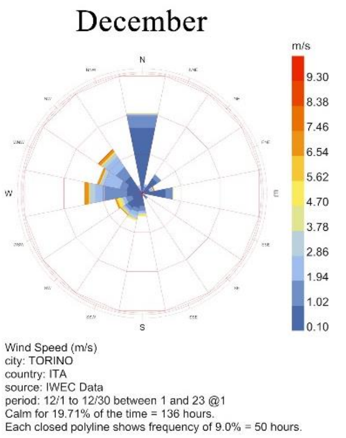
Turin

North west direction

Wind speed 9 m/s

December





Fig(26): Turin strongest wind in December with speed 9 m/s and north west direction

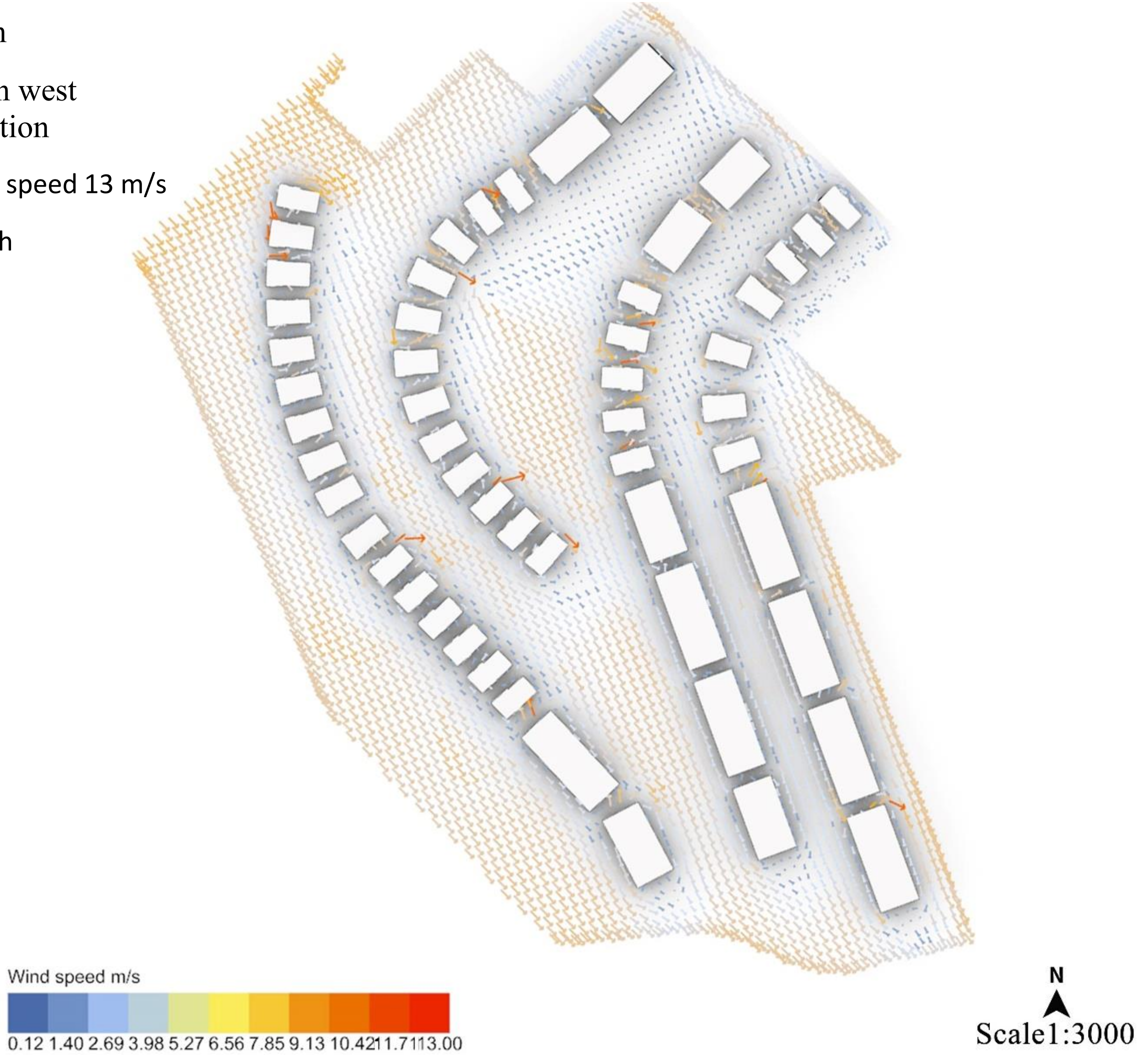
In December the strongest wind reach 9 m/s from north west direction which occur 10% of the hours, the distribution of the wind speed in the center and on the edges reach 8 m/s and around the building the wind reach 2 m/s, so the town house windows have low speed around 1.8 m/s and for the standalone villa and the twin villas windows the speed is from 2 m/s and can reach 8 m/s.

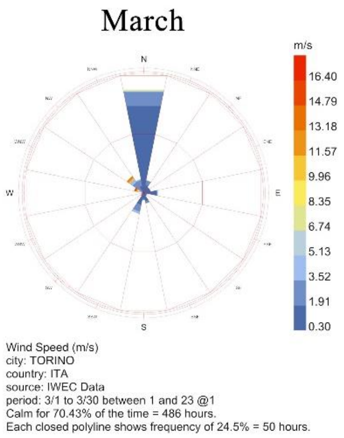
Turin

North west direction

Wind speed 13 m/s

March





Fig(27): Turin strongest wind in March with speed 13 m/s and north west direction

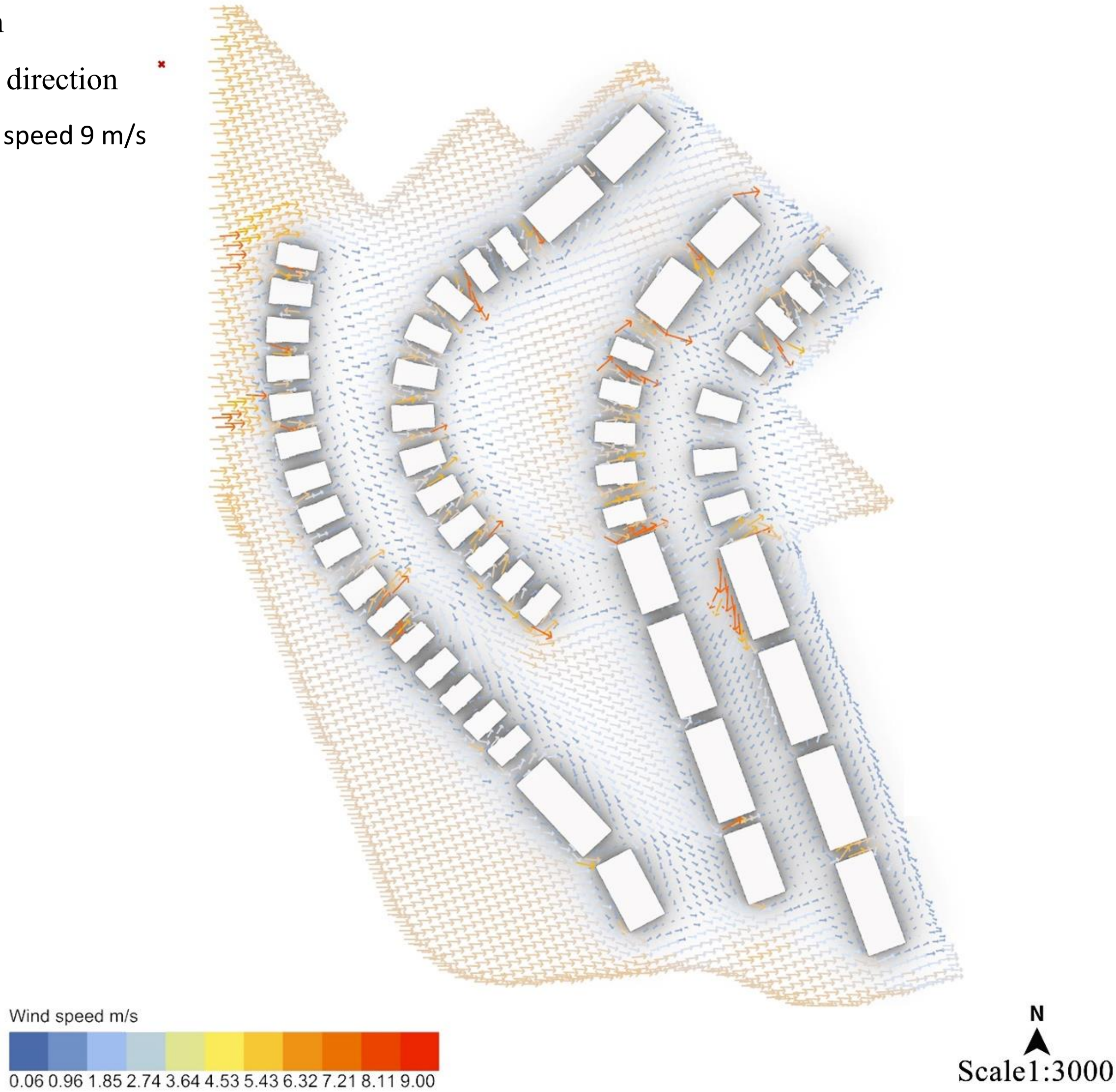
In march the strongest wind can reach 13 m/s from the north west direction that can occur 8% of the hours, the wind speed in the center and edges can reach 8 m/s, and around the buildings the speed is 4 m/s, for the town house windows the speed outside can be 3 m/s and for the standalone villa and twin house windows the speed is higher that can reach 11 m/s with average 5 m/s.

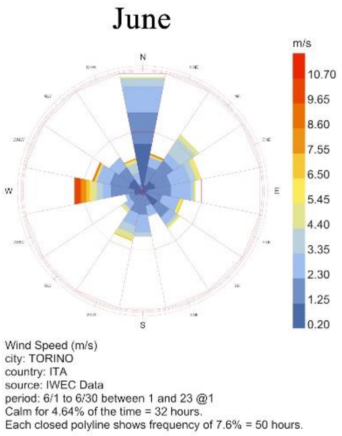
Turin

West direction

Wind speed 9 m/s

June





Fig(28): Turin strongest wind in June with speed 9 m/s and west direction

In June in Turin the strongest speed is 9 m/s from the west direction, the average wind speed in the center of the complex is 3 m/s, around the town house windows the average speed is 2 m/s, and around the standalone villa and twin house windows the speed is higher around 5 m/s.

Urban Solar radiation:

The simulation run to calculate the direct solar radiation is to study the sun path analysis, through setting two different time periods summer from 21 June to 21 august and winter from 21 October to 21 December, in the whole day time from 8 am to 4 pm in two climates Cairo and Turin using EPW files as shown in fig(29) and fig (30) using ladybug for grasshopper.

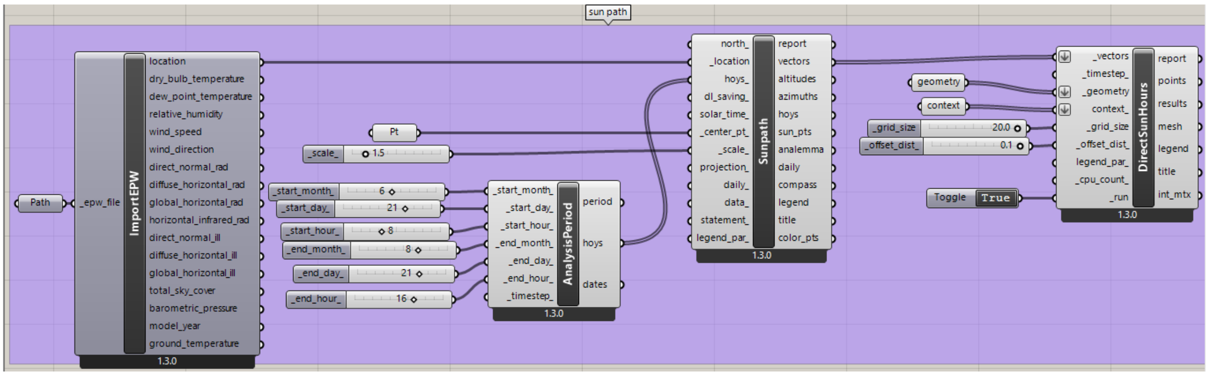


Fig (29): Summer 21 June to 21 August from 8 am to 4 pm in ladybug tool

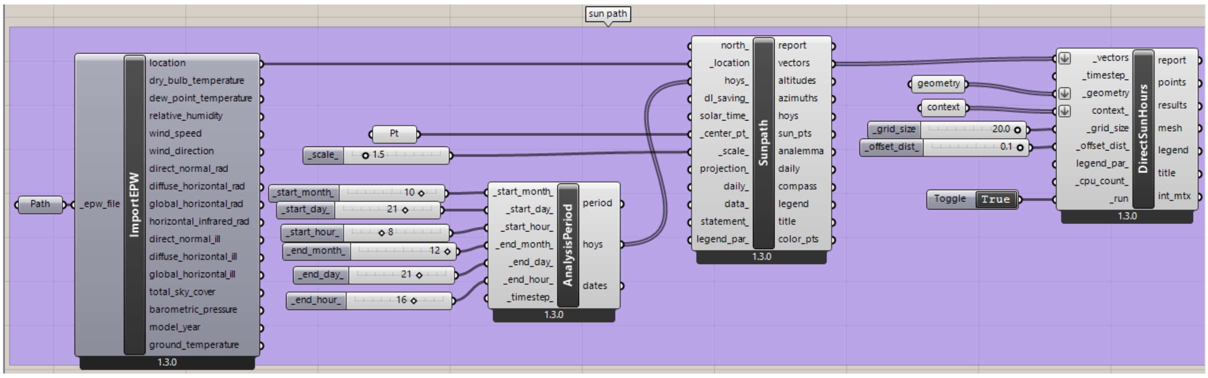
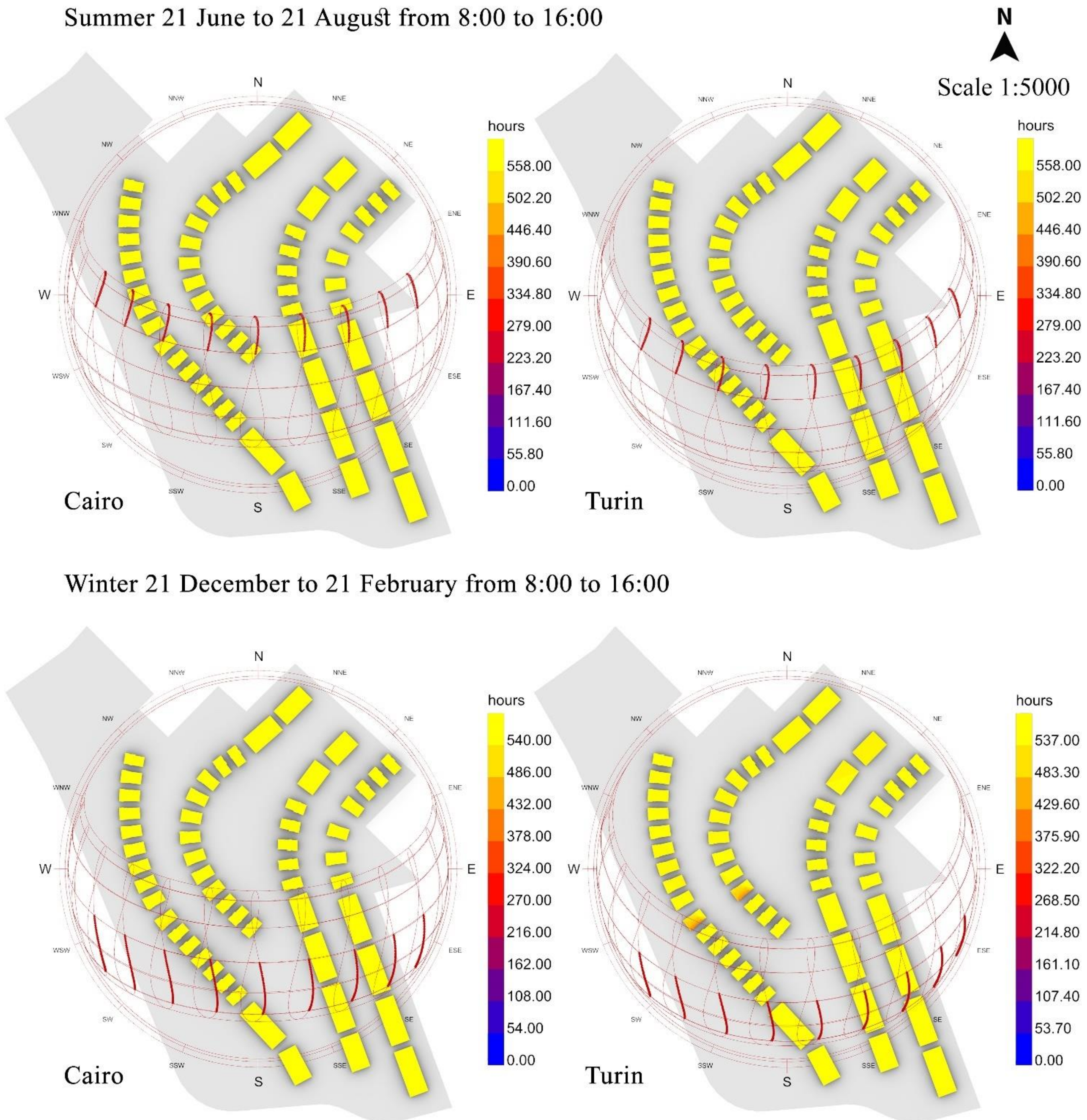


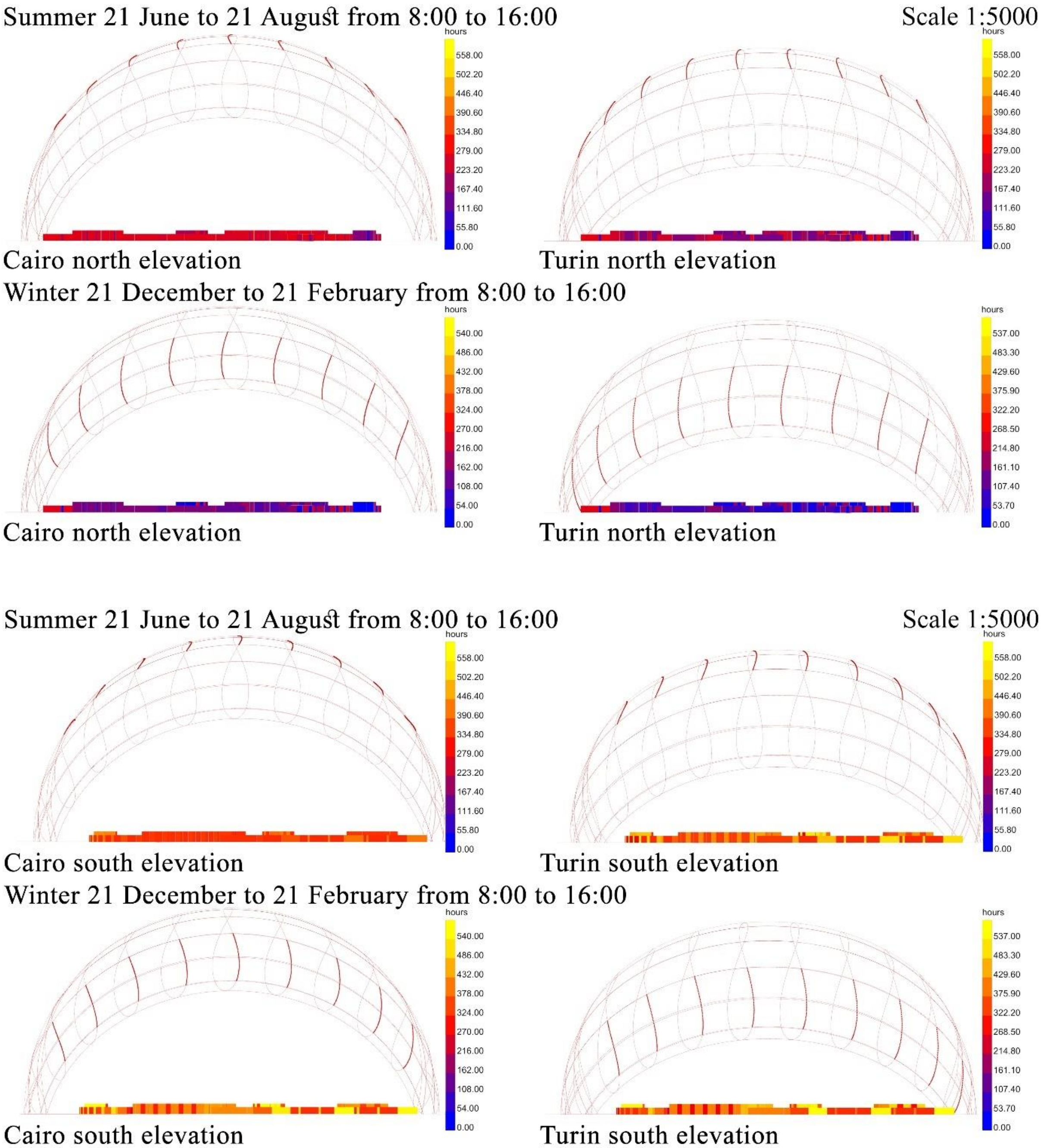
Fig (30): Winter 21 October to 21 December from 8 am to 4 pm in ladybug tool

Direct solar radiation



Fig(31): The direct solar radiation on the roof both in Cairo and Turin in summer and winter

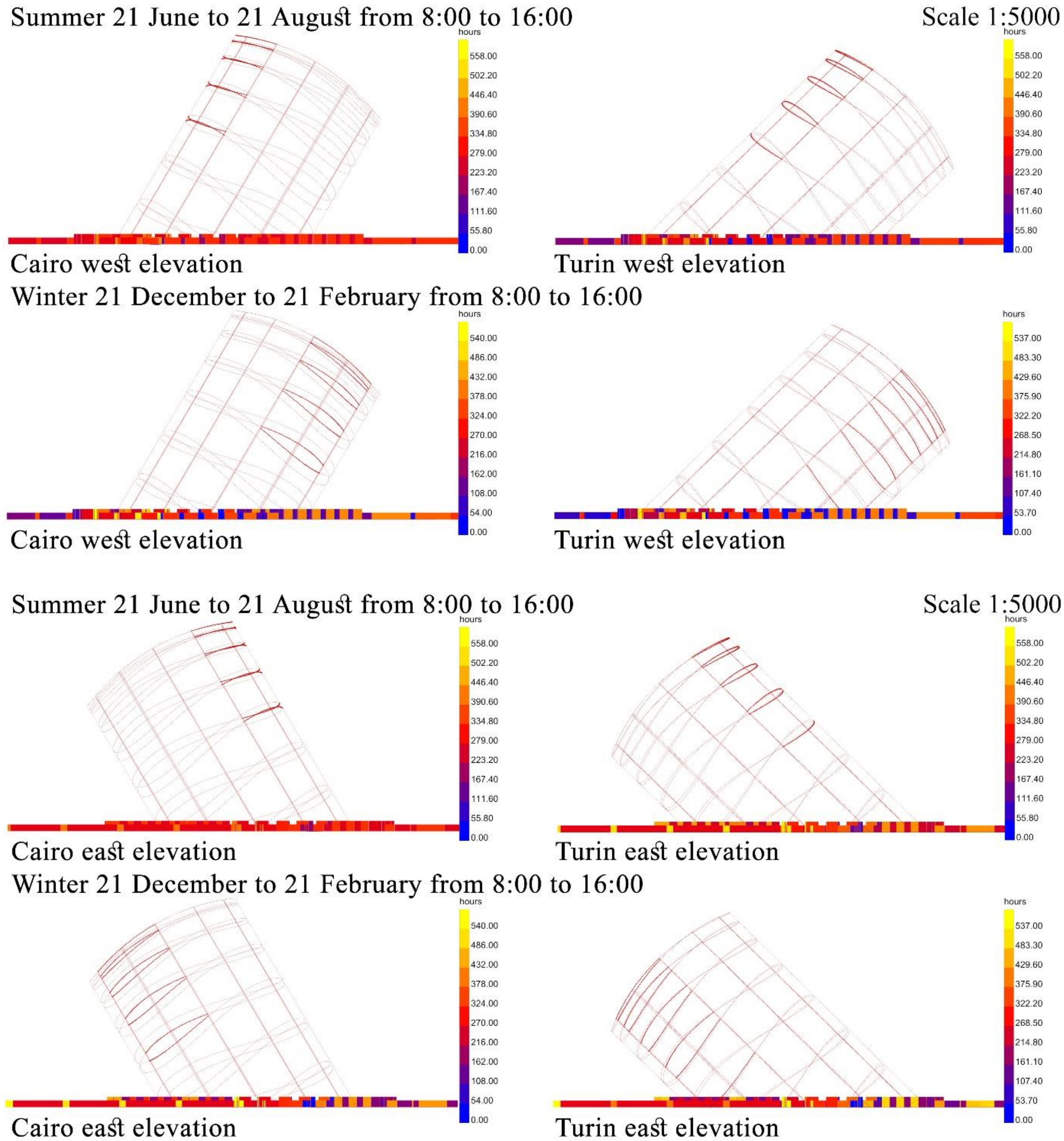
In analysing the layout there is a direct sunlight which differ from summer from 21 June to 21 august and winter from 21 October to 21 December, in the whole day time from 8 am to 4 pm. The range in summer both in Cairo and Turin is approximately 558 hours, but in winter the range is 537 hours. The analysis is carried on two months which is 60 days and 1440 hours, in conclusion 39% of the hours the roof is exposed to direct sunlight while in winter the percentage is 37%.



Fig(31) shows the direct solar radiation on the north and south both in Cairo and Turin in summer and winter

From analysing the direct solar radiation on the north elevation both in Cairo and Turin, the direct solar radiation in summer in Cairo is around 279 hours which is nearly equal 19%, In Turin the direct radiation is around 223 hours which is equal to 15% of the hours per two months of summer from 21 June to 21 august. In winter the direct solar radiation hours, in Cairo the direct solar radiation hours is 162 hours which is approximately equal to 11%, in Turin the hours which the north elevation is exposed to direct radiation is 107 hours which is 7% of the hours per the two months of winter.

The south elevation is the elevation that is maximum exposed to the direct solar radiation, in summer in Cairo the south elevation is exposed around 390 hours approximately equal to 27%, in Turin the elevation is exposed 426 hours 29% of the hours. In winter the south elevation in Cairo and Turin is approximately 324 hours from 1440 hours per two months which is approximately equal to 25%.



Fig(32): The direct solar radiation on east and west both in Cairo and Turin in summer and winter

From analysing the west elevation direct solar radiation in Cairo and Turin, the direct solar radiation in summer in Cairo is around 334 hours which is nearly equal 23%, In Turin the direct radiation is around 223 which is equal to 15% of the hours per two months of summer from 21 June to 21 august. In winter the direct solar radiation hours, in Cairo the direct solar radiation hours is 216 hours which is approximately equal to 15%, in Turin the hours which the west elevation is exposed to direct radiation is 161 hours which is 11% of the hours per the two months of winter.

The east elevation is exposed to the direct solar radiation in summer in Cairo 390 hours approximately equal to 27%, in Turin the elevation is exposed 334 hours 23% of the hours. In winter the south elevation in Cairo and Turin is approximately 375 hours from 1440 hours per two months which is approximately equal to 26%.

Conclusion

	Roof	*North*	*South*	*East*	*west*
Summer	446	362	306	167	334
Winter	148	148	37	37	167

Table (6): The direct solar radiation in 1440 hours for two months

In conclusion the direct solar radiation on the roof in summer (from 21 June to 21 August from 8 am to 4 pm) is the heights façade facing the maximum direct sun hours so to solve that the roof must be insulated or double roofed. The east façade is having the least direct sun hours both in summer and winter, then the south façade.

Materials

Most of the residential buildings in Egypt are constructed simple as a concrete frame with red brick from the low-income buildings to high income buildings the only difference is through the decorations and services, although in the past in Egypt the building system was different the buildings used to be as bearing wall system and they used more earth materials as stones, lime bricks and mud which positively affected the internal thermal comfort and the energy consumption. After changing the structure systems from bearing walls to concrete structure where the columns and beams are the main element, the walls are acting as just a cover with the minimum coast element.

Walls materials in Cairo

In Egypt, due to the increase in population and the rapid constructions in the residential sector with considering low coast which reflected in using the bricks as half brick 12 cm without taking into consideration the U value or the thermal transmittance which directly affects the inner thermal comfort, also the walls mostly are used without any thermal insulation or without having even an air gape between the two blocks of walls. In Egypt in the past the wall thickness reached 50 cm which directly reflected on the thermal transmittance and the inner comfort, when comparing the old building techniques and the new building techniques and comparing the material and the thickness which reflects on the U values, the comparison shows how the increase in population and the consideration of the cost is affecting the thermal comfort.

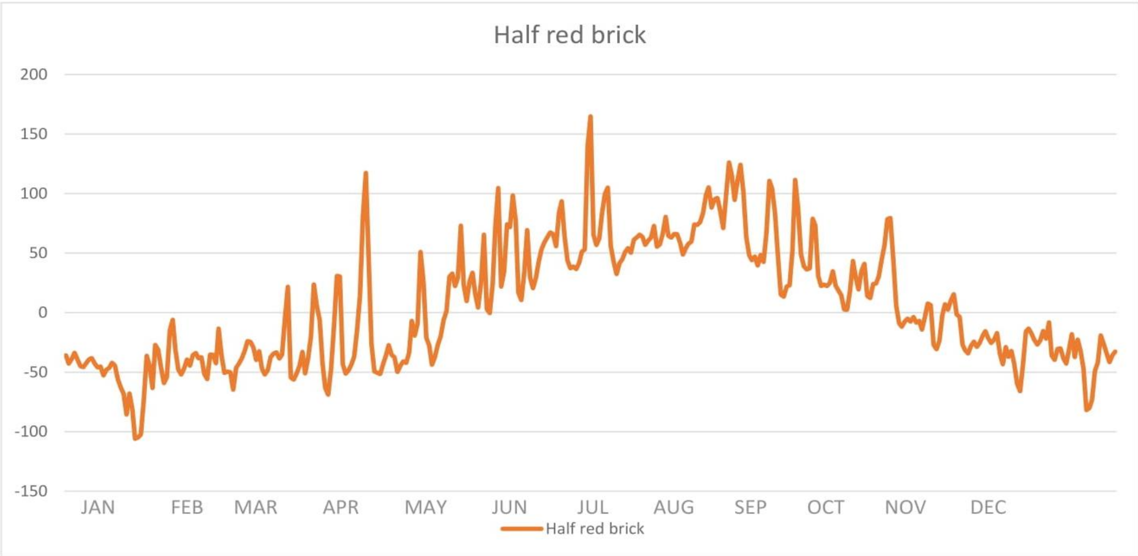
In comparing different materials that are listed below with different wall thickness that is used in Egypt as external walls.

Brick	*Material*	*Wall thickness*
Red brick	Fired clay brick	12 cm-25 cm
Cement brick	cement	12cm – 40 cm
Limestone	Limestone	40 cm – 60 cm
Straw brick	Rice straw	12 cm
Earth brick	Compressed earth block	15 cm

Table (7): The building materials and thickness in Egypt

Red brick

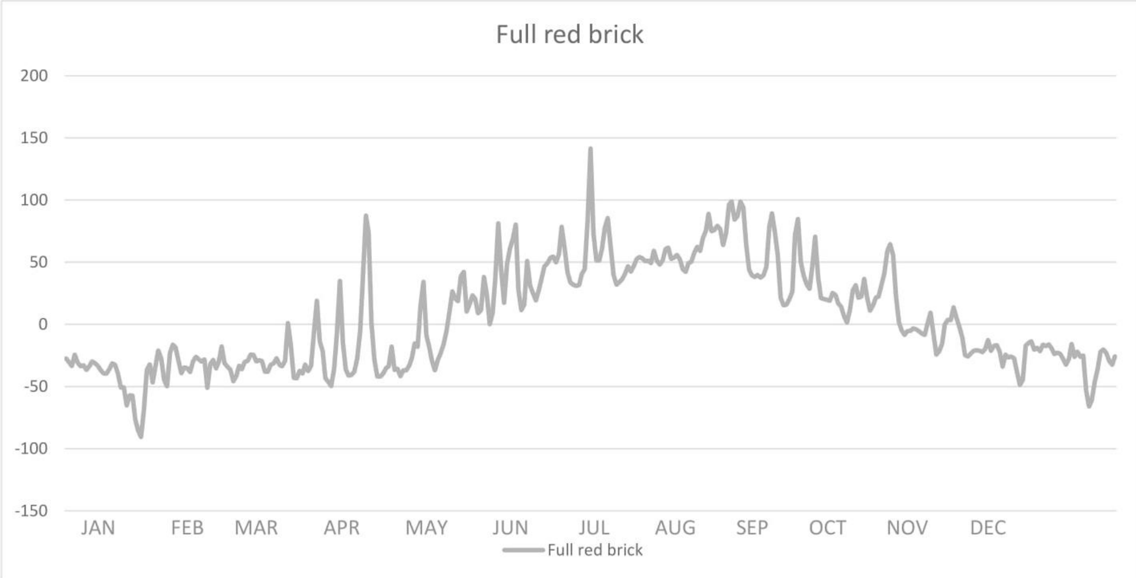
Red brick is the most widely used brick in Egypt, as it is the cheapest and most available in the Egyptian market, due to the availability of the clay and mud from the Nile river the red brick was the most widely used bricks in Egypt, the mud and clay are exposed to high heated ovens to be dried until the high dam in Aswan was built which decreased the mud from the Nile river until 1980 the government banned the usage of natural mud and clay and replaced it with artificial bricks. The dimension of the brick is 25x12x7 cm but due to the low cost planning most of the low income residential they use half brick 12x12x7 cm, the bricks is used mostly with inner and outer layer of plaster. In fig(33) the half red brick wall with two plaster layers with U-value of 2.594 w/m²-k. In fig(34) the red brick wall with two plaster layers with U-value of 1.833 w/m²-k



Fig(33): The thermal heat balance for half red brick material in Cairo climate

Half red brick	
Thermal conductivity	0.75 W/m.k
Specific heat capacity	880 J/(kg.K)
Density	1730 Kg/m³
Mass density	207.6 Kg/m²

Half red brick wall	
Periodical thermal transmittance	*1.771 W/(m²k)*
Thermal resistance	0.386 m²k/W
Thermal transmittance	2.594 W/(m²k)
Time lag	4.62 h



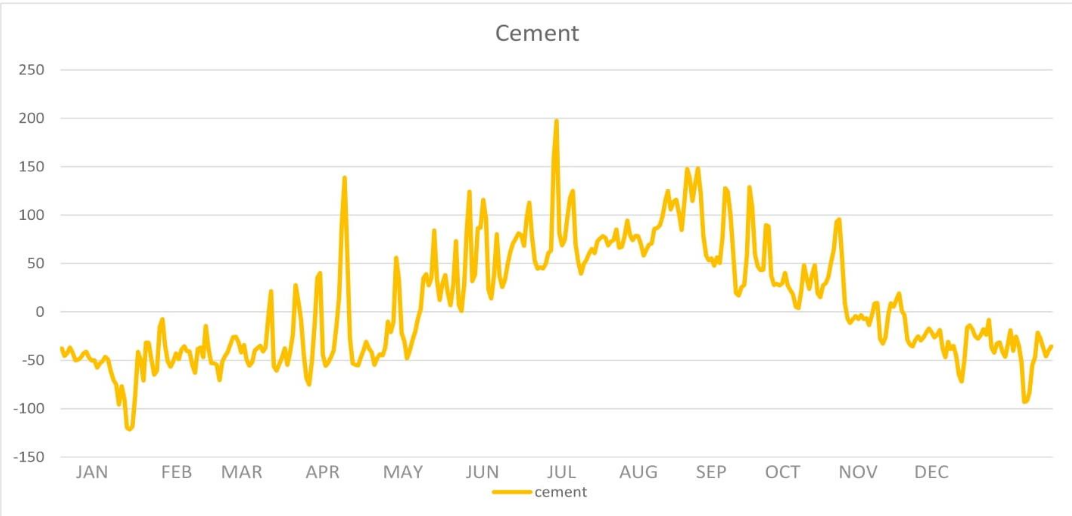
Fig(34): The thermal heat balance for full red brick material in Cairo climate

Full red brick	
Thermal conductivity	0.75 W/m.k
Specific heat capacity	880 J/(kg.K)
Density	1730 Kg/m³
Mass density	432.5 Kg/m²

Full red brick wall	
Periodical thermal transmittance	*0.577 W/(m²k)*
Thermal resistance	0.559 m²k/W
Thermal transmittance	1.789 W/(m²k)
Time lag	8.95 h

Cement brick

The cement blocks are used as either hollow blocks or normal blocks, the hollow blocks are more environmental as they have some holes that act as an air gap while the normal blocks are less environmental. The cement blocks are the most un-environmental type of blocks as the blocks is made of a mixture of powdered Portland cement, sand, water and gravel which is moulded inside a machine. The cement is having a negative impact on the environment in the whole production process as the process is producing a large CO2 emission, in 2014, CO2 emissions from cement production for Egypt was 6,664 thousand metric tons. CO2 emissions from cement production of Egypt increased from 329 thousand metric tons in 1965 to 6,664 thousand metric tons in 2014 growing at an average annual rate of 6.85%, also Egypt is having a problem in the manufacturing of cement in 2014, the Egyptian Initiative for Personal Rights published a report on alleged labour rights and environmental by Titan Cement in Egypt, as not all the workers are working under permeant contracts. There are two types of cement bricks used in Egypt the normal brick cement the brick thickness is 12 cm wall and used with U-value 3.343 w/m²-k, and the other type is the hollow cement brick which is more sustainable as the hollow brick is acting as an air gap and wall insulation, the hollow brick with dimension 40x20x12 cm and U-value wall of 2.676 w/m²-k.

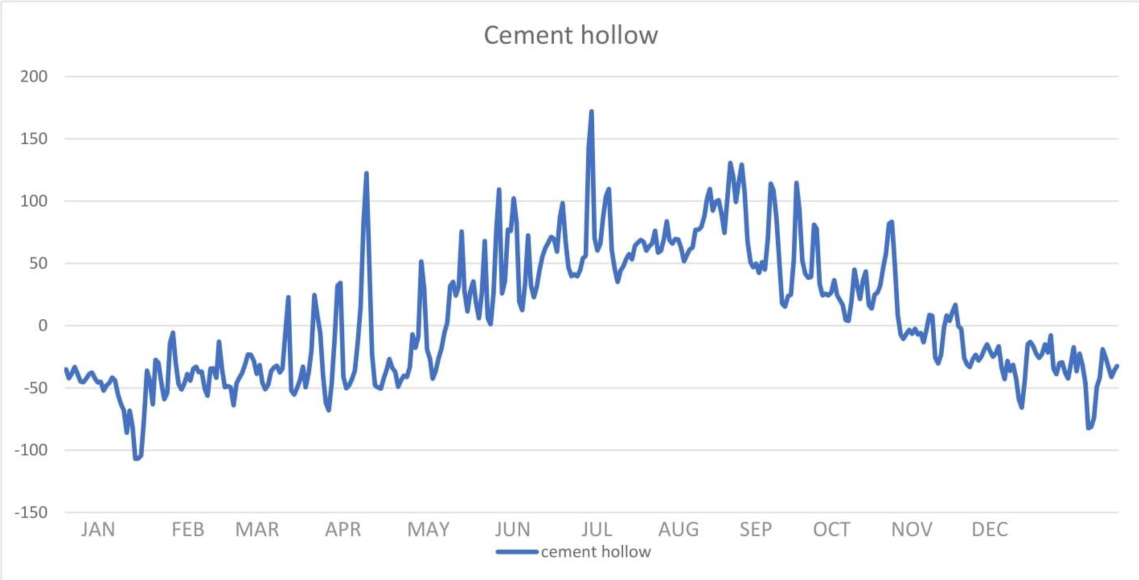


Fig(35): The thermal heat balance for cement brick material in Cairo climate

Cement brick	
Thermal conductivity	1.63 W/m.k
Specific heat capacity	1000 J/(kg.K)
Density	2300 Kg/m³
Mass density	276 Kg/m²

Cement wall	
Periodical thermal transmittance	*2.029 W/(m²k)*
Thermal resistance	0.299 m²k/W
Thermal transmittance	3.343 W/(m²k)
Time lag	4.67 h

"Home." Brickco, 6 July 2020, https://brickco.com.eg/%d9%85%d9%86%d8%aa%d8%ac%d8%a7%d8%aa-%d8%a7%d9%84%d8%b7%d9%88%d8%a8-%d8%a7%d9%84%d8%a7%d8%b3%d9%85%d9%86%d8%aa%d9%8a/.



Fig(36): The thermal heat balance for cement hollow brick material in Cairo climate

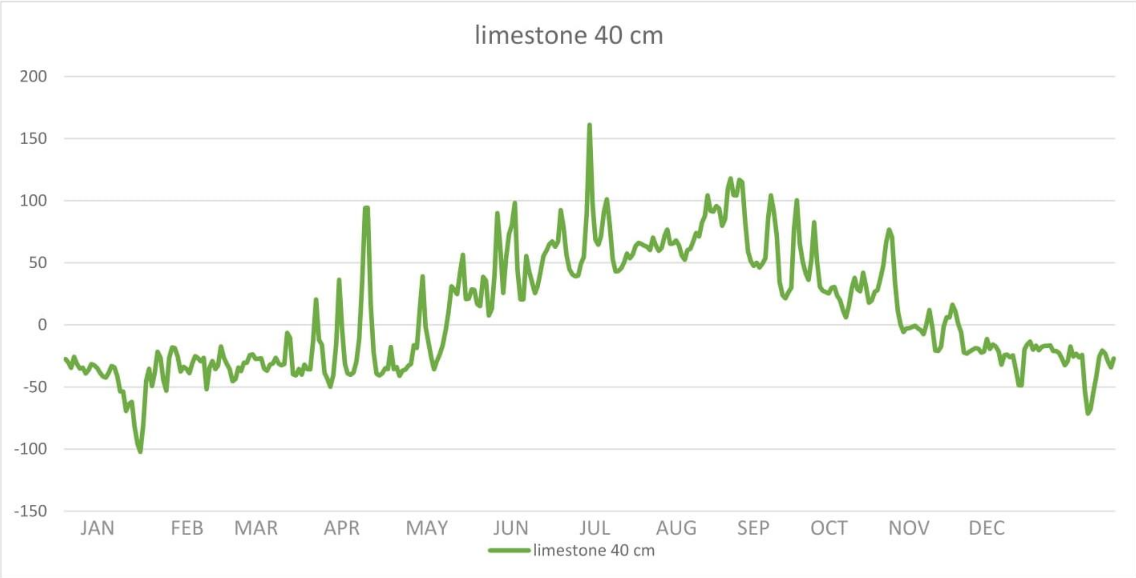
Cement hollow brick	
Thermal conductivity	1.35 W/m.k
Specific heat capacity	840 J/(kg.K)
Density	1220 Kg/m³
Mass density	244 Kg/m²

Cement hollow wall	
Periodical thermal transmittance	1.762 W/(m²k)
Thermal resistance	0.374 m²k/W
Thermal transmittance	2.676 W/(m²k)
Time lag	4.77 h

Limestone brick

The limestone bricks were used in Egypt since the pharaonic period, as they used the limestone blocks in building the pyramids, and it had also been used in the Islamic period to build the houses at that time as it was used as thermal insulation materials with big thickness walls to decrease the thermal transmittance as it keeps the inner comfort whether the outside temperature is high or low.

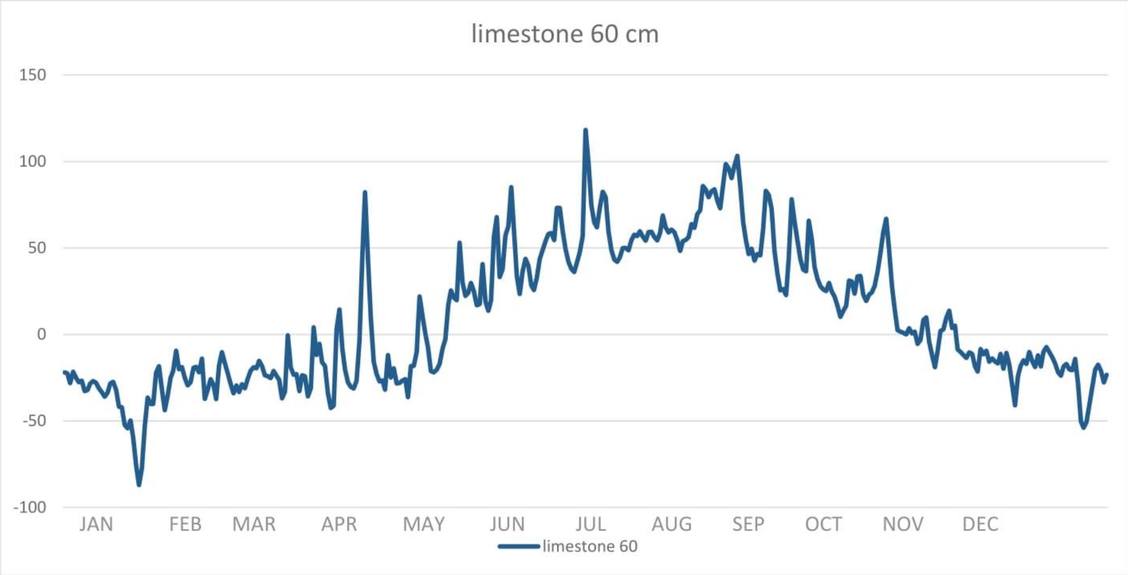
In Egypt in the recent years the limestone bricks are not used anymore, it is used to be during the Islamic era, it was used in two thickness 40cm wall with U-value of 2.29 w/m²-k and 60 cm wall with U-value 1.754 w/m²-k.



Fig(37): The thermal heat balance for limestone 40 cm brick material in Cairo climate

Limestone 40 cm brick	
Thermal conductivity	1.5 W/m.k
Specific heat capacity	720 J/(kg.K)
Density	2180 Kg/m³
Mass density	872 Kg/m²
Periodical thermal transmittance	0.623 W/(m²k)
Thermal resistance	0.437 m²k/W
Thermal transmittance	2.29 W/(m²k)
Time lag	9.35 h

Fahmy, Mohammad, et al. "Generic Energy Efficiency Assessment for Heritage Buildings; Wekalat El-Ghouri as a Case Study, Cairo, Egypt." Energy Procedia, vol. 156, 2019, pp. 166–171., https://doi.org/10.1016/j.egypro.2018.11.122.



Fig(38): The thermal heat balance for limestone 60 cm brick material in Cairo climate

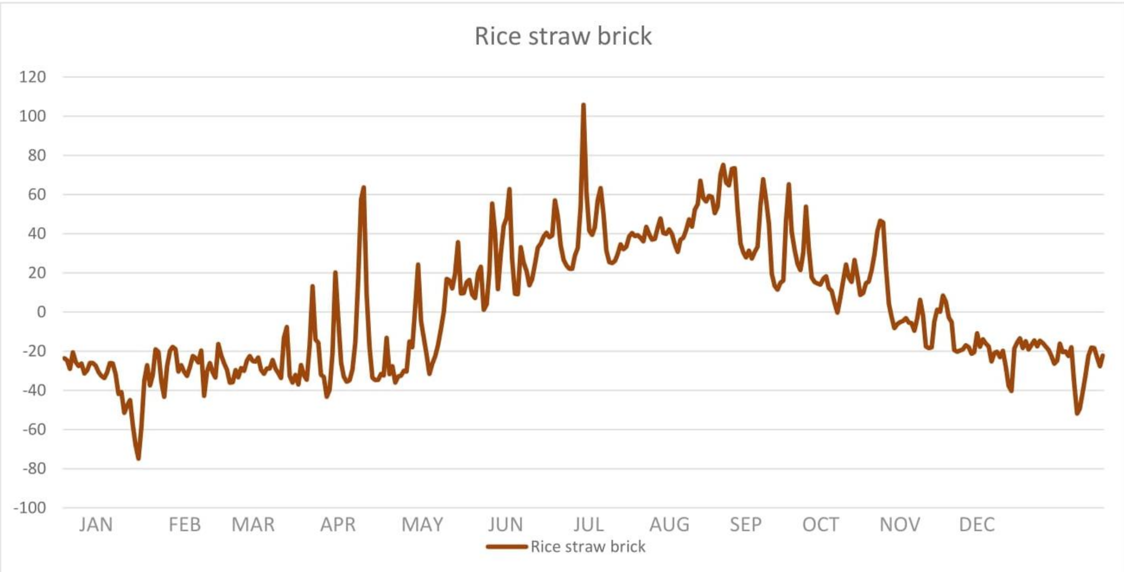
Limestone 60 cm brick	
Thermal conductivity	1.5 W/m.k
Specific heat capacity	720 J/(kg.K)
Density	2180 Kg/m³
Mass density	1308 Kg/m²
Periodical thermal transmittance	0.181 W/(m²k)
Thermal resistance	0.57 m²k/W
Thermal transmittance	1.754 W/(m²k)
Time lag	14.05 h

Proposed materials

According to the increase in usage of sustainable materials in Egypt, there are several studies that are used as recycled, two of those materials are analysed below the rice straw bricks and the compressed earth bricks

Rice straw bricks

Egypt is having a huge number of rice yields as Egypt is considered as one of the world's top countries of producing rice, rough rice yield for 2015/16 is estimated at 7.25 tons per hectare, and according to that a large amount of rice straw is left unused. In Egypt farmers used to burn the rice straw which causes large amounts of air pollutants and also cause black clouds which is a thick layer of smog that spread across Cairo, which cause a lot of environmental problems. The Egyptian government produced Law No. 4/1994 which banned the burning of rice straw, there is an agreement signed between the ministry of agriculture and ministry of environment to produce organic fertilizers and non-conventional feedstuffs. The rice straw is mixed with amount of cement to produce bricks which is also acting as a thermal insulation, also this type of bricks can be considered as a low coast material in the Egyptian market. The suggested brick dimensions are 25x12x13 cm and the wall U-value is 1.233 w/m²-k.



Fig(39): The thermal heat balance for rice straw brick material in Cairo climate

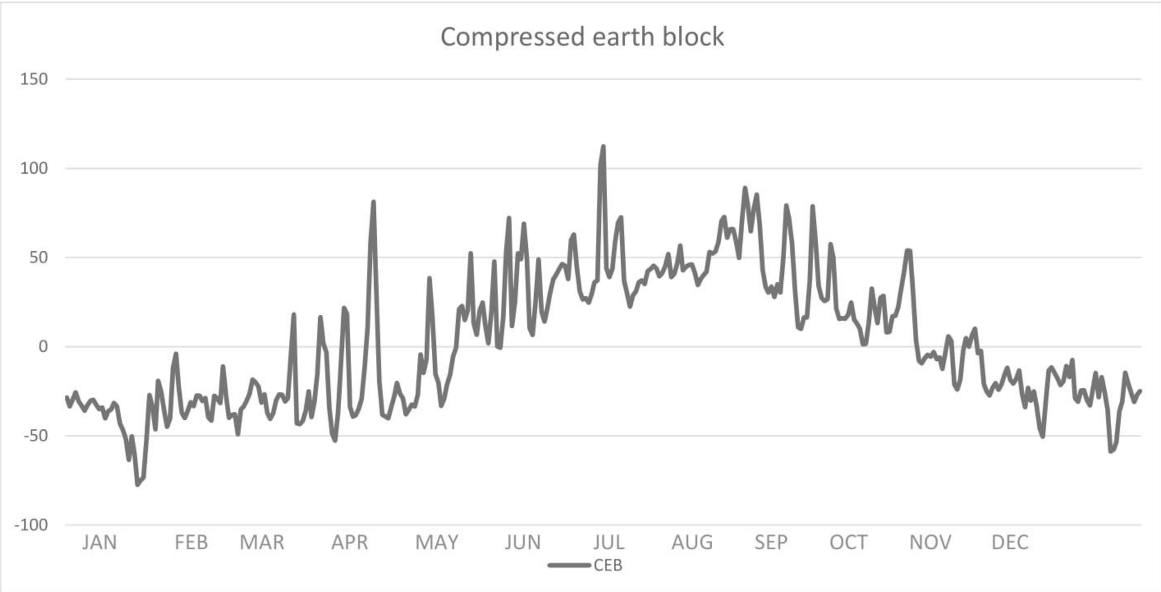
Rice straw brick	
Thermal conductivity	0.41 W/m.k
Specific heat capacity	1000 J/(kg.K)
Density	1545 Kg/m³
Mass density	185.4 Kg/m²

Rice straw wall	
Periodical thermal transmittance	0.255 W/(m²k)
Thermal resistance	0.835 m²k/W
Thermal transmittance	1.197 W/(m²k)
Time lag	11.59 h

"Egypt Recycles over 1.4 Million Tons of Rice Straw to Prevent 'Black Cloud' Pollution - Politics - Egypt." Ahram Online, https://english.ahram.org.eg/NewsContent/1/64/388040/Egypt/Politics-/Egypt-recycles-over--million-tons-of-rice-straw-to.aspx.
M. Allam, and G. Garas. Recycled Chopped Rice Straw–Cement Bricks. Vol. 40, WIT Transactions on Ecology and the Environment, 2010.

Compressed earth blocks

The usage of compressed earth blocks is back to the old Egyptian period, this period is known for the usage of stones for the templates and pyramids however the earth blocks was used to build the residential houses at that period of time, and it was not only used to build walls but also used to build vaults and domes which was so economically and technically simple process, when comparing earth blocks constructions to stones constructions it was more environmental, adaptable and cause more inner comfort. In the recent years also the earth blocks started to refresh in the Egyptian market to achieve more sustainable approach. The size of the compressed earth block is 30x15x9 cm to build a wall with U-value of 1.45 w/m²-k.



Fig(40): The thermal heat balance for compressed earth block material in Cairo climate

CEB brick	
Thermal conductivity	0.52 W/m.k
Specific heat capacity	1260 J/(kg.K)
Density	2050 Kg/m³
Mass density	307.5 Kg/m²

CEB wall	
Periodical thermal transmittance	0.66 W/(m²k)
Thermal resistance	0.514 m²k/W
Thermal transmittance	1.945 W/(m²k)
Time lag	8.54 h

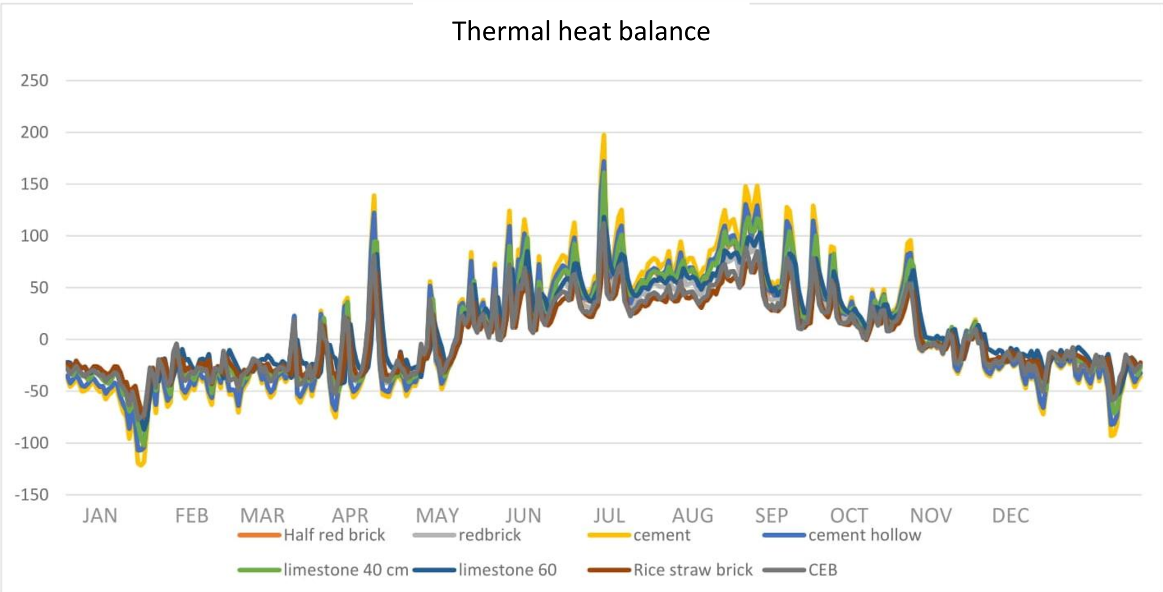
MarwanMostafa. “Experimental Analysis of Compressed Earth Block (CEB) with Banana Fibers Resisting Flexural and Compression Forces.” Case Studies in Construction Materials, edited by NasimUddin, vol. 5, 2016.

Conclusion

From the previous analysis, it is clear that both the thickness of the wall and the material affects the U-value and also the total heat gain from the wall, the heights and lowest heat gain is from the cement whether it is a total block or hollow block, then comes the red brick with both thickness 12 and 25 cm, and the limestone is in the third place the 60 cm wall is more environmental than the 40 cm wall, the best environmental materials are compressed earth block and then the rice straw brick. All those materials are used without thermal insulation just inner and outer layer of plaster and all of them are analysed on the same case study (case study1) and location using design builder data analysis.

This analysis shows how the wall material can affect the inner comfort as long as the skeleton system is the construction system that is used in Egypt so the walls cover a big area of the whole building so the material of the wall is one of the most important elements that should be studied and analysed.

Brick	*Thickness*	*U-value*
Half red brick	12	2.595
Red brick	25	1.833
Cement	12	3.343
Cement hollow	40	2.676
Limestone	40	2.29
Limestone	60	1.754
Rice straw brick	25	1.233
Compressed earth brick	30	1.455

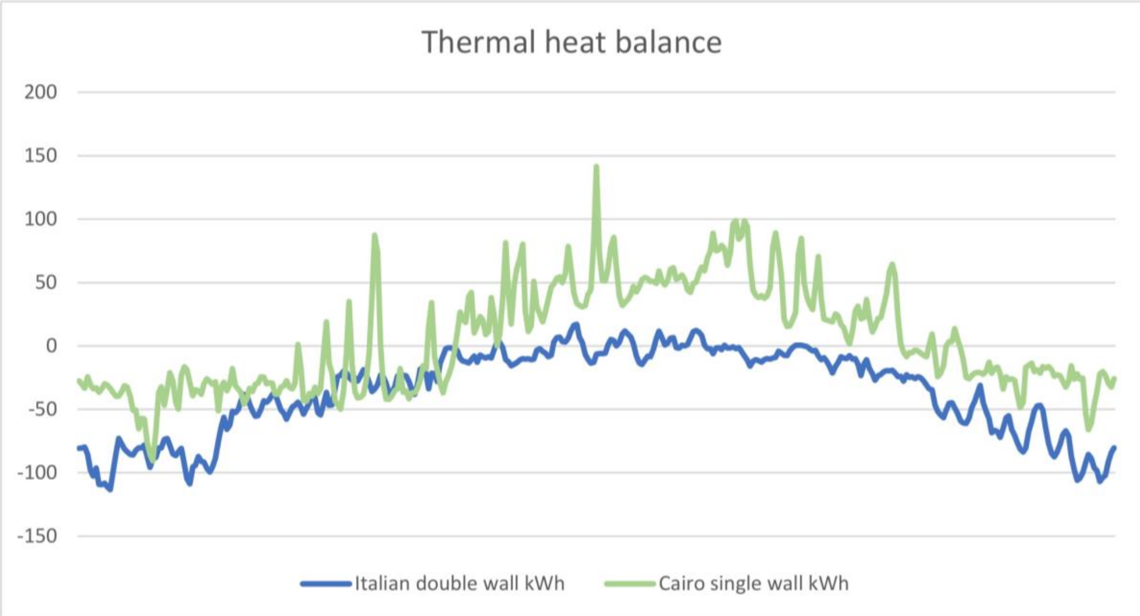


Fig(41): show the thermal heat balance for all the wall material in Cairo climate

Emery, Virginia L., 2011, Mud-Brick Architecture. In Willeke Wendrich (ed.), UCLA Encyclopedia of Egyptology, Los Angeles. http://digital2.library.ucla.edu/viewItem.do?ark=21198/zz0026w9hb

Case study building wall material

In the original case in Cairo the wall used is simple red brick and plaster wall with U-value1.833. According to the Italian regulations legislative decree 192/2005 latest modification 2019/2020 the U-value for the wall for climate E as Turin is located in climate E should not be more than 0.24 and in the Italian case a double wall consists from inside of plaster, 15 cm brick, 3 cm air gap, 4 cm insulation, 15 cm brick and plaster and the U-value is equal to 0.4. The next graph represents the thermal heat balance which is mainly affected by the outside weather and the U-value in the two cases, in Cairo most of the heat balance is represented as heat gain and in Turin the heat balance is most heat loss.



Fig(42): The thermal heat balance for wall used in Cairo and Turin

Ezilda Costanzo, et al. "Concerted Action Energy Performance of Buildings." EPBD Implementation in Italy, Dec. 2016.

Window glazing in Cairo case comparison

In Egypt there were four types of glass suggested by building energy efficiency codes with different U-value, solar heat gain coefficient SHGC and thermal transmittance T_{vis}. The type of glass number 4 is already used in the real complex. Through comparing the useful daylight illuminance UDIa, spatial daylight autonomy SDA, annual sunlight exposure ASE, blinds open and average lux gives a better understanding of the difference between the glass types and which one of them is more suitable to be used with the climate in Cairo.

Glass types

The simulation is running in Cairo through Climate Studio Solemma, with brick wall 50%

Name	*Category*	*SHGC*	T_{vis}	*U-value*
G1 Gray glass 6.4 mm	Single	0.65	0.65	5.76
G2 Glass 6.4 mm Stainless Steel Cover 14%	Single reflective	0.25	0.12	5.36
G3 Clear glass 6.4 mm	Double	0.45	0.4	3.71
G4 Glass 6.4 mm Stainless Steel Cover 30%	Double reflective	0.15	0.27	2.66

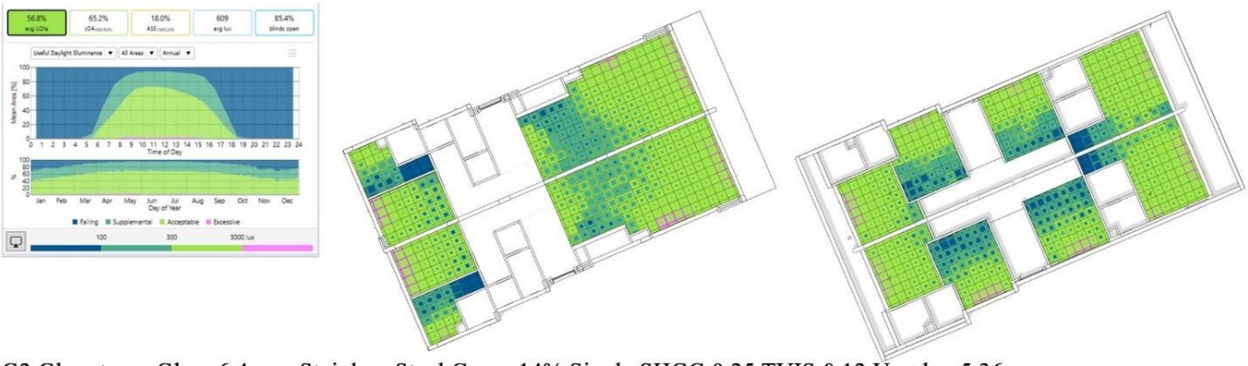
Table (8): The SHGC, T_{vis} and U-value for different glazing types

reflectance, white aluminium frames 70% reflectance, concrete floor and different glass types according to the above table, manual blinds were used for the windows used when needed with 15.4% light transmittance as recommended by LEEDV4 2% Rule. All of the above materials are used in the real case study in Cairo and G4 is the type of glass that is used in the case.

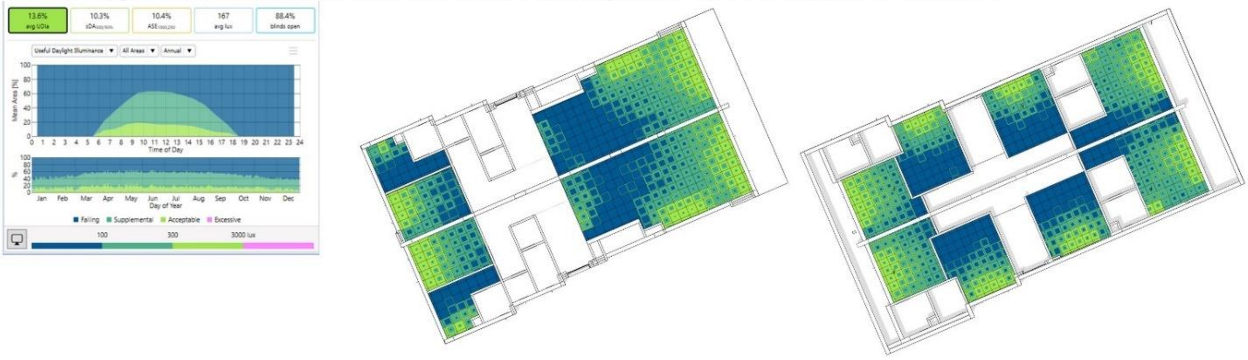
UDIa Useful daylight autonomous

Case study 1 1:300 Ground Floor plan First Floor plan

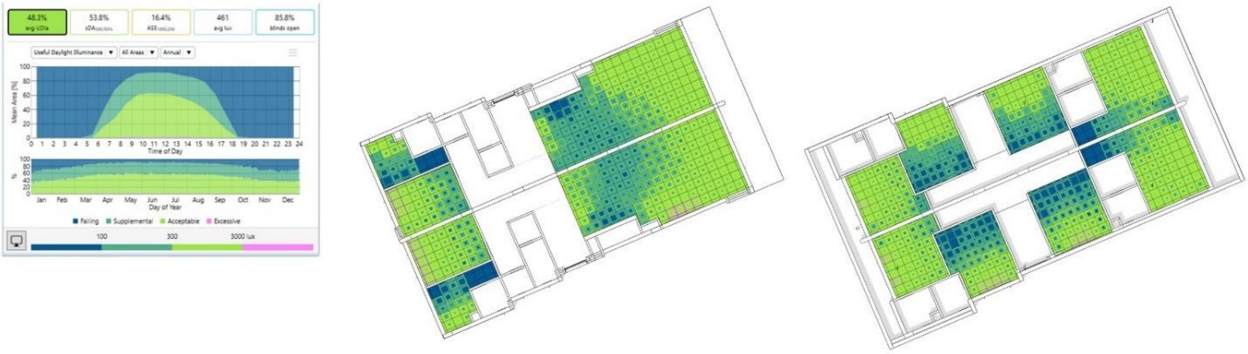
G1 Glass type: Gray glass 6.4 mm Single SHGC:0.65 TVIS:0.65 U-value:5.76



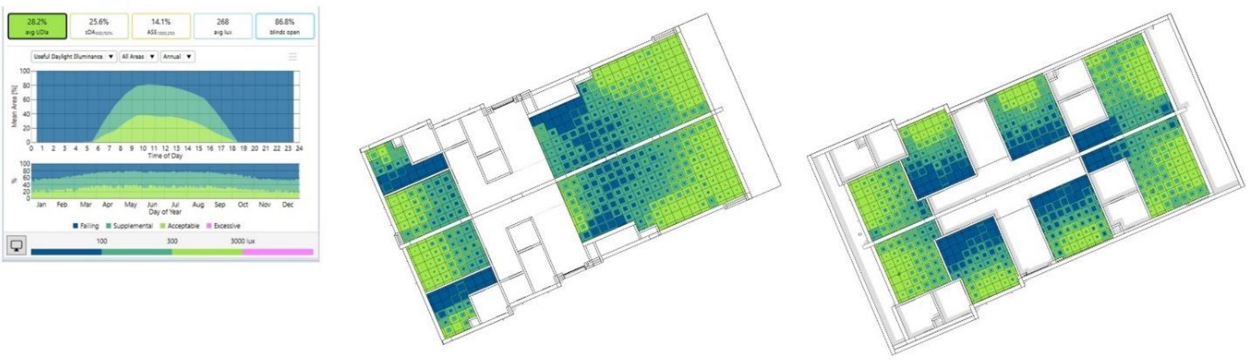
G2 Glass type: Glass 6.4 mm Stainless Steel Cover 14% Single SHGC:0.25 TVIS:0.12 U-value:5.36



G3 Glass type: Gray glass 6.4 mm Double SHGC:0.45 TVIS:0.4 U-value:3.71



G4 Glass type: Glass 6.4 mm Stainless Steel Cover 30% Double SHGC:0.15 TVIS:0.27 U-value:2.66



Fig(43): UDIa simulation comparison between the four types of glass

UDIa is a percentage that is specified according to the average lux per year so in fig(43) and fig(44)G1 the annual average lux for all the building is 56.8%, G2 is 13.6%, G3 48.3% and G4 28.2%, there is a direct relation between the light transmittance and useful daylight autonomous, as the T_{vis} decrease the UDI decrease. The UDIa is specified in the following range:

Failing: Less than 100 lux.
Supplemental: Between 100 and 300 lux.
Autonomous: Between 300 and 3000 lux.
Excessive: More than 3000 lux.

				G1				G2				G3				G4			
	Area m²	WWR %	WFR %	UDI_ fail	UDI_ supp	UDI_ acce	UDI_ exce	UDI_ fail	UDI_ supp	UDI_ acce	UDI_ exce	UDI_ fail	UDI_ supp	UDI_ acce	UDI_ exce	UDI_ fail	UDI_ supp	UDI_ acce	UDI_ exce
Unit A																			
Ground floor																			
Bedroom	9.3	9%	15%	37%	34%	29%	0%	79%	18%	3%	0%	43%	37%	20%	0%	63%	27%	11%	0%
Living room	54	38%	29%	10%	33%	56%	1%	52%	34%	14%	0%	16%	37%	46%	0%	33%	39%	28%	0%
Kitchen	14.4	67%	47%	15%	21%	62%	2%	46%	37%	17%	0%	17%	30%	52%	1%	26%	45%	29%	0%
First floor																			
Bedroom 1	15.5	55%	43%	8%	16%	75%	2%	28%	51%	21%	0%	11%	20%	68%	1%	16%	42%	42%	0%
Bedroom 2	17.3	32%	18%	17%	36%	46%	1%	63%	28%	9%	0%	24%	39%	37%	0%	46%	34%	20%	0%
Living room	22.3	26%	14%	16%	37%	47%	1%	63%	29%	8%	0%	22%	40%	38%	0%	42%	39%	19%	0%
Bedroom 3	22	30%	39%	10%	17%	72%	1%	36%	51%	13%	0%	13%	24%	63%	0%	22%	48%	31%	0%
Unit B																			
Ground floor																			
Bedroom	9.3	9%	15%	37%	34%	29%	1%	75%	18%	7%	0%	45%	31%	24%	0%	64%	23%	13%	0%
Living room	54	38%	29%	9%	31%	58%	2%	50%	37%	13%	0%	14%	38%	48%	1%	30%	41%	29%	0%
Kitchen	14.4	67%	47%	10%	16%	69%	4%	31%	44%	26%	0%	13%	23%	63%	2%	18%	40%	42%	0%
First floor																			
Bedroom 1	15.5	55%	43%	8%	15%	75%	2%	26%	52%	21%	0%	10%	20%	69%	1%	16%	41%	43%	0%
Bedroom 2	17.3	32%	18%	28%	34%	36%	2%	65%	24%	11%	0%	35%	33%	31%	1%	53%	27%	19%	0%
Living room	22.3	26%	14%	29%	33%	37%	2%	67%	23%	11%	0%	37%	32%	30%	1%	52%	29%	19%	0%
Bedroom 3	22	30%	39%	10%	16%	73%	1%	34%	53%	13%	0%	13%	23%	64%	0%	20%	44%	36%	0%

Fig(44): UDIa simulation comparison for each of the living areas between the four types of glass

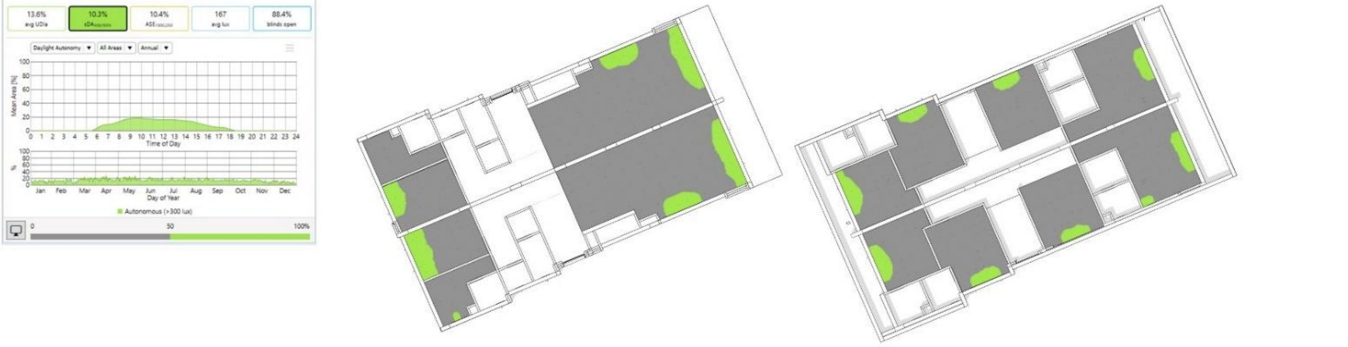
G1 with T_{vis} equals to 0.65 reflected on the average UDIa to be autonomous, G2 with the least T_{vis} 0.12 reflected on the average UDIA to be failing, G3 with T_{vis} of 0.4 reflected on the average UDIA to be supplemental, and G4 with T_{vis} 0.27 reflected on the average UDIA to be supplemental.

Spatial Daylight Autonomy sDA

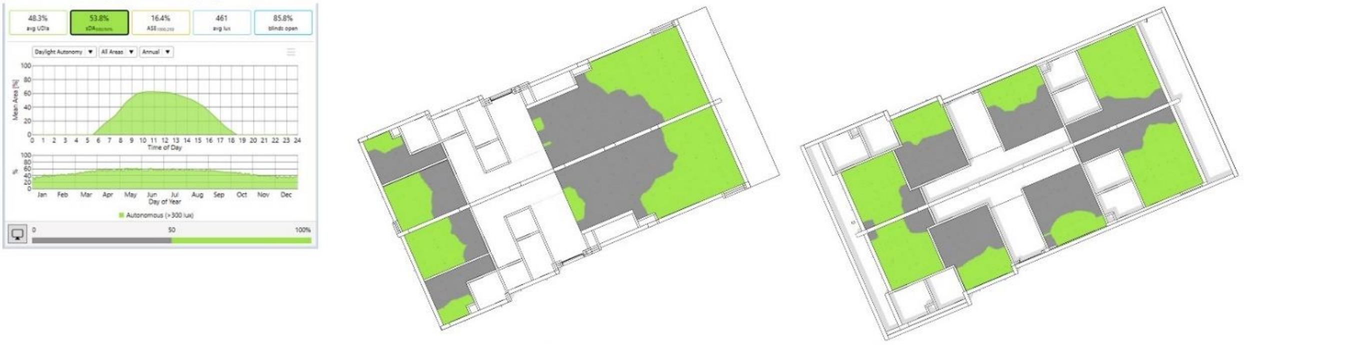
Case study 1 1:300 | Ground Floor plan | First Floor plan

G1 Glass type: Gray glass 6.4 mm Single SHGC:0.65 TVIS:0.65 U-value:5.76

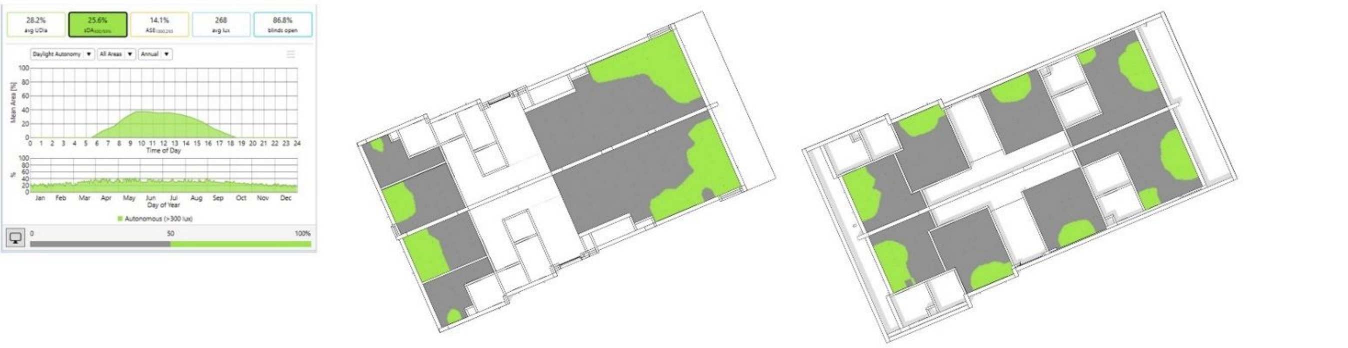
G2 Glass type: Glass 6.4 mm Stainless Steel Cover 14% Single SHGC:0.25 TVIS:0.12 U-value:5.36



G3 Glass type: Gray glass 6.4 mm Double SHGC:0.45 TVIS:0.4 U-value:3.71



G4 Glass type: Glass 6.4 mm Stainless Steel Cover 30% Double SHGC:0.15 TVIS:0.27 U-value:2.66



Fig(45): SDA simulation comparison between the four types of glass

Spatial Daylight Autonomy sDA

	Area m²	WWR %	WFR %	G1 sDA	G2 sDA	G3 sDA	G4 sDA
			Unit A				
			Ground floor				
Bedroom	9.3	9%	15%	22%	0%	22%	6%
Living room	54	38%	29%	63%	10%	50%	29%
Kitchen	14.4	67%	47%	69%	14%	54%	26%
			First floor				
Bedroom 1	15.5	55%	43%	95%	16%	88%	35%
Bedroom 2	17.3	32%	18%	48%	8%	40%	17%
Living room	22.3	26%	14%	51%	6%	39%	20%
Bedroom 3	22	30%	39%	85%	7%	71%	22%
			Unit B				
			Ground floor				
Bedroom	9.3	9%	15%	28%	6%	28%	6%
Living room	54	38%	29%	64%	11%	50%	29%
Kitchen	14.4	67%	47%	91%	29%	71%	43%
			First floor				
Bedroom 1	15.5	55%	43%	93%	12%	86%	33%
Bedroom 2	17.3	32%	18%	40%	8%	37%	17%
Living room	22.3	26%	14%	41%	8%	31%	18%
Bedroom 3	22	30%	39%	86%	10%	71%	29%

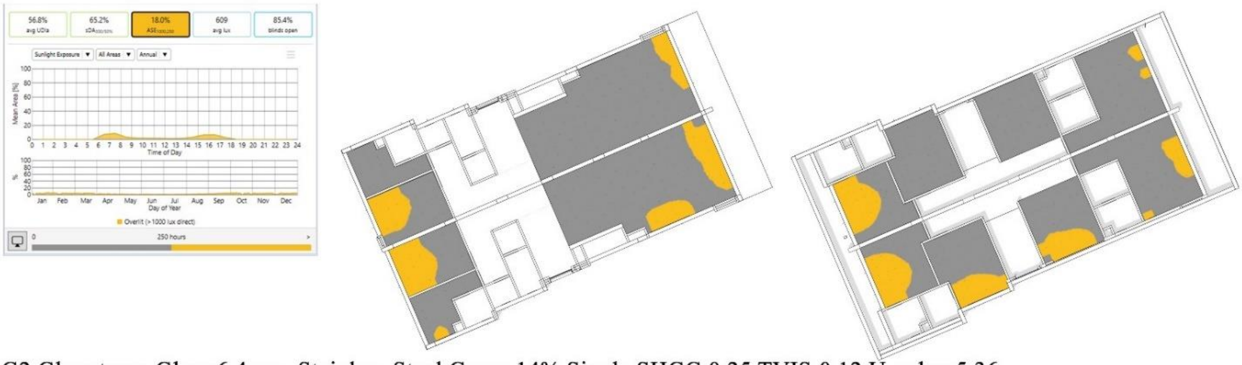
Fig(46) SDA simulation comparison for each of the living areas between the four types of glass

Spatial daylight autonomy is the percentage of the occupied area that meet is more than 50% of the occupied hours of the target illuminance level 300 lux, the green area represent daylit area which means that this area is tachiving more than 300 illuminance motr than 50% of the hours, to run this simulation manual blinds of 15.4% light transmitance have been used, according to the simulation G1 is achiving 65.2%, G2 10.3%, G3 53.8% and G4 25.6%.

Annual sunlight exposure ASE

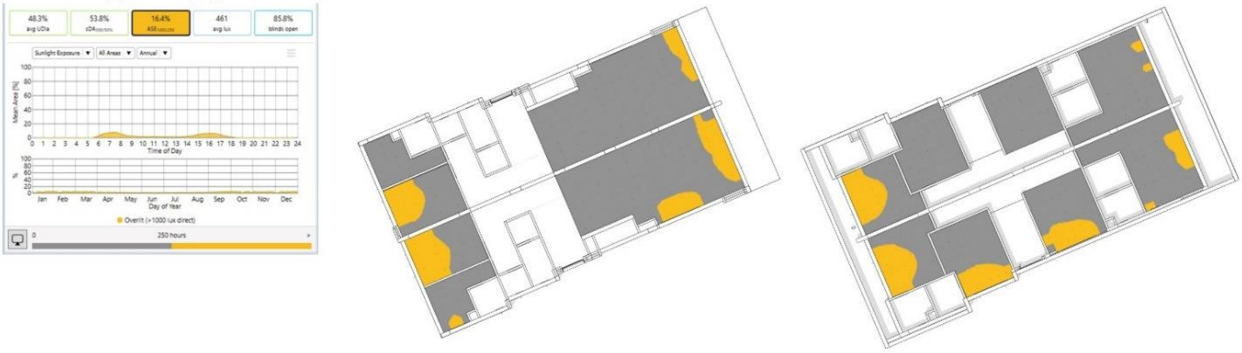
Case study 1 1:300 | Ground Floor plan | First Floor plan

G1 Glass type: Gray glass 6.4 mm Single SHGC:0.65 TVIS:0.65 U-value:5.76

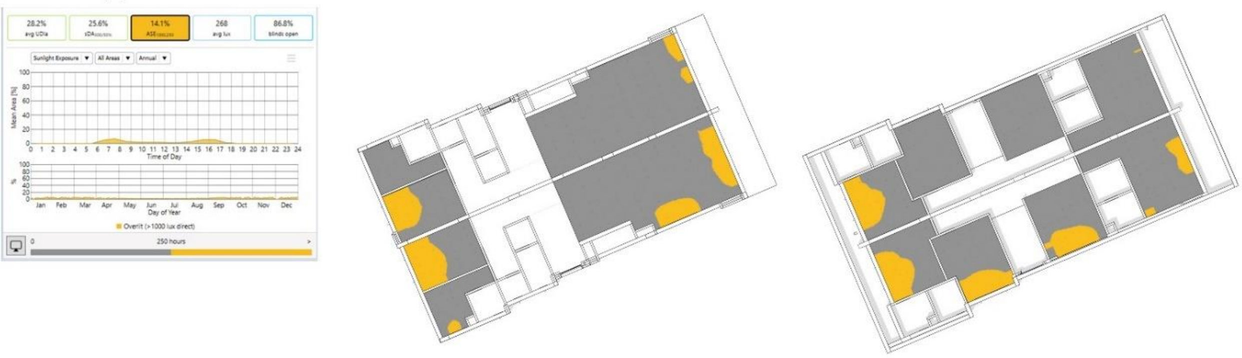


G2 Glass type: Glass 6.4 mm Stainless Steel Cover 14% Single SHGC:0.25 TVIS:0.12 U-value:5.36

G3 Glass type: Gray glass 6.4 mm Double SHGC:0.45 TVIS:0.4 U-value:3.71



G4 Glass type: Glass 6.4 mm Stainless Steel Cover 30% Double SHGC:0.15 TVIS:0.27 U-value:2.66



Fig(47): ASE simulation comparison between the four types of glass

Annual sunlight exposure ASE

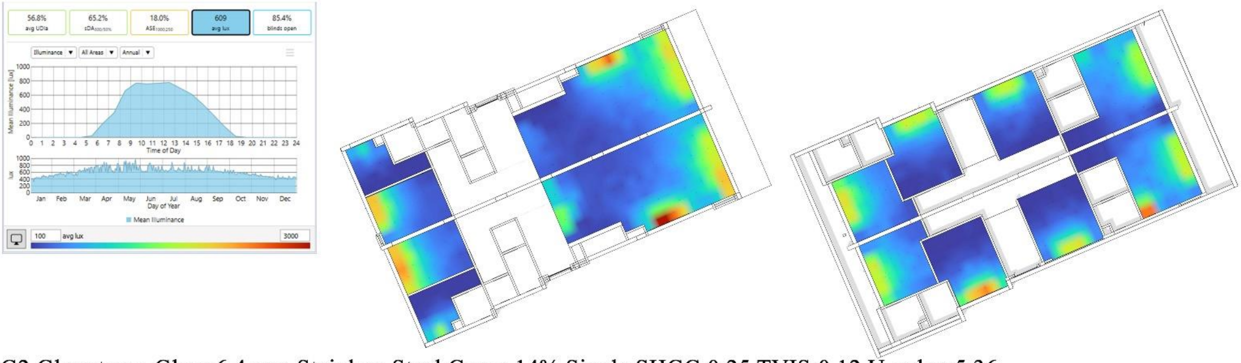
				G1			G2			G3			G4		
	Area m²	WWR %	WFR %	ASE	Blinds not used	Blinds used	ASE	Blinds not used	Blinds used	ASE	Blinds not used	Blinds used	ASE	Blinds not used	Blinds used
Unit A															
Ground floor															
Bedroom	9.3	9%	15%	0%	100%	0%	0%	100%	0%	0%	100%	0%	0%	100%	0%
Living room	54	38%	29%	5%	95%	5%	0%	96%	4%	4%	95%	5%	3%	95%	5%
Kitchen	14.4	67%	47%	40%	74%	26%	29%	79%	21%	37%	74%	26%	34%	76%	24%
First floor															
Bedroom 1	15.5	55%	43%	51%	79%	21%	30%	84%	16%	44%	80%	20%	37%	82%	18%
Bedroom 2	17.3	32%	18%	0%	98%	2%	0%	98%	2%	0%	98%	2%	0%	98%	2%
Living room	22.3	26%	14%	0%	95%	5%	0%	96%	4%	0%	95%	5%	0%	95%	5%
Bedroom 3	22	30%	39%	5%	96%	4%	0%	97%	3%	3%	96%	4%	2%	97%	3%
Unit B															
Ground floor															
Bedroom	9.3	9%	15%	6%	94%	6%	6%	94%	6%	6%	94%	6%	6%	94%	6%
Living room	54	38%	29%	16%	81%	19%	9%	84%	16%	15%	81%	19%	13%	82%	18%
Kitchen	14.4	67%	47%	51%	74%	26%	37%	79%	21%	49%	74%	26%	43%	76%	24%
First floor															
Bedroom 1	15.5	55%	43%	51%	79%	21%	30%	84%	16%	42%	80%	20%	35%	82%	18%
Bedroom 2	17.3	32%	18%	29%	69%	31%	21%	73%	27%	29%	69%	31%	25%	71%	29%
Living room	22.3	26%	14%	27%	63%	37%	20%	69%	31%	27%	64%	36%	24%	66%	34%
Bedroom 3	22	30%	39%	14%	94%	6%	2%	96%	4%	14%	95%	5%	10%	95%	5%

Fig(48): ASE and blinds used simulation comparison for each of the living areas between the four types of

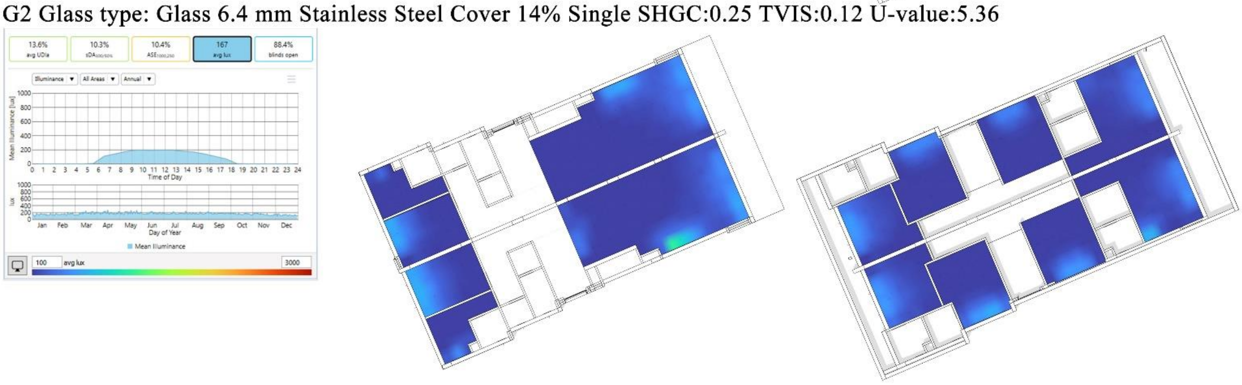
The annual sunlight exposure is the percentage of the occupied area that receives more than 1000 lux for more than 250 hours per year, the simulation is calculated with the blinds open, in case the area receives 1000 lux this means that the area is in the discomfort area. The simulation result shows that G2 achieve the minimum blind closed 11.6% of the time and ASE 10.4%, G4 ASE 14.1% and blinds closed 13.2%, G3 ASE 16.4% and blinds closed 14.2% of the year and G1 ASE 18% and blinds closed 14.6%.

Case study 1 1:300 Ground Floor plan First Floor plan

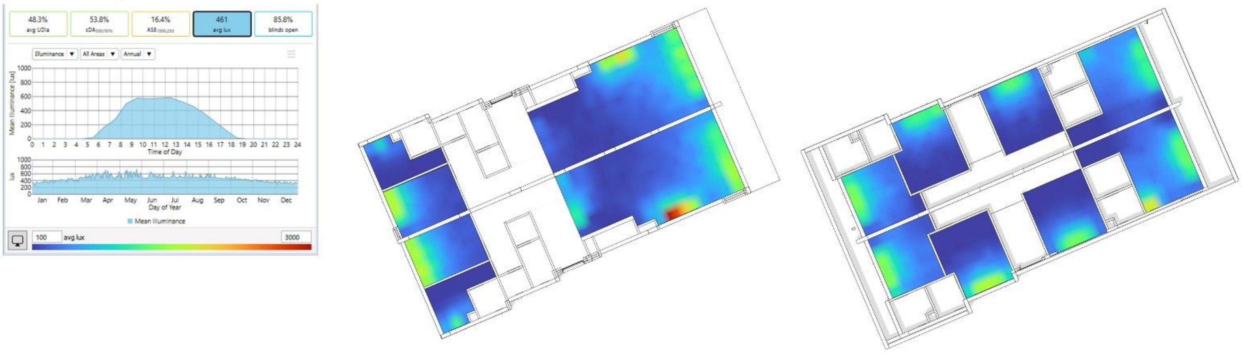
G1 Glass type: Gray glass 6.4 mm Single SHGC:0.65 TVIS:0.65 U-value:5.76



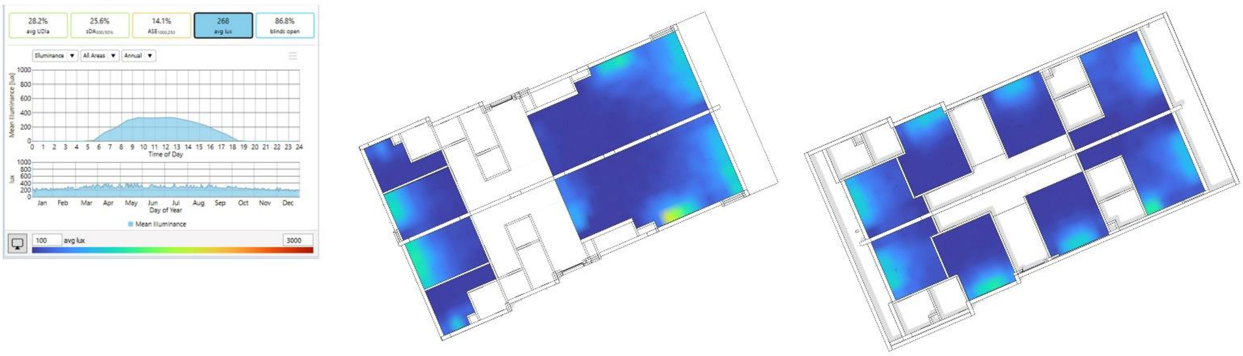
G2 Glass type: Glass 6.4 mm Stainless Steel Cover 14% Single SHGC:0.25 TVIS:0.12 U-value:5.36



G3 Glass type: Gray glass 6.4 mm Double SHGC:0.45 TVIS:0.4 U-value:3.71



G4 Glass type: Glass 6.4 mm Stainless Steel Cover 30% Double SHGC:0.15 TVIS:0.27 U-value:2.66



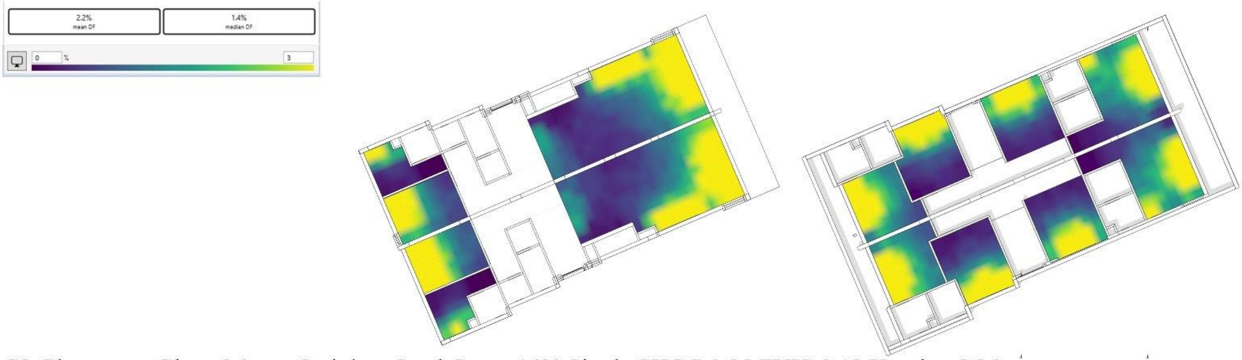
Fig(49): Average illuminance simulation comparison between the four types of glass

	Area m²	WWR %	WFR %	G1 Mean Lux	G2 Mean Lux	G3 Mean Lux	G4 Mean Lux
			Unit A				
			Ground floor				
Bedroom	9.3	9%	15%	263	66	205	120
Living room	54	38%	29%	599	157	446	257
Kitchen	14.4	67%	47%	654	196	504	296
			First floor				
Bedroom 1	15.5	55%	43%	778	228	589	356
Bedroom 2	17.3	32%	18%	482	122	357	204
Living room	22.3	26%	14%	464	117	353	198
Bedroom 3	22	30%	39%	634	168	485	268
			Unit B				
			Ground floor				
Bedroom	9.3	9%	15%	323	91	251	145
Living room	54	38%	29%	676	179	512	294
Kitchen	14.4	67%	47%	852	259	640	400
			First floor				
Bedroom 1	15.5	55%	43%	775	231	601	362
Bedroom 2	17.3	32%	18%	488	141	373	224
Living room	22.3	26%	14%	446	132	341	208
Bedroom 3	22	30%	39%	718	187	535	305

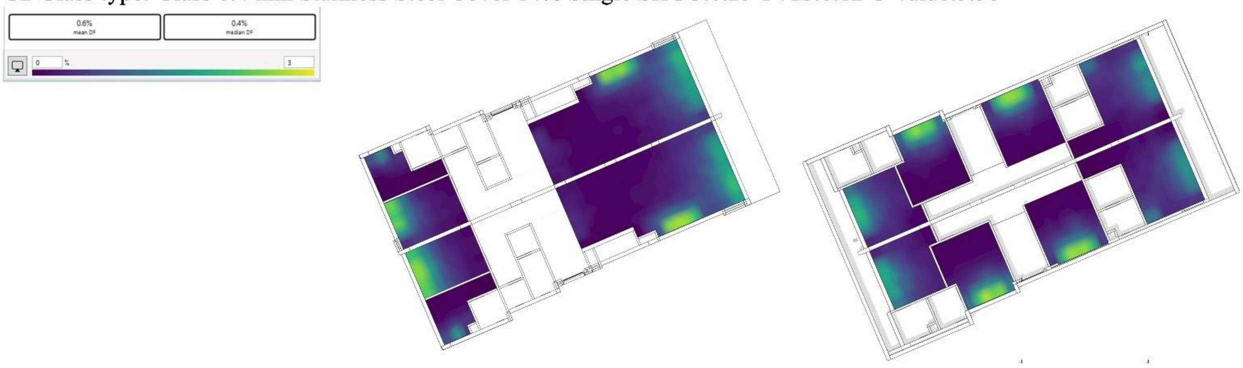
The simulation in fig(49) calculates the average annual illuminance, G1 average illuminance is 609 which is considered as the highest illuminance, G2 gives the lowest average annual illuminance 167 illuminance, G3 461 illuminance and G4 268 illuminance.

Case study 1 1:300 Ground Floor plan First Floor plan

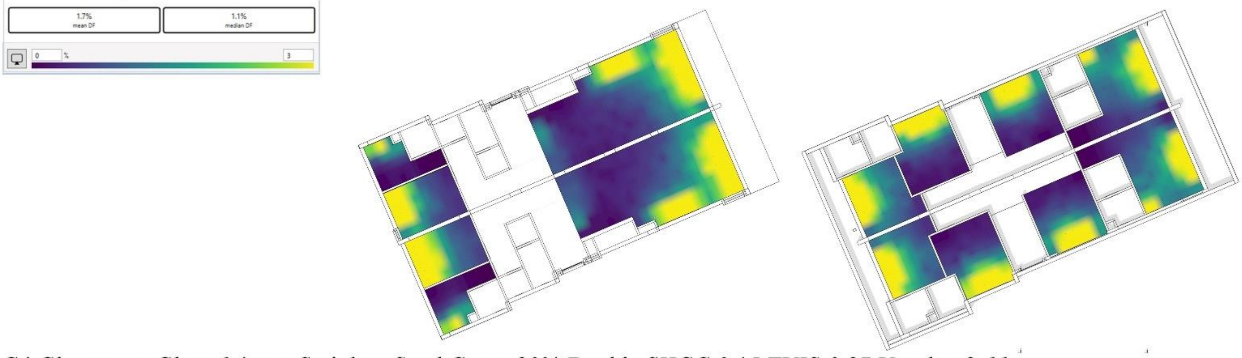
G1 Glass type: Gray glass 6.4 mm Single SHGC:0.65 TVIS:0.65 U-value:5.76



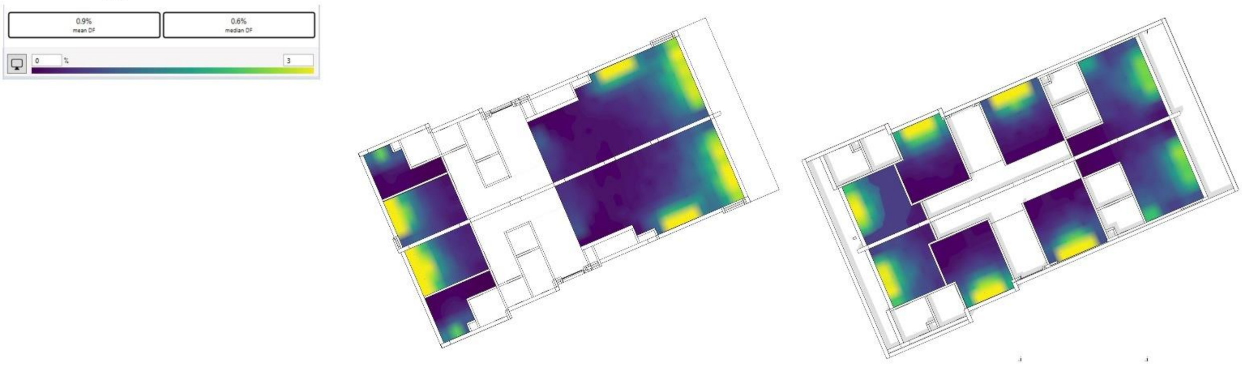
G2 Glass type: Glass 6.4 mm Stainless Steel Cover 14% Single SHGC:0.25 TVIS:0.12 U-value:5.36



G3 Glass type: Gray glass 6.4 mm Double SHGC:0.45 TVIS:0.4 U-value:3.71



G4 Glass type: Glass 6.4 mm Stainless Steel Cover 30% Double SHGC:0.15 TVIS:0.27 U-value:2.66



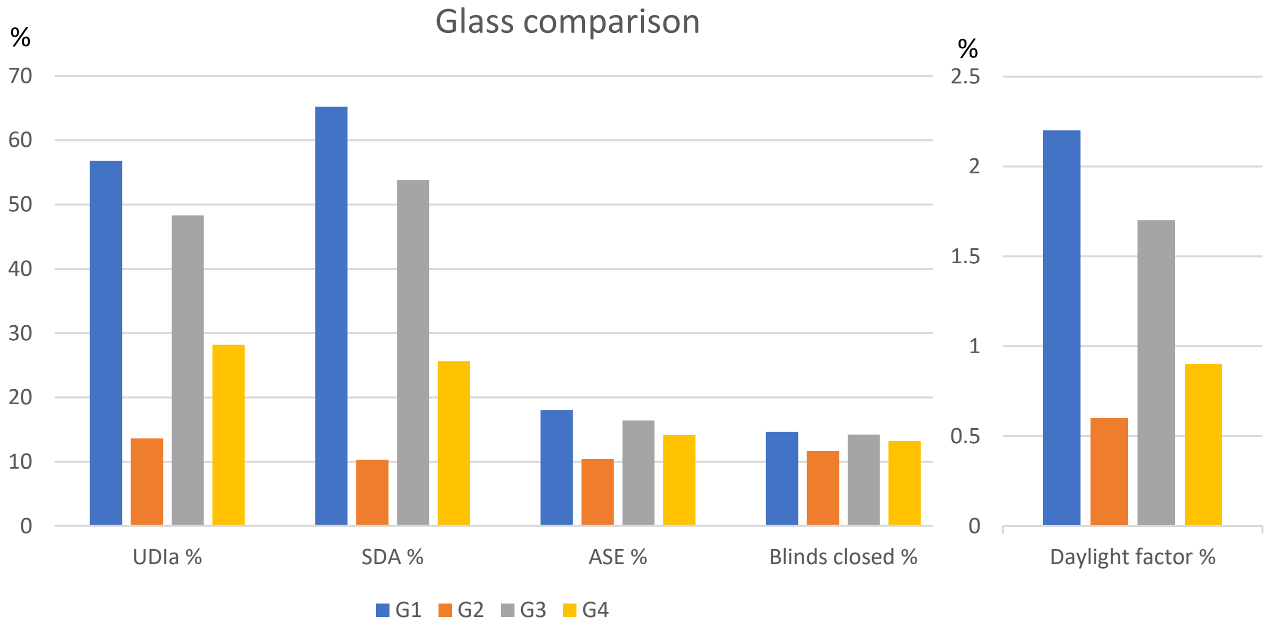
Fig(50): Daylight factor simulation comparison between the four types of glass

	Area m²	WWR %	WFR %	G1		G2		G3		G4	
				Mean DF	Median DF	Mean DF	Median DF	Mean DF	Median DF	Mean DF	Median DF
Unit A											
Ground floor											
Bedroom	9.3	9%	15%	1%	0%	0%	0%	1%	0%	0%	0%
Living room	54	38%	29%	2%	1%	1%	0%	2%	1%	1%	0%
Kitchen	14.4	67%	47%	3%	2%	1%	0%	2%	1%	1%	1%
First floor											
Bedroom 1	15.5	55%	43%	3%	2%	1%	0%	2%	1%	1%	1%
Bedroom 2	17.3	32%	18%	2%	1%	1%	0%	2%	1%	1%	0%
Living room	22.3	26%	14%	2%	1%	1%	0%	2%	1%	1%	0%
Bedroom 3	22	30%	39%	2%	2%	1%	0%	2%	1%	1%	1%
Unit B											
Ground floor											
Bedroom	9.3	9%	15%	1%	0%	0%	0%	1%	0%	0%	0%
Living room	54	38%	29%	2%	1%	1%	0%	2%	1%	1%	1%
Kitchen	14.4	67%	47%	3%	2%	1%	0%	3%	2%	1%	1%
First floor											
Bedroom 1	15.5	55%	43%	3%	2%	1%	1%	2%	2%	1%	1%
Bedroom 2	17.3	32%	18%	2%	1%	1%	0%	2%	1%	1%	0%
Living room	22.3	26%	14%	2%	1%	1%	0%	2%	1%	1%	0%
Bedroom 3	22	30%	39%	2%	2%	1%	0%	2%	1%	1%	1%

Fig(51): mean and median daylight factor simulation comparison for each of the living areas between the four types of glass

The daylight factor is the percentage between the illuminance inside one point in the building and the illuminance outside the building, G1 type of glass daylight factor is 2.2%, G2 0.6%, G3 1.7% and G4 0.9%.

Conclusion



Fig(52): Graph to summarize the comparison daylight availability of the four types of glass

From the results G2 type of glass with lowest thermal transmittance 0.12 is achieving the lowest percentage of UDIA. SDA, ASE, blinds closed and daylight factor, G1 have the highest thermal transmittance 0.65 and the highest UDIA, SDA, ASE, blinds closed and daylight factor.

Egyptian regulation analysis shaded glass ratio

According to Egyptian codes to improve energy efficiency in residential buildings ECP 306-2005 section 3 page 19-20, In general Egypt was divided into eight different climate zones, the project lies in Cairo and delta zone. There are two factors solar heat gain coefficient SHGC which is the fraction of solar radiation admitted through the window glass and the shaded glass ratio SGR which is the percentage of the shaded part of glass to the whole area of the window, the thermal resistance should not be less than 0.42, the SHGC and SGR determined through the window to wall ratio and the orientation of the window whether it is oriented to north, south, east, west, north east, north west, south east and south west. The following table shows the building requirements for Cairo and delta zone SHGC and SGR.

	Thermal resistance	Roof insulation Rvalue	SHGC solar heat gain coefficient			
			WWR <10	10 >WWR <20	20 >WWR <30	WWR <30
N	0.82	0.42	Unrequired	Unrequired	0.71	0.67
NE/NW	1.18	0.67	0.65	0.55	0.45	0.35
E/W	1.5	1.1	0.55	0.45	0.35	0.27
SE/SW	1.32	0.92	0.55	0.45	0.35	0.27
S	1.04	0.64	0.71	0.64	0.55	0.5

	SGR shaded glass ratio			
	WWR <10	10 >WWR <20	20 >WWR <30	WWR <30
N	Unrequired	Unrequired	40%	50%
NE/NW	50%	60%	70%	80%
E/W	60%	70%	80%	90%
SE/SW	60%	70%	80%	90%
S	50%	60%	70%	80%

Table (9): Egyptian codes for solar heat gain coefficient and shaded glass ratio

In general, all the windows facing north, north east or north west meet the Egyptian SGR requirements, and the windows facing south, south east and south west don't comply with the requirements which mean that there is a lack in the design related to the shading devices, windows facing east and west elevations don't meet the requirements, if shading devices can be added to windows facing east and west it can increase the SGR ratio to comply the requirements.

Case 1

	Floor area	WWR	Direction	SHGC	SHGC required	comply with requirements	SGR	SGR required	comply with requirements
Twin house (Unit A)									
Ground floor									
Bedroom	9.3	9%	W	0.17	0.55	✓	98%	60%	✓
Living room	54	38%	N,NE	0.17	0.67	✓	97%	80%	✓
Kitchen	14.4	67%	W	0.17	0.27	✓	53%	90%	
First floor									
Bedroom 1	15.5	55%	W	0.17	0.27	✓	62%	90%	
Bedroom 2	17.3	32%	W,NW	0.17	0.3	✓	98%	90%	✓
Living room	22.3	26%	N	0.17	0.71	✓	93%	40%	✓
Bedroom 3	22	30%	NE	0.17	0.45	✓	100%	70%	✓
Twin house (Unit B)									
Ground floor									
Bedroom	9.3	9%	SW	0.17	0.55	✓	66%	60%	✓
Living room	54	38%	E,SE	0.17	0.27	✓	68%	90%	
Kitchen	14.4	67%	SW	0.17	0.27	✓	53%	90%	
First floor									
Bedroom 1	15.5	55%	SW	0.17	0.27	✓	61%	90%	
Bedroom 2	17.3	32%	S,SW	0.17	0.27	✓	63%	80%	
Living room	22.3	26%	SE	0.17	0.35	✓	62%	80%	
Bedroom 3	22	30%	E,SE	0.17	0.27	✓	66%	80%	

Case 2

	Floor area (m^2)	WWR%	Direction	SHGC	SHGC required	comply with requirements	SGR	SGR required	comply with requirements
Stand alone Villa									
Ground floor									
Kitchen	18	23%	S	0.17	0.55	✓	33%	70%	
Bedroom 1	9.4	14%	W	0.17	0.45	✓	56%	70%	
Living room	104	34%	N,NE,E	0.17	0.27	✓	91%	90%	✓
Bedroom 2	14	21%	S	0.17	0.55	✓	78%	70%	✓
First floor									
Bedroom 1	20	38%	SW	0.17	0.27	✓	29%	90%	
Living room	18	30%	SE	0.17	0.27	✓	56%	90%	
Bedroom 2	25	39%	NE	0.17	0.35	✓	92%	80%	✓
Bedroom 3	22	29%	NE	0.17	0.45	✓	95%	70%	✓
Kitchen	12	13%	N	0.17	Unrequired	✓	93%	Unrequired	✓
Bedroom 4	20	29%	SW	0.17	0.35	✓	27%	80%	
Second floor									
Bedroom	21	26%	S	0.17	0.55	✓	33%	70%	

Case 3

	Floor area (m²)	WWR%	Direction	SHGC	SHGC required	comply with requirements	SGR	SGR required	comply with requirements
				Stand alone Villa					
				Ground floor					
Kitchen	18	23%	NW	0.17	0.45	✓	78%	70%	✓
Bedroom 1	9.4	14%	W	0.17	0.45	✓	47%	70%	
Living room	104	34%	E,SE	0.17	0.27	✓	94%	90%	✓
Bedroom 2	14	21%	N	0.17	0.71	✓	95%	40%	✓
				First floor					
Bedroom 1	20	38%	NW	0.17	0.35	✓	89%	80%	✓
Living room	18	30%	SW	0.17	0.27	✓	45%	90%	
Bedroom 2	25	39%	S	0.17	0.5	✓	48%	80%	
Bedroom 3	22	29%	SE	0.17	0.35	✓	55%	80%	
Kitchen	12	13%	E	0.17	0.45	✓	100%	70%	✓
Bedroom 4	20	29%	N	0.17	0.67	✓	74%	50%	✓
				Second floor					
Bedroom	21	26%	NW	0.17	0.45	✓	73%	70%	✓
Living room	23	19%	SE	0.17	0.45	✓	47%	70%	✓

Case 4

	Floor area (m²)	WWR%	Direction	SHGC	SHGC required	comply with requirement	SGR	SGR required	comply with requirements
				Town house					
				Ground floor					
Kitchen	13	34%	SE	0.17	0.27	✓	65%	90%	
Living room	49	46%	NW	0.17	0.35	✓	83%	80%	✓
				First floor					
Bedroom 1	20	29%	SE	0.17	0.35	✓	77%	80%	
Bedroom 2	19	55%	W	0.17	0.27	✓	84%	90%	
Bedroom 3	20	18%	NW	0.17	0.55	✓	70%	60%	

Case 5

	Floor area (m²)	WWR	Direction	SHGC	SHGC	SHGC required	comply with requirements	SGR	SGR required	comply with requirements
					Twin house (Unit A)					
					Ground floor					
Bedroom	9.3	9%	NW	0.55	0.17	0.65	✓	0%	50%	
Living room	54	38%	NE,E	0.67	0.17	0.3	✓	63%	80%	
Kitchen	14.4	67%	W	Not allowed	0.17	0.27	✓	59%	90%	
					First floor					
Bedroom 1	15.5	55%	W	Not allowed	0.17	0.27	✓	64%	90%	
Bedroom 2	17.3	32%	NW	Not allowed	0.17	0.35	✓	0%	80%	
Living room	22.3	26%	N	0.71	0.17	0.71	✓	0%	40%	
Bathroom 3	22	30%	NE		0.17	0.35	✓	88%	80%	✓
					Twin house (Unit B)					
					Ground floor					
Bedroom	9.3	9%	SW	0.55	0.17	0.55	✓	62%	60%	✓
Living room	54	38%	E,SE	Not allowed	0.17	0.27	✓	76%	90%	
Kitchen	14.4	67%	W	Not allowed	0.17	0.27	✓	58%	90%	
					First floor					
Bedroom 1	15.5	55%	W	Not allowed	0.17	0.27	✓	64%	90%	
Bedroom 2	17.3	32%	SW	Not allowed	0.17	0.27	✓	58%	90%	
Living room	22.3	26%	S,SE	Not allowed	0.17	0.35	✓	46%	70%	
Bedroom 3	22	30%	E	Not allowed	0.17	0.27	✓	91%	90%	✓

Table (10): The SHGC and SGR in the five case studies

Cairo and Turin cases

Daylight availability

According to LEED V4.1 regulations the SDA must exceed 300 Lux for 50% of the working hours per day, the SDA should not be less than 40%, and the annual sunlight exposure ASE must not exceed 10% if it exceeds 10% it means that the space addresses glare which means that the space need shading device to decrease the glare, a balance between the SDA and ASE should be achieved to prevent glare.

There is another requirement for the daylight simulation according to LEED V4.1 that the illuminance level should be between 300 lux and 3000 lux for 9 am and 3 pm on a clear sky in equinox day, if the illuminance exceeds 3000 the space is facing glare which need to be solved using shading system.

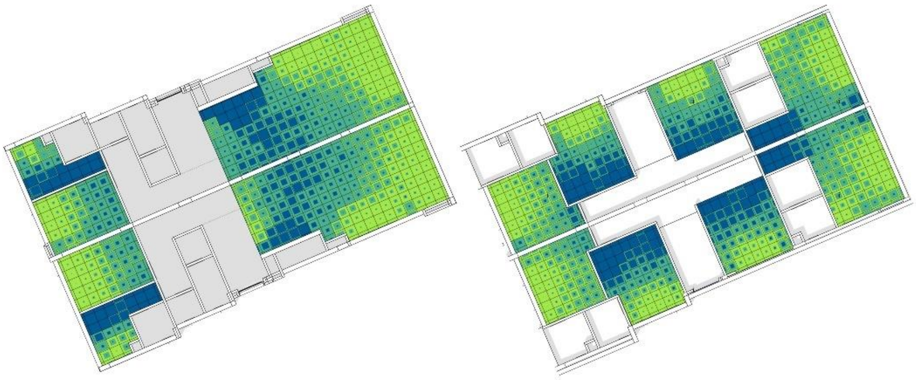
Daylight factor is another metric that should be simulated, the more the daylight factor the more daylight is available in the space, in case the DF is less than 1% it can be considered no daylight and artificial light will be used as only using natural daylight will not be efficient, if the DF is more than 2% it means that there is daylight but artificial light will still be used, if DF is more than 3% so there is enough daylight and no artificial light will be used which will save more energy, so as higher the number of DF the better the daylight quality and less energy will be used on artificial light.

In Egypt the regulations are focusing only on the illuminance which will be analysed in the next section, as according to the Egyptian codes to improve energy efficiency in residential buildings ECP 306-2005 rules are limiting the illuminance with minimum, maximum and average by each space according to the function of the space.

The aim of this comparison is to understand how the climate and the built environment change the building materials and specifically the window glazing, the glazing that is used in Cairo is the one used in the real case study which is 6.4 mm double glass, SHGC 0.15, T_{vis} 0.27 and U-value 2.66. In Turin the used case material is the selective glazing SHGC 0.31. T_{vis} 0.604 and U-value 2.66. In comparing the two used glazing the solar heat gain coefficient and thermal transmittance in Turin is double the glass that is used in Cairo which allow more useful daylight illuminance, spatial daylight autonomy, annual sunlight exposure, average illuminance and daylight factor, and less blinds closed during the year in the case of Turin than the case in Cairo.

Climate Studio Solemma is used for the daylight availability simulations, the materials that were used for the simulation is brick wall 50% reflectance, white aluminium frames 70% reflectance and concrete floor, there are manual blinds that are used on all the windows with light transmittance 15.4%.

Location: Cairo Case study 1 1:300 Ground Floor plan First Floor plan
Glass type: Double glass 6.4 mm Stainless Steel Cover 30% SHGC:0.15 TVIS:0.27 U- value:2.66

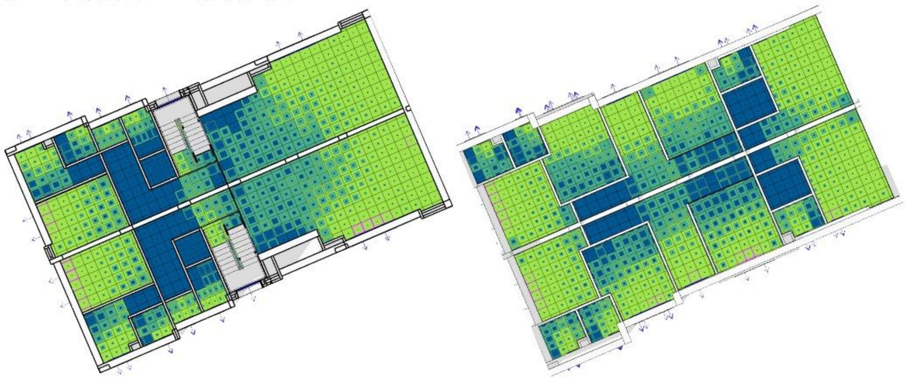
avg UDIa: 28.2%


sDA: 25.6%

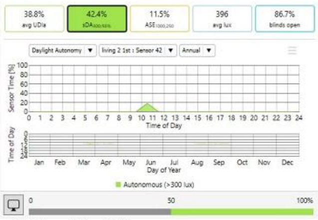

ASE: 14.1%
Blinds closed 13.2%

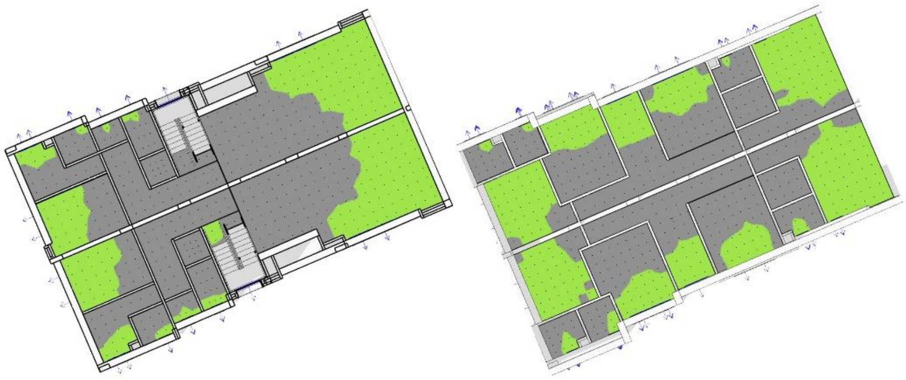
Fig(53): The simulation for UDIA, SDA, ASE and blinds closed percentage in Cairo in case study 1

Location: Turin Case study 1 1:300 Ground Floor plan First Floor plan
Glass type: Double glass SHGC:0.31 TVIS:0.604 U-value:1.36

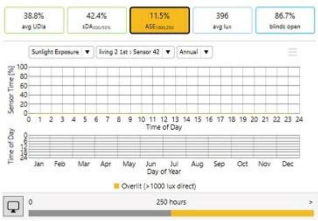


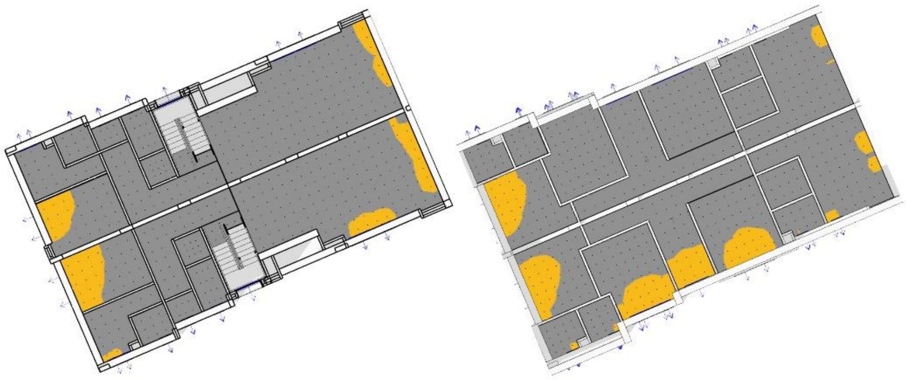
avg UDIa: 38.8%





sDA: 42.4%



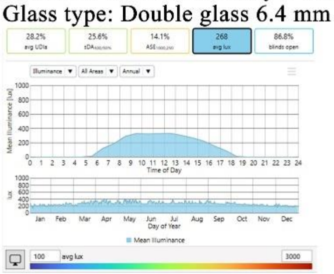


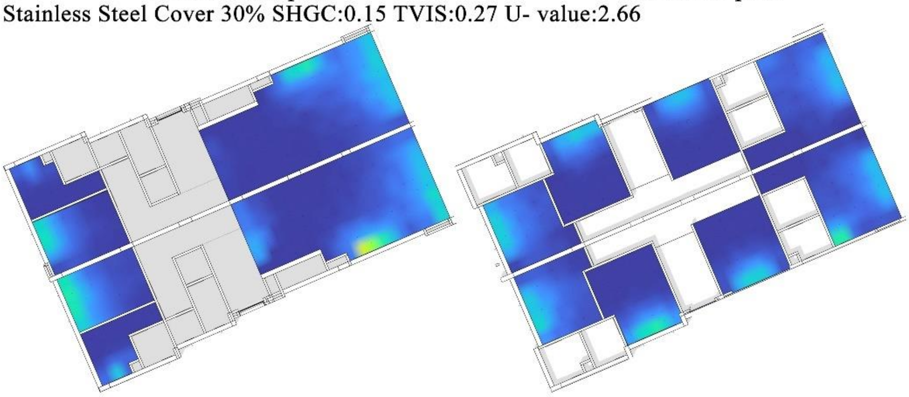
ASE: 11.5%
Blinds closed 13.3%

Fig(54): The simulation for UDIA, SDA, ASE and blinds closed percentage in Turin in case study 1

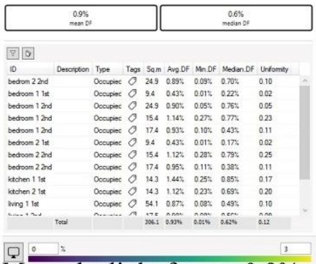
Location: Cairo Case study 1 1:300 Ground Floor plan First Floor plan

Glass type: Double glass 6.4 mm Stainless Steel Cover 30% SHGC:0.15 TVIS:0.27 U- value:2.66



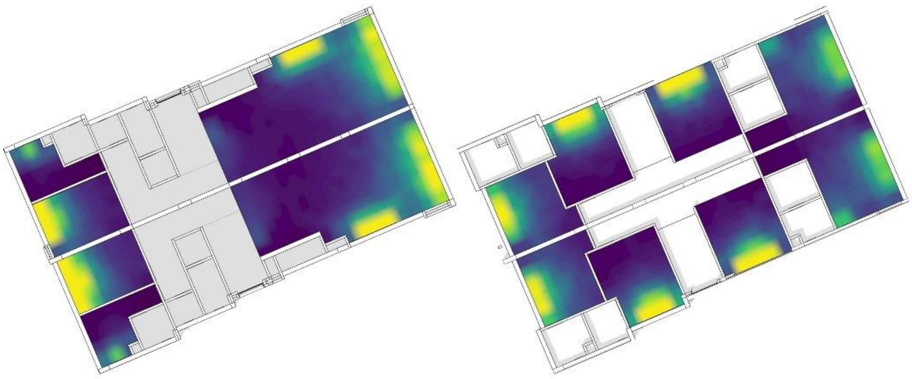


avg lux: 268



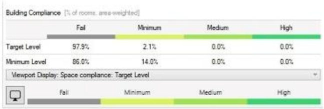
0.9% mean DF	0.6% median DF

ID	Description	Type	Tags	Sq.m	Avg.DF	Min.DF	Median.DF	Uniformity
bedrom 2 2nd		Occupiec		24.9	0.89%	0.09%	0.70%	0.10
bedroom 1 1st		Occupiec		9.4	0.43%	0.01%	0.22%	0.02
bedroom 1 2nd		Occupiec		24.9	0.90%	0.05%	0.76%	0.05
bedroom 1 2nd		Occupiec		15.4	1.14%	0.27%	0.77%	0.23
bedroom 1 2nd		Occupiec		17.4	0.93%	0.10%	0.43%	0.11
bedroom 2 1st		Occupiec		9.4	0.43%	0.01%	0.17%	0.02
bedroom 2 2nd		Occupiec		15.4	1.12%	0.28%	0.79%	0.25
bedroom 2 2nd		Occupiec		17.4	0.95%	0.11%	0.38%	0.11
kitchen 1 1st		Occupiec		14.3	1.44%	0.25%	0.85%	0.17
kitchen 2 1st		Occupiec		14.3	1.12%	0.23%	0.69%	0.20
living 1 1st		Occupiec		54.1	0.87%	0.08%	0.49%	0.10
	Total			306.1	0.93%	0.01%	0.62%	0.12



Mean daylight factor: 0.9%

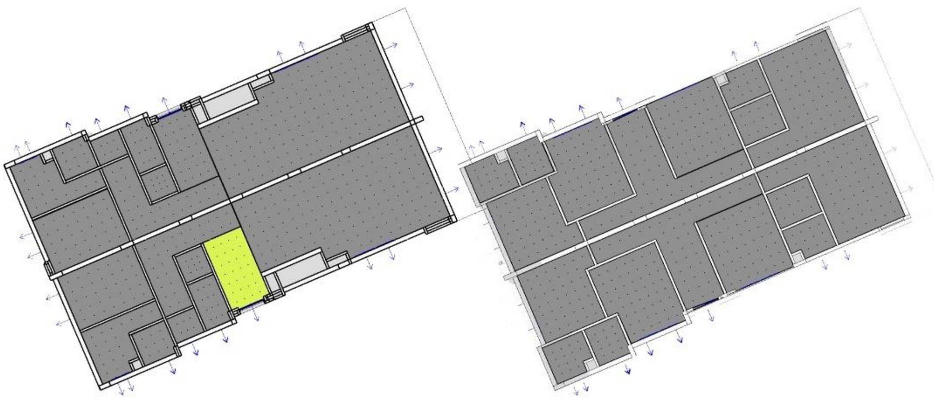
Median daylight factor: 0.6%



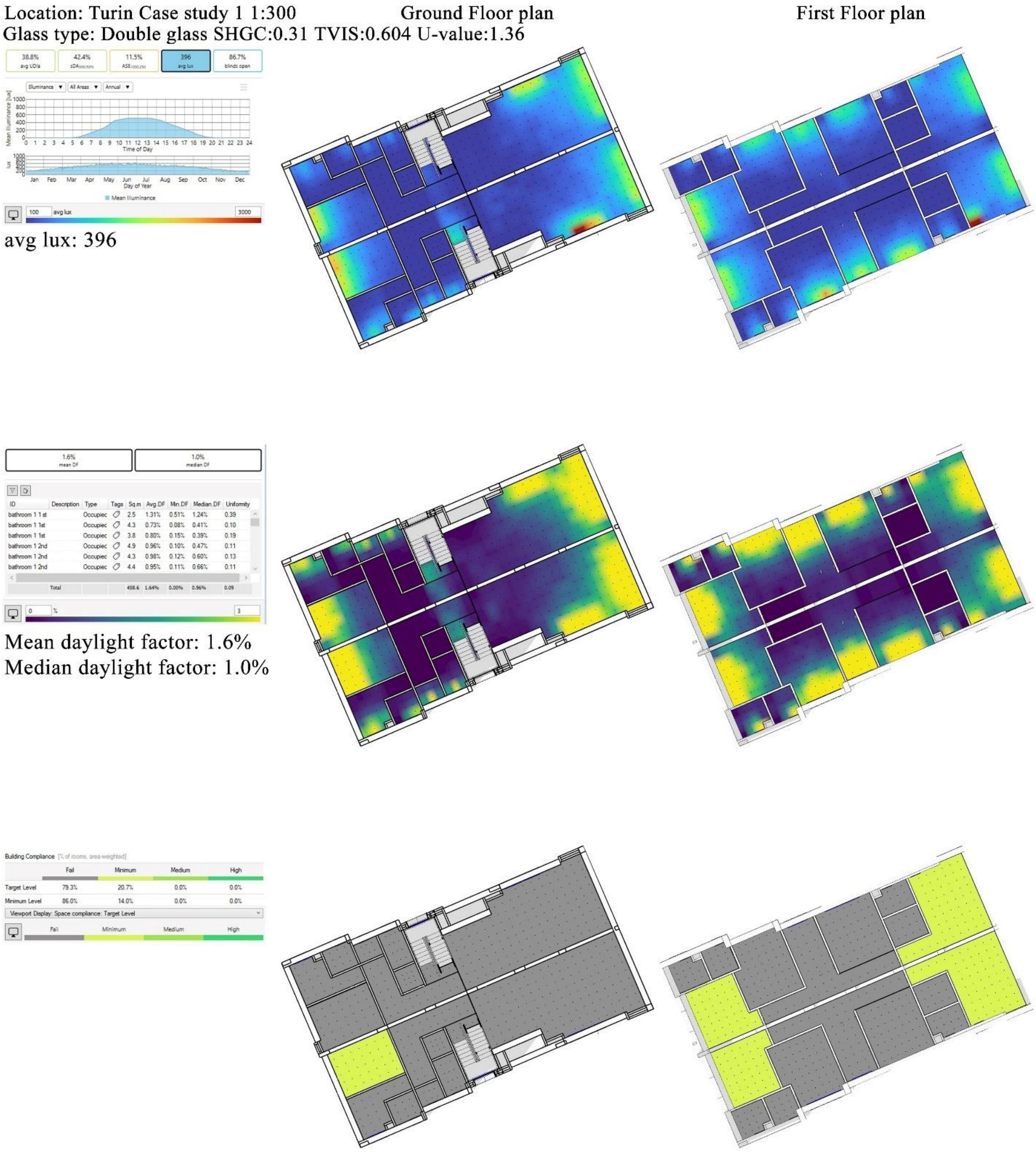
Building Compliance [% of rooms, area-weighted]

	Fail	Minimum	Medium	High
Target Level	97.9%	2.1%	0.0%	0.0%
Minimum Level	86.0%	14.0%	0.0%	0.0%

Viewport Display: Space compliance: Target Level

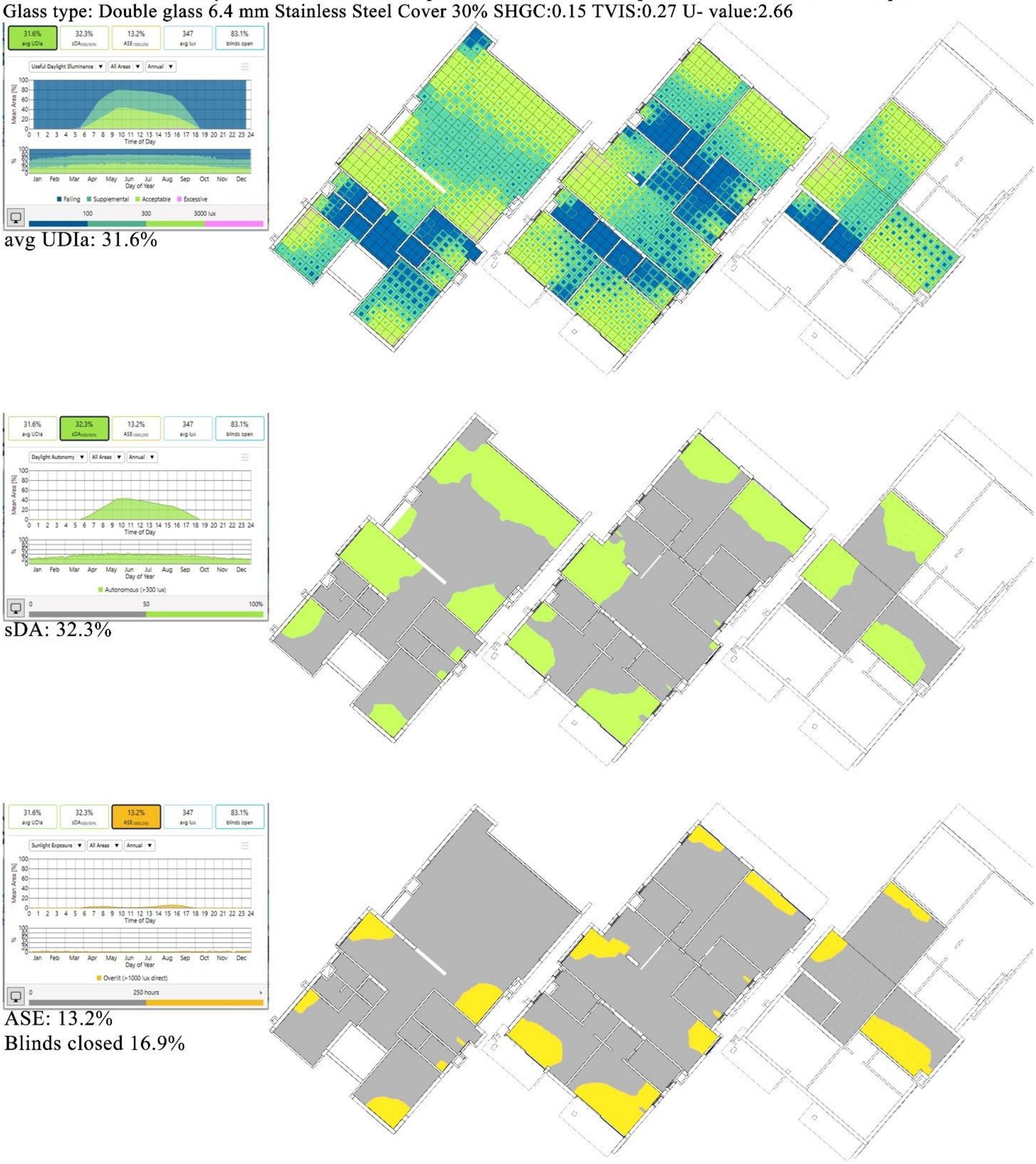


Fig(55): The simulation for average illuminance and daylight factor in Cairo in case study 1

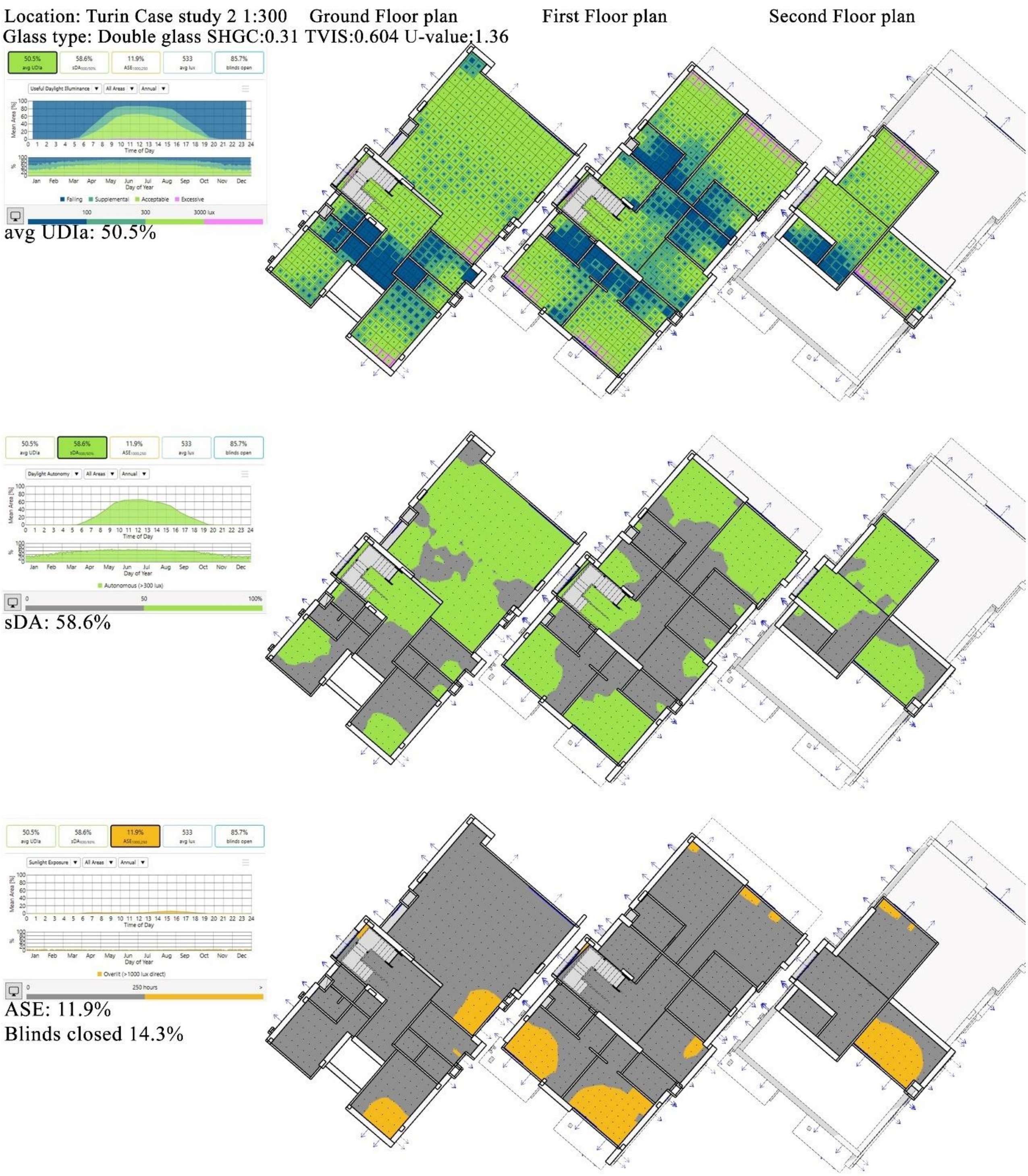


Fig(56): The simulation for average illuminance and daylight factor in Turin in case study 1

Location: Cairo Case study 2 1:300 Ground Floor plan First Floor plan Second Floor plan
Glass type: Double glass 6.4 mm Stainless Steel Cover 30% SHGC:0.15 TVIS:0.27 U- value:2.66

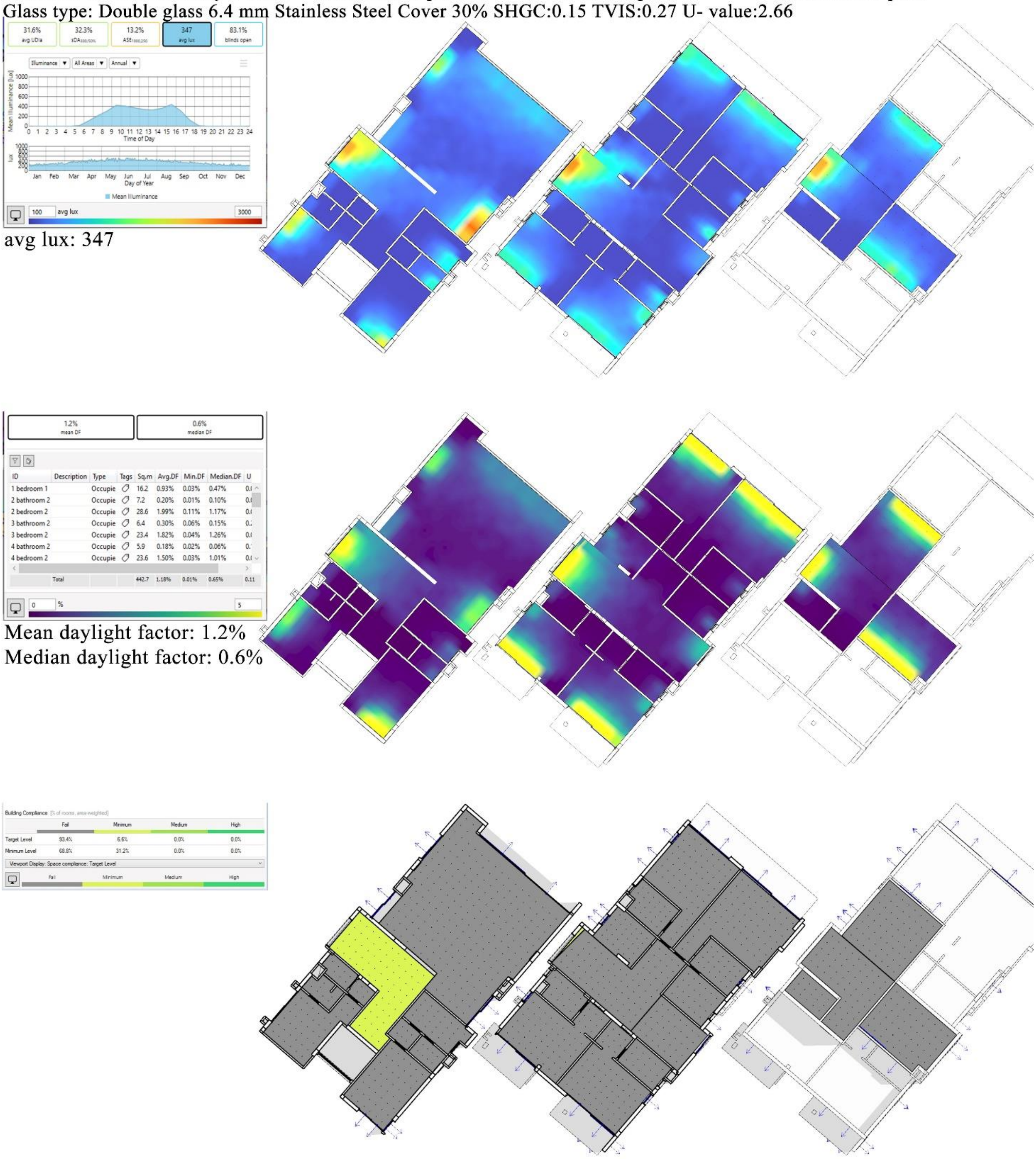


Fig(57): The simulation for UDIA, SDA, ASE and blinds closed percentage in Cairo in case study 2

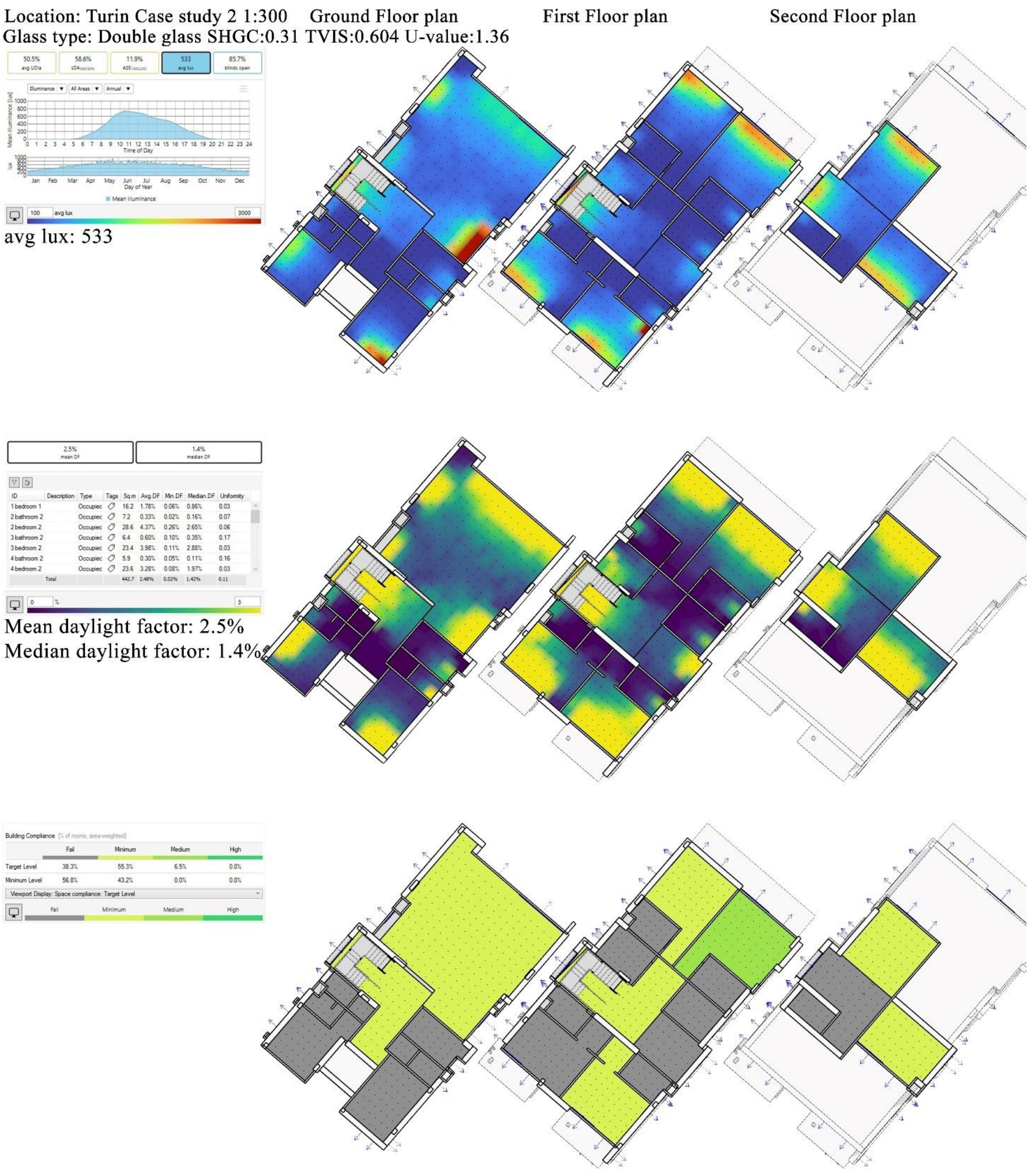


Fig(58): The simulation for UDIA, SDA, ASE and blinds closed percentage in Turin in case study 2

Location: Cairo Case study 2 1:300 Ground Floor plan First Floor plan Second Floor plan
Glass type: Double glass 6.4 mm Stainless Steel Cover 30% SHGC:0.15 TVIS:0.27 U- value:2.66



Fig(59): The simulation for average illuminance and daylight factor in Cairo in case study 2

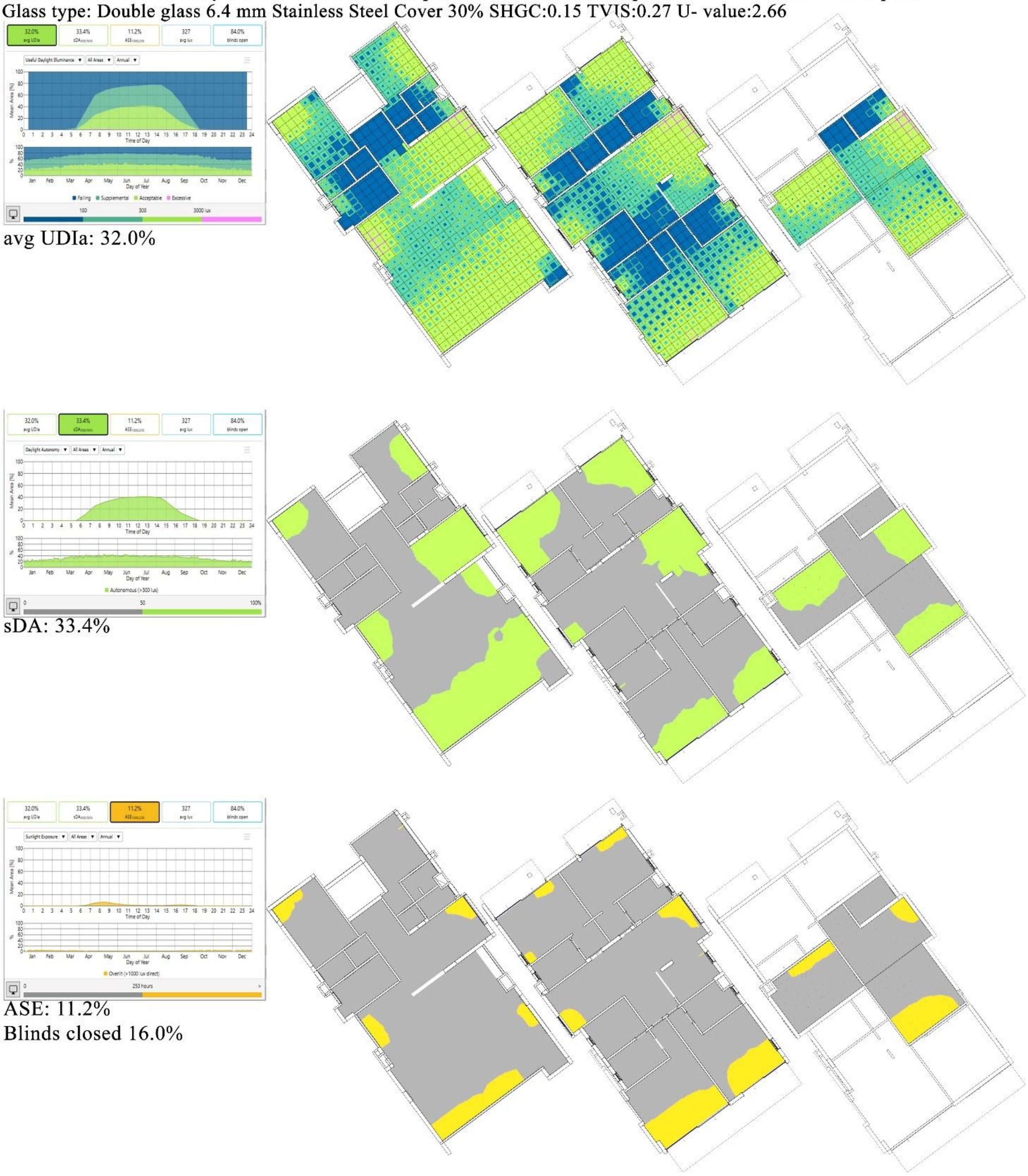


ID	Description	Type	Tags	Sq.m	Avg.DF	Min.DF	Median.DF	Uniformity
1 bedroom 1		Occupiec		16.2	1.78%	0.06%	0.86%	0.03
2 bathroom 2		Occupiec		7.2	0.33%	0.02%	0.16%	0.07
2 bedroom 2		Occupiec		28.6	4.37%	0.26%	2.65%	0.06
3 bathroom 2		Occupiec		6.4	0.60%	0.10%	0.35%	0.17
3 bedroom 2		Occupiec		23.4	3.98%	0.11%	2.88%	0.03
4 bathroom 2		Occupiec		5.9	0.30%	0.05%	0.11%	0.16
4 bedroom 2		Occupiec		23.6	3.28%	0.08%	1.97%	0.03
	Total			442.7	2.48%	0.02%	1.42%	0.11

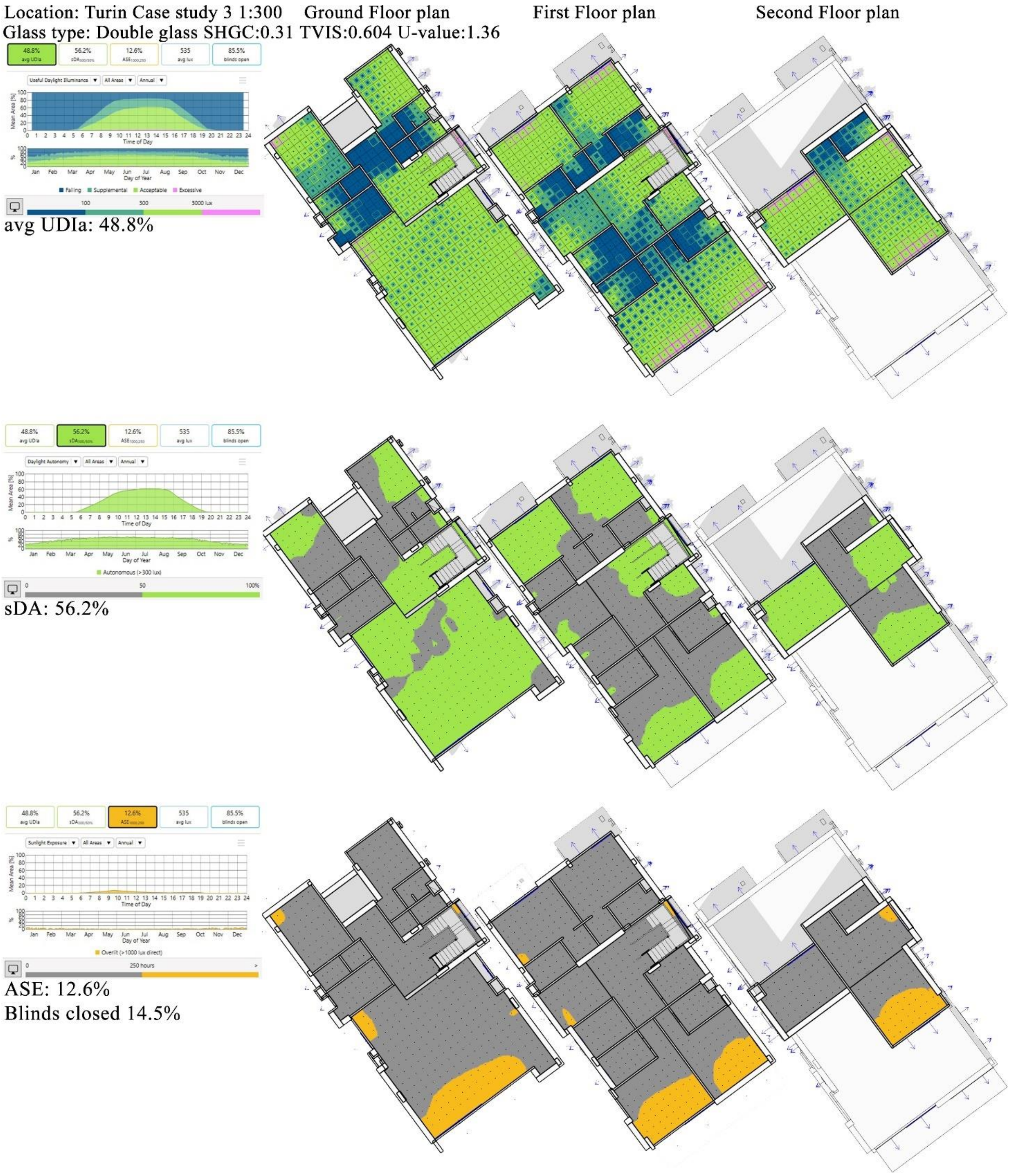
	Fail	Minimum	Medium	High
Target Level	38.3%	55.3%	6.5%	0.0%
Minimum Level	56.8%	43.2%	0.0%	0.0%

Fig(60): The simulation for average illuminance and daylight factor in Turin in case study 2

Location: Cairo Case study 3 1:300 Ground Floor plan First Floor plan Second Floor plan
Glass type: Double glass 6.4 mm Stainless Steel Cover 30% SHGC:0.15 TVIS:0.27 U- value:2.66



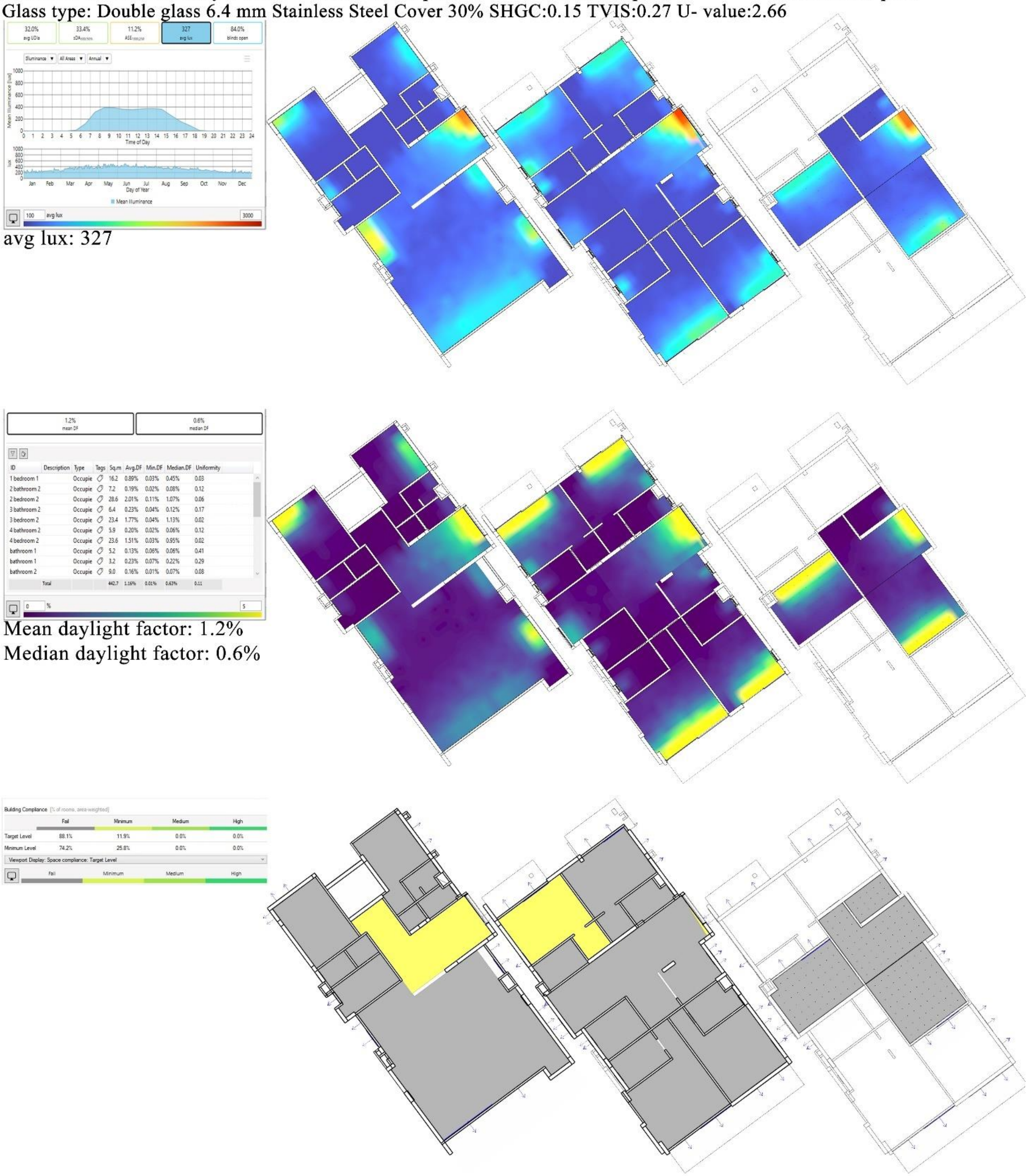
Fig(61): The simulation for UDIA, SDA, ASE and blinds closed percentage in Cairo in case study 3



Fig(62): The simulation for UDIA, SDA, ASE and blinds closed percentage in Turin in case study 3

Location: Cairo Case study 3 1:300 Ground Floor plan First Floor plan Second Floor plan

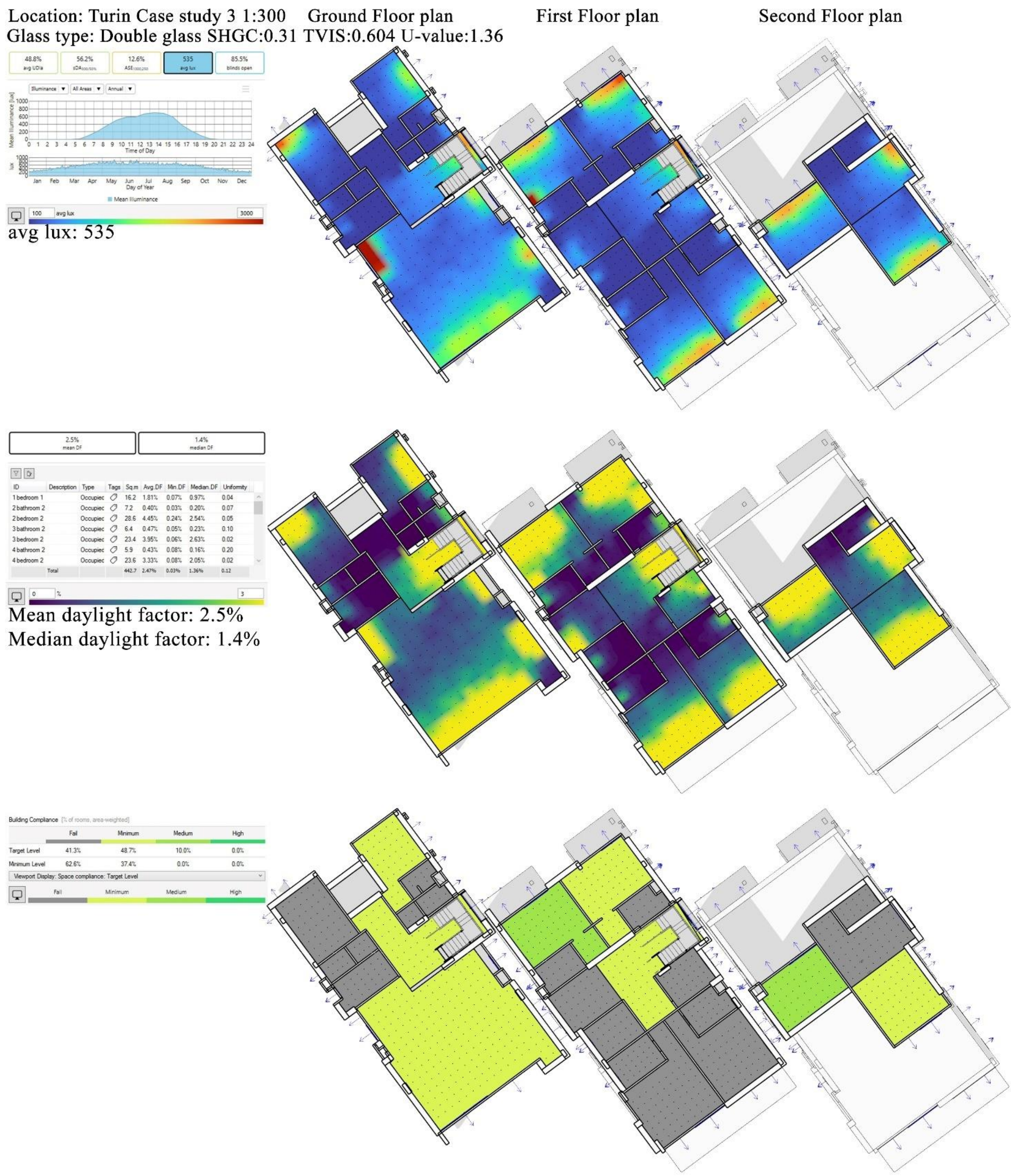
Glass type: Double glass 6.4 mm Stainless Steel Cover 30% SHGC:0.15 TVIS:0.27 U- value:2.66



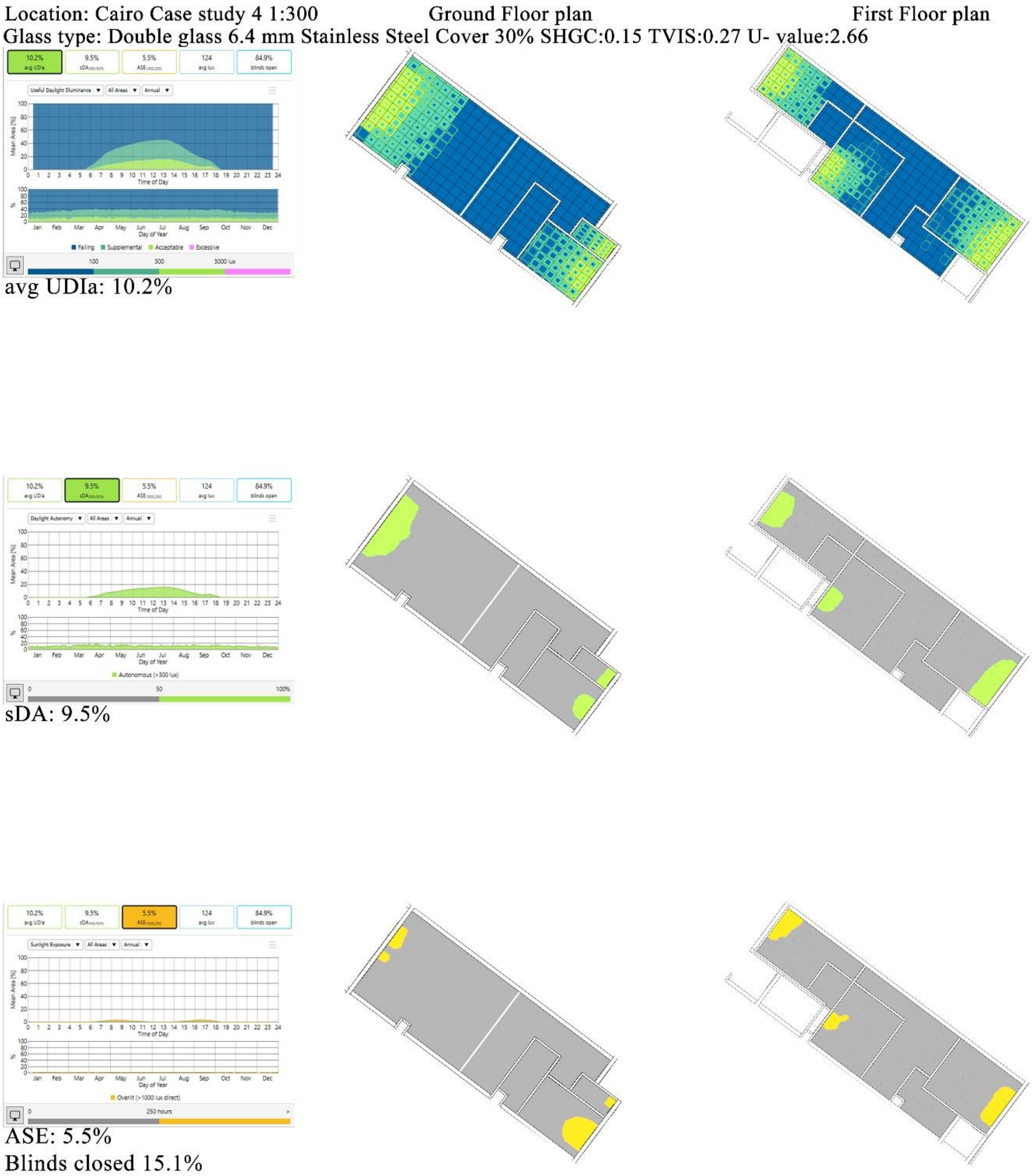
ID	Description	Type	Tags	Sq.m	Avg.DF	Min.DF	Median.DF	Uniformity
1 bedroom 1		Occupie		16.2	0.89%	0.03%	0.45%	0.03
2 bathroom 2		Occupie		7.2	0.19%	0.02%	0.08%	0.12
2 bedroom 2		Occupie		28.6	2.01%	0.11%	1.07%	0.06
3 bathroom 2		Occupie		6.4	0.23%	0.04%	0.12%	0.17
3 bedroom 2		Occupie		23.4	1.77%	0.04%	1.13%	0.02
4 bathroom 2		Occupie		5.9	0.20%	0.02%	0.06%	0.12
4 bedroom 2		Occupie		23.6	1.51%	0.03%	0.95%	0.02
bathroom 1		Occupie		5.2	0.13%	0.06%	0.06%	0.41
bathroom 1		Occupie		3.2	0.23%	0.07%	0.22%	0.29
bathroom 2		Occupie		9.0	0.16%	0.01%	0.07%	0.08
	Total			442.7	1.16%	0.01%	0.63%	0.11

	Fail	Minimum	Medium	High
Target Level	88.1%	11.9%	0.0%	0.0%
Minimum Level	74.2%	25.8%	0.0%	0.0%

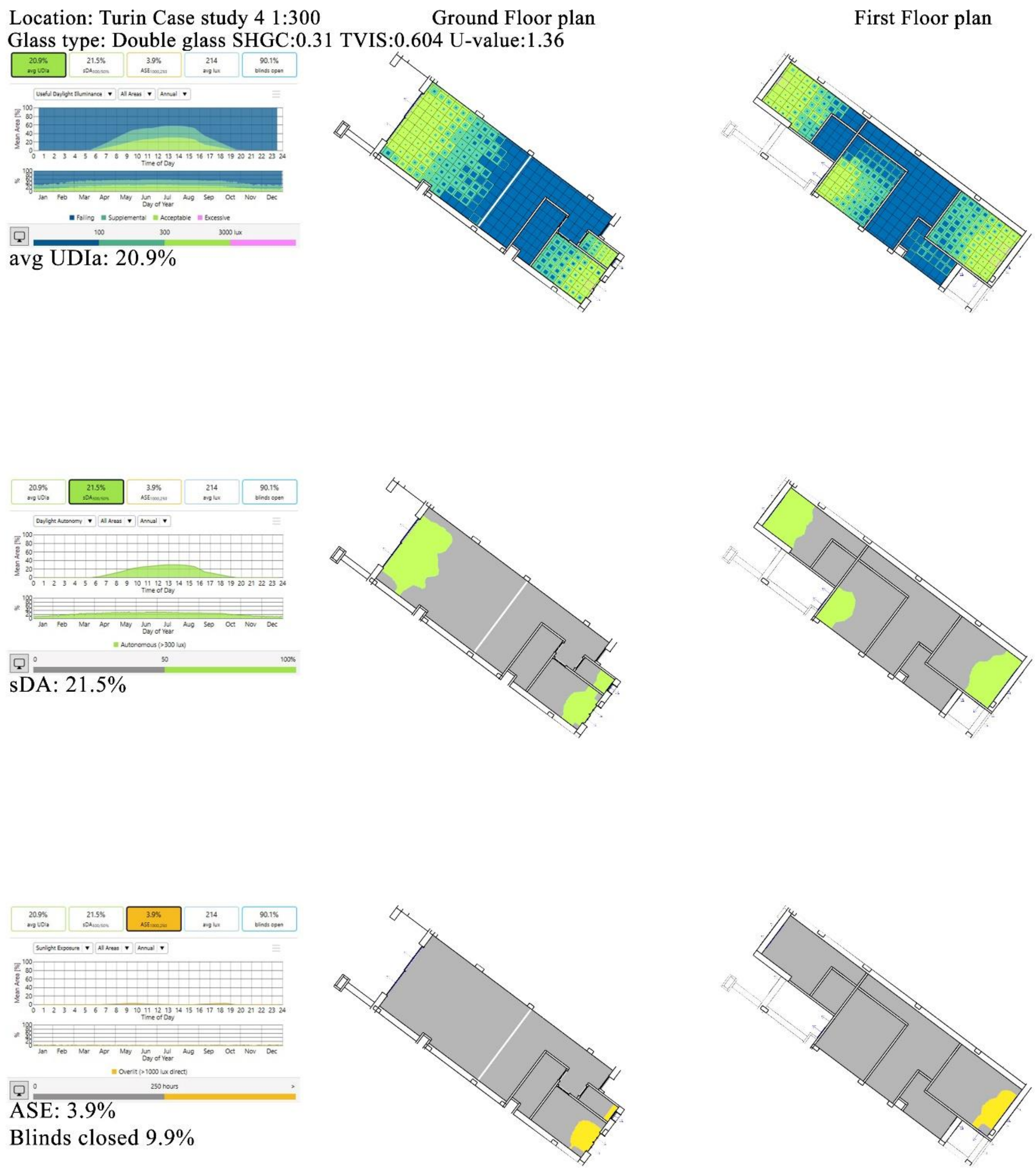
Fig(63): The simulation for average illuminance and daylight factor in Cairo in case study 3



Fig(64): The simulation for average illuminance and daylight factor in Turin in case study 3



Fig(65): The simulation for UDIA, SDA, ASE and blinds closed percentage in Cairo in case study 4

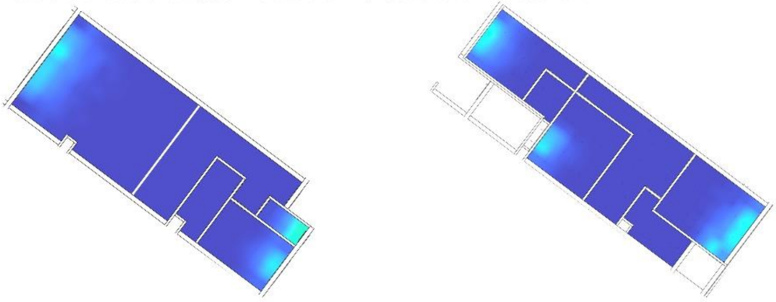


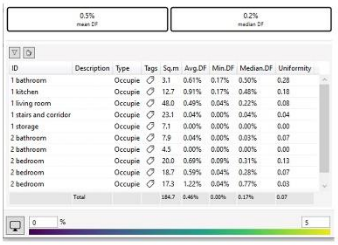
Fig(66): The simulation for UDIA, SDA, ASE and blinds closed percentage in Turin in case study 4

Location: Cairo Case study 4 1:300 Ground Floor plan First Floor plan

Glass type: Double glass 6.4 mm Stainless Steel Cover 30% SHGC:0.15 TVIS:0.27 U- value:2.66

avg lux: 124

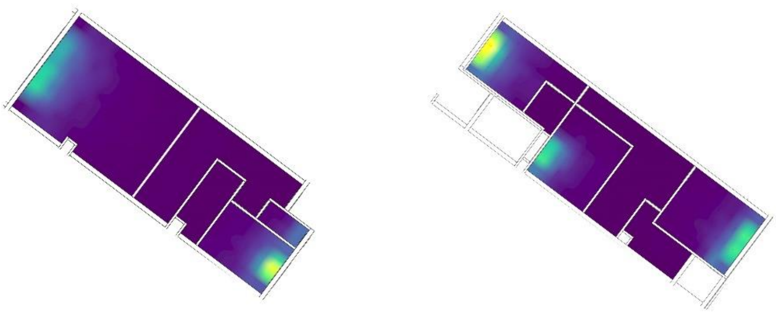


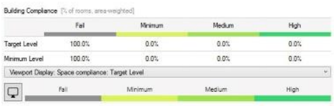


ID	Description	Type	Tags	Sq.m	Avg.DF	Min.DF	Median.DF	Uniformity
1 bathroom		Occupie		3.1	0.61%	0.17%	0.50%	0.28
1 kitchen		Occupie		12.7	0.91%	0.17%	0.48%	0.18
1 living room		Occupie		48.0	0.49%	0.04%	0.22%	0.08
1 stairs and corridor		Occupie		23.1	0.04%	0.00%	0.04%	0.04
1 storage		Occupie		7.1	0.00%	0.00%	0.00%	0.00
2 bathroom		Occupie		7.9	0.04%	0.00%	0.03%	0.07
2 bathroom		Occupie		4.5	0.00%	0.00%	0.00%	0.00
2 bedroom		Occupie		20.0	0.69%	0.09%	0.31%	0.13
2 bedroom		Occupie		18.7	0.59%	0.04%	0.28%	0.07
2 bedroom		Occupie		17.3	1.22%	0.04%	0.77%	0.03
	Total			184.7	0.46%	0.00%	0.17%	0.07

Mean daylight factor: 0.5%

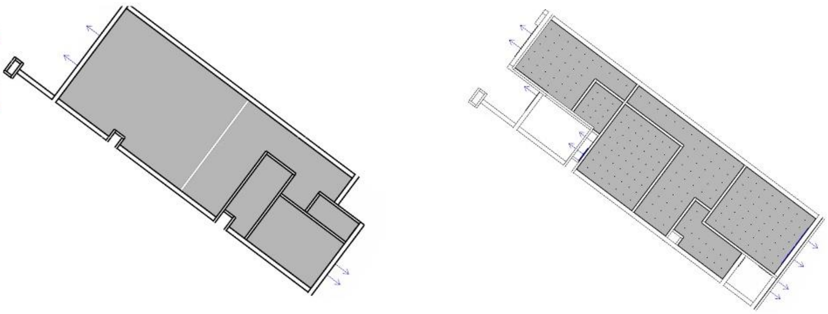
Median daylight factor: 0.2%



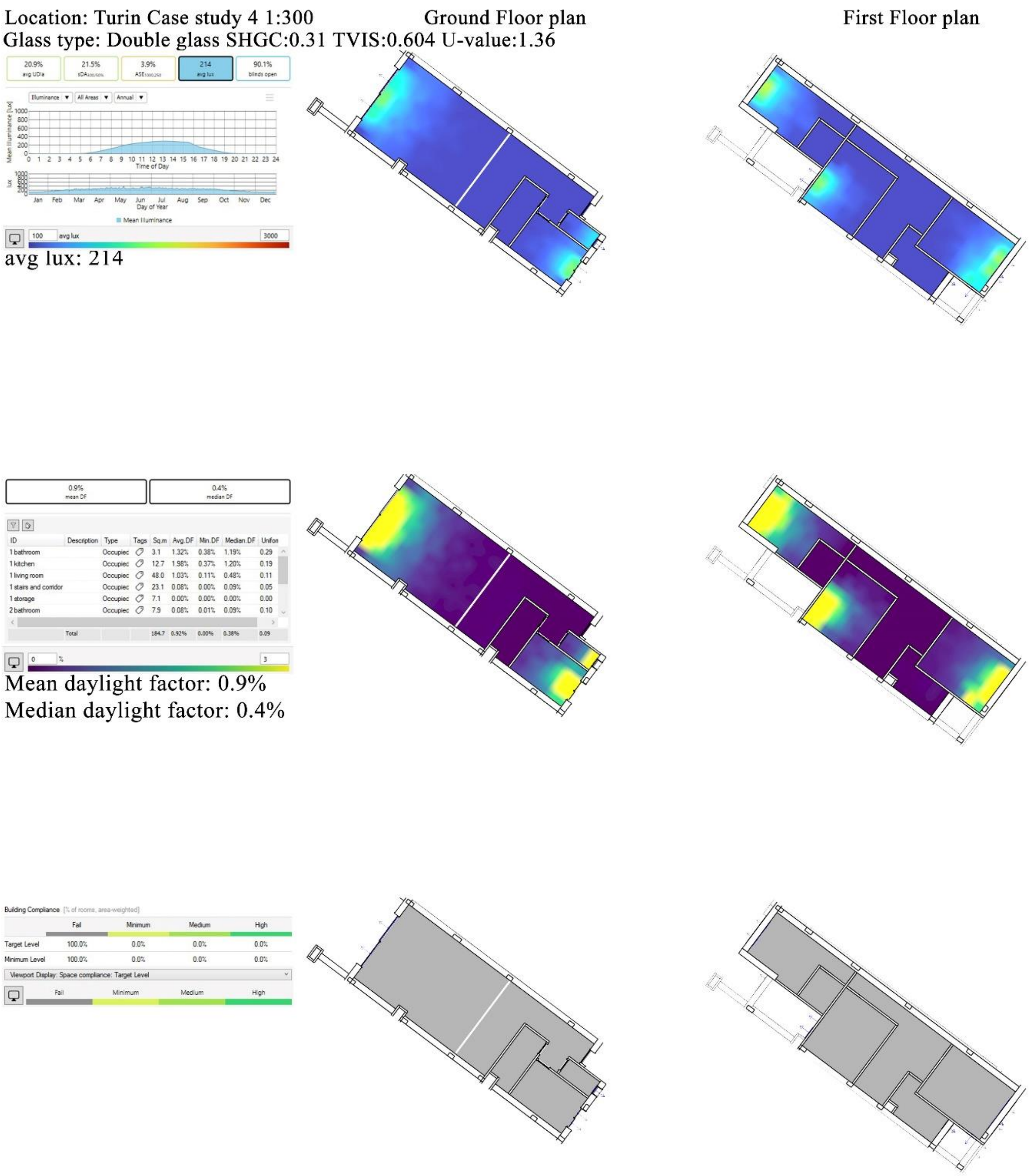


Building Compliance [% of rooms, area-weighted]

	Fail	Minimum	Medium	High
Target Level	100.0%	0.0%	0.0%	0.0%
Minimum Level	100.0%	0.0%	0.0%	0.0%



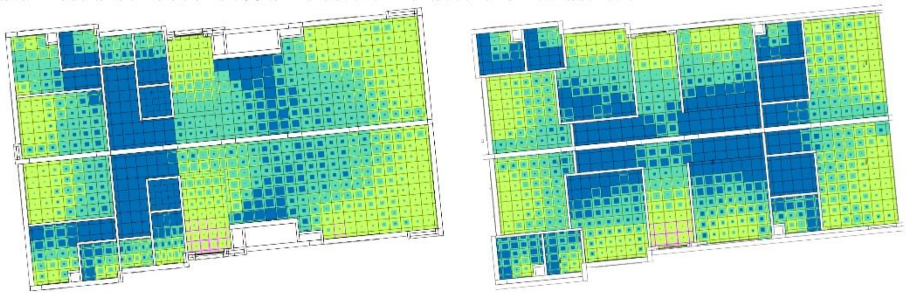
Fig(67): The simulation for average illuminance and daylight factor in Cairo in case study 4



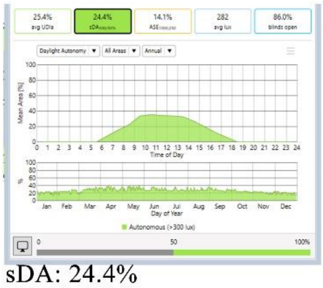
Fig(68): The simulation for average illuminance and daylight factor in Turin in case study 4

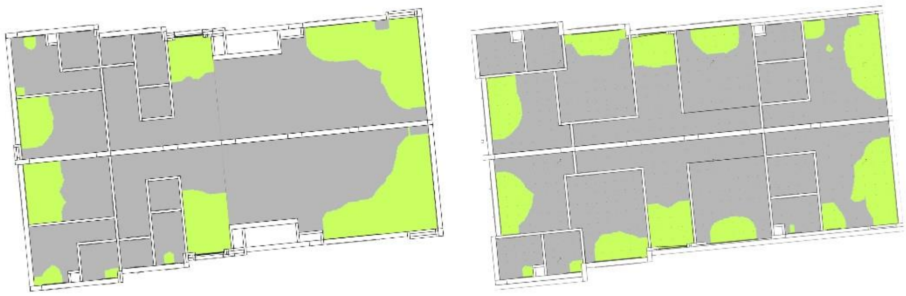
Location: Cairo Case study 5 1:300 Ground Floor plan First Floor plan

Glass type: Double glass 6.4 mm Stainless Steel Cover 30% SHGC:0.15 TVIS:0.27 U- value:2.66



avg UDIa: 25.4%



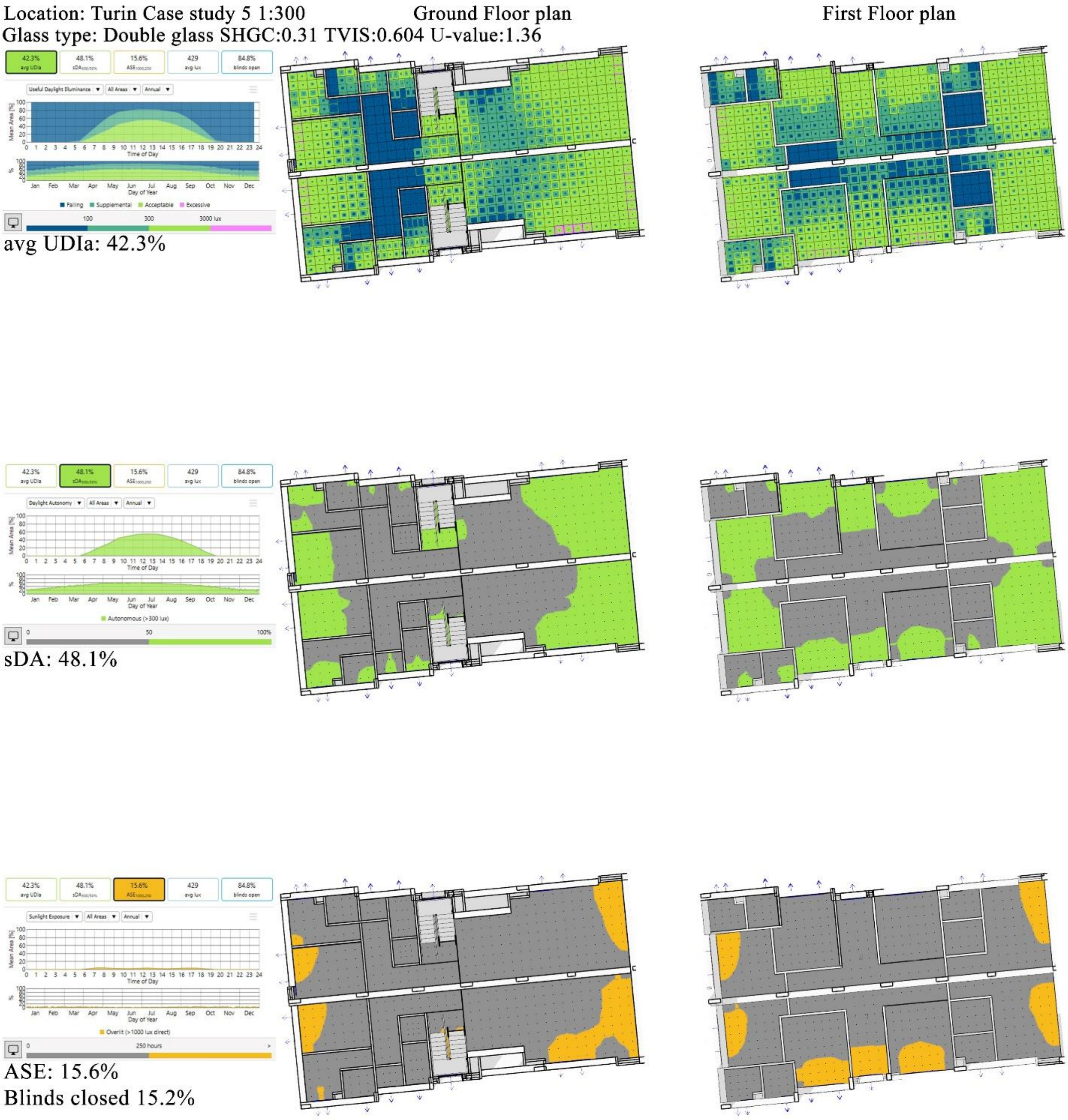


sDA: 24.4%

ASE: 14.1%

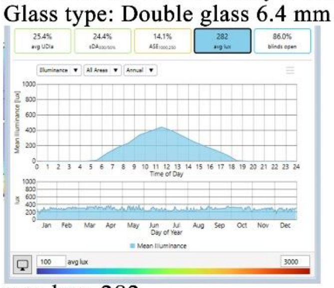
Blinds closed 14.0%

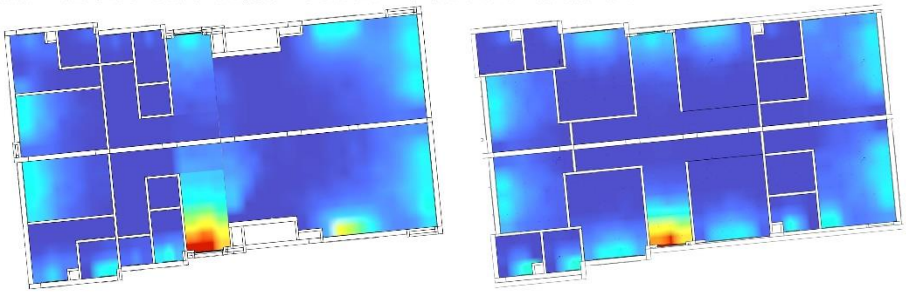
Fig(69): The simulation for UDIA, SDA, ASE and blinds closed percentage in Cairo in case study 5



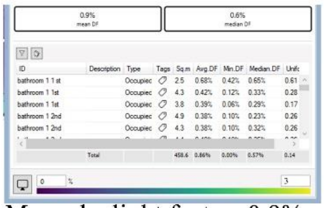
Fig(70): The simulation for UDIA, SDA, ASE and blinds closed percentage in Turin in case study 5

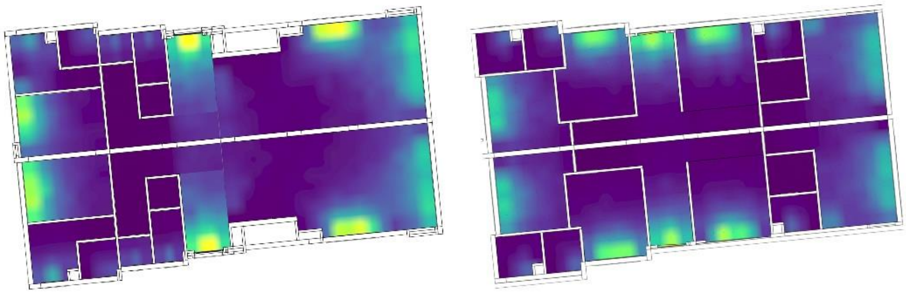
Location: Cairo Case study 5 1:300 Ground Floor plan First Floor plan
Glass type: Double glass 6.4 mm Stainless Steel Cover 30% SHGC:0.15 TVIS:0.27 U- value:2.66





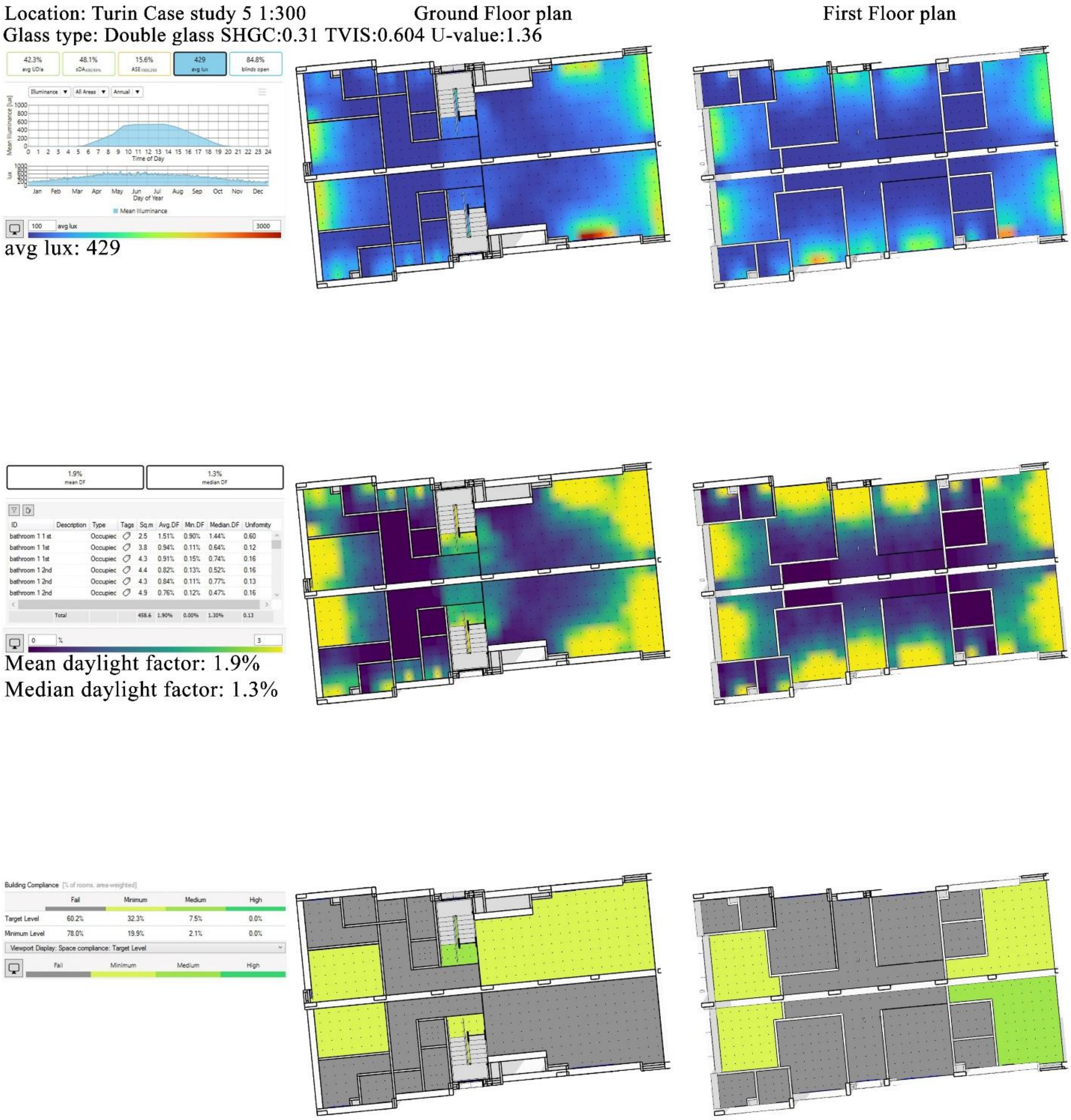
avg lux: 282





Mean daylight factor: 0.9%
Median daylight factor: 0.6%

Fig(71): The simulation for average illuminance and daylight factor in Cairo in case study 5



Fig(73): The simulation for average illuminance and daylight factor in Turin in case study 5

Conclusion

	Case 1	Case 2	Case 3	Case 4	Case 5
UDIA Cairo Turin	28.2% 38.8%	31.6% 50.5%	32% 48.8%	10.2% 20.9%	25.4% 42.3%
SDA Cairo Turin	25.6% 42.4%	32.3% 58.6%	33.4% 56.2%	9.5% 21.5%	24.4% 48.1%
ASE Cairo Turin	14.1% 11.5%	13.2% 11.9%	11.2% 12.6%	5.5% 3.9%	14.1% 15.6%
Blinds closed Cairo Turin	13.2% 13.3%	16.9% 14.3%	16% 14.5%	15.1% 9.9%	14% 15.2%
Avg Lux Cairo Turin	268 396	347 533	327 535	124 214	282 429
DF Cairo Turin	0.9% 1.6%	1.2% 2.5%	1.2% 2.5%	0.5% 0.9%	0.9% 1.9%

Table (11): The daylight availability in the five case studies in Cairo and Turin

AS per the above results table from the simulation, the spatial daylight autonomy SDA percentage in Turin is much higher than in Cairo, and comply with LEED V4.1 regulations as per the regulations the SDA should not be less than 40% in all the cases in Turin the SDA comply with the regulations except in case 4, but the annual sunlight exposure ASE is exceeding the limit 10% as stated in LEED v4.1 in both cases in Cairo and in Turin which means that there is a glare problem that needs to be solved using shading devices except in case study 4. Both the SDA and ASE percentages reflect on the blinds closed percentage as the blinds are used in the case of direct solar exposure and as the blinds are closed the less view to the outside, in general in Turin with selective type of glass the blinds are used less than in Egypt, except in case 5.

Useful daylight illuminance UDIA in Turin is achieving higher percentage than in Cairo, which indicates that the average illuminance per year, the UDIA is failing if average lux is less than 100 lux, if between 100 lux and 300 lux it is supplement, if between 300 lux and 3000 lux it is autonomous and if more than 3000 lux it is excessive. In the case of Turin, the UDIA percentage considered as autonomous while in Cairo it is considered as supplemental. The Daylight factor percentage in Turin is higher than in Egypt which means that there is indoor daylight quality in Turin than in Cairo.

Illuminance

In general Egypt can be considered having a clear sky most of the year, so the natural light should be used instead of the artificial light to decrease the energy consumption, as per the housing and Building National Research Centre lighting and cooling systems consumes 44% of the total residential building energy.

According to Egyptian codes to improve energy efficiency in residential buildings ECP 306-2005 section 7 page 55-56, The light intensity (lux) differs in zones according to the function of the zone shown in table (12), table (12) shows the intensity in different building rooms, the code indicates different devices, their luminosity, and life cycle. It defines minimum and maximum required luminosity values for each space based on the function. There is another requirement for the daylight simulation according to LEED V4.1 that the illuminance level should be between 300 lux and 3000 lux for 9 am and 3 pm on a clear sky in equinox day, if the illuminance exceeds 3000 the space is facing glare which need to be solved using shading system.

From fig(74) to fig(83) shows the simulations for Cairo in clear sky and Turin in overcast sky all run in simulation albedo 20% and it is studied more in annex A. The simulation run in 21 of the months of June, September and December that represent summer, fall and winter respectively, in four times of the day in the month of June 9 am, 12 pm, 15 pm and 18 pm, in September and December at 9 am, 12 pm and 15 pm. In the following tables if the average is below the minimum illuminance level it is highlighted in light red and if it is above the illuminance level required by the Egyptian codes it is highlighted in blue.

Space	*Min (lux)*	*Average (lux)*	*Max (lux)*
Bedroom	50	75	100
Guest room	200	300	400
Living room	200	300	500
Bathroom	100	150	300
Kitchen	100	200	400
Corridors and stairs	100	150	200

Table (12): The illuminance requirements according to the Egyptian requirements

Case 1 Cairo

	Jun-09	Jun-12	Jun-15	Jun-18	Sep-09	Sep-12	Sep-15	Dec-09	Dec-12	Dec-15
Unit A										
Ground floor										
Bedroom	68	99	103	100	101	96	54	59	104	57
Bathroom 2	62	83	85	89	91	93	38	56	106	51
Storage	3	2	3	1	3	2	2	1	3	2
Bathroom 2	57	77	71	19	84	96	35	58	88	40
Stairs and corridor	219	341	342	127	271	277	152	193	285	162
living	244	214	154	61	237	173	113	145	162	106
kitchen	135	265	340	475	127	188	341	97	185	490
First floor										
Bathroom 1	47	71	85	90	50	47	36	35	49	33
Bedroom 1	140	272	368	460	130	222	442	103	230	542
Bathroom 2	48	75	86	90	54	54	40	39	53	37
Bedroom 2	95	153	155	325	111	114	84	85	112	76
stairs and corridor	95	142	146	134	111	113	75	76	107	67
living room	99	162	168	251	112	113	90	86	112	79
Bathroom 3	46	77	88	91	49	50	42	40	49	35
dressing	0	0	0	0	0	0	0	0	0	0
Bedroom 3	280	214	131	115	240	135	111	155	117	88

	Jun-09	Jun-12	Jun-15	Jun-18	Sep-09	Sep-12	Sep-15	Dec-09	Dec-12	Dec-15
Unit B										
Ground floor										
Bedroom	93	107	85	42	117	125	54	65	144	95
Bathroom 1	85	97	72	33	134	113	49	42	134	78
storage	30	38	27	10	53	43	16	120	76	18
Bathroom 2	68	88	62	25	124	113	35	45	116	55
stairs and corridor	321	379	202	76	409	350	143	441	465	194
living room	265	220	151	58	144	300	114	339	388	240
kitchen	181	348	406	374	170	260	469	128	268	485
First floor										
Bathroom 1	77	87	43	24	149	103	41	198	134	66
Bedroom 1	138	275	359	426	129	222	440	105	237	634
Bathroom 2	77	94	47	27	130	106	40	247	147	71
Bedroom 2	155	190	99	51	205	207	87	405	264	133
stairs and corridor	142	170	99	40	192	148	76	270	222	102
living room	163	202	105	50	183	213	92	247	299	307
Bathroom 3	87	85	47	21	178	113	44	174	143	63
dressing	0	0	0	0	0	0	0	0	0	0
Bedroom 3	290	218	123	62	283	156	112	328	417	94

Fig(74): Table of the average illuminance in Case study 1 in Cairo

In case study one in Cairo the spaces don't compy with LEED V4.1 illuinance regulations except in unit A on the ground floor kitchen at 3 pm and bedroom 1 on the first floor at 3 pm. Unit B the space don't comply with the requirements except the kitchen in the ground floor at 3 pm and bedroom 1 in the first floor at 3 pm.

Case 1 Turin

	Jun-09	Jun-12	Jun-15	Jun-18	Sep-09	Sep-12	Sep-15	Dec-09	Dec-12	Dec-15
Unit A										
Ground floor										
Bedroom	115	161	133	66	74	118	95	22	61	39
Bathroom 2	95	124	99	44	65	92	77	18	47	34
Storage	155	220	197	94	114	176	128	33	93	64
Bathroom 2	104	134	118	52	66	98	78	20	48	37
Stairs and corridor	232	301	263	124	154	237	181	42	119	78
living	234	318	280	131	162	246	190	45	126	82
kitchen	324	449	374	176	218	337	259	63	176	117
First floor										
Bathroom 1	120	154	139	61	77	125	99	23	66	38
Bedroom 1	329	453	389	184	222	347	267	62	178	115
Bathroom 2	117	160	136	68	85	139	93	25	67	42
Bedroom 2	223	300	259	125	154	236	188	43	122	78
stairs and corridor	205	282	238	119	140	218	171	39	112	72
living room	99	162	168	251	112	113	90	86	112	79
Bathroom 3	127	174	149	73	82	135	102	22	62	44
dressing	0	0	0	0	0	0	0	0	0	0
Bedroom 3	247	338	290	138	171	262	205	48	134	88

	Jun-09	Jun-12	Jun-15	Jun-18	Sep-09	Sep-12	Sep-15	Dec-09	Dec-12	Dec-15
Unit B										
Ground floor										
Bedroom	121	171	138	65	78	126	106	24	64	41
Bathroom 1	99	140	112	53	65	105	85	19	56	35
storage	177	262	224	102	116	181	144	36	105	64
Bathroom 2	101	139	127	61	71	117	77	19	57	35
stairs and corridor	224	309	269	130	165	248	196	44	126	84
living room	239	327	282	133	164	246	193	45	128	83
kitchen	430	579	484	232	287	450	345	80	233	147
First floor										
Bathroom 1	115	161	149	70	83	126	95	23	61	44
Bedroom 1	325	452	378	184	227	348	263	63	177	118
Bathroom 2	132	167	151	64	92	124	105	23	68	42
Bedroom 2	246	342	285	135	167	250	198	47	129	84
stairs and corridor	206	283	246	119	139	219	172	39	113	72
living room	255	340	296	139	169	261	200	47	135	88
Bathroom 3	131	157	155	70	83	135	101	23	64	40
dressing	0	0	0	0	0	0	0	0	0	0
Bedroom 3	251	333	299	139	170	263	211	47	136	88

Fig(75): Table of the average illuminance in Case study 1 in Turin

In case study one in Turin the spaces don’t compy with LEED V4.1 illuinance regulations in all the living spaces.

Case 2 Cairo

Space ID	Jun-09	Jun-12	Jun-15	Jun-18	Sep-09	Sep-12	Sep-15	Dec-09	Dec-12	Dec-15
Ground floor										
kitchen	164	288	331	104	304	572	856	327	613	652
bathroom 1	118	116	48	22	405	115	43	422	149	33
bedroom 1	70	59	26	14	597	54	26	610	69	20
livingroom	388	276	382	66	702	217	266	717	257	100
stairs and corridor	266	291	657	91	290	235	567	180	254	124
bathroom 2	41	36	63	59	52	38	41	37	42	20
bathroom 3	89	66	99	24	87	65	37	59	81	22
bedroom 2	198	219	570	310	215	193	208	141	203	100
First floor										
bedroom 1	197	439	428	296	410	655	820	390	567	785
bathroom 1	75	67	29	15	335	66	27	488	763	21
living room	370	149	85	77	432	137	73	305	283	49
bathroom 2	69	51	22	11	61	43	22	81	56	16
dressing	84	62	28	13	619	60	24	592	87	21
bedroom 2	788	406	183	101	303	198	160	173	165	133
bedroom 3	402	322	189	91	237	164	155	135	140	109
bathroom 3	33	41	60	21	36	29	36	21	28	16
kitchen	122	161	257	87	129	121	322	88	116	86
stairs and corridor	197	244	218	194	214	177	248	161	179	107
bathroom 4	41	30	46	9	57	40	33	29	48	12
bedroom 4	153	356	506	279	167	455	613	159	484	726
Second floor										
bedroom	211	504	810	147	267	462	665	282	688	735
living room	343	374	201	180	285	201	167	169	167	121
Stairs and corridor	0	0	0	0	0	0	0	0	0	0
bathroom	32	48	90	102	34	32	60	27	32	26

Fig(76): Table of the average illuminance in Case study 2 in Cairo

The illuminance average in Cairo doesn't comply with the requirements in the living room on the first floor although the WWR is 30% the illuminance is less than the required range, all the bedrooms exceeds the required illuminance as the according to the requirements the bedrooms should not exceed 100 illuminance which is very low. According to LEED V4.1 the range should be between 300 lux and 3000 lux on the 21 of september at 9 am and 3 pm, on the ground floor all the living spaces comlpy with the requirement except in bedroom 2 at 9 am, bedroom 2, bedroom 1 and livingroom at 3 pm, on the first floor all the spaces comply with the requirements exept bedroom 3 and bedroom 4 at 9 am and living, bedroom 2 and bedroom 3 at 3 pm, in the second floor all the spaces don't comply with the requirement except bedroom at 3 pm.

Case 2 Turin

Space ID	Jun-09	Jun-12	Jun-15	Jun-18	Sep-09	Sep-12	Sep-15	Dec-09	Dec-12	Dec-15
					Ground floor					
kitchen	310	424	376	177	212	335	255	61	168	109
bathroom 1	119	178	140	66	86	132	103	23	66	42
bedroom 1	85	105	95	43	56	86	62	15	45	27
livingroom	237	325	280	132	164	251	194	46	128	84
stairs and corridor	410	566	483	229	275	437	336	78	225	143
bathroom 2	44	57	47	23	28	43	29	8	21	15
bathroom 3	49	77	61	27	37	58	46	10	33	17
bedroom 2	235	310	274	125	156	246	199	44	125	80
					First floor					
bedroom 1	505	689	593	280	348	534	421	97	280	178
bathroom 1	76	97	97	46	55	88	63	15	42	27
living room	170	236	200	95	116	180	139	32	94	58
bathroom 2	56	74	61	32	36	56	46	11	29	18
dressing	64	90	71	37	42	70	53	13	33	22
bedroom 2	568	777	672	316	392	591	459	108	304	200
bedroom 3	387	528	458	216	268	408	327	75	213	136
bathroom 3	49	63	56	27	31	48	38	10	24	17
kitchen	207	257	239	115	133	210	163	38	108	69
stairs and corridor	363	490	426	203	250	378	296	69	196	129
bathroom 4	33	39	40	17	18	34	28	7	21	11
bedroom 4	421	584	504	235	289	448	346	80	228	150
					Second floor					
bedroom	580	810	697	328	402	619	488	114	317	207
living room	493	686	589	280	343	514	408	95	268	174
Stairs and corridor	0	0	0	0	0	0	0	0	0	0
bathroom	69	95	87	40	49	81	63	13	42	23

Fig(77): Table of the average illuminance in Case study 2 in Turin

In Turin the illuminance is less than the requirements in most of the service spaces as bathroom and above average in the bedrooms. According to LEED V4.1 the ground floor all the spaces don’t comply with the requirements nether at 9 am nor 3 pm, first floor the spaces comply with the requirements in bedroom 1 and bedroom 2 at 9 am, bedroom 1, bedroom 2, bedroom 3 and bedroom 4 at 3 pm, the second floor all the living spaces comply with the requirements.

Case 3 Cairo

Space ID	Jun-09	Jun-12	Jun-15	Jun-18	Sep-09	Sep-12	Sep-15	Dec-09	Dec-12	Dec-15
kitchen	144	251	387	433	127	159	467	94	131	120
bathroom 1	90	63	120	58	54	65	159	27	73	28
bedroom 1	58	34	59	16	36	42	25	15	44	14
livingroom	464	280	397	135	286	242	193	615	424	140
stairs and corridor	500	308	241	97	462	235	261	165	237	178
bathroom 2	58	35	41	17	23	37	54	11	48	32
bathroom 3	100	72	80	28	77	75	99	30	88	65
bedroom 2	388	230	213	78	180	205	242	103	206	156
Second floor										
bedroom 1	189	354	479	498	158	185	423	123	167	133
bathroom 1	48	47	89	45	33	44	89	16	48	32
living room	125	132	554	80	92	138	511	56	134	86
bathroom 2	38	36	58	11	30	44	106	17	64	22
dressing	40	48	76	31	37	61	326	24	74	471
bedroom 2	666	473	186	100	644	447	206	701	657	207
bedroom 3	376	377	156	82	465	339	165	394	320	162
bathroom 3	68	41	34	13	46	30	33	21	32	28
kitchen	280	163	118	50	227	119	122	115	114	91
stairs and corridor	474	251	175	74	395	180	194	148	178	142
bathroom 4	69	40	37	15	26	33	42	14	33	28
bedroom 4	183	302	597	537	150	157	223	111	138	121
Third floor										
bedroom	191	431	471	349	162	233	375	124	172	195
living room	549	431	196	90	645	405	212	626	569	193
stairs and corridor	464	275	181	73	438	210	181	218	206	128
bathroom	90	49	31	15	40	32	31	23	29	24

Fig(78): Table of the average illuminance in Case study 3 in Cairo

In case three most of the spaces comply with the requirements or exceed the range. In the ground floor all the spaces don’t meet the LEED V4.1 requirements except the kitchen at 3 pm, in the first floor all the spaces don’t meet the requirements except bedroom 2 and bedroom 3 at 9 am and bedroom 1 and living at 3 pm, second floor the spaces don’t meet the requirement except living room at 9 am and bedroom at 3 pm.

Case 3 Turin

Space ID	Jun-09	Jun-12	Jun-15	Jun-18	Sep-09	Sep-12	Sep-15	Dec-09	Dec-12	Dec-15
Ground floor										
kitchen	304	413	356	170	205	307	249	58	167	107
bathroom 1	35	48	45	22	26	38	31	6	19	13
bedroom 1	35	48	40	20	25	37	28	6	17	12
livingroom	216	300	260	123	149	232	179	42	118	77
stairs and corridor	460	616	536	255	312	477	376	86	251	161
bathroom 2	62	96	76	37	46	66	47	13	37	24
bathroom 3	63	90	81	34	42	63	54	12	34	23
bedroom 2	234	323	274	130	163	248	198	44	128	80
First floor										
bedroom 1	494	678	592	281	341	529	410	96	270	174
bathroom 1	63	88	75	32	40	57	50	13	36	21
living room	141	195	171	86	98	147	120	28	79	50
bathroom 2	34	48	41	21	26	37	32	6	20	14
dressing	47	70	56	27	34	52	40	10	26	17
bedroom 2	562	769	674	317	389	592	465	109	303	200
bedroom 3	384	540	461	220	269	417	319	77	213	136
bathroom 3	49	65	56	24	34	49	37	9	26	18
kitchen	204	282	241	113	135	224	161	40	110	71
stairs and corridor	378	519	448	214	256	396	313	72	209	132
bathroom 4	50	67	62	30	36	53	41	10	27	17
bedroom 4	429	581	499	239	291	449	347	81	232	150
Second floor										
bedroom	590	809	703	327	405	620	482	111	319	207
living room	492	678	590	279	340	530	410	95	276	173
stairs and corridor	302	404	356	165	205	321	246	57	162	106
bathroom	74	96	79	42	54	74	58	13	39	26

Fig(79): Table of the average illuminance in Case study 3 in Turin

In Turin, in the ground floor all the spaces don’t comply with LEED V4.1 requirements, the first floor don’t comply with the requirements except bedroom 1 and bedroom 2 at 9 am and all the bedrooms comply with the requirements, the second floor all the living spaces comply with the requirements.

Case 4 Cairo

Space ID	Jun-09	Jun-12	Jun-15	Jun-18	Sep-09	Sep-12	Sep-15	Dec-09	Dec-12	Dec-15
Ground floor										
bathroom	165	110	51	24	531	110	42	470	138	34
kitchen	505	197	98	48	552	157	85	788	341	68
Bedroom	0	0	0	0	0	0	0	0	0	0
stairs and corridor	13	18	18	37	12	15	14	8	11	8
living room	84	137	492	445	78	90	329	52	70	62
First floor										
bedroom 1	209	178	93	45	646	170	87	720	620	76
bathroom 1	0	0	0	0	0	0	0	0	0	0
stairs and corridor	1	1	1	4	1	1	1	0	1	0
bedroom 2	58	128	781	699	44	84	505	37	61	78
bathroom 2	17	15	8	4	24	15	8	59	17	6
bedroom 3	127	246	727	723	118	143	718	92	115	141

Fig(80): Table of the average illuminance in Case study 4 in Cairo

Case 4 Turin

Space ID	Jun-09	Jun-12	Jun-15	Jun-18	Sep-09	Sep-12	Sep-15	Dec-09	Dec-12	Dec-15
Ground floor										
bathroom	164	249	192	109	119	171	129	31	95	61
kitchen	259	351	303	143	172	269	206	49	142	91
Bedroom	0	0	0	0	0	0	0	0	0	0
stairs and corridor	11	14	12	6	7	11	9	2	6	4
living room	131	179	155	74	91	137	108	25	72	46
First floor										
bedroom 1	156	266	183	85	106	158	126	29	83	54
bathroom 1	0		0	0	0	0	0	0	0	1
stairs and corridor	1	1	1	0	0	1	0	0	0	0
bedroom 2	167		194	91	113	170	134	31	88	59
bathroom 2	11	15	12	6	7	12	9	2	5	3
bedroom 3	291		352	163	197	308	232	56	157	105

Fig(81): Table of the average illuminance in Case study 4 in Turin

In case study four in Cairo the spaces don't comply with the LEED V4.1 requirements except in the ground floor living room at 3 pm and first floor bedroom 1 at 9 am. In Turin all the spaces don't comply with the LEED V4.1 requirements.

Case 5 Cairo

	Jun-09	Jun-12	Jun-15	Jun-18	Sep-09	Sep-12	Sep-15	Dec-09	Dec-12	Dec-15
Unit A										
Ground floor										
Bedroom	90	157	150	130	77	101	183	61	94	405
Bathroom 1	51	81	62	58	41	47	46	32	46	33
Storage	71	112	77	54	59	67	56	47	64	47
Bathroom 2	44	76	52	50	41	53	46	35	44	35
Stairs and corrido	211	362	228	197	179	214	184	149	187	149
living room	248	221	148	155	241	152	131	389	142	105
kitchen	145	274	351	584	137	183	338	104	152	465
First Floor										
Bathroom 1	42	66	53	44	36	46	38	28	35	27
Bedroom 1	136	261	406	555	127	182	398	99	164	533
Bathroom 2	49	71	58	53	36	45	41	31	41	29
Bedroom 2	105	160	120	114	85	101	89	69	91	67
Stairs and corrido	96	155	111	87	85	107	90	68	96	71
living room	104	167	130	126	86	101	93	69	90	69
Bathroom 3	41	69	50	48	36	46	35	29	37	32
dressing room	0	0	0	0	0	0	0	0	0	0
Bedroom 3	342	249	142	78	343	160	129	289	140	100

	Jun-09	Jun-12	Jun-15	Jun-18	Sep-09	Sep-12	Sep-15	Dec-09	Dec-12	Dec-15
Unit B										
Ground floor										
Bedroom	68	125	61	28	114	121	95	125	192	150
Bathroom 1	56	102	53	20	121	145	71	291	222	139
Storage	82	167	72	33	190	207	73	253	220	189
Bathroom 2	54	89	49	24	107	129	68	135	215	118
Stairs and corrido	219	419	186	85	498	349	249	551	673	433
living room	256	234	137	69	553	646	347	465	649	482
kitchen	177	341	414	420	165	231	471	125	197	435
First Floor										
Bathroom 1	43	79	43	19	97	101	63	131	139	129
Bedroom 1	134	260	389	533	128	185	510	99	164	422
Bathroom 2	48	78	39	19	96	113	68	138	230	123
Bedroom 2	116	205	101	47	309	412	132	264	326	687
stairs and corrido	106	182	96	41	463	590	123	438	500	220
living room	116	205	104	49	215	213	157	626	621	513
Bathroom 3	44	87	46	20	123	144	61	178	222	117
dressing room	0	0	0	0	0	0	0	0	0	0
Bedroom 3	354	257	140	71	375	456	135	444	565	116

Fig(82): Table of the average illuminance in Case study 5 in Cairo

In case study five in Cairo the spaces don't compy with LEED V4.1 illuinance regulations except in unit A on the ground kitchen at 3 pm and on the first floor bedroom 3 at 9 am and bedroom 1 at 3 pm. Unit B the spaces don't comply with the requirements except in the ground floor the livingroom at 9 am and living room and kitchen at 3 pm, first floor bedroom 2 and bedroom 3 at 9 am and bedroom 1 at 3 pm.

Case 5 Turin

	Jun-09	Jun-12	Jun-15	Jun-18	Sep-09	Sep-12	Sep-15	Dec-09	Dec-12	Dec-15
Unit A										
Ground Floor										
Bedroom	214	277	255	116	139	228	175	41	109	76
Bathroom 1	136	160	143	75	83	128	94	23	66	40
Storage	186	250	222	119	141	237	163	40	110	63
Bathroom 2	126	178	145	78	87	134	99	26	72	44
Stairs and corridor	632	882	747	356	428	683	509	121	350	220
living room	275	370	323	153	187	285	226	52	149	95
kitchen	344	458	410	198	241	365	291	66	186	118
First floor										
Bathroom 1	105	147	121	57	70	111	79	21	57	39
Bedroom 1	328	438	382	181	223	343	263	64	180	115
Bathroom 2	106	150	139	57	73	108	92	21	60	35
Bedroom 2	226	311	273	123	156	240	184	43	125	79
Stairs and corridor	218	283	259	117	145	225	172	40	114	76
living room	249	337	291	140	172	263	209	47	136	87
Bathroom 3	111	147	137	62	77	111	89	22	62	38
dressing room	0	0	0	0	0	0	0	0	0	0
Bedroom 3	286	389	336	160	199	299	233	53	155	100

	Jun-09	Jun-12	Jun-15	Jun-18	Sep-09	Sep-12	Sep-15	Dec-09	Dec-12	Dec-15
Unit B										
Ground Floor										
Bedroom	138	194	164	77	91	154	120	27	73	47
Bathroom 1	119	156	145	71	79	109	100	20	63	46
Storage	170	262	217	111	142	196	167	37	103	67
Bathroom 2	112	165	133	64	76	119	96	22	64	43
Stairs and corridor	621	856	723	344	428	666	506	118	337	211
living room	268	366	315	150	182	278	218	51	145	94
kitchen	403	557	489	228	286	426	343	80	223	141
First floor										
Bathroom 1	104	134	119	57	70	111	83	19	58	35
Bedroom 1	332	450	398	183	221	341	270	62	178	115
Bathroom 2	113	155	123	64	73	116	91	22	63	36
Bedroom 2	233	326	283	134	162	257	194	46	130	83
stairs and corridor	210	285	251	118	144	220	172	39	112	72
living room	236	306	272	127	150	248	188	44	123	82
Bathroom 3	112	143	123	67	75	114	91	22	60	39
dressing room	0	0	0	0	0	0	0	0	0	0
Bedroom 3	286	389	346	163	196	308	241	54	155	99

Fig(83): Table of the average illuminance in Case study 5 in Turin

In case study five in Turin the spaces don't compy with LEED V4.1 illuinance regulations except in unit B on the ground floor kitchen at 3 pm.

Ventilation

The ventilation is the amount of fresh air required for ventilation through the building to create the optimal condition, to provide the indoor thermal comfort through the building a good air quality is needed to remove contamination and indoor pollution and to prevent the sick building syndrome and health effect, in case the amount of fresh air is below the required it can cause contamination, discomfort for the inhabitants and pollution and in case it is above the average it can cause discomfort for the inhabitants. The main source of natural air ventilation is the window openings through stack ventilation or cross ventilation or air infiltration but is some countries the natural ventilation is not enough and it is required to have mechanical ventilation which lead to the increase in the usage of the energy consumption. To avoid the usage of mechanical ventilation and to avoid the usage of extra energy the air flow inside the building has to be carefully studied either through cross ventilation or stack ventilation through the design of the openings to face each other to ensure the flow of natural air through the building.

In Egyptian codes to improve energy efficiency in residential buildings ECP 306-2005 section 4 page 39, the regulations require the following regulations for the average ventilation required for breathing in tabe(). According to the Italian regulations Ministerial Decree 05.07.75 the natural ventilation dwelling should range from 0.3-0.5 ACH air changes per hour, the air changes per hour is the number of times the total air volume is replaced by fresh air in one hour.

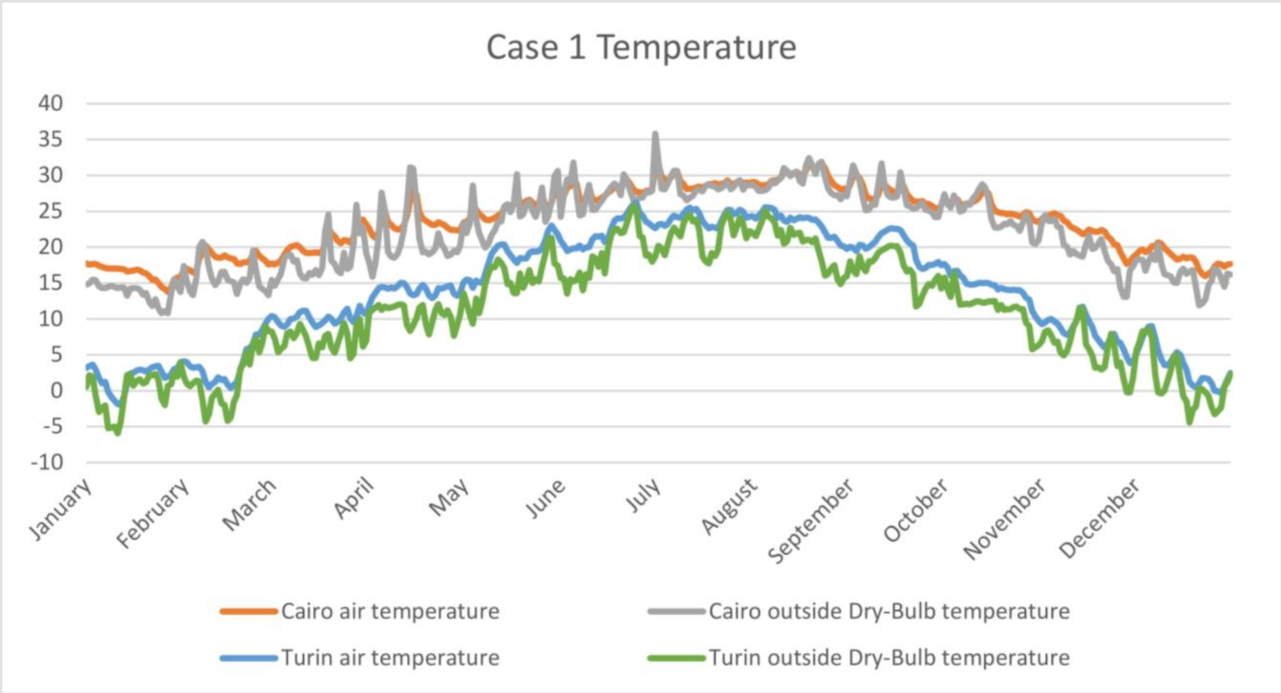
The average ventilation required for breathing

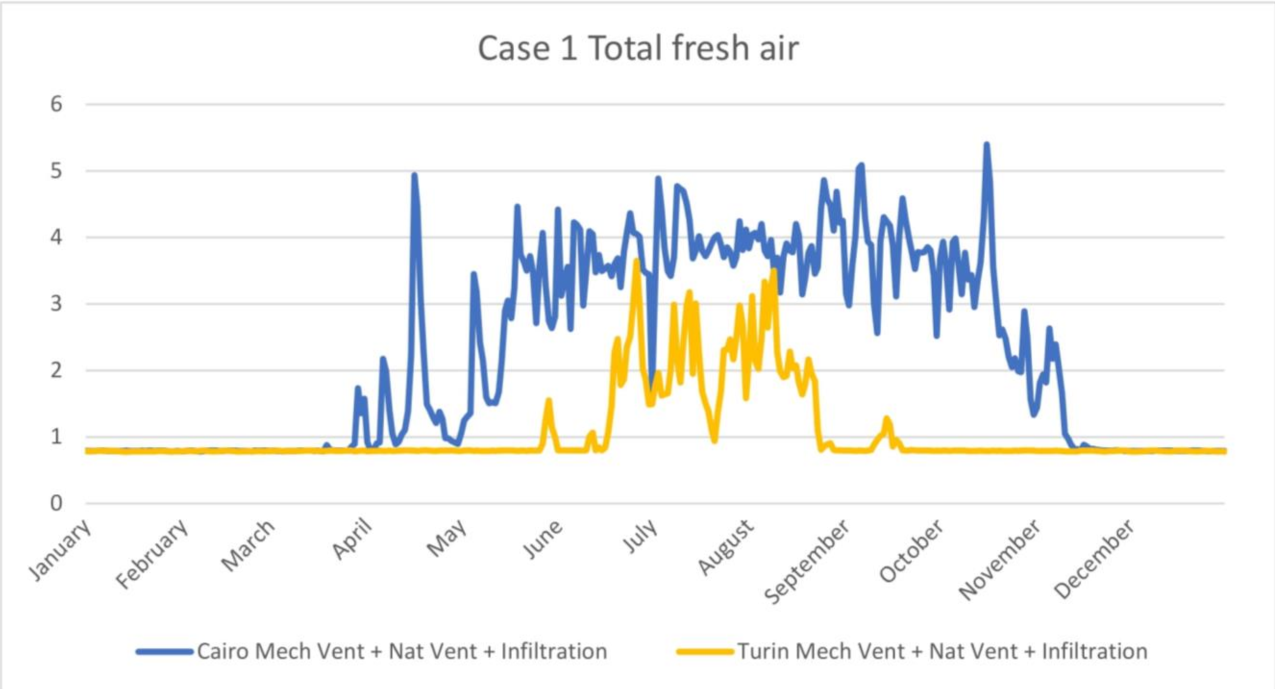
Activity	Required ventilation	Ach
Living	0.8 L/Sec	0.96
Light work	1.3-2.6 L/Sec	1.56-3.12
Medium work	2.6-3.9 L/Sec	3.12-4.68
Hard work	3.9-5.3 L/Sec	4.68-6.36
Very hard work	5.3-6.4 L/Sec	6.36-7.68

Table (13): Egyptian regulations for the natural ventilations.

Dimitroulopoulou, C. "Ventilation in European Dwellings: A Review." Building and Environment, vol. 47, 2012, pp. 109–125., https://doi.org/10.1016/j.buildenv.2011.07.016.

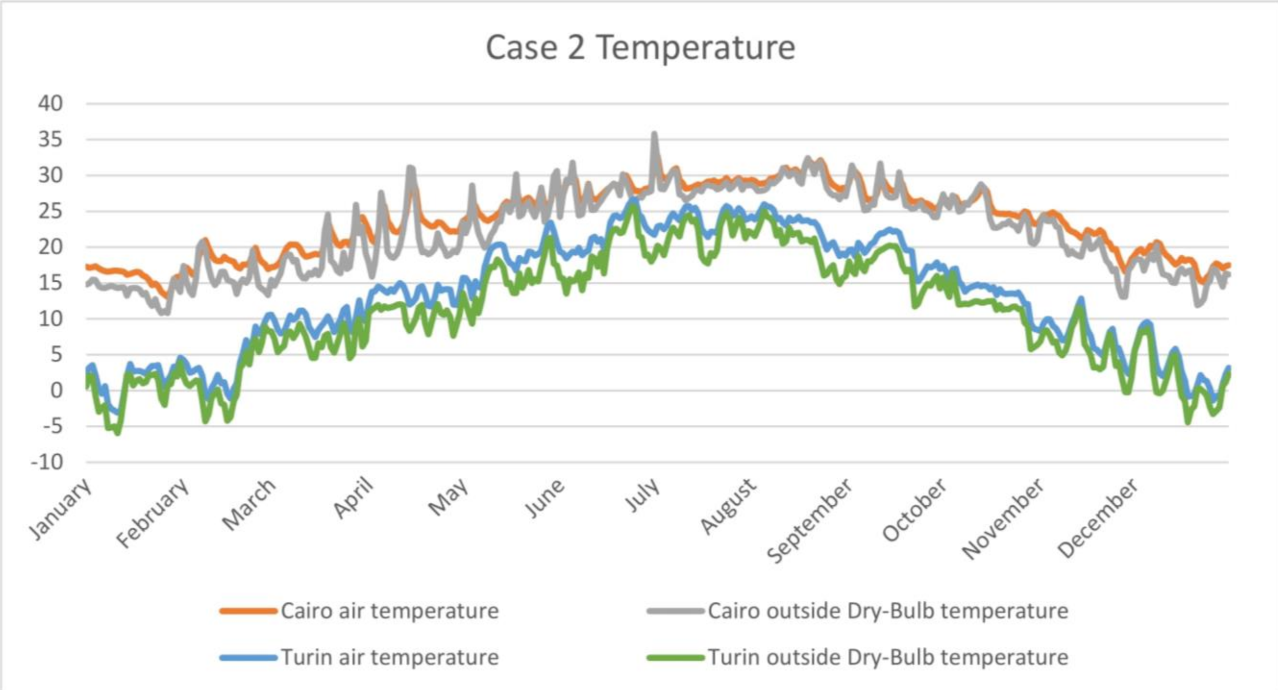
Case 1

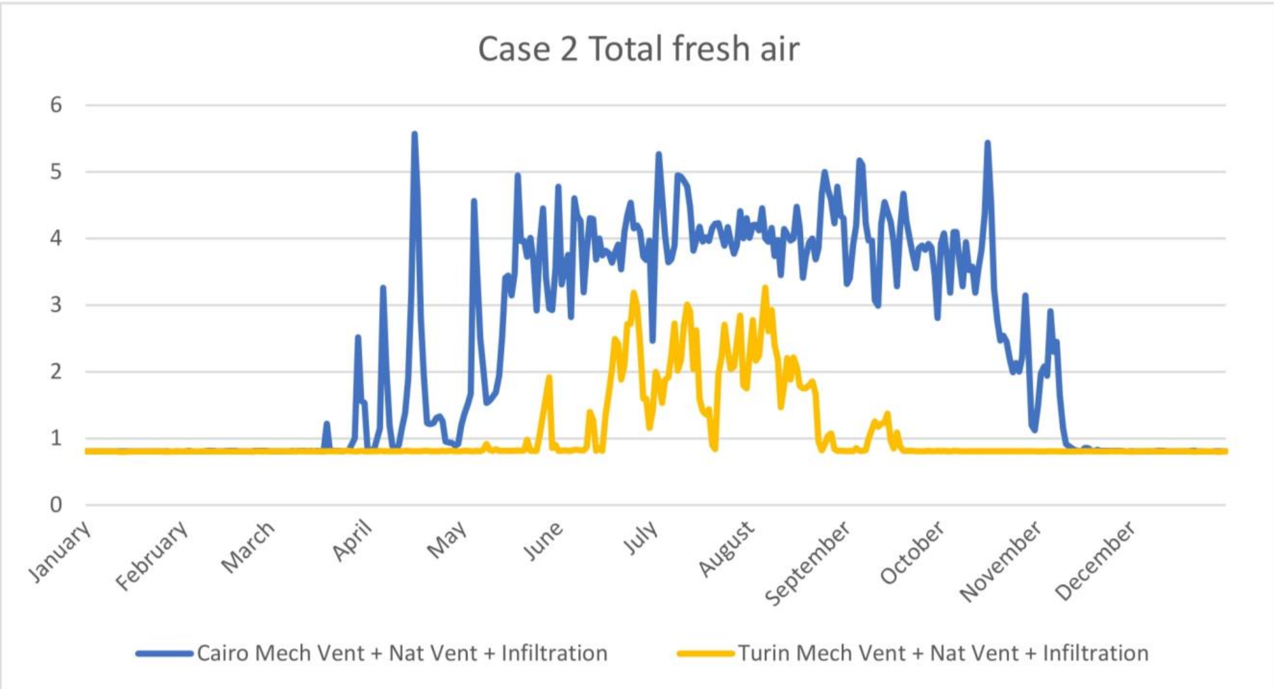




Fig(84): Graph for natural ventilation and temperature inside and outside the building in Cairo and Turin for case study 1

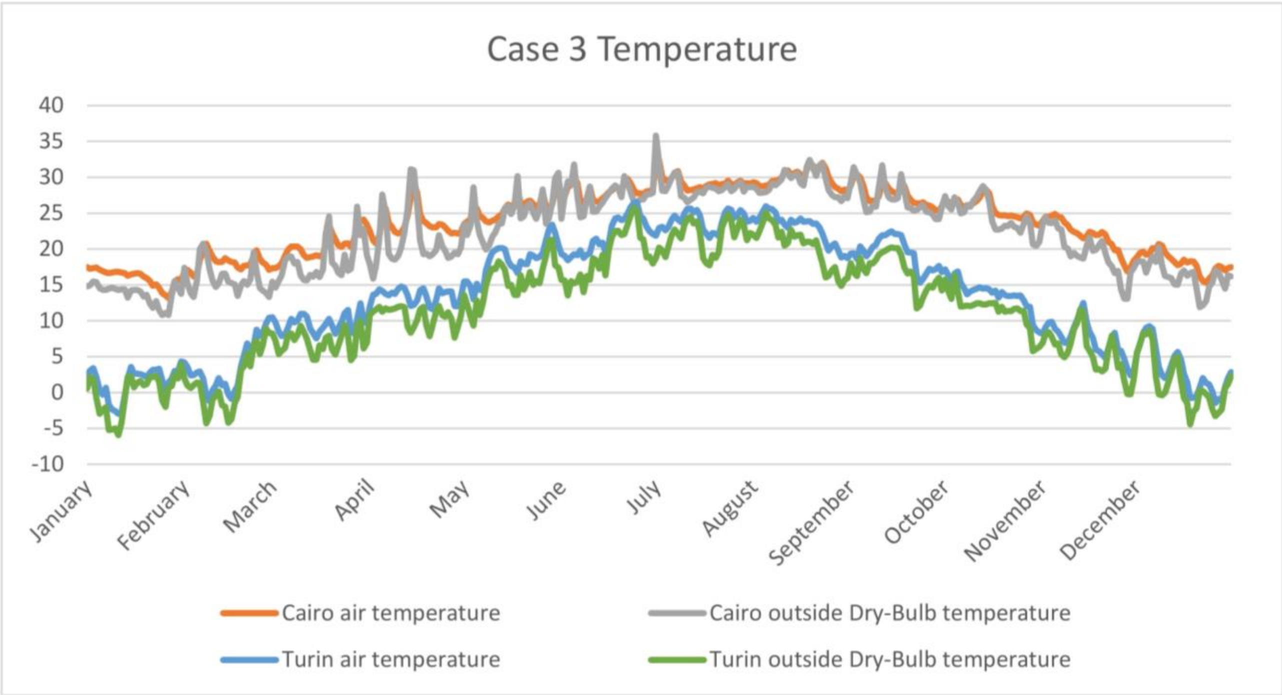
Case 2

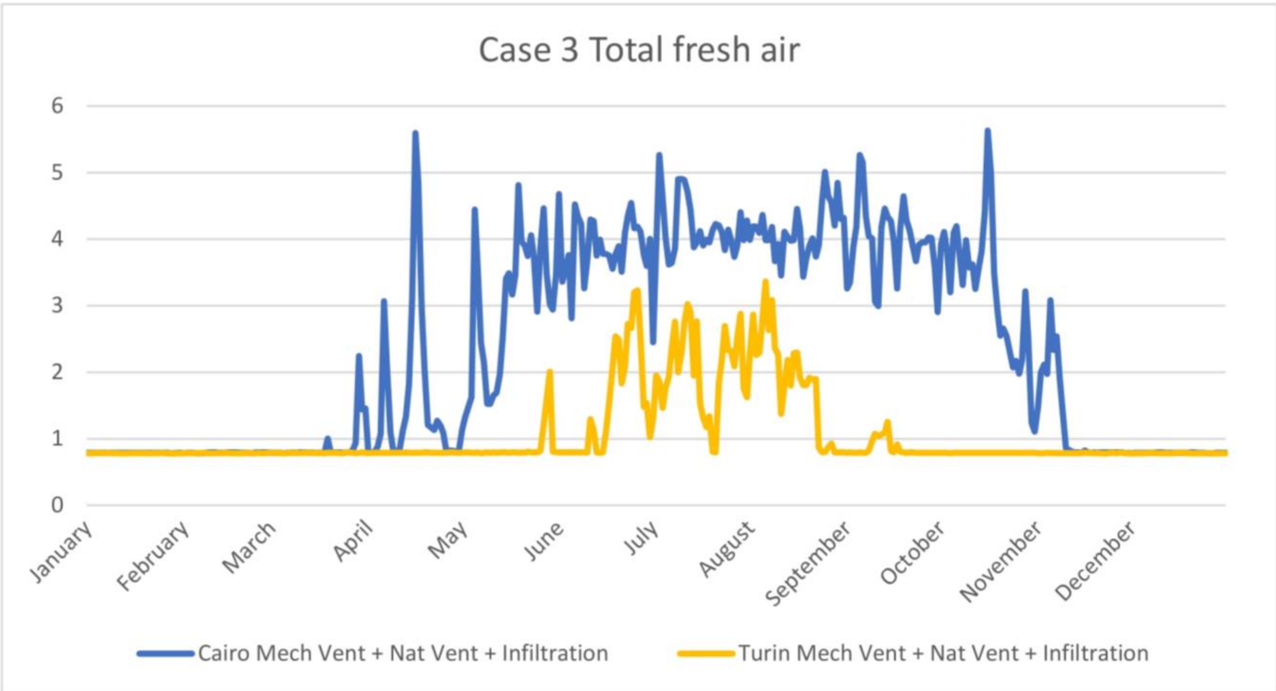




Fig(85): Graph for natural ventilation and temperature inside and outside the building in Cairo and Turin for case study 2

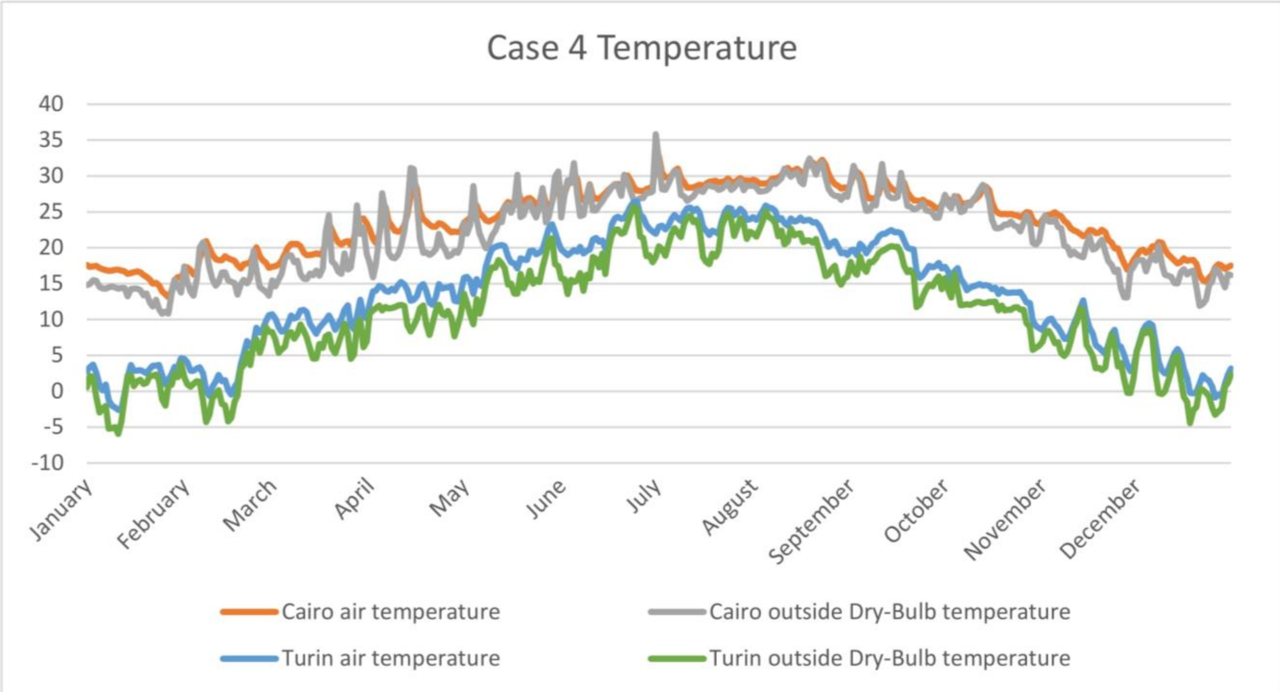
Case 3

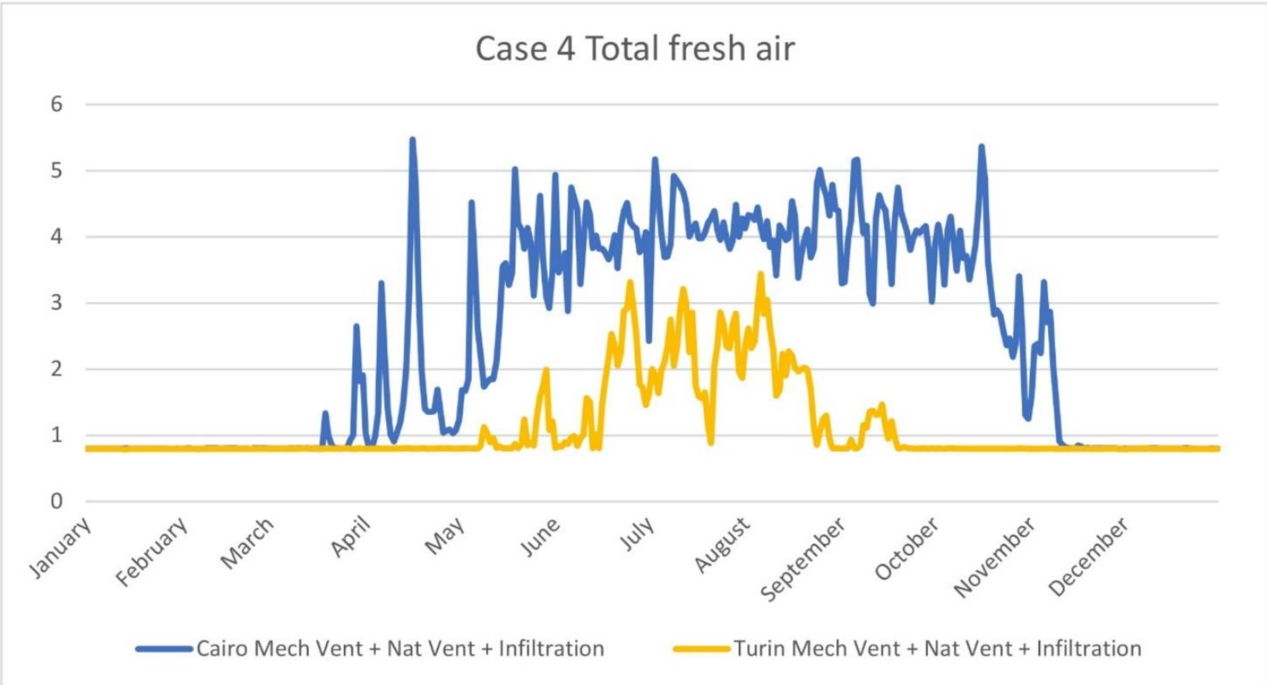




Fig(86): Graph for natural ventilation and temperature inside and outside the building in Cairo and Turin for case study 3

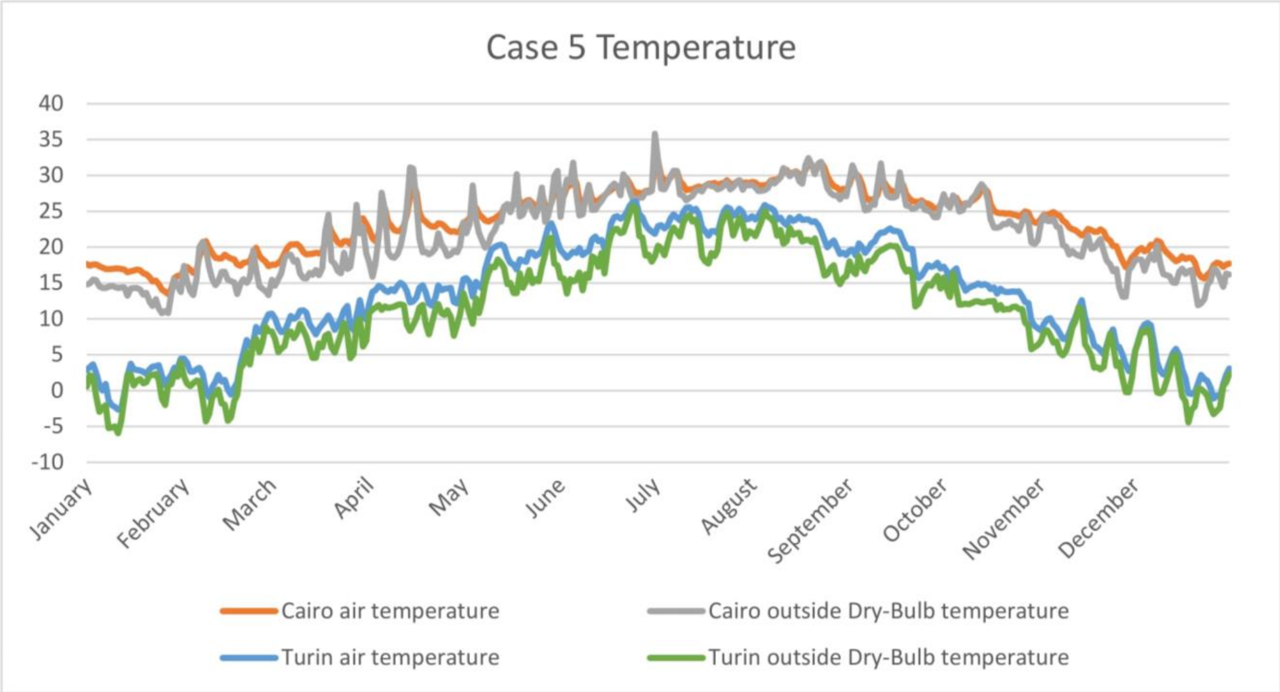
Case 4

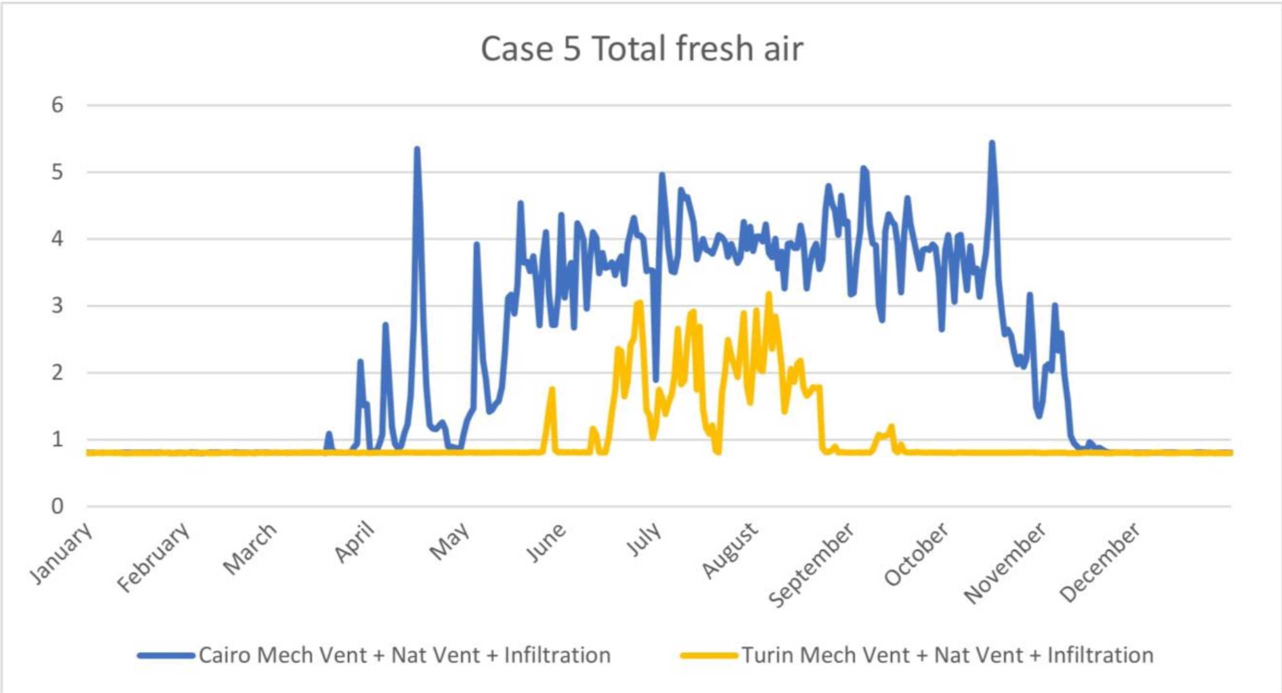




Fig(87): Graph for natural ventilation and temperature inside and outside the building in Cairo and Turin for case study 4

Case 5





Fig(88): Graph for natural ventilation and temperature inside and outside the building in Cairo and Turin for case study 1

In general, in all the five cases, the total amount of fresh air in Cairo is 0.9 from December to April and it increase in the summer due to the high temperature and the increase of opening the window for fresh air, in Cairo the results comply with the Egyptian regulations. In Turin the average fresh air rate is 0.9 from October until June which exceeds the Italian regulations which means that the windows need to be less used.

Proposals

Cairo proposal

The first proposal is in Cairo, the aim of this proposal is to provide more daylight quality through changing the glazing type and adding shading devices, the glazing that is used in the real case study SHGC 0.15 and T_{VIS} 0.27 which result ASE 14.1%, SDA 25.6% and blinds closed 13.2% of the time which doesn't meet the LEED V4.1 requirements, so by changing the glazing material to SHGC 0.27 and T_{VIS} 0.68 which is nearly the double the original case, this will increase the SDA and decrease ASE and blinds closed percentage, by increasing SDA and decreasing ASE it can comply with the LEED V4.1 requirement and by decreasing blinds closed percentage it can decrease the glare and provide more view to the pyramids view which will help the main selling concept of the company. There are horizontal shading devices added to the windows exposed to the east direction and horizontal and vertical shading devices added to the windows exposed to the south and west elevations, the aim of adding the shading device is to decrease the glare and increase the view to the outside view the pyramid's view which is the main selling concept of the company.

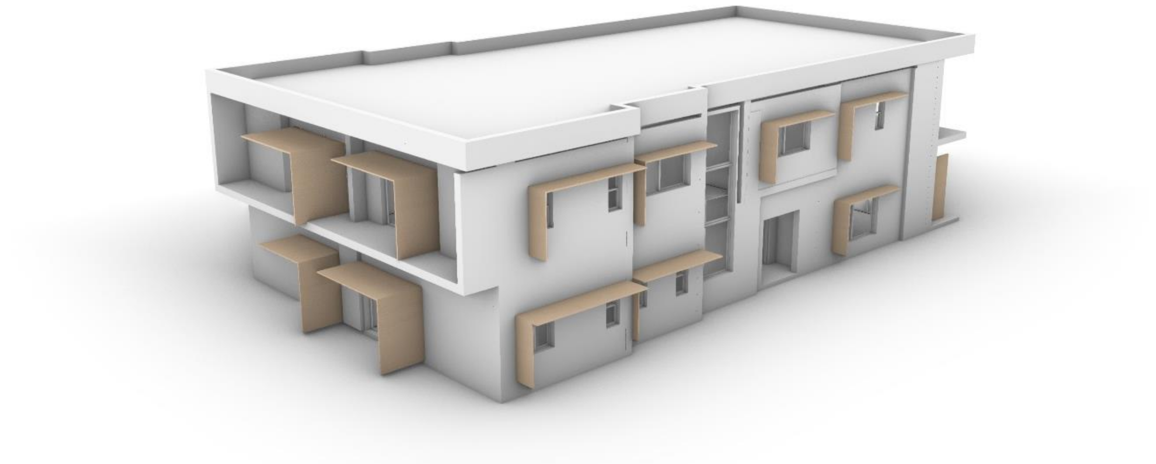


Fig (89): Case study proposal in Cairo with vertical and horizontal shading device south west view

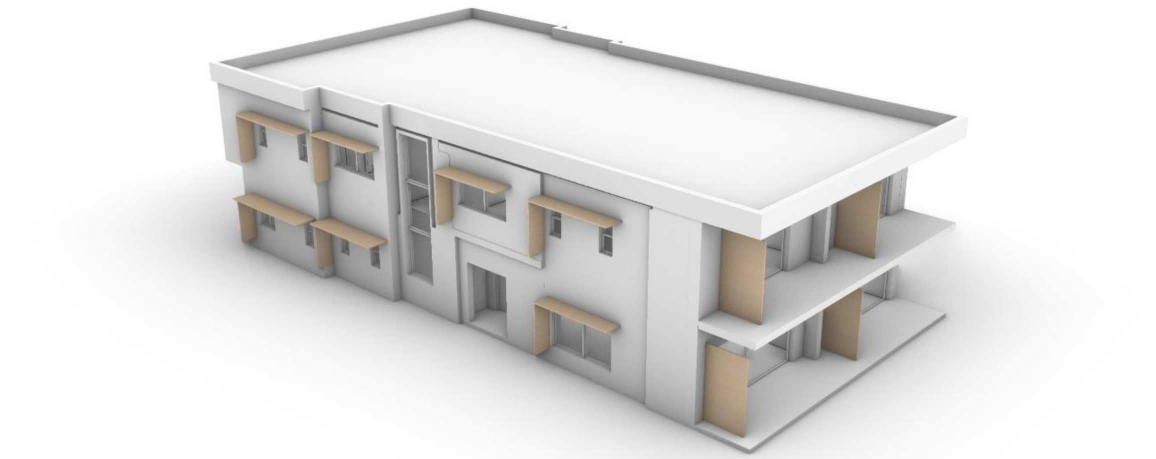


Fig (90): Case study proposal in Cairo with vertical and horizontal shading device south east view

Shaded glass ratio SGR

	Floor area	WWR	Direction	SHGC	SHGC required	comply with requirements	SGR	SGR required	comply with requirements
Twin house (Unit A)									
Ground floor									
Bedroom	9.3	9%	W	0.17	0.55	✓	98%	60%	✓
Living room	54	38%	N,NE	0.17	0.67	✓	97%	80%	✓
Kitchen	14.4	67%	W	0.17	0.27	✓	53%	90%	
First floor									
Bedroom 1	15.5	55%	W	0.17	0.27	✓	62%	90%	
Bedroom 2	17.3	32%	W,NW	0.17	0.3	✓	98%	90%	✓
Living room	22.3	26%	N	0.17	0.71	✓	93%	40%	✓
Bedroom 3	22	30%	NE	0.17	0.45	✓	100%	70%	✓
Twin house (Unit B)									
Ground floor									
Bedroom	9.3	9%	SW	0.17	0.55	✓	66%	60%	✓
Living room	54	38%	E,SE	0.17	0.27	✓	68%	90%	
Kitchen	14.4	67%	SW	0.17	0.27	✓	53%	90%	
First floor									
Bedroom 1	15.5	55%	SW	0.17	0.27	✓	61%	90%	
Bedroom 2	17.3	32%	S,SW	0.17	0.27	✓	63%	80%	
Living room	22.3	26%	SE	0.17	0.35	✓	62%	80%	
Bedroom 3	22	30%	E,SE	0.17	0.27	✓	66%	80%	

Fig (91): Shaded glass ratio in the original case in Cairo

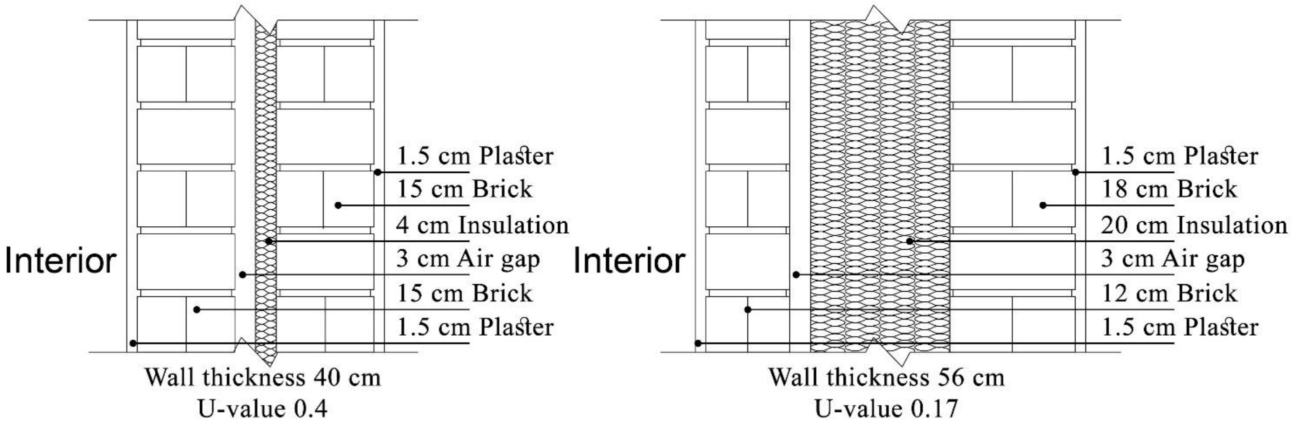
	Floor area	WWR	Direction	SHGC	SHGC required	under requirements	SGR	SGR	SGR required	under requirements
Twin house (Unit A)										
Ground floor										
Bedroom	9.3	9%	W	0.17	0.55	✓	100%	98%	60%	✓
Living room	54	38%	N,NE	0.17	0.67	✓	100%	97%	80%	✓
Kitchen	14.4	67%	W	0.17	0.27	✓	100%	76%	90%	✓
First floor										
Bedroom 1	15.5	55%	W	0.17	0.27	✓	100%	80%	90%	
Bedroom 2	17.3	32%	W,NW	0.17	0.3	✓	100%	98%	90%	✓
Living room	22.3	26%	N	0.17	0.71	✓	100%	93%	40%	✓
Bedroom 3	22	30%	NE	0.17	0.45	✓	100%	100%	70%	✓
Twin house (Unit B)										
Ground floor										
Bedroom	9.3	9%	SW	0.17	0.55	✓	100%	100%	60%	✓
Living room	54	38%	E,SE	0.17	0.27	✓	100%	100%	90%	✓
Kitchen	14.4	67%	SW	0.17	0.27	✓	100%	76%	90%	
First floor										
Bedroom 1	15.5	55%	SW	0.17	0.27	✓	100%	76%	90%	
Bedroom 2	17.3	32%	S,SW	0.17	0.27	✓	89%	99%	80%	✓
Living room	22.3	26%	SE	0.17	0.35	✓	90%	99%	80%	✓
Bedroom 3	22	30%	E,SE	0.17	0.27	✓	98%	100%	80%	✓

Fig (92): Shaded glass ratio in the proposed case in Cairo

The addition of the shading device increased the shaded glass ratio which is the percentage between the shaded part to the window area, to meet the Egyptian codes in section 3 page 19-20 in all the spaces except the spaces with high window to wall ratio as the kitchen in both units in the ground floor and bedroom 1 in the first floor in both units, the WWR in the kitchen is 67% and in bedroom 1 55% facing west and south west.

Turin proposal

In order to increase the building efficiency and increase the daylight quality in Turin, the glazing type changes from selective glass with SHGC 0.31 and T_{VIS} 0.604 to low emissive glass SHGC 0.678 and T_{VIS} 0.804, the wall thickness also increased from 40 cm to 56 cm as shown in fig(93) mainly through increasing the insulation layer, to decrease the U-value to comply with the new Italian regulations.



Fig(93): Wall used in Turin layers, thickness and U-value

The simulation from fig(94) to fig(96) show the SDA, ASE, DF and blinds closed, the simulation run through Climate Studio with different types of glass in different locations Cairo and Turin. Cairo 1 is the original case study as the actual case built in Cairo, Turin 1 is run using selective type of glass and wall thickness of 40 cm, Cairo 2 is the proposed case in Cairo with different glazing type and the addition of shading devices vertical on the east exposed windows and horizontal and vertical shading devices on the west and south exposed windows, Turin 2 is run through using low emissive glass type and 56 cm wall thickness. The simulation run only in case study 1 to show the main idea.

	SHGC	T_{VIS}	U-value	Wall thickness
Cairo 1	0.15	0.27	2.66	25 cm
Turin 1	0.31	0.604	1.36	40 cm
Cairo 2	0.277	0.68	1.62	25 cm
Turin 2	0.678	0.804	1.45	56 cm

Table (14): The results of daylight availability for the two proposals in Cairo and Turin

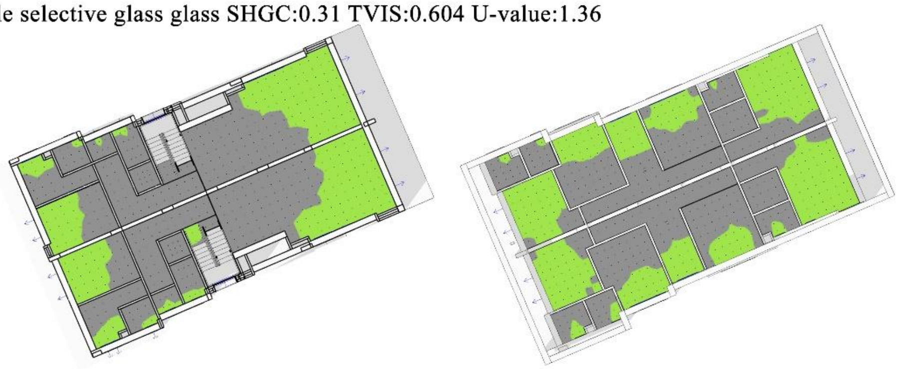
Case study 1 1:300 Ground Floor plan First Floor plan

Location: Cairo Glass type: Glass 6.4 mm Stainless Steel Cover 30% Double SHGC:0.15 TVIS:0.27 U-value:2.66

sDA: 25.6%

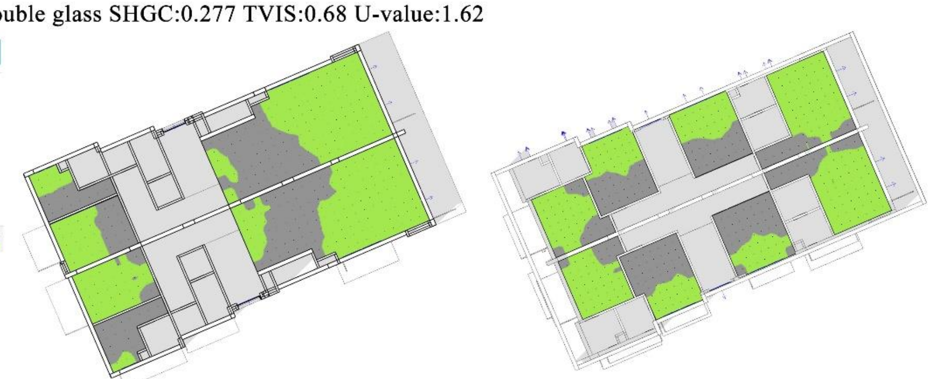
Location: Turin Glass type: Double selective glass glass SHGC:0.31 TVIS:0.604 U-value:1.36

sDA: 42.4%



Location: Cairo Glass type: Double glass SHGC:0.277 TVIS:0.68 U-value:1.62

sDA: 62.0%



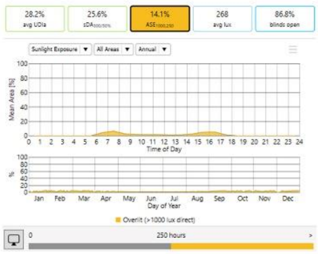
Location: Turin Glass type: Double low emissive glass SHGC:0.678 TVIS:0.804 U-value:1.45

sDA: 65.3%

Fig(94): The simulation for SDA in case study 1 for the four cases the original case in Cairo, Turin case and two proposals for Cairo and Turin

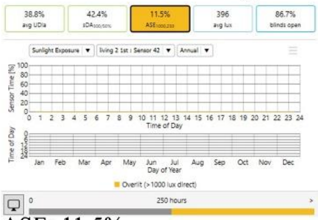
Case study 1 1:300 Ground Floor plan First Floor plan

Location: Cairo Glass type: Glass 6.4 mm Stainless Steel Cover 30% Double SHGC:0.15 TVIS:0.27 U-value:2.66

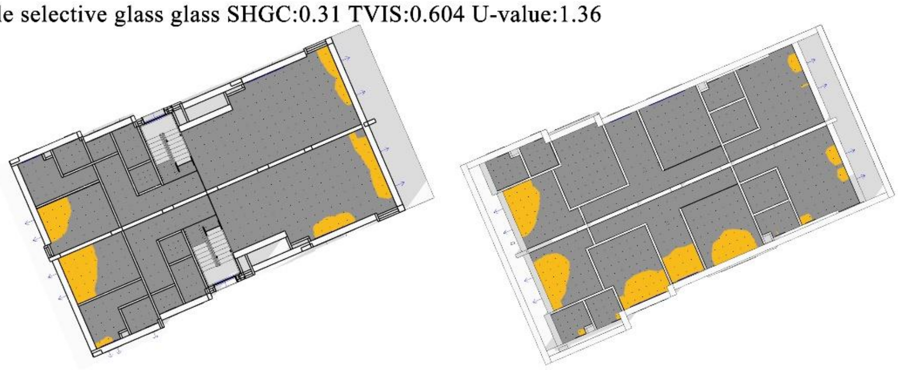


ASE: 14.1%
Blinds closed: 13.2%

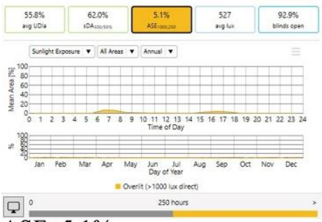
Location: Turin Glass type: Double selective glass glass SHGC:0.31 TVIS:0.604 U-value:1.36



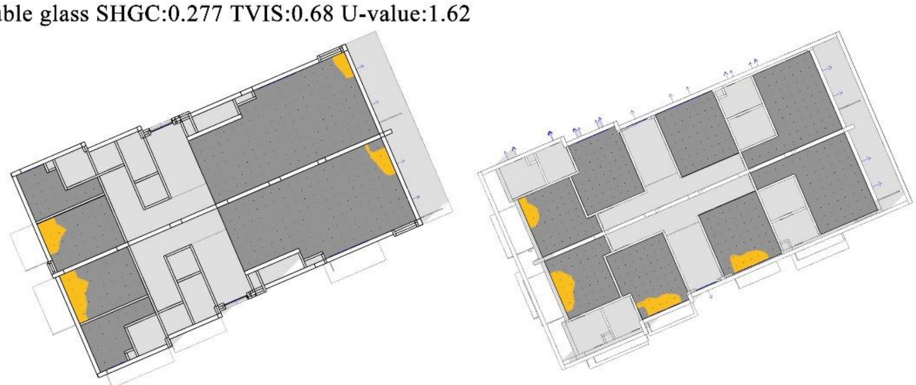
ASE: 11.5%
Blinds closed: 13.3%



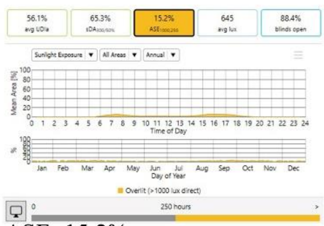
Location: Cairo Glass type: Double glass SHGC:0.277 TVIS:0.68 U-value:1.62



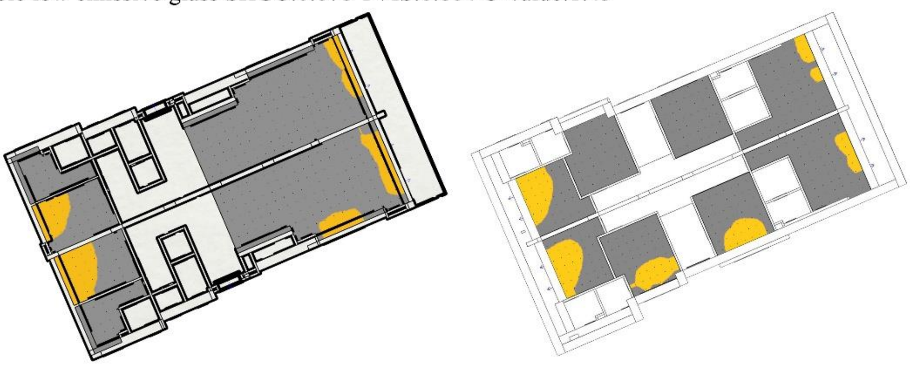
ASE: 5.1%
Blinds closed: 7.1%



Location: Turin Glass type: Double low emissive glass SHGC:0.678 TVIS:0.804 U-value:1.45



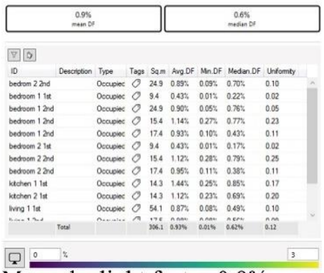
ASE: 15.2%
Blinds closed: 11.6%



Fig(95): The simulation for ASE and blinds closed in case study 1 for the four cases the original case in Cairo, Turin case and two proposals for Cairo and Turin

Case study 1 1:300 Ground Floor plan First Floor plan

Location: Cairo Glass type: Glass 6.4 mm Stainless Steel Cover 30% Double SHGC:0.15 TVIS:0.27 U-value:2.66

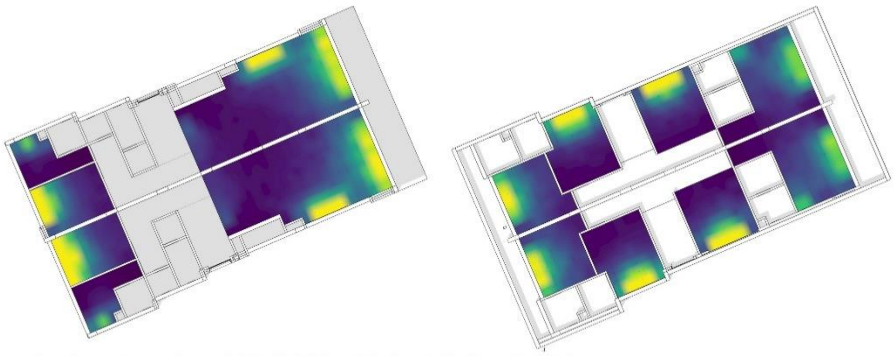


0.9% mean DF | 0.6% median DF

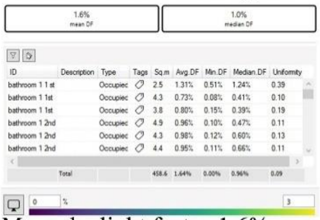
ID	Description	Type	Tags	Sq.m	Avg.DF	Min.DF	Median.DF	Uniformity
bedrom 2 2nd		Occupiec		24.9	0.89%	0.09%	0.70%	0.10
bedroom 1 1st		Occupiec		9.4	0.43%	0.01%	0.22%	0.02
bedroom 1 2nd		Occupiec		24.9	0.90%	0.05%	0.76%	0.05
bedroom 1 2nd		Occupiec		15.4	1.14%	0.27%	0.77%	0.23
bedroom 1 2nd		Occupiec		17.4	0.93%	0.10%	0.43%	0.11
bedroom 2 1st		Occupiec		9.4	0.43%	0.01%	0.17%	0.02
bedroom 2 2nd		Occupiec		15.4	1.12%	0.28%	0.79%	0.25
bedroom 2 2nd		Occupiec		17.4	0.95%	0.11%	0.38%	0.11
kitchen 1 1st		Occupiec		14.3	1.44%	0.25%	0.85%	0.17
kitchen 2 1st		Occupiec		14.3	1.12%	0.23%	0.69%	0.20
living 1 1st		Occupiec		54.1	0.87%	0.08%	0.49%	0.10
	Total			306.1	0.93%	0.01%	0.62%	0.12

0 % 3

Mean daylight factor:0.9%
Median daylight factor:0.6%



Location: Turin Glass type: Double selective glass glass SHGC:0.31 TVIS:0.604 U-value:1.36

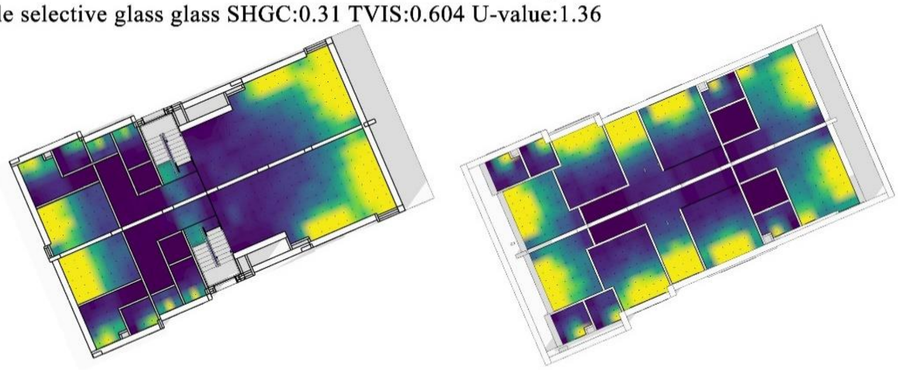


1.6% mean DF | 1.0% median DF

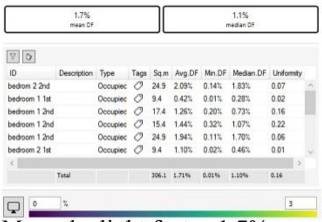
ID	Description	Type	Tags	Sq.m	Avg.DF	Min.DF	Median.DF	Uniformity
bathroom 1 1 st		Occupiec		2.5	1.31%	0.51%	1.24%	0.39
bathroom 1 1st		Occupiec		4.3	0.73%	0.08%	0.41%	0.10
bathroom 1 1st		Occupiec		3.8	0.80%	0.15%	0.39%	0.19
bathroom 1 2nd		Occupiec		4.9	0.96%	0.10%	0.47%	0.11
bathroom 1 2nd		Occupiec		4.3	0.98%	0.12%	0.60%	0.13
bathroom 1 2nd		Occupiec		4.4	0.95%	0.11%	0.66%	0.11
	Total			458.6	1.64%	0.00%	0.96%	0.09

0 % 3

Mean daylight factor:1.6%
Median daylight factor:1.0%



Location: Cairo Glass type: Double glass SHGC:0.277 TVIS:0.68 U-value:1.62

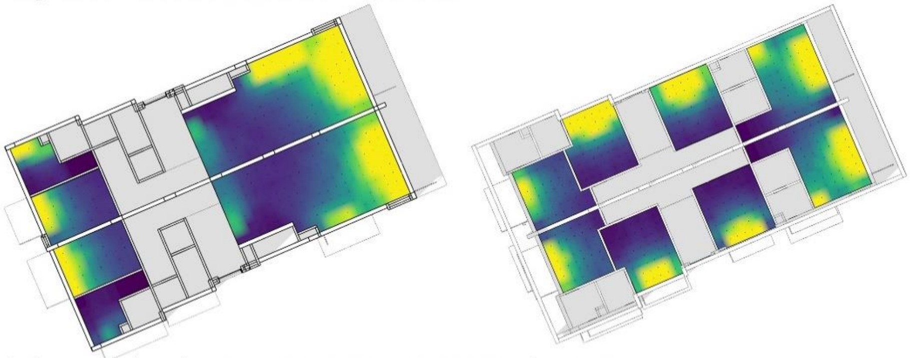


1.7% mean DF | 1.1% median DF

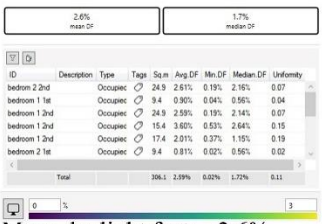
ID	Description	Type	Tags	Sq.m	Avg.DF	Min.DF	Median.DF	Uniformity
bedrom 2 2nd		Occupiec		24.9	2.09%	0.14%	1.83%	0.07
bedroom 1 1st		Occupiec		9.4	0.42%	0.01%	0.28%	0.02
bedroom 1 2nd		Occupiec		17.4	1.26%	0.20%	0.73%	0.16
bedroom 1 2nd		Occupiec		15.4	1.44%	0.32%	1.07%	0.22
bedroom 1 2nd		Occupiec		24.9	1.94%	0.11%	1.70%	0.06
bedroom 2 1st		Occupiec		9.4	1.10%	0.02%	0.46%	0.01
	Total			306.1	1.71%	0.01%	1.10%	0.16

0 % 3

Mean daylight factor:1.7%
Median daylight factor:1.1%



Location: Turin Glass type: Double low emissive glass SHGC:0.678 TVIS:0.804 U-value:1.45

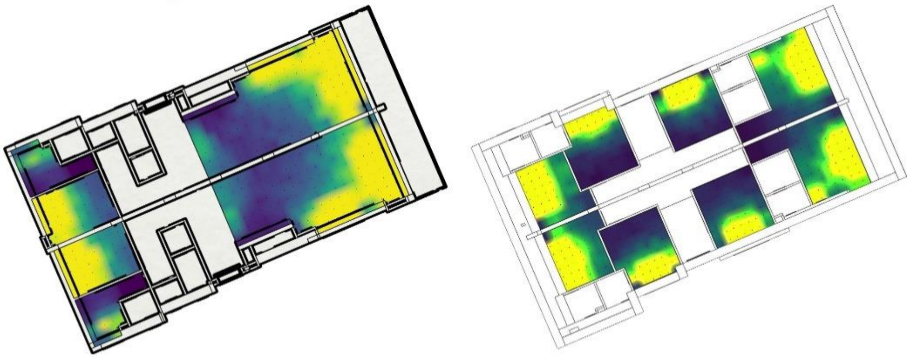


2.6% mean DF | 1.7% median DF

ID	Description	Type	Tags	Sq.m	Avg.DF	Min.DF	Median.DF	Uniformity
bedrom 2 2nd		Occupiec		24.9	2.61%	0.19%	2.16%	0.07
bedroom 1 1st		Occupiec		9.4	0.90%	0.04%	0.56%	0.04
bedroom 1 2nd		Occupiec		24.9	2.59%	0.19%	2.14%	0.07
bedroom 1 2nd		Occupiec		15.4	3.60%	0.53%	2.64%	0.15
bedroom 1 2nd		Occupiec		17.4	2.01%	0.37%	1.15%	0.19
bedroom 2 1st		Occupiec		9.4	0.81%	0.02%	0.56%	0.02
	Total			306.1	2.59%	0.02%	1.72%	0.11

0 % 3

Mean daylight factor:2.6%
Median daylight factor:1.7%



Fig(96): The simulation for daylight factor in case study 1 for the four cases the original case in Cairo, Turin case and two proposals for Cairo and Turin

	SDA	ASE	Blinds closed	DF
Cairo 1	25.6%	14.1%	13.2%	0.9%
Turin 1	42.4%	11.5%	13.3%	1.6%
Cairo 2	62%	5.1%	7.1%	1.7%
Turin 2	65.3%	15.2%	11.6%	2.6%

Table (15): The results of SDA, ASE,DF and blinds closed in the four cases

The above table(15) show the results of the simulation that is run through the two original cases and the two proposed cases, from the comparison it is clear that the addition of the shading devices and the changing of the glazing type changes the daylight quality results in Cairo, SDA percentage nearly doubled from 25.6% to 62%, ASE decreased from 14.1% to 5.1% and the daylight factor increased from 0.9% to 1.7%, the new results comply with LEED V4.1 requirements as the SDA reached 62% and it is required more than 40% for one point and more than 50% for two point and the new result meet the two points, ASE required to be less than 10% in LEED V4.1 requirements and the new result is 5.1%, daylight factor in the new proposal reached 1.7% which is considered as good quality but there is still artificial light that needs to be used, and this doesn't meet the Italian requirements that the daylight factor should not be less than 2%. The blinds usage decreased nearly to half of the time which is better for the increasing of the pyramid view that meet the Selling concept of the company.

In Turin the new proposal using low emissive glass instead of selective glass and increasing the wall thickness from 40 cm to 56 cm, this increased the SDA from 42.4% to 65.3% which comply with two points in LEED V4.1 instead of one point, the ASE increased from 14.1% to 15.2% which is a negative point because according to LEED V4.1 it should be less than 10%, but the new glazing increased the daylight factor from 1.6% to 2.6% which comply with the Italian regulations that the daylight factor should exceed 2%, and the blinds closed less in the new proposal from 13.3% to 11.6%. The increase in the wall thickness reflects on the inner area of the space which can be also a negative point.

Cairo

	Jun-09	Jun-12	Jun-15	Jun-18	Sep-09	Sep-12	Sep-15	Dec-09	Dec-12	Dec-15
				Ground floor						
				Unit A						
Bedroom	179	245	263	267	248	253	139	152	276	150
Bathroom 2	166	213	242	242	248	227	113	156	261	145
Storage	155	220	197	94	114	176	128	33	93	64
Bathroom 2	144	178	198	53	247	217	85	156	237	128
Stairs and corridor	232	301	263	124	154	237	181	42	119	78
living	584	523	383	149	559	438	280	320	413	263
kitchen	284	476	495	1530	260	338	640	176	272	2373
				First floor						
Bathroom 1	116	193	214	239	127	129	100	98	120	89
Bedroom 1	238	405	558	1729	222	311	696	156	274	2993
Bathroom 2	121	197	221	236	147	139	99	104	143	93
Bedroom 2	255	395	393	842	295	294	221	217	295	192
stairs and corridor	245	374	381	342	291	296	189	203	281	178
living room	262	416	433	649	291	295	234	223	289	202
Bathroom 3	121	196	212	247	116	141	107	96	138	90
dressing	0	0	0	0	0	0	0	0	0	0
Bedroom 3	636	491	308	274	499	322	263	292	273	209

	Jun-09	Jun-12	Jun-15	Jun-18	Sep-09	Sep-12	Sep-15	Dec-09	Dec-12	Dec-15
				Ground floor						
				Unit B						
Bedroom	111	166	171	78	165	146	99	87	1739	66
Bathroom 1	118	152	183	74	3488	134	90	70	3225	80
storage	177	262	224	102	116	181	144	36	105	64
Bathroom 2	144	178	198	53	247	217	85	156	237	128
stairs and corridor	224	309	269	130	165	248	196	44	126	84
living room	556	450	326	117	578	605	244	517	1336	187
kitchen	367	607	1618	1019	328	456	800	216	388	4445
				First floor						
Bathroom 1	114	154	97	50	231	124	73	2385	254	63
Bedroom 1	255	456	616	1763	232	373	833	170	351	4573
Bathroom 2	161	172	112	63	2731	157	91	2816	2562	129
Bedroom 2	244	302	217	101	426	275	161	3402	2071	168
stairs and corridor	362	424	256	98	2843	2348	194	2947	4742	236
living room	238	310	230	88	1027	264	169	3859	2708	174
Bathroom 3	123	143	102	39	237	134	72	1668	2739	59
dressing	0	0	0	0	0	0	0	0	0	0
Bedroom 3	645	480	278	134	517	309	251	344	763	204

Fig(97): Table of the average illuminance in Case study 1 in Cairo proposed case

In Cairo the new proposal which is studied in more details in annex B, is closer to meet LEED V4.1 than the original case, Unit A in the ground floor the kitchen at 9 am and living room and kitchen at 3 pm meet the requirements, first floor bedroom 3 at 9 am and bedroom 1 at 3 pm meet the requirements, unit B in the ground floor living room, kitchen at 9 am and kitchen at 3 pm meet the requirements and the first floor bedroom 2, bedroom 3 and living room at 9 am and bedroom 1 at 3 pm meet the requirements.

Turin

	Jun-09	Jun-12	Jun-15	Jun-18	Sep-09	Sep-12	Sep-15	Dec-09	Dec-12	Dec-15
				Ground floor						
				Unit A						
Bedroom	107	150	130	61	77	114	86	19	60	36
Bathroom 2	69	60	78	40	47	76	55	14	42	25
Storage	155	220	197	94	114	176	128	33	93	64
Bathroom 2	62	110	77	44	47	67	51	14	40	22
Stairs and corridor	232	301	263	124	154	237	181	42	119	78
living	324	442	387	186	222	339	270	63	178	114
kitchen	433	593	508	240	305	451	353	83	239	151
				First floor						
Bathroom 1	101	126	138	63	77	108	91	22	55	42
Bedroom 1	436	200	509	242	300	461	364	83	241	151
Bathroom 2	102	134	141	63	72	119	88	21	62	40
Bedroom 2	254	677	305	150	171	271	211	48	134	89
stairs and corridor	265	357	300	145	176	270	213	50	146	96
living room	265	364	305	148	183	275	213	51	142	94
Bathroom 3	109	158	116	54	71	106	97	20	58	38
dressing	0	0	0	0	0	0	0	0	0	0
Bedroom 3	322	423	378	178	214	333	259	60	173	113

	Jun-09	Jun-12	Jun-15	Jun-18	Sep-09	Sep-12	Sep-15	Dec-09	Dec-12	Dec-15
				Ground floor						
				Unit B						
Bedroom	115	164	134	63	74	121	97	21	63	41
Bathroom 1	72	112	92	41	54	74	65	16	44	27
storage	177	262	224	102	116	181	144	36	105	64
Bathroom 2	66	82	91	44	46	75	59	14	38	24
stairs and corridor	224	309	269	130	165	248	196	44	126	84
living room	331	444	393	183	227	347	271	64	178	114
kitchen	559	768	655	323	383	596	456	108	309	199
				First floor						
Bathroom 1	103	149	135	60	77	117	84	20	61	38
Bedroom 1	432	681	519	245	308	464	361	82	239	153
Bathroom 2	101	128	124	55	77	133	93	20	62	37
Bedroom 2	249	383	314	140	175	258	205	47	137	87
stairs and corridor	263	360	304	145	177	277	217	51	144	94
living room	264	367	321	150	186	282	216	49	147	91
Bathroom 3	92	189	126	60	76	113	81	20	50	30
dressing	0	0	0	0	0	0	0	0	0	0
Bedroom 3	325	335	373	177	216	338	253	62	172	112

Fig(98): Table of the average illuminance in Case study 1 in Turin proposed case

The new proposal in Turin using low emissive glass don’t comply with the LEED V4.1 requirements, as the spaces that meet the requirements are kitchen at 9 am and 3 pm and bedroom 1 at 9 am and 3 pm in the two units unit A and Unit B.

Conclusion

The comparative thesis showed the main difference between the two cities from different perspectives, and from analysing the comparison a case study was proposed to increase the efficiency of the building. The thesis was analysing different perspective as following:

1- The comparison between the climate conditions showed differences as Cairo is located 30.13° north and Turin 45.22° north, reflected in the climate conditions the temperature range, wind speed and direction, rain and humidity. Sky cover and solar radiation all those factors reflect on the build environment and the indoor temperature. Simulation on the urban solar radiation and wind distribution run to show the general difference between the two climates cause this can show how the climates reflects on the urban scale.

2- There is another factor that reflects on the built environment that was discussed in the thesis is the building materials. There is a comparison between the building materials in Egypt to understand more about the materials and which material is more sustainable to use from the thermal heat balance perspective, some of those materials were used in the Islamic era in Egypt as limestone and others are suggested by researchers for to use materials that have less negative impact on the environment as compressed earth blocks and rice straw bricks the usage of those materials can be more useful than using the standard red brick wall. Another simulation run through the building walls in Cairo and Turin to show the thermal heat balance resulted from the building material which gives an indication that the double wall with air gap and insulation can be more effective than a single red brick wall.

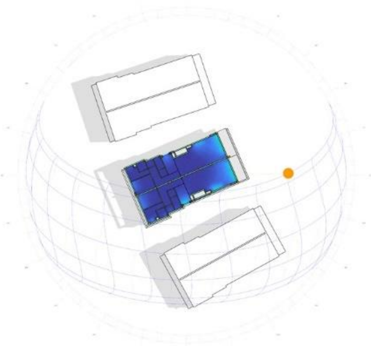
   There is another comparison between the glazing materials proposed in the Egyptian regulation codes, those four glazing types have different SHGC and T_{VIS} which reflected on the UDIA, ASE and SDA the glass that gave the highest daylight availability is G1 with thermal transmittance 0.68 but the one that was used in the real case study was having thermal transmittance equal 0.27 which didn't allow the required daylight factor.

3- Another comparison between the real case results in Cairo and another results in Turin that got from a simulation that run into the same case study but in Turin climate and with the materials that is used in the Italian traditional building on five different buildings with different orientations, the comparison showed that the daylight availability needs to be modified especially when complying the results with Italian, Egyptian and LEED V4.1 regulations. The simulation showed the effect of SHGC and T_{VIS} on the daylight availability as the glass material that is used in Cairo SHGC 0.15 and T_{VIS} 0.27 and in Turin SHGC 0.31 and T_{VIS} 0.604 which is double the properties in Cairo. Which reflected on SDA in Cairo 25.6% and in Turin 42.4%, ASE in Cairo 14.1% and in Turin 11.5% and DF in Cairo 0.9% and in Turin 1.6%.

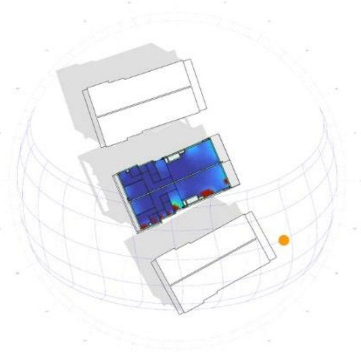
4- The previous comparison between Cairo and Turin showed that if the thermal of the glass in Cairo doubled it can reflect on the daylight availability which leads to the proposed case in Cairo. Through changing the glazing type and adding shading devices to decrease the ASE a proposal in Cairo is simulated to show how those two factors and change the daylight availability and decrease the blinds closed percentage to allow more view to the pyramids. Turin proposal is a modern case with 20 cm wall insulation and low emissive glass instead of selective glass to show how those factors reflect on the daylight availability.

Annex A

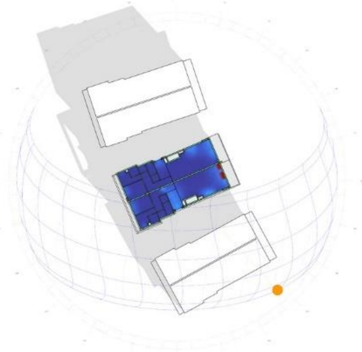
Case study 1 Ground floor 1:1000



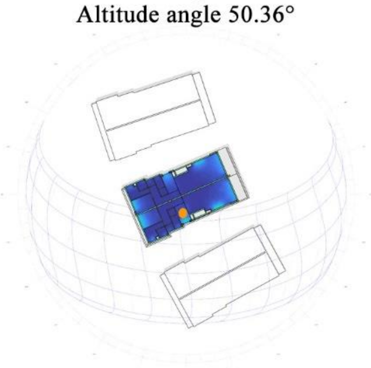
21 June 9:00
Azimuth angle 88.83°
Altitude angle 50.36°



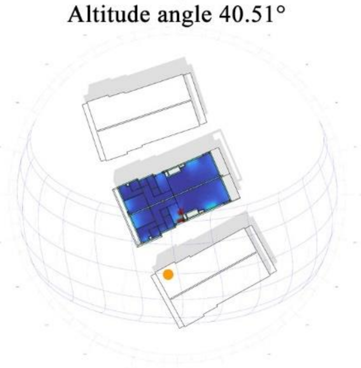
21 September 9:00
Azimuth angle 188.62°
Altitude angle 40.51°



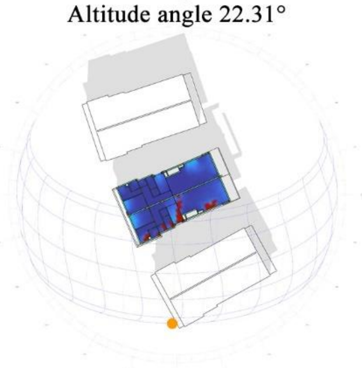
21 December 9:00
Azimuth angle 137.33°
Altitude angle 22.31°



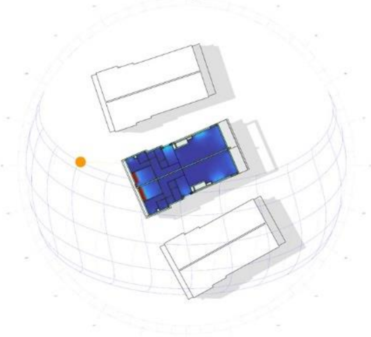
21 June 12:00
Azimuth angle 187.49°
Altitude angle 83.26°



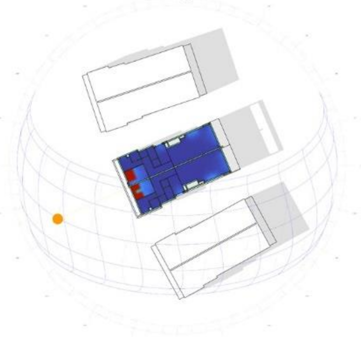
21 September 12:00
Azimuth angle 186.35°
Altitude angle 60.30°



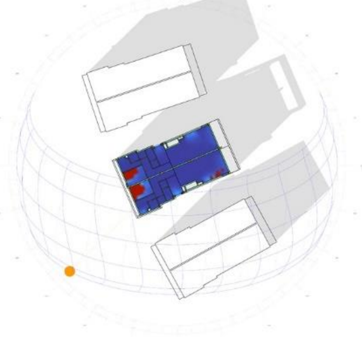
21 December 12:00
Azimuth angle 182.13°
Altitude angle 36.40°



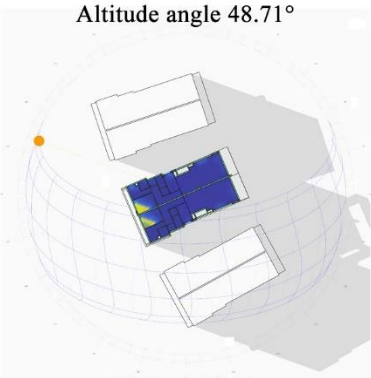
21 June 15:00
Azimuth angle 272.07°
Altitude angle 48.71°



21 September 15:00
Azimuth angle 246.31°
Altitude angle 35.57°



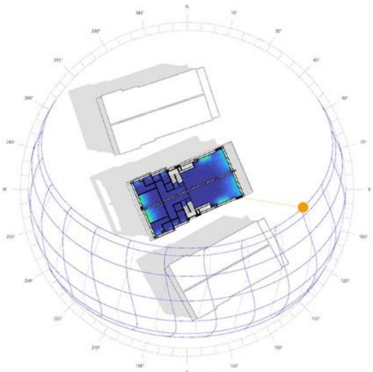
21 December 15:00
Azimuth angle 225.45°
Altitude angle 20.05°



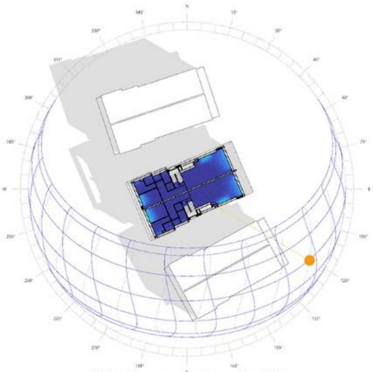
21 June 18:00
Azimuth angle 290.07°
Altitude angle 10.75°

Location: Cairo
Clear sky Ground albedo: 0.2
Glass type: Double glass 6.4 mm Stainless Steel Cover 30%
SHGC:0.15 TVIS:0.27 U-value:2.66

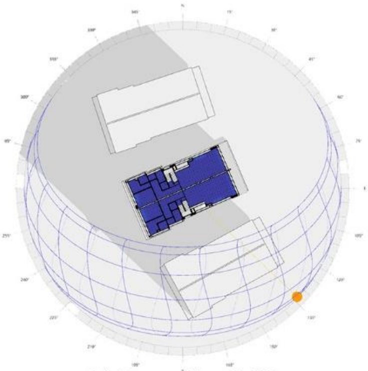
Case study 1 ground floor 1:1000



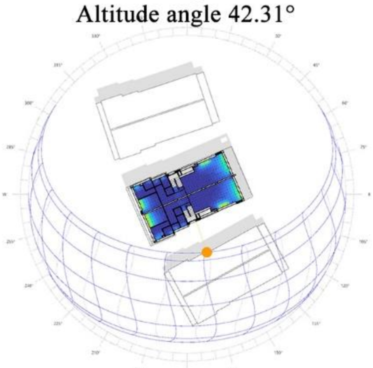
21 June 9:00
Azimuth angle 98.82°
Altitude angle 42.31°



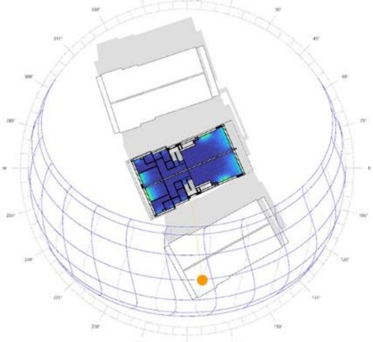
21 September 9:00
Azimuth angle 119.80°
Altitude angle 27.04°



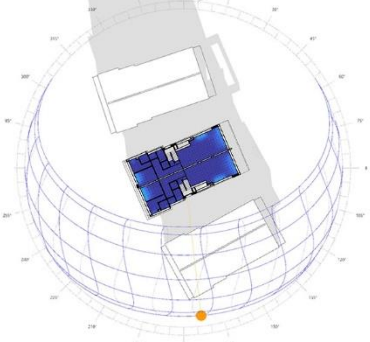
21 December 9:00
Azimuth angle 133.39°
Altitude angle 6.71°



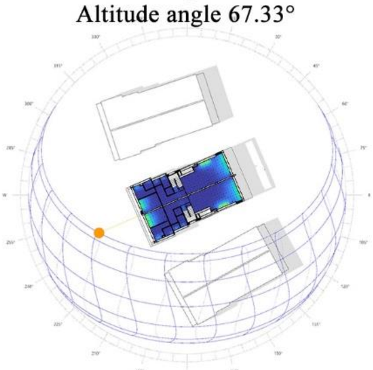
21 June 12:00
Azimuth angle 161.16°
Altitude angle 67.33°



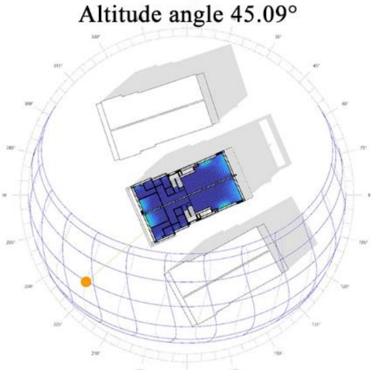
21 September 12:00
Azimuth angle 172.04°
Altitude angle 45.09°



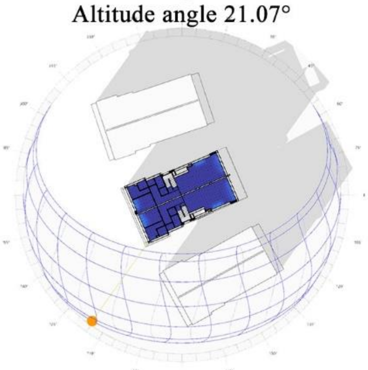
21 December 12:00
Azimuth angle 173.23°
Altitude angle 21.07°



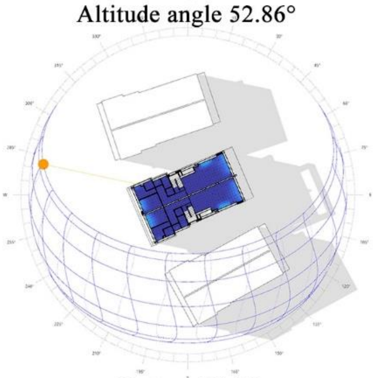
21 June 15:00
Azimuth angle 246.75°
Altitude angle 52.86°



21 September 15:00
Azimuth angle 229.51°
Altitude angle 33.42°



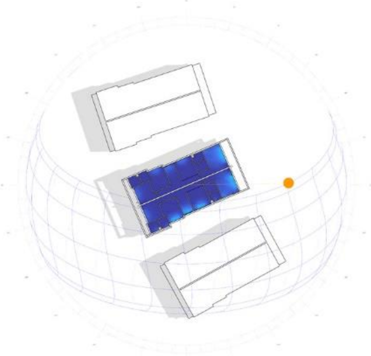
21 December 15:00
Azimuth angle 215.54°
Altitude angle 13.09°



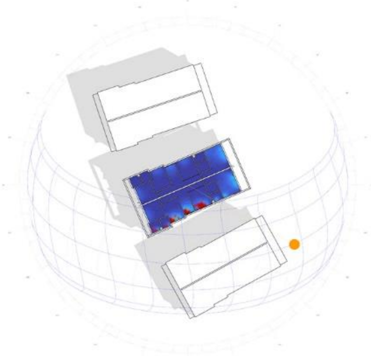
21 June 18:00
Azimuth angle 281.92°
Altitude angle 21.72°

Location: Turin
Overcast sky
Ground albedo: 0.2
Glass type: Double glass
SHGC:0.31 TVIS:0.604 U-value:1.36

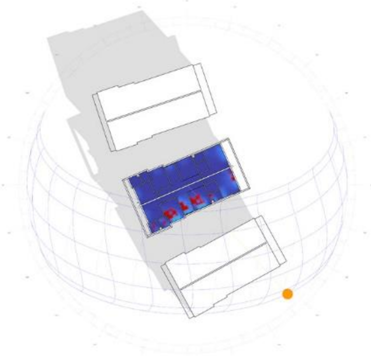
Case study 1 first floor 1:1000



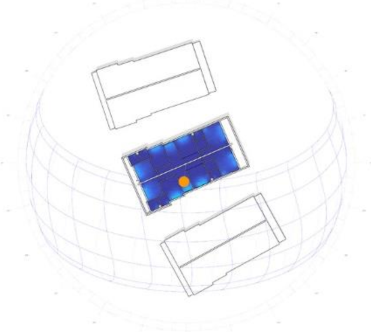
21 June 9:00
Azimuth angle 88.83°
Altitude angle 50.36°



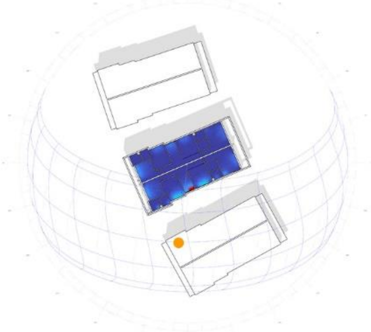
21 September 9:00
Azimuth angle 188.62°
Altitude angle 40.51°



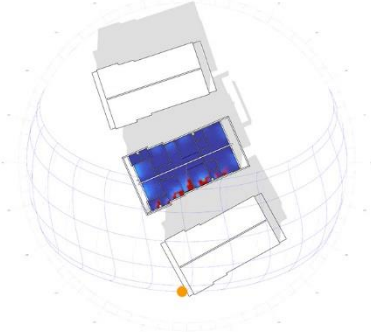
21 December 9:00
Azimuth angle 137.33°
Altitude angle 22.31°



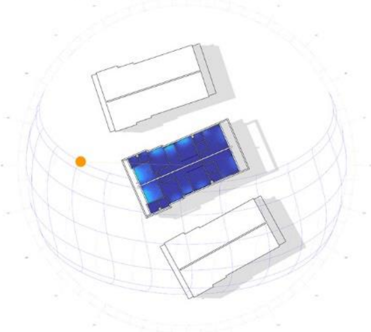
21 June 12:00
Azimuth angle 187.49°
Altitude angle 83.26°



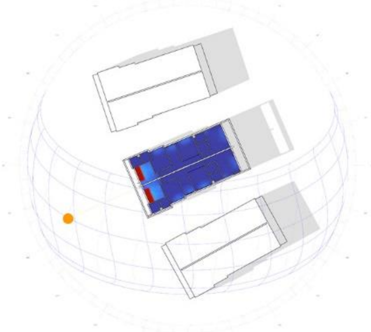
21 September 12:00
Azimuth angle 186.35°
Altitude angle 60.30°



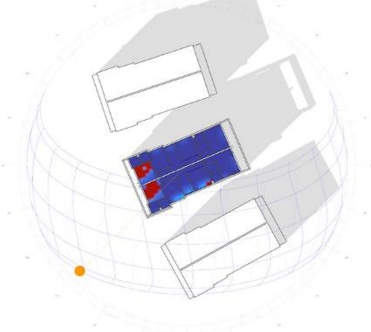
21 December 12:00
Azimuth angle 182.13°
Altitude angle 36.40°



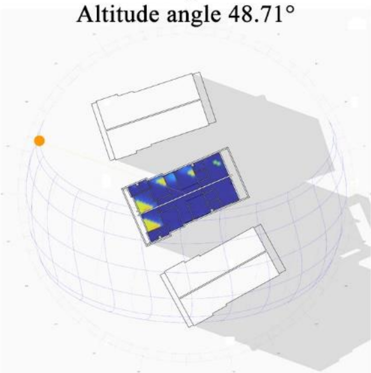
21 June 15:00
Azimuth angle 272.07°
Altitude angle 48.71°



21 September 15:00
Azimuth angle 246.31°
Altitude angle 35.57°

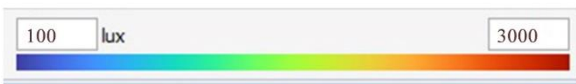


21 December 15:00
Azimuth angle 225.45°
Altitude angle 20.05°

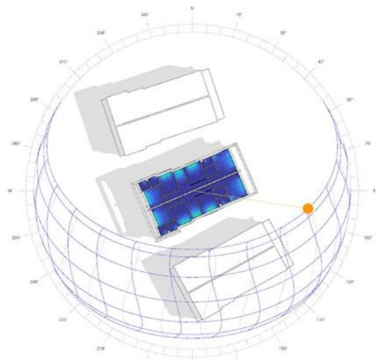


21 June 18:00
Azimuth angle 290.07°
Altitude angle 10.75°

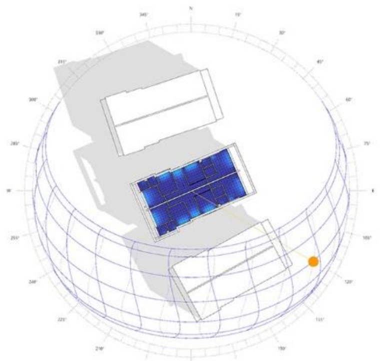
Location: Cairo
Clear sky
Ground albedo: 0.2
Glass type: Double glass 6.4 mm Stainless Steel Cover 30%
SHGC:0.15 TVIS:0.27 U-value:2.66



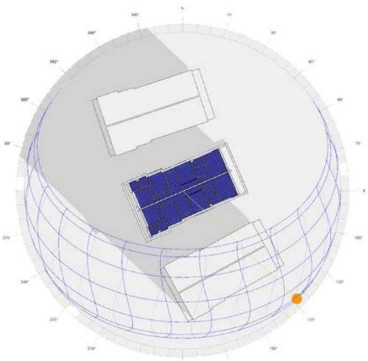
Case study 1 first floor 1:1000



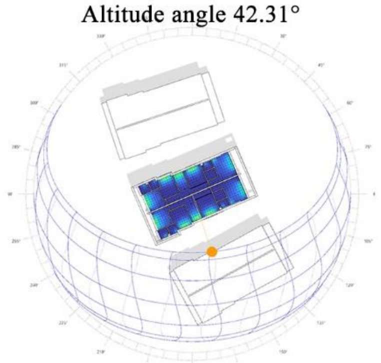
21 June 9:00
Azimuth angle 98.82°
Altitude angle 42.31°



21 September 9:00
Azimuth angle 119.80°
Altitude angle 27.04°



21 December 9:00
Azimuth angle 133.39°
Altitude angle 6.71°



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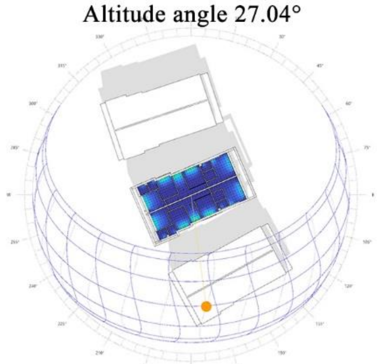
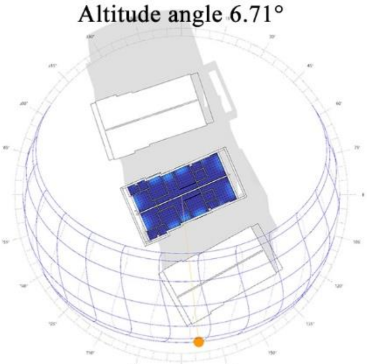
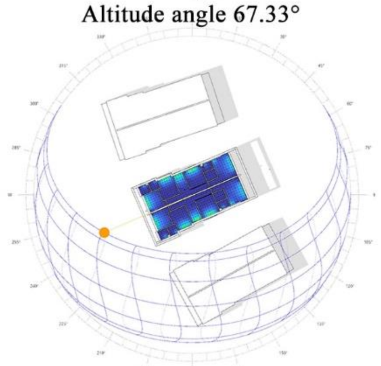
Azimuth angle 161.16°
Altitude angle 67.33°



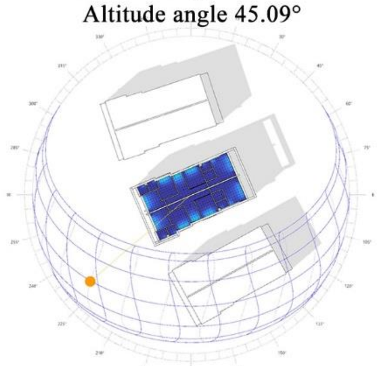
21 September 12:00
Azimuth angle 172.04°
Altitude angle 45.09°



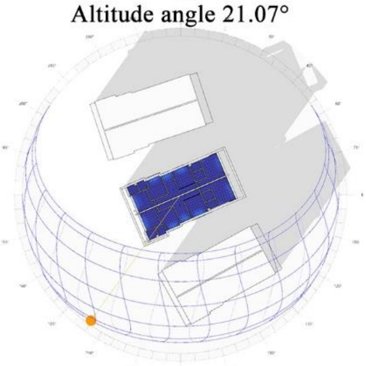
21 December 12:00
Azimuth angle 173.23°
Altitude angle 21.07°



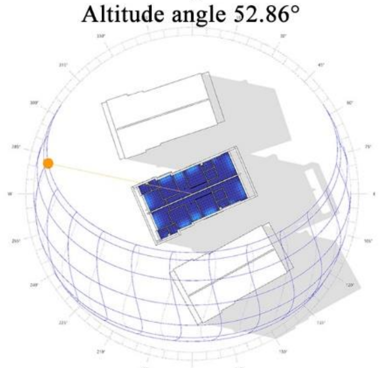
21 June 15:00
Azimuth angle 246.75°
Altitude angle 52.86°



21 September 15:00
Azimuth angle 229.51°
Altitude angle 33.42°

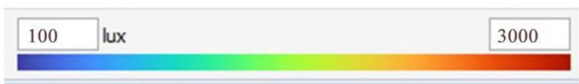


21 December 15:00
Azimuth angle 215.54°
Altitude angle 13.09°

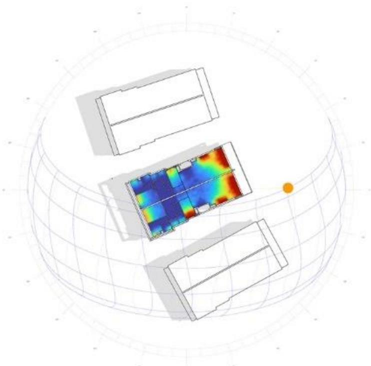


21 June 18:00
Azimuth angle 281.92°
Altitude angle 21.72°

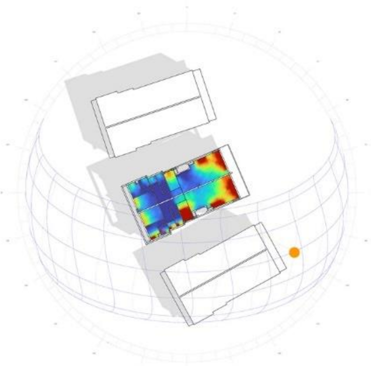
Location: Turin
Overcast sky
Ground albedo: 0.2
Glass type: Double glass
SHGC:0.31 TVIS:0.604 U-value:1.36



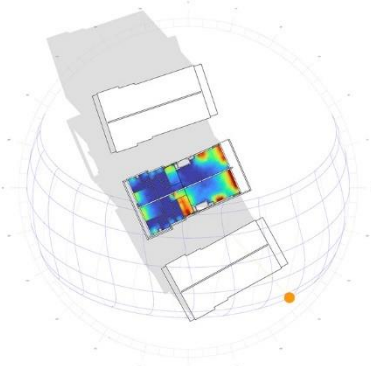
Case study 1 Ground floor 1:1000



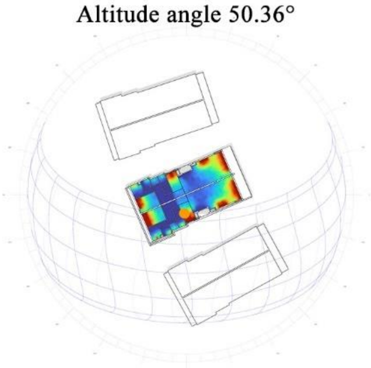
21 June 9:00
Azimuth angle 88.83°
Altitude angle 50.36°



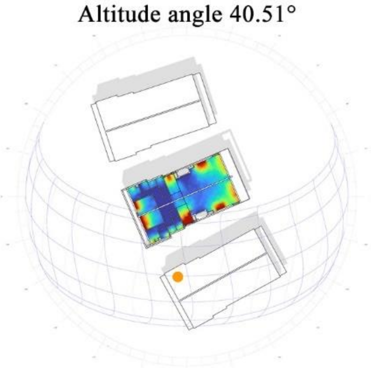
21 September 9:00
Azimuth angle 188.62°
Altitude angle 40.51°



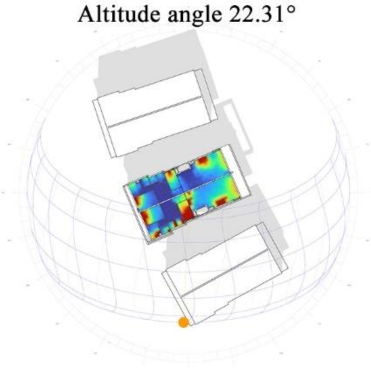
21 December 9:00
Azimuth angle 137.33°
Altitude angle 22.31°



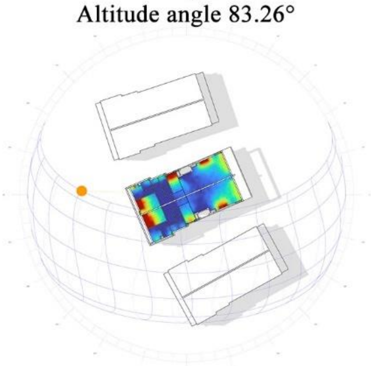
21 June 12:00
Azimuth angle 187.49°
Altitude angle 83.26°



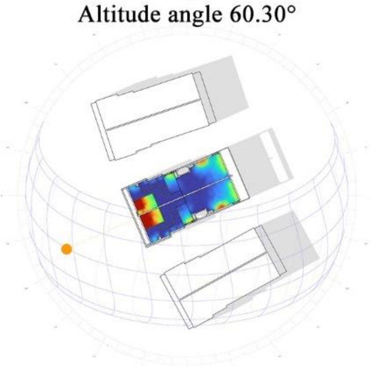
21 September 12:00
Azimuth angle 186.35°
Altitude angle 60.30°



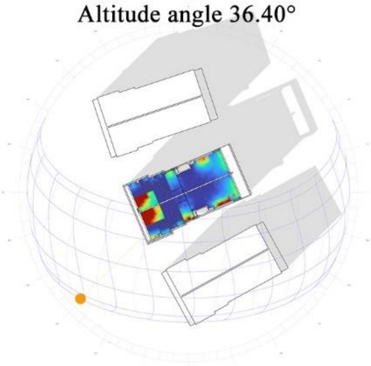
21 December 12:00
Azimuth angle 182.13°
Altitude angle 36.40°



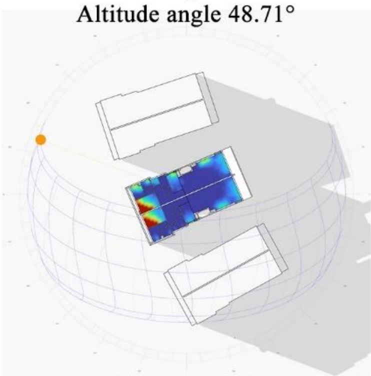
21 June 15:00
Azimuth angle 272.07°
Altitude angle 48.71°



21 September 15:00
Azimuth angle 246.31°
Altitude angle 35.57°

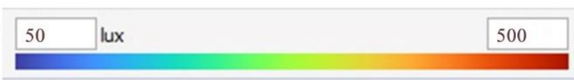


21 December 15:00
Azimuth angle 225.45°
Altitude angle 20.05°

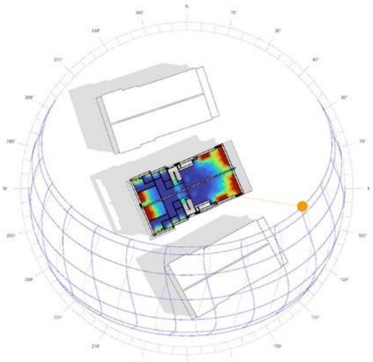


21 June 18:00
Azimuth angle 290.07°
Altitude angle 10.75°

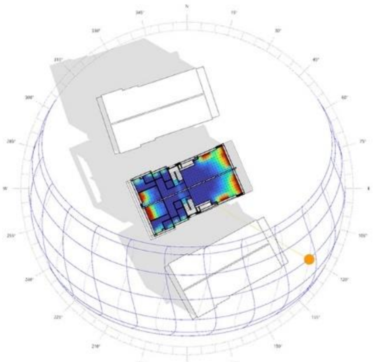
Location: Cairo
Clear sky Ground albedo: 0.2
Glass type: Double glass 6.4 mm Stainless Steel Cover 30%
SHGC:0.15 TVIS:0.27 U-value:2.66



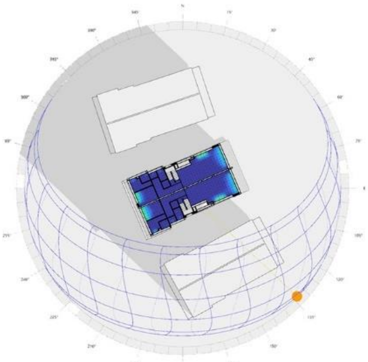
Case study 1 Ground floor 1:1000



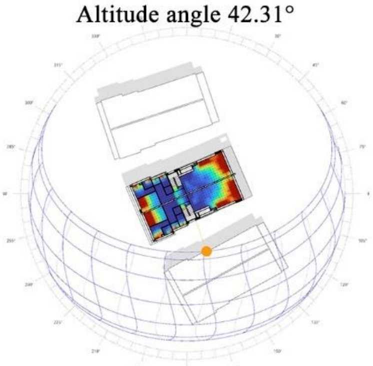
21 June 9:00
Azimuth angle 98.82°
Altitude angle 42.31°



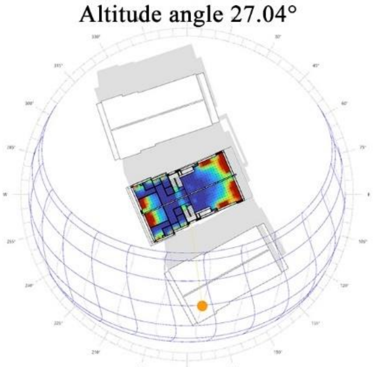
21 September 9:00
Azimuth angle 119.80°
Altitude angle 27.04°



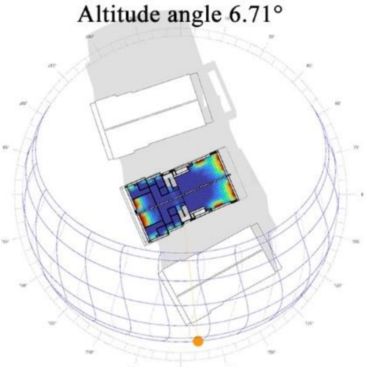
21 December 9:00
Azimuth angle 133.39°
Altitude angle 6.71°



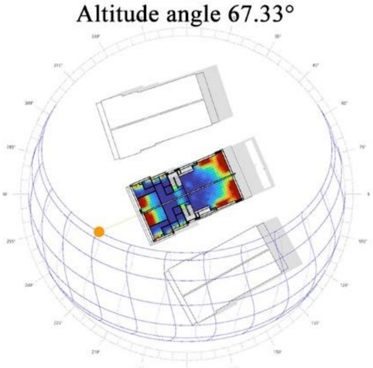
21 June 12:00
Azimuth angle 161.16°
Altitude angle 67.33°



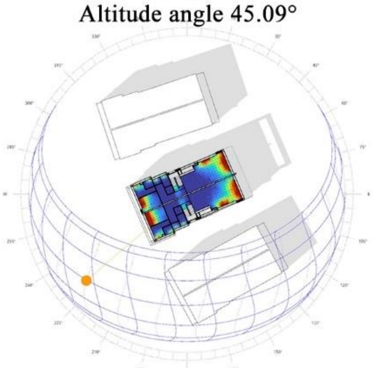
21 September 12:00
Azimuth angle 172.04°
Altitude angle 45.09°



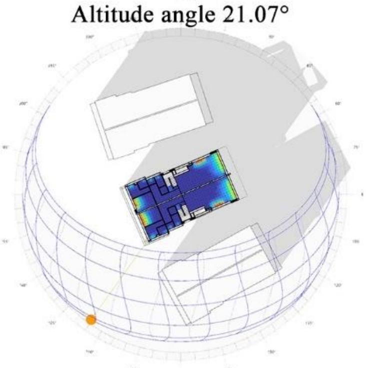
21 December 12:00
Azimuth angle 173.23°
Altitude angle 21.07°



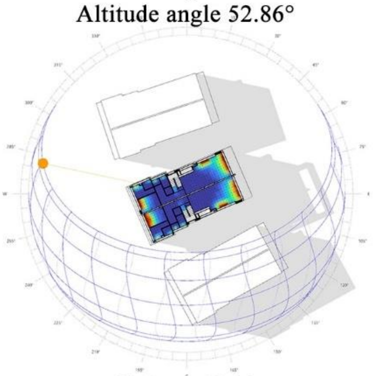
21 June 15:00
Azimuth angle 246.75°
Altitude angle 52.86°



21 September 15:00
Azimuth angle 229.51°
Altitude angle 33.42°

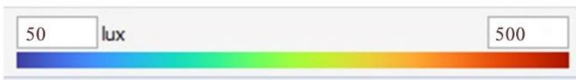


21 December 15:00
Azimuth angle 215.54°
Altitude angle 13.09°

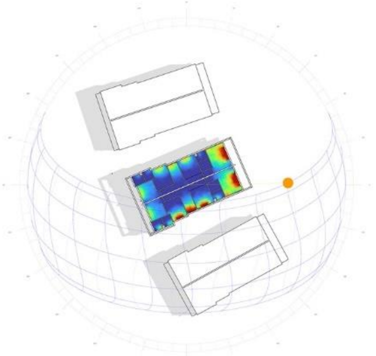


21 June 18:00
Azimuth angle 281.92°
Altitude angle 21.72°

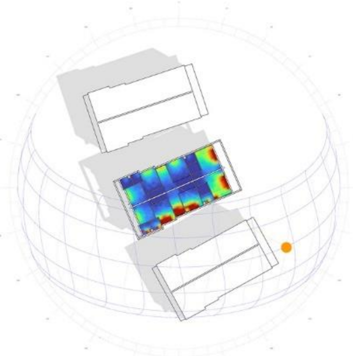
Location: Turin
Overcast sky Ground albedo: 0.2
Glass type: Double glass
SHGC:0.31 TVIS:0.604 U-value:1.36



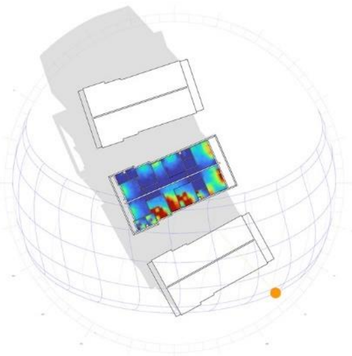
Case study 1 first floor 1:1000



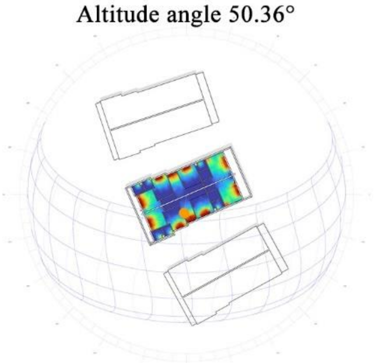
21 June 9:00
Azimuth angle 88.83°
Altitude angle 50.36°



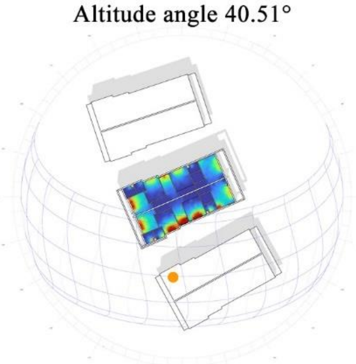
21 September 9:00
Azimuth angle 188.62°
Altitude angle 40.51°



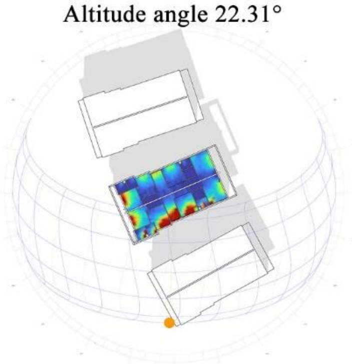
21 December 9:00
Azimuth angle 137.33°
Altitude angle 22.31°



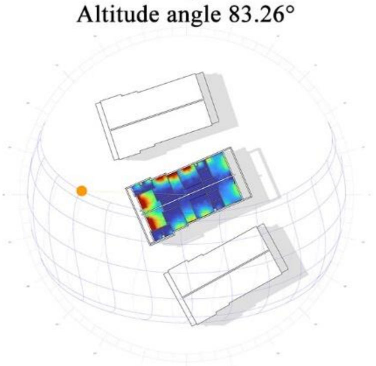
21 June 12:00
Azimuth angle 187.49°
Altitude angle 83.26°



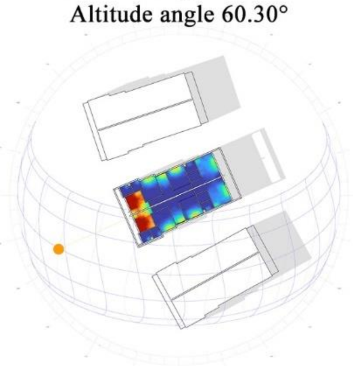
21 September 12:00
Azimuth angle 186.35°
Altitude angle 60.30°



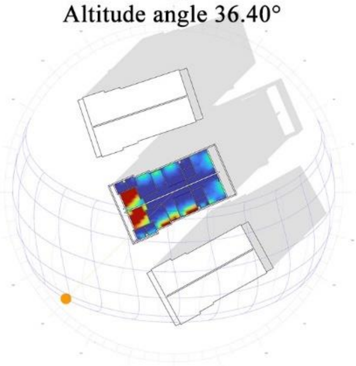
21 December 12:00
Azimuth angle 182.13°
Altitude angle 36.40°



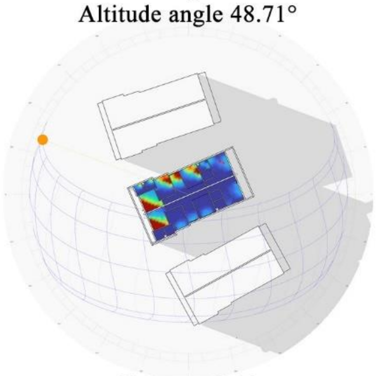
21 June 15:00
Azimuth angle 272.07°
Altitude angle 48.71°



21 September 15:00
Azimuth angle 246.31°
Altitude angle 35.57°

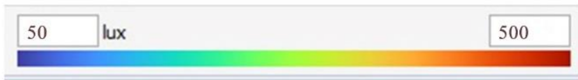


21 December 15:00
Azimuth angle 225.45°
Altitude angle 20.05°

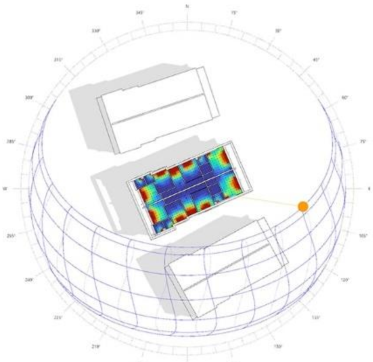


21 June 18:00
Azimuth angle 290.07°
Altitude angle 10.75°

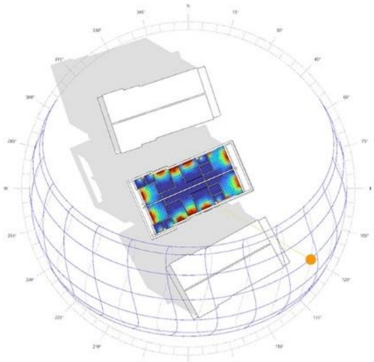
Location: Cairo
Clear sky Ground albedo: 0.2
Glass type: Double glass 6.4 mm Stainless Steel Cover 30%
SHGC:0.15 TVIS:0.27 U-value:2.66



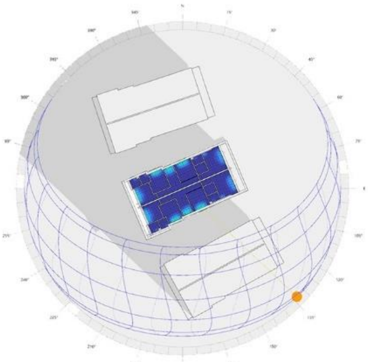
Case study 1 first floor 1:1000



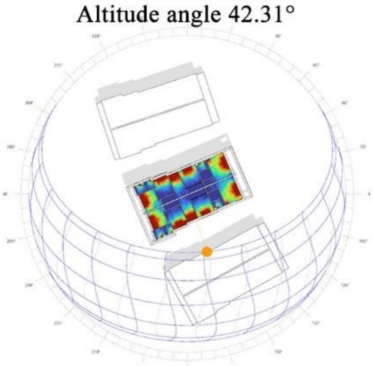
21 June 9:00
Azimuth angle 98.82°
Altitude angle 42.31°



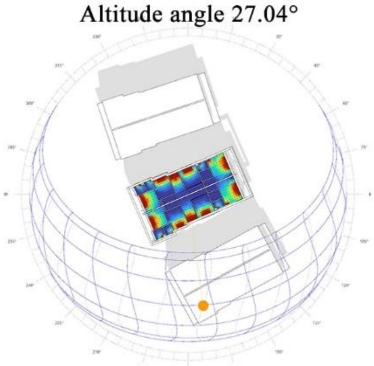
21 September 9:00
Azimuth angle 119.80°
Altitude angle 27.04°



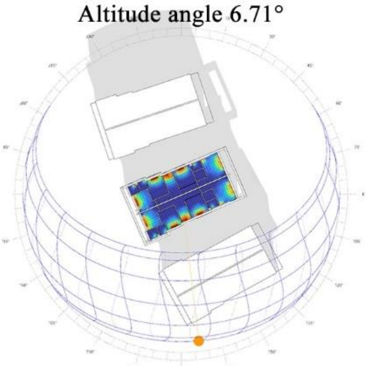
21 December 9:00
Azimuth angle 133.39°
Altitude angle 6.71°



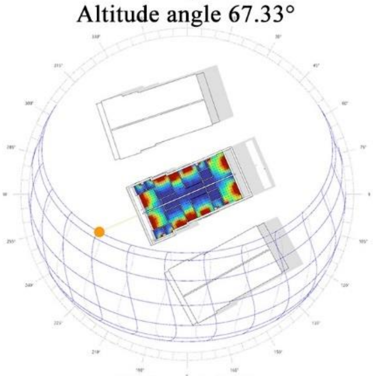
21 June 12:00
Azimuth angle 161.16°
Altitude angle 67.33°



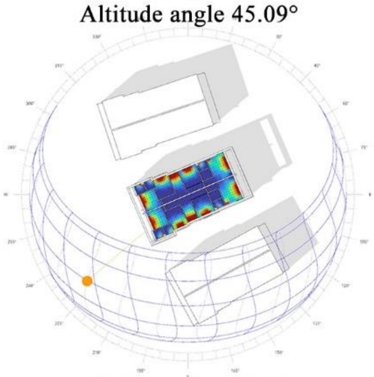
21 September 12:00
Azimuth angle 172.04°
Altitude angle 45.09°



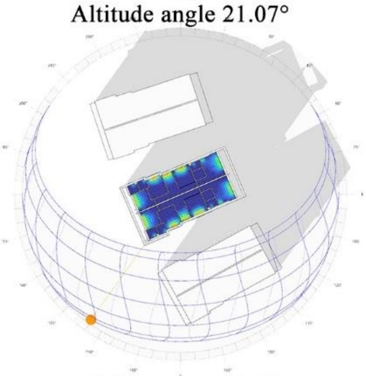
21 December 12:00
Azimuth angle 173.23°
Altitude angle 21.07°



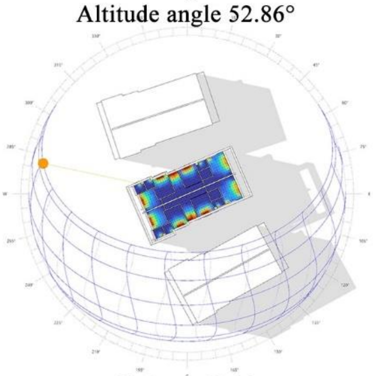
21 June 15:00
Azimuth angle 246.75°
Altitude angle 52.86°



21 September 15:00
Azimuth angle 229.51°
Altitude angle 33.42°

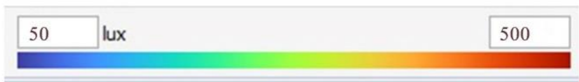


21 December 15:00
Azimuth angle 215.54°
Altitude angle 13.09°

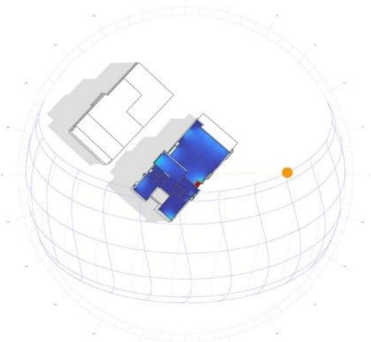


21 June 18:00
Azimuth angle 281.92°
Altitude angle 21.72°

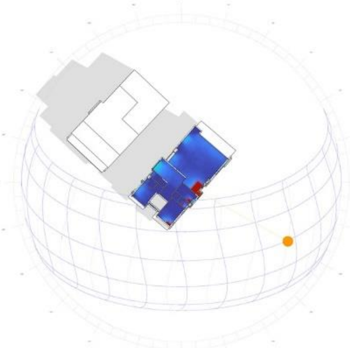
Location: Turin
Overcast sky
Ground albedo: 0.2
Glass type: Double glass
SHGC:0.31 TVIS:0.604 U-value:1.36



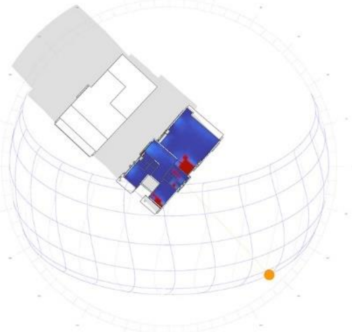
Case study 2 Ground floor 1:1000



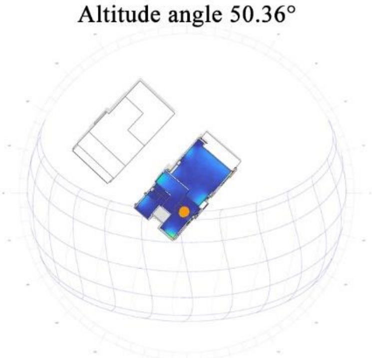
21 June 9:00
Azimuth angle 88.83°
Altitude angle 50.36°



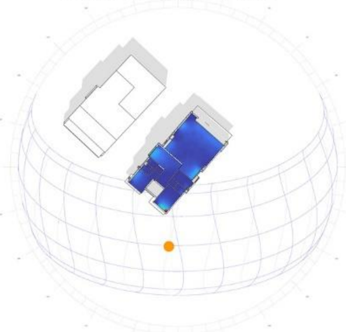
21 September 9:00
Azimuth angle 188.62°
Altitude angle 40.51°



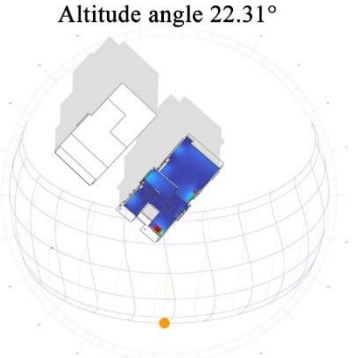
21 December 9:00
Azimuth angle 137.33°
Altitude angle 22.31°



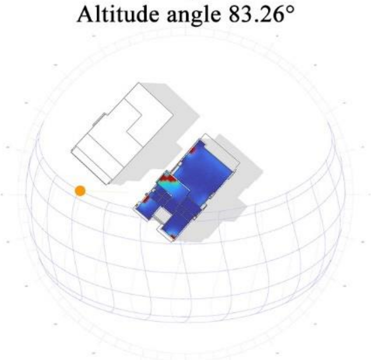
21 June 12:00
Azimuth angle 187.49°
Altitude angle 83.26°



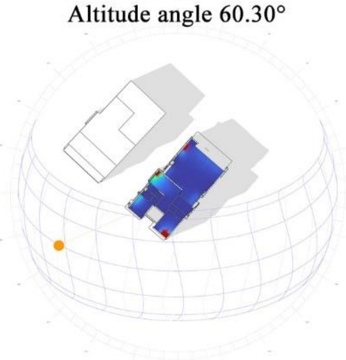
21 September 12:00
Azimuth angle 186.35°
Altitude angle 60.30°



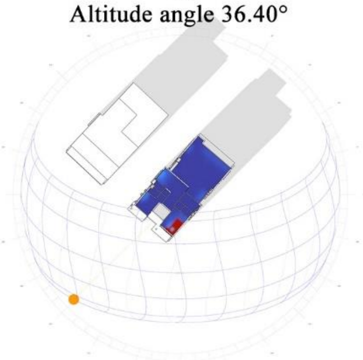
21 December 12:00
Azimuth angle 182.13°
Altitude angle 36.40°



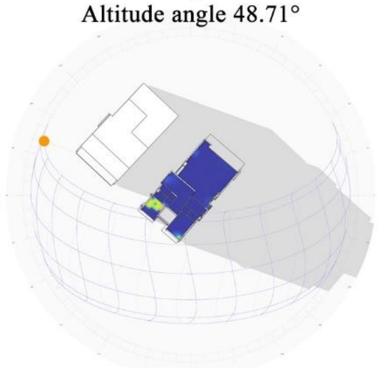
21 June 15:00
Azimuth angle 272.07°
Altitude angle 48.71°



21 September 15:00
Azimuth angle 246.31°
Altitude angle 35.57°

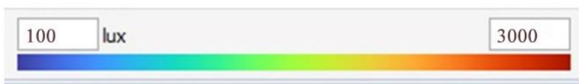


21 December 15:00
Azimuth angle 225.45°
Altitude angle 20.05°

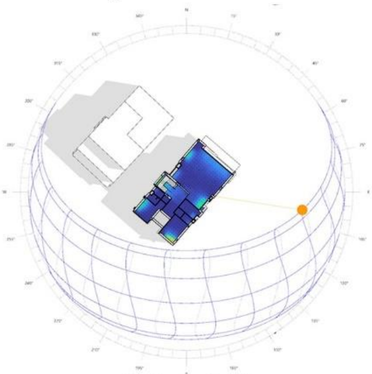


21 June 18:00
Azimuth angle 290.07°
Altitude angle 10.75°

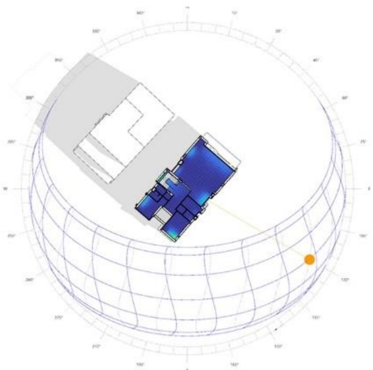
Location: Cairo
Clear sky
Ground albedo: 0.2
Glass type: Double glass 6.4 mm Stainless Steel Cover 30%
SHGC:0.15 TVIS:0.27 U-value:2.66



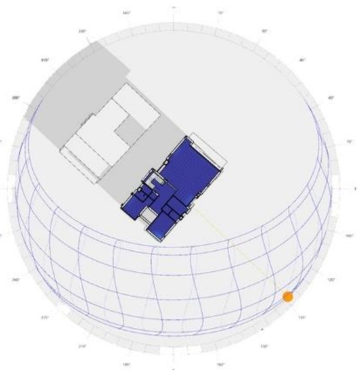
Case study 2 Ground floor 1:1000



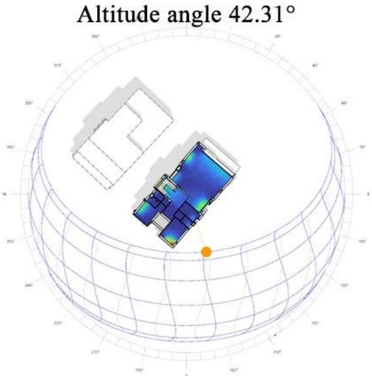
21 June 9:00
Azimuth angle 98.82°
Altitude angle 42.31°



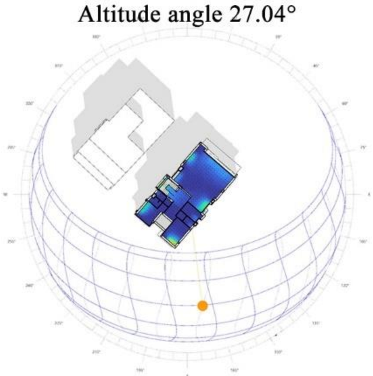
21 September 9:00
Azimuth angle 119.80°
Altitude angle 27.04°



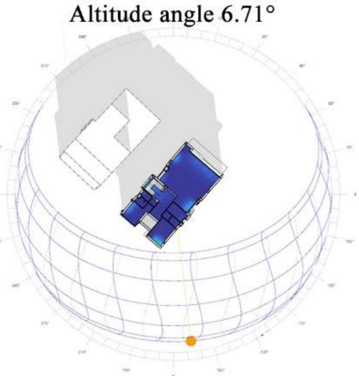
21 December 9:00
Azimuth angle 133.39°
Altitude angle 6.71°



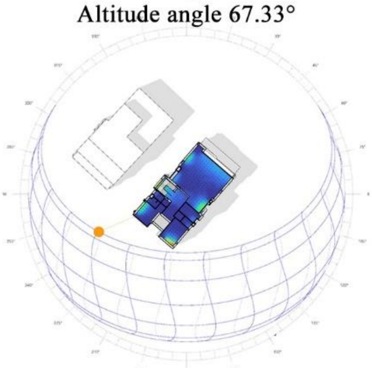
21 June 12:00
Azimuth angle 161.16°
Altitude angle 67.33°



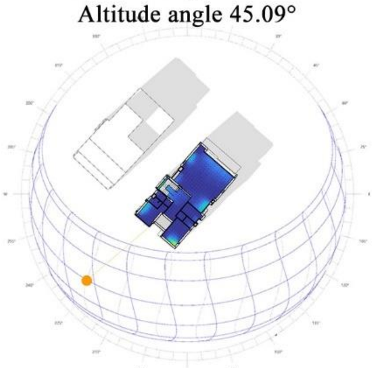
21 September 12:00
Azimuth angle 172.04°
Altitude angle 45.09°



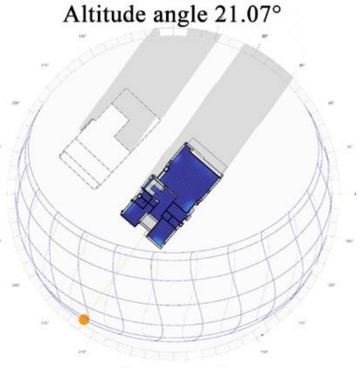
21 December 12:00
Azimuth angle 173.23°
Altitude angle 21.07°



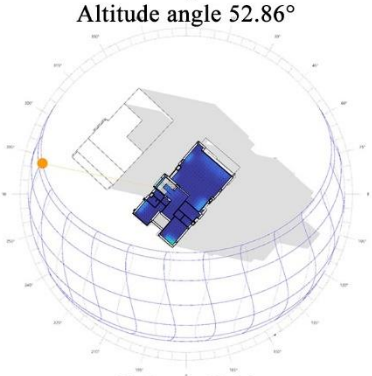
21 June 15:00
Azimuth angle 246.75°
Altitude angle 52.86°



21 September 15:00
Azimuth angle 229.51°
Altitude angle 33.42°



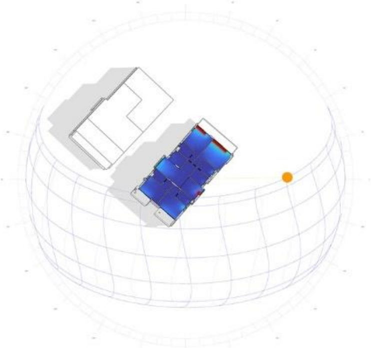
21 December 15:00
Azimuth angle 215.54°
Altitude angle 13.09°



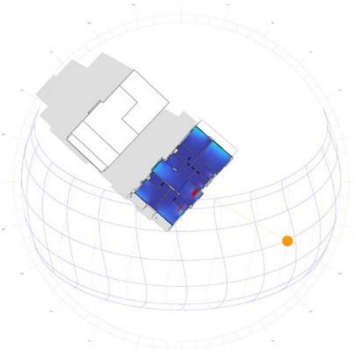
21 June 18:00
Azimuth angle 281.92°
Altitude angle 21.72°

Location: Turin
Overcast sky
Ground albedo: 0.2
Glass type: Double glass
SHGC:0.31 TVIS:0.604 U-value:1.36

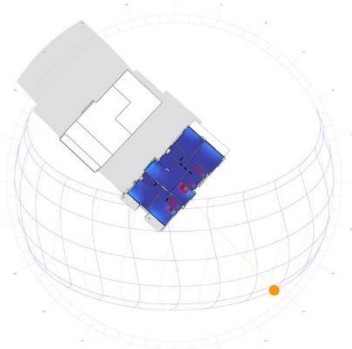
Case study 2 First floor 1:1000



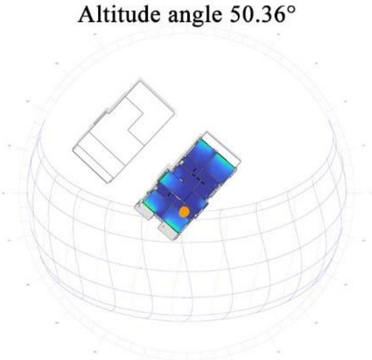
21 June 9:00
Azimuth angle 88.83°
Altitude angle 50.36°



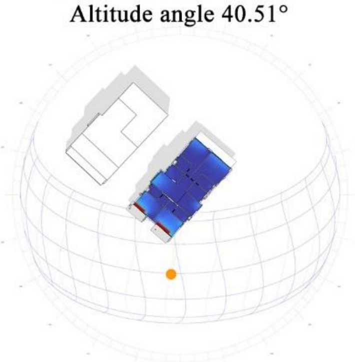
21 September 9:00
Azimuth angle 188.62°
Altitude angle 40.51°



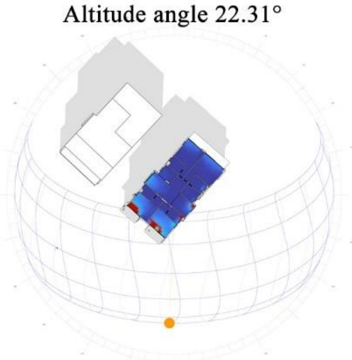
21 December 9:00
Azimuth angle 137.33°
Altitude angle 22.31°



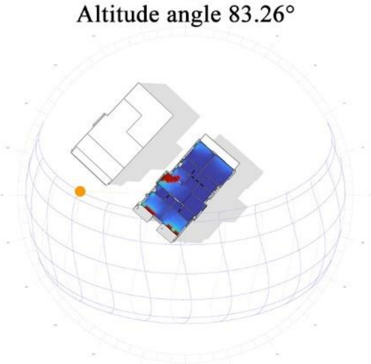
21 June 12:00
Azimuth angle 187.49°
Altitude angle 83.26°



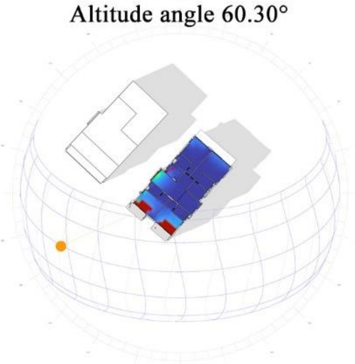
21 September 12:00
Azimuth angle 186.35°
Altitude angle 60.30°



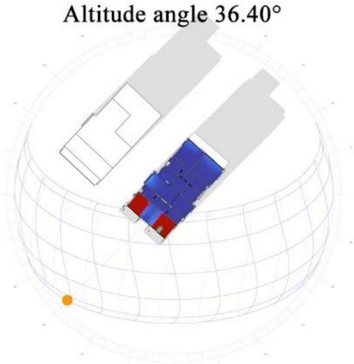
21 December 12:00
Azimuth angle 182.13°
Altitude angle 36.40°



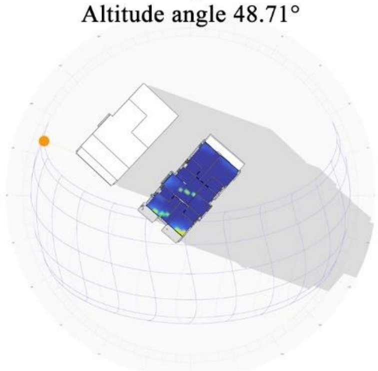
21 June 15:00
Azimuth angle 272.07°
Altitude angle 48.71°



21 September 15:00
Azimuth angle 246.31°
Altitude angle 35.57°

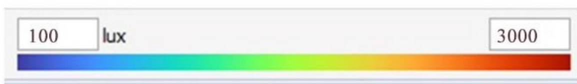


21 December 15:00
Azimuth angle 225.45°
Altitude angle 20.05°

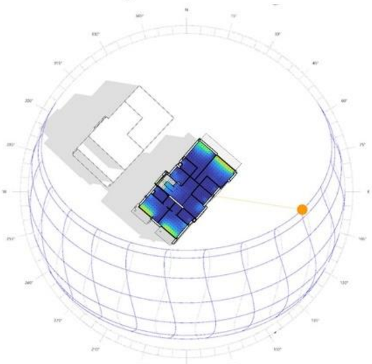


21 June 18:00
Azimuth angle 290.07°
Altitude angle 10.75°

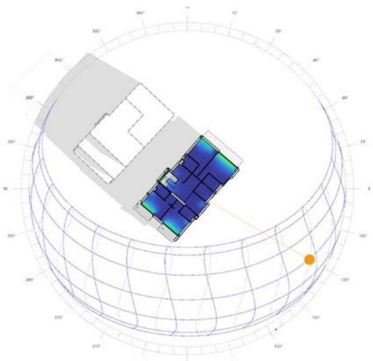
Location: Cairo
Clear sky Ground albedo: 0.2
Glass type: Double glass 6.4 mm Stainless Steel Cover 30%
SHGC:0.15 TVIS:0.27 U-value:2.66



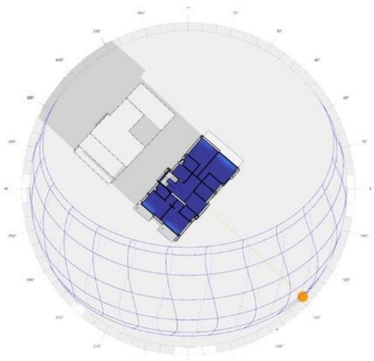
Case study 2 First floor 1:1000



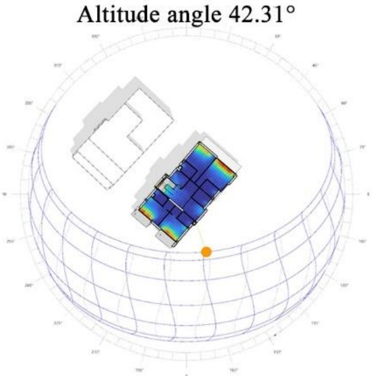
21 June 9:00
Azimuth angle 98.82°
Altitude angle 42.31°



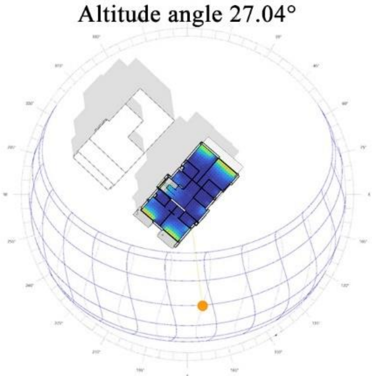
21 September 9:00
Azimuth angle 119.80°
Altitude angle 27.04°



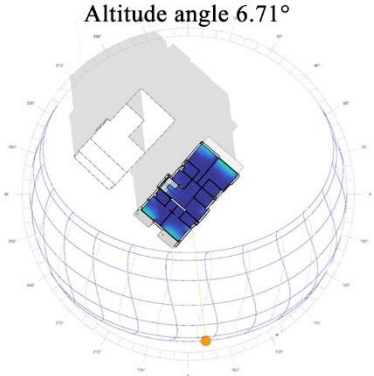
21 December 9:00
Azimuth angle 133.39°
Altitude angle 6.71°



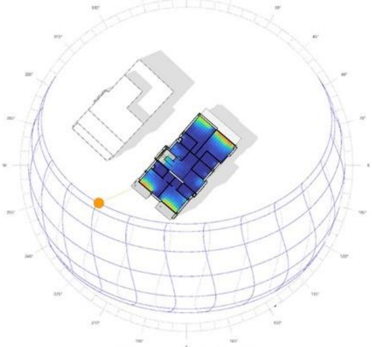
21 June 12:00
Azimuth angle 161.16°
Altitude angle 67.33°



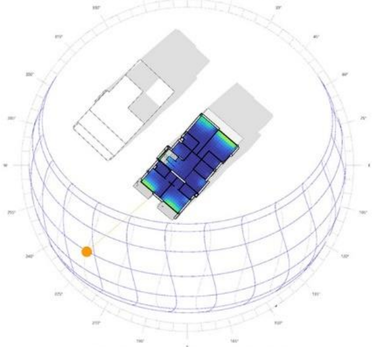
21 September 12:00
Azimuth angle 172.04°
Altitude angle 45.09°



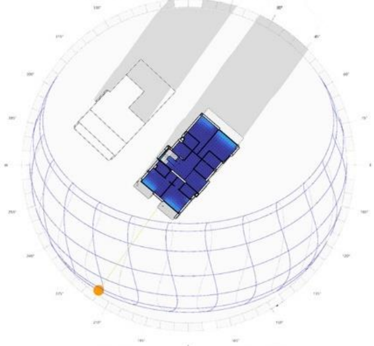
21 December 12:00
Azimuth angle 173.23°
Altitude angle 21.07°



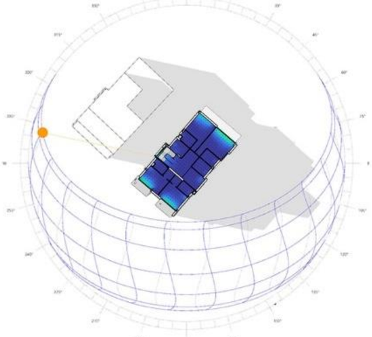
21 June 15:00
Azimuth angle 246.75°
Altitude angle 52.86°



21 September 15:00
Azimuth angle 229.51°
Altitude angle 33.42°

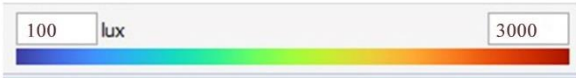


21 December 15:00
Azimuth angle 215.54°
Altitude angle 13.09°

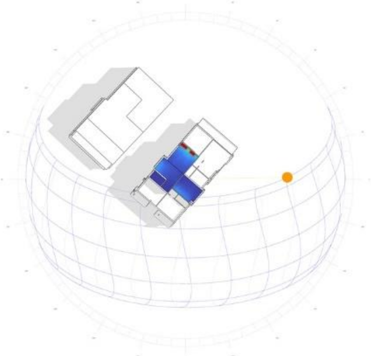


21 June 18:00
Azimuth angle 281.92°
Altitude angle 21.72°

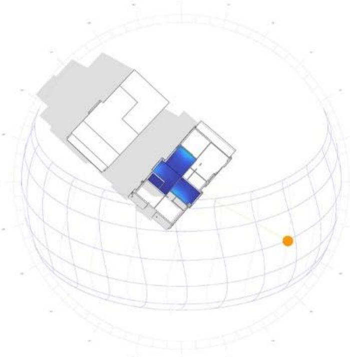
Location: Turin
Overcast sky
Ground albedo: 0.2
Glass type: Double glass
SHGC:0.31 TVIS:0.604 U-value:1.36



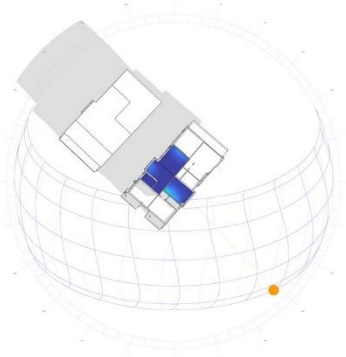
Case study 2 second floor 1:1000



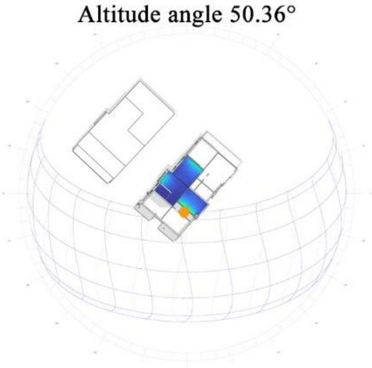
21 June 9:00
Azimuth angle 88.83°
Altitude angle 50.36°



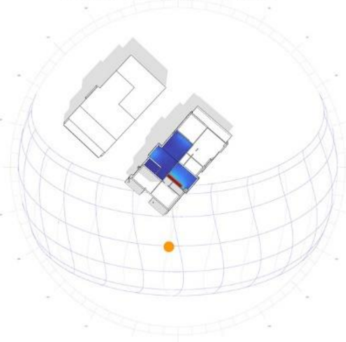
21 September 9:00
Azimuth angle 188.62°
Altitude angle 40.51°



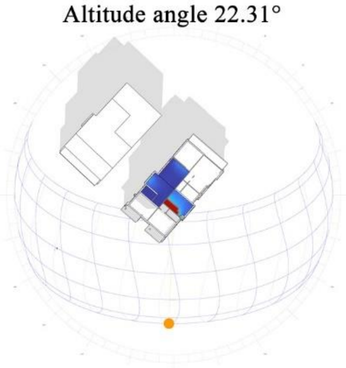
21 December 9:00
Azimuth angle 137.33°
Altitude angle 22.31°



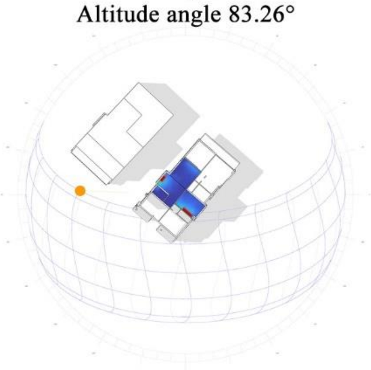
21 June 12:00
Azimuth angle 187.49°
Altitude angle 83.26°



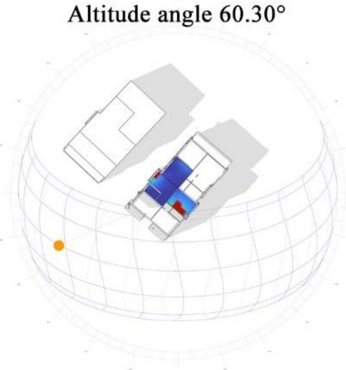
21 September 12:00
Azimuth angle 186.35°
Altitude angle 60.30°



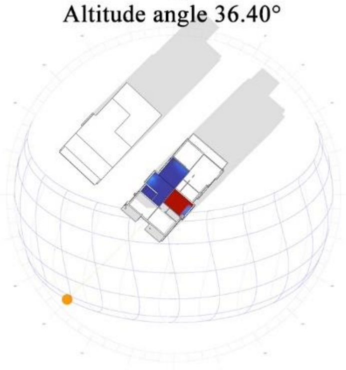
21 December 12:00
Azimuth angle 182.13°
Altitude angle 36.40°



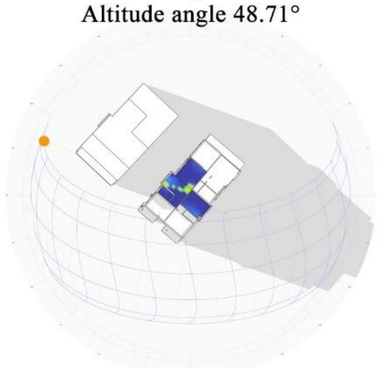
21 June 15:00
Azimuth angle 272.07°
Altitude angle 48.71°



21 September 15:00
Azimuth angle 246.31°
Altitude angle 35.57°

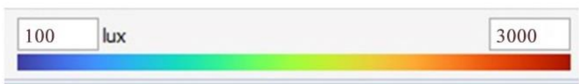


21 December 15:00
Azimuth angle 225.45°
Altitude angle 20.05°

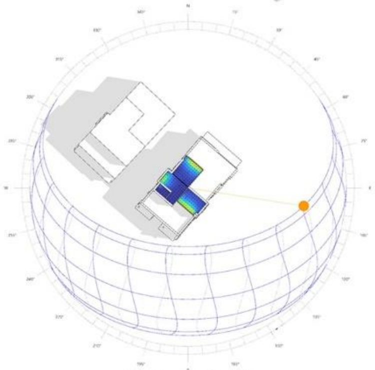


21 June 18:00
Azimuth angle 290.07°
Altitude angle 10.75°

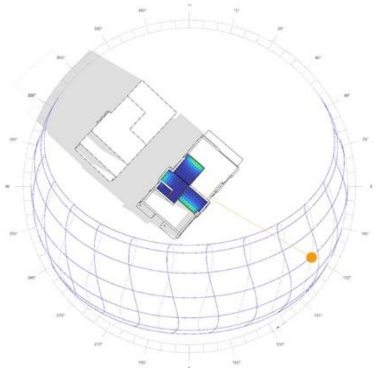
Location: Cairo
Clear sky Ground albedo: 0.2
Glass type: Double glass 6.4 mm Stainless Steel Cover 30%
SHGC:0.15 TVIS:0.27 U-value:2.66



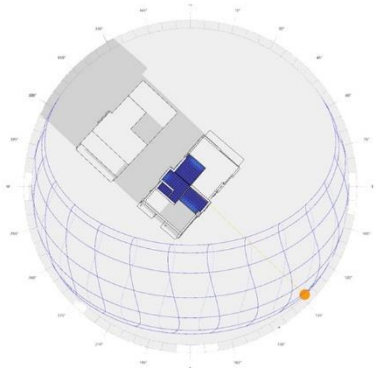
Case study 2 second floor 1:1000



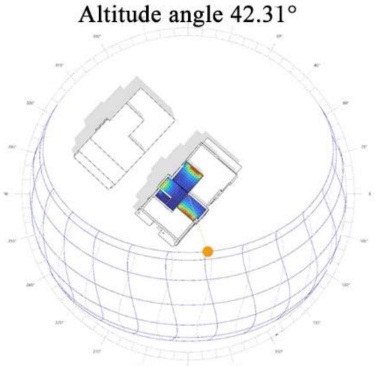
21 June 9:00
Azimuth angle 98.82°
Altitude angle 42.31°



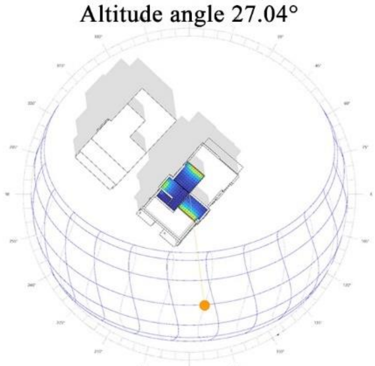
21 September 9:00
Azimuth angle 119.80°
Altitude angle 27.04°



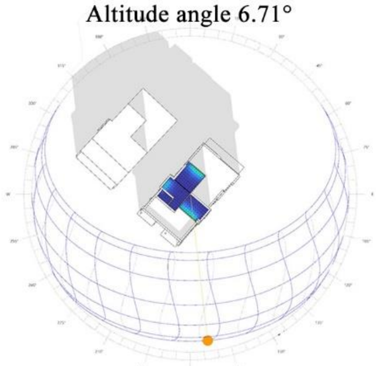
21 December 9:00
Azimuth angle 133.39°
Altitude angle 6.71°



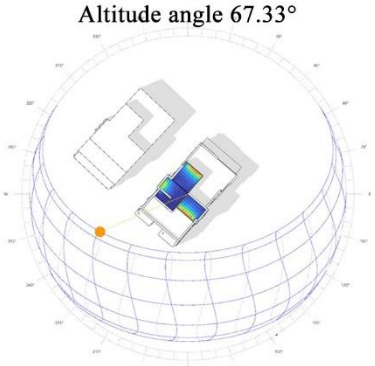
21 June 12:00
Azimuth angle 161.16°
Altitude angle 67.33°



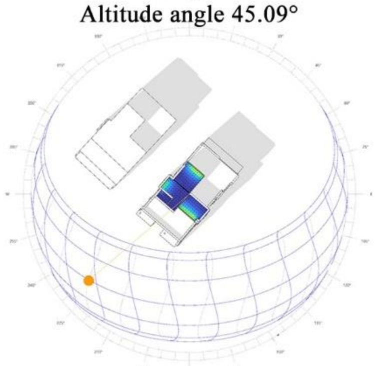
21 September 12:00
Azimuth angle 172.04°
Altitude angle 45.09°



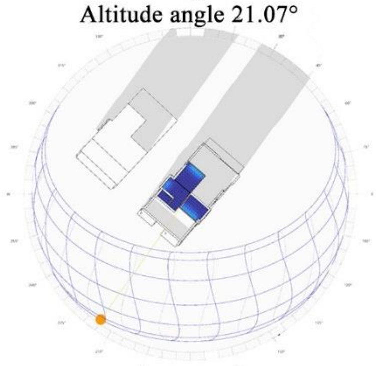
21 December 12:00
Azimuth angle 173.23°
Altitude angle 21.07°



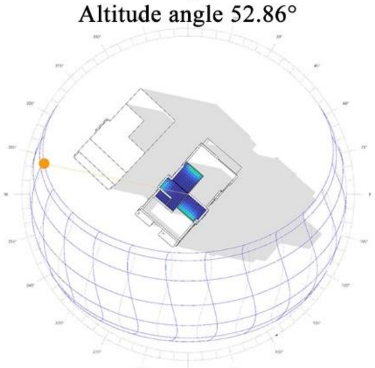
21 June 15:00
Azimuth angle 246.75°
Altitude angle 52.86°



21 September 15:00
Azimuth angle 229.51°
Altitude angle 33.42°

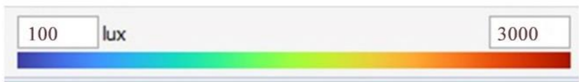


21 December 15:00
Azimuth angle 215.54°
Altitude angle 13.09°

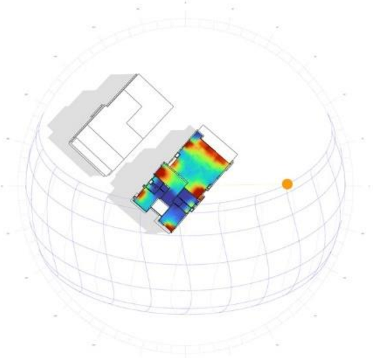


21 June 18:00
Azimuth angle 281.92°
Altitude angle 21.72°

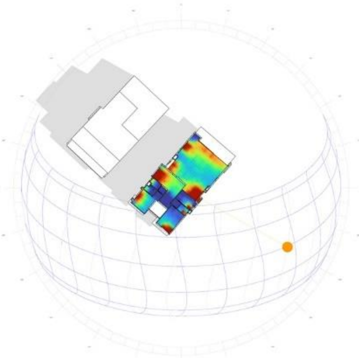
Location: Turin
Overcast sky Ground albedo: 0.2
Glass type: Double glass
SHGC:0.31 TVIS:0.604 U-value:1.36



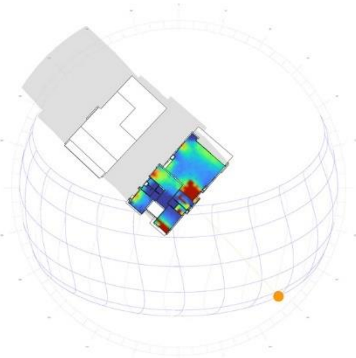
Case study 2 Ground floor 1:1000



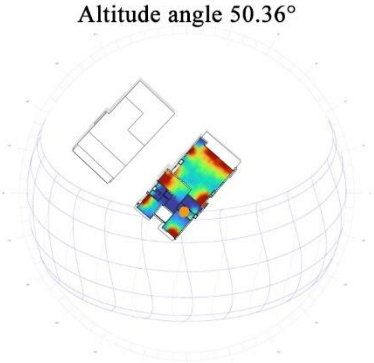
21 June 9:00
Azimuth angle 88.83°
Altitude angle 50.36°



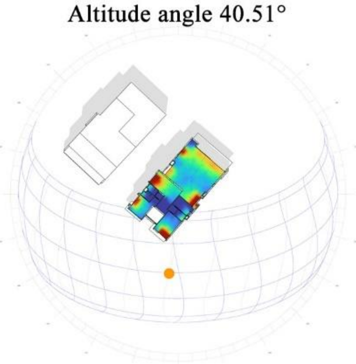
21 September 9:00
Azimuth angle 188.62°
Altitude angle 40.51°



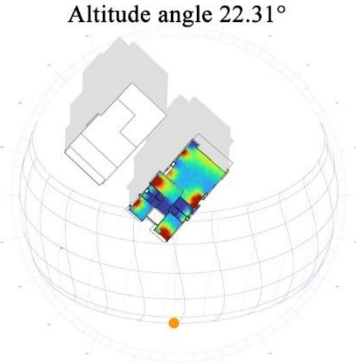
21 December 9:00
Azimuth angle 137.33°
Altitude angle 22.31°



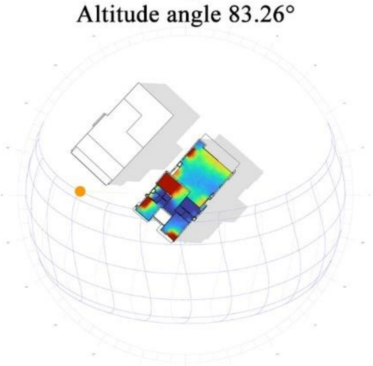
21 June 12:00
Azimuth angle 187.49°
Altitude angle 83.26°



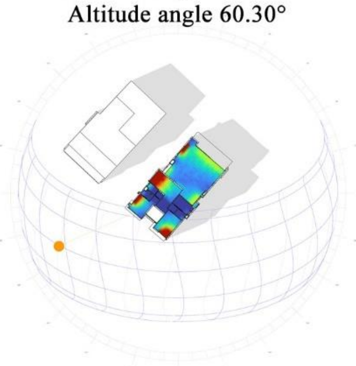
21 September 12:00
Azimuth angle 186.35°
Altitude angle 60.30°



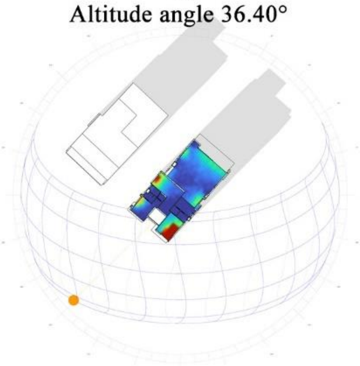
21 December 12:00
Azimuth angle 182.13°
Altitude angle 36.40°



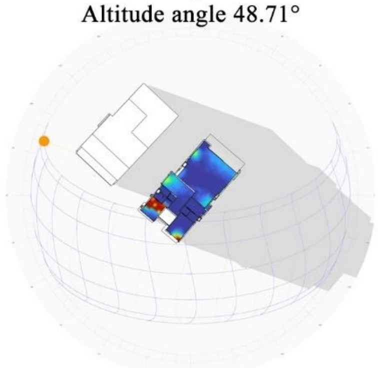
21 June 15:00
Azimuth angle 272.07°
Altitude angle 48.71°



21 September 15:00
Azimuth angle 246.31°
Altitude angle 35.57°

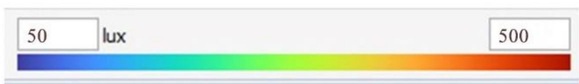


21 December 15:00
Azimuth angle 225.45°
Altitude angle 20.05°

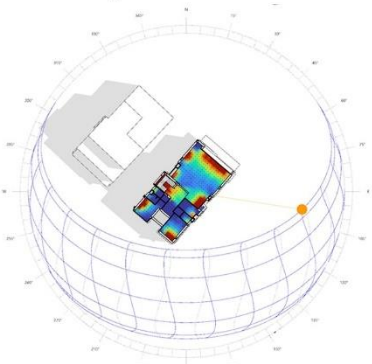


21 June 18:00
Azimuth angle 290.07°
Altitude angle 10.75°

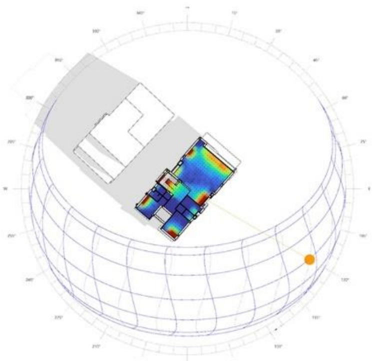
Location: Cairo
Clear sky Ground albedo: 0.2
Glass type: Double glass 6.4 mm Stainless Steel Cover 30%
SHGC:0.15 TVIS:0.27 U-value:2.66



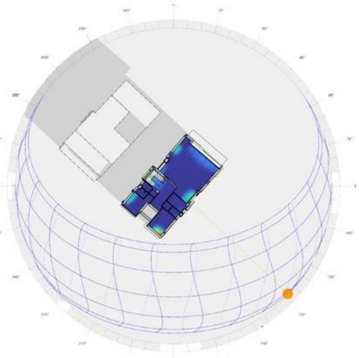
Case study 2 Ground floor 1:1000



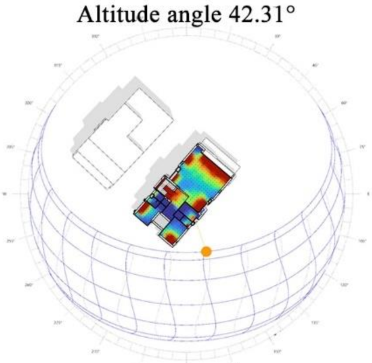
21 June 9:00
Azimuth angle 98.82°
Altitude angle 42.31°



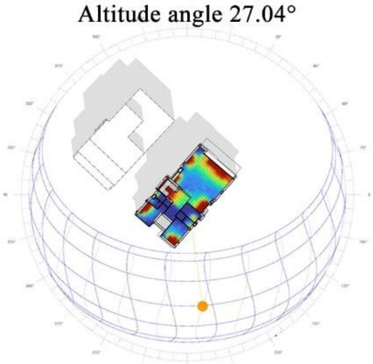
21 September 9:00
Azimuth angle 119.80°
Altitude angle 27.04°



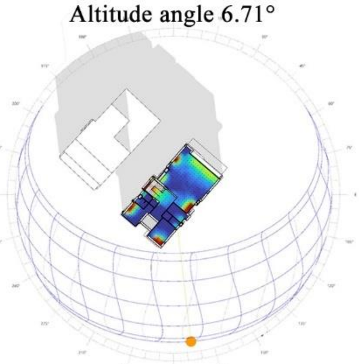
21 December 9:00
Azimuth angle 133.39°
Altitude angle 6.71°



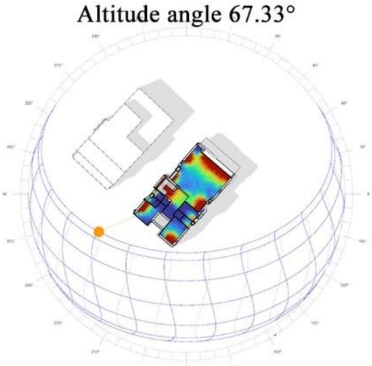
21 June 12:00
Azimuth angle 161.16°
Altitude angle 67.33°



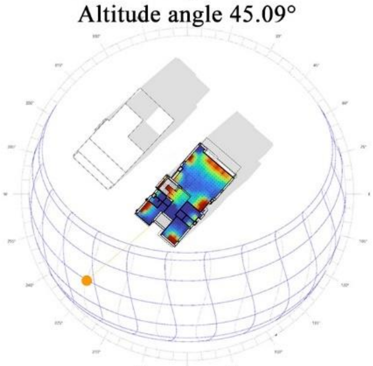
21 September 12:00
Azimuth angle 172.04°
Altitude angle 45.09°



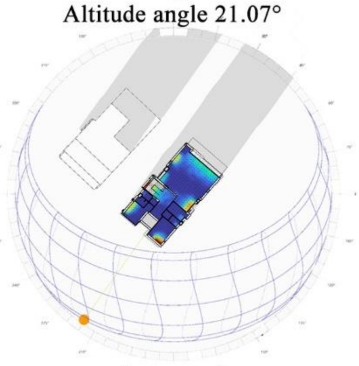
21 December 12:00
Azimuth angle 173.23°
Altitude angle 21.07°



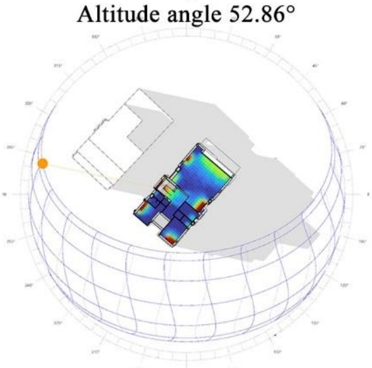
21 June 15:00
Azimuth angle 246.75°
Altitude angle 52.86°



21 September 15:00
Azimuth angle 229.51°
Altitude angle 33.42°

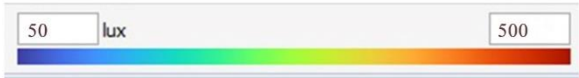


21 December 15:00
Azimuth angle 215.54°
Altitude angle 13.09°

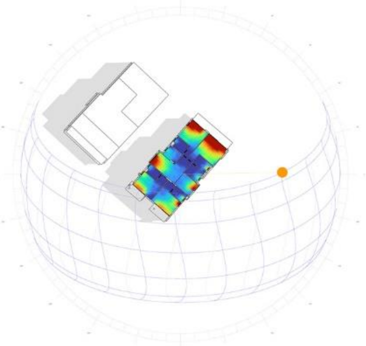


21 June 18:00
Azimuth angle 281.92°
Altitude angle 21.72°

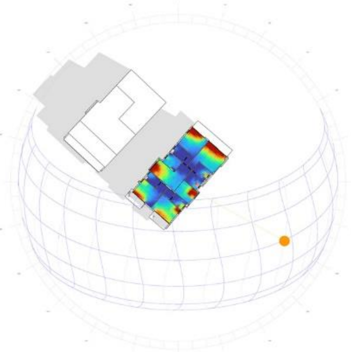
Location: Turin
Overcast sky
Ground albedo: 0.2
Glass type: Double glass
SHGC:0.31 TVIS:0.604 U-value:1.36



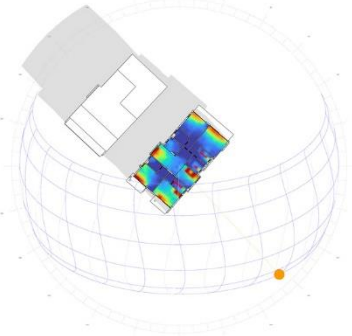
Case study 2 First floor 1:1000



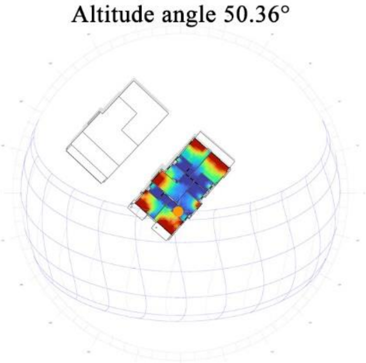
21 June 9:00
Azimuth angle 88.83°
Altitude angle 50.36°



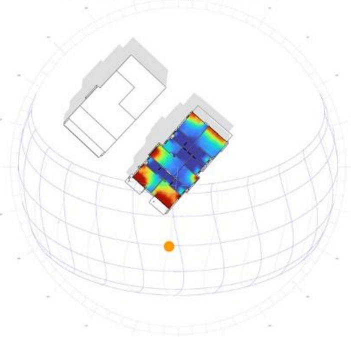
21 September 9:00
Azimuth angle 188.62°
Altitude angle 40.51°



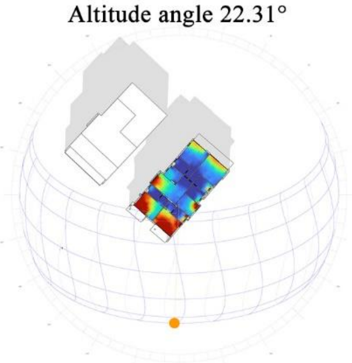
21 December 9:00
Azimuth angle 137.33°
Altitude angle 22.31°



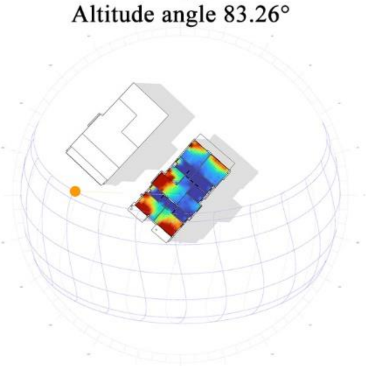
21 June 12:00
Azimuth angle 187.49°
Altitude angle 83.26°



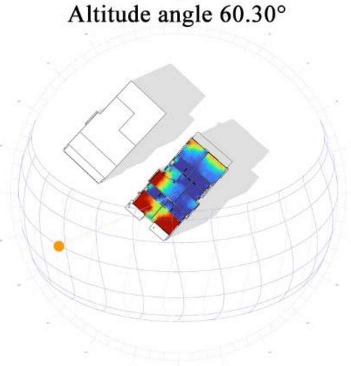
21 September 12:00
Azimuth angle 186.35°
Altitude angle 60.30°



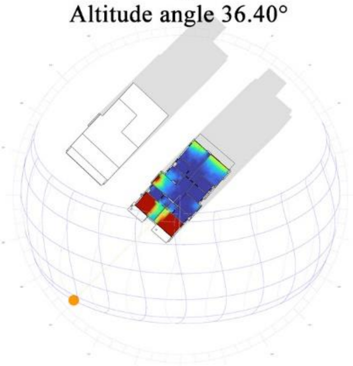
21 December 12:00
Azimuth angle 182.13°
Altitude angle 36.40°



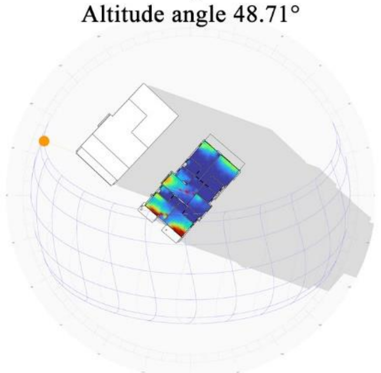
21 June 15:00
Azimuth angle 272.07°
Altitude angle 48.71°



21 September 15:00
Azimuth angle 246.31°
Altitude angle 35.57°



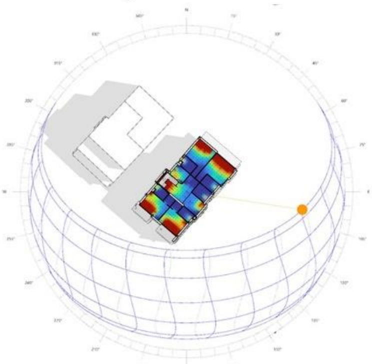
21 December 15:00
Azimuth angle 225.45°
Altitude angle 20.05°



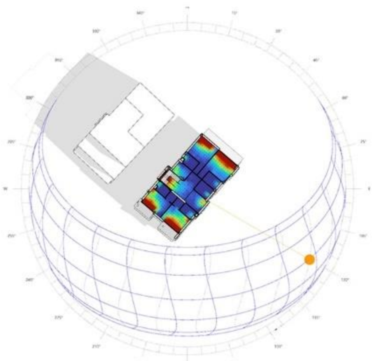
21 June 18:00
Azimuth angle 290.07°
Altitude angle 10.75°

Location: Cairo
Clear sky   Ground albedo: 0.2
Glass type: Double glass 6.4 mm Stainless Steel Cover 30%
SHGC:0.15 TVIS:0.27 U-value:2.66

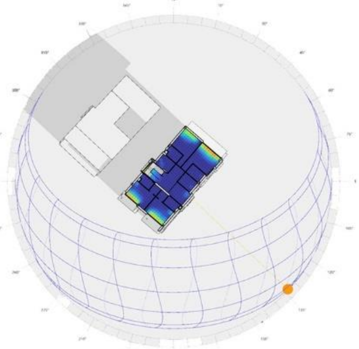
Case study 2 First floor 1:1000



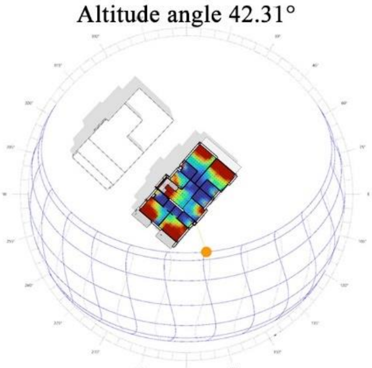
21 June 9:00
Azimuth angle 98.82°
Altitude angle 42.31°



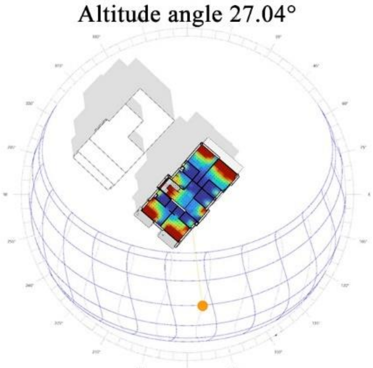
21 September 9:00
Azimuth angle 119.80°
Altitude angle 27.04°



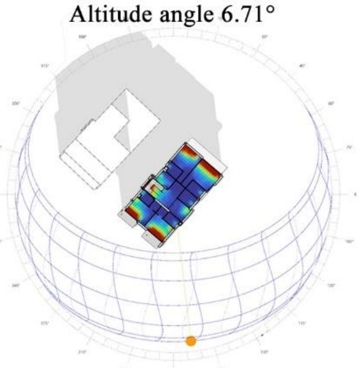
21 December 9:00
Azimuth angle 133.39°
Altitude angle 6.71°



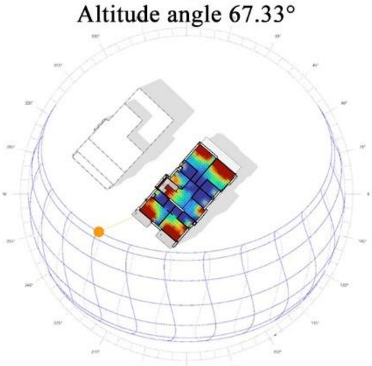
21 June 12:00
Azimuth angle 161.16°
Altitude angle 67.33°



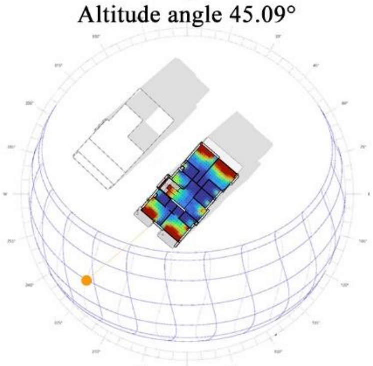
21 September 12:00
Azimuth angle 172.04°
Altitude angle 45.09°



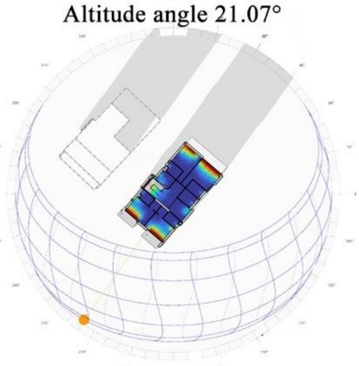
21 December 12:00
Azimuth angle 173.23°
Altitude angle 21.07°



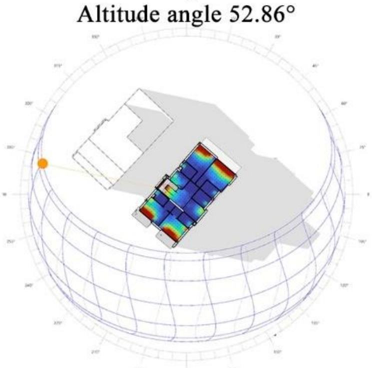
21 June 15:00
Azimuth angle 246.75°
Altitude angle 52.86°



21 September 15:00
Azimuth angle 229.51°
Altitude angle 33.42°

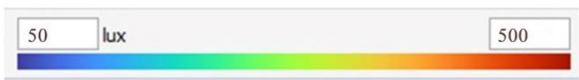


21 December 15:00
Azimuth angle 215.54°
Altitude angle 13.09°

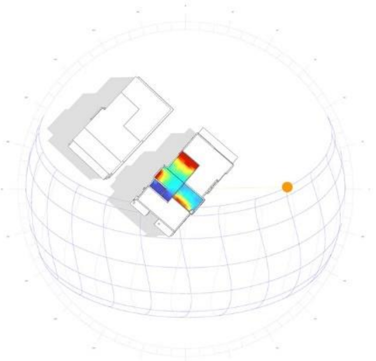


21 June 18:00
Azimuth angle 281.92°
Altitude angle 21.72°

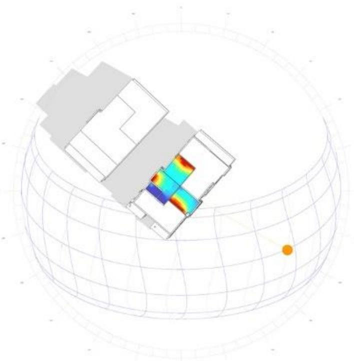
Location: Turin
Overcast sky
Ground albedo: 0.2
Glass type: Double glass
SHGC:0.31 TVIS:0.604 U-value:1.36



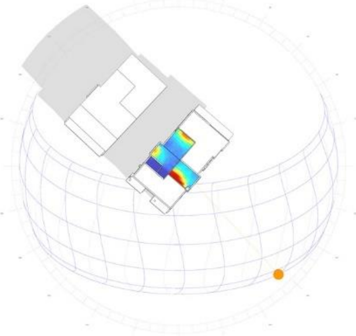
Case study 2 second floor 1:1000



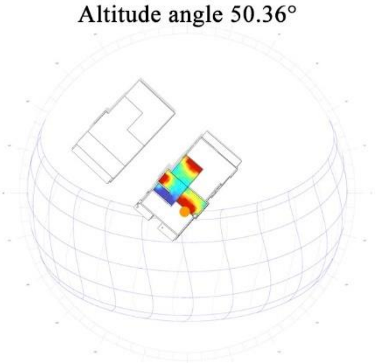
21 June 9:00
Azimuth angle 88.83°
Altitude angle 50.36°



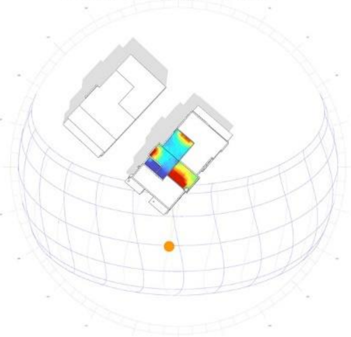
21 September 9:00
Azimuth angle 188.62°
Altitude angle 40.51°



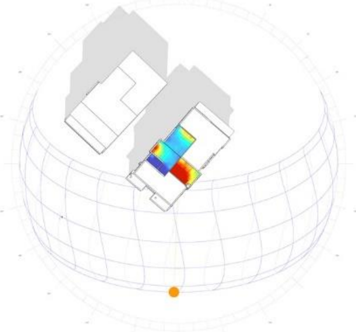
21 December 9:00
Azimuth angle 137.33°
Altitude angle 22.31°



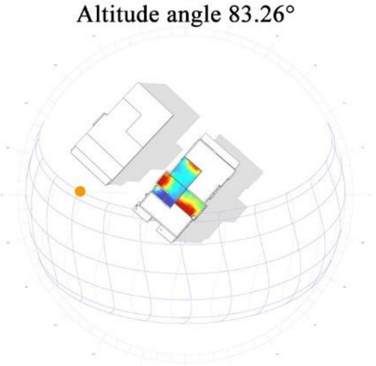
21 June 12:00
Azimuth angle 187.49°
Altitude angle 83.26°



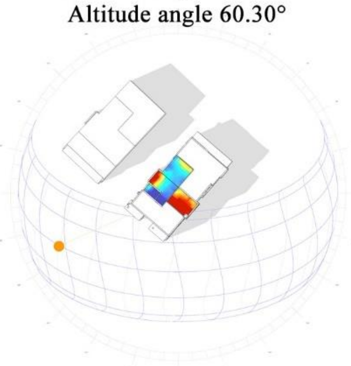
21 September 12:00
Azimuth angle 186.35°
Altitude angle 60.30°



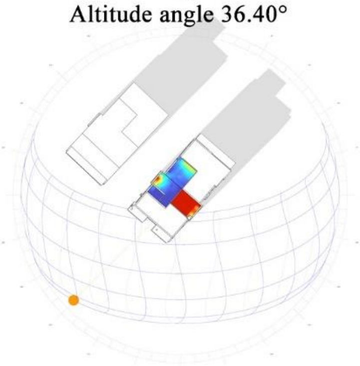
21 December 12:00
Azimuth angle 182.13°
Altitude angle 36.40°



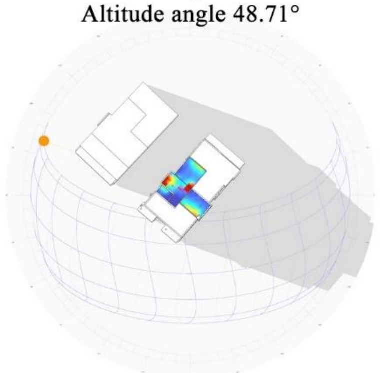
21 June 15:00
Azimuth angle 272.07°
Altitude angle 48.71°



21 September 15:00
Azimuth angle 246.31°
Altitude angle 35.57°



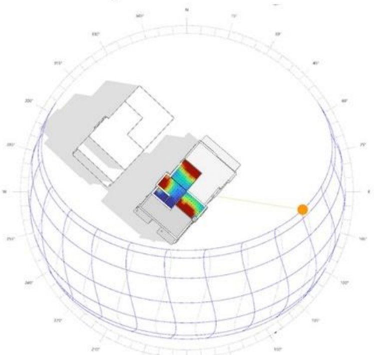
21 December 15:00
Azimuth angle 225.45°
Altitude angle 20.05°



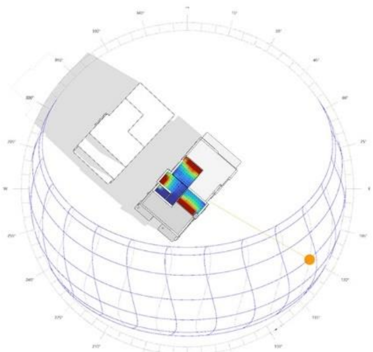
21 June 18:00
Azimuth angle 290.07°
Altitude angle 10.75°

Location: Cairo
Clear sky Ground albedo: 0.2
Glass type: Double glass 6.4 mm Stainless Steel Cover 30%
SHGC:0.15 TVIS:0.27 U-value:2.66

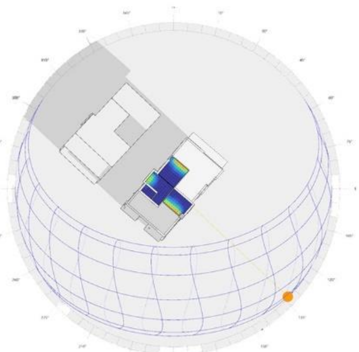
Case study 2 Second floor 1:1000



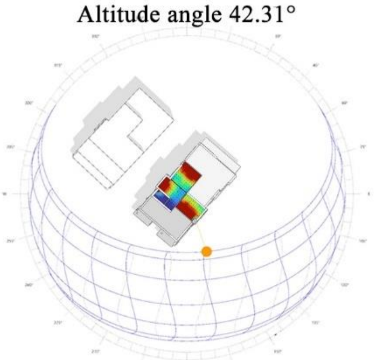
21 June 9:00
Azimuth angle 98.82°
Altitude angle 42.31°



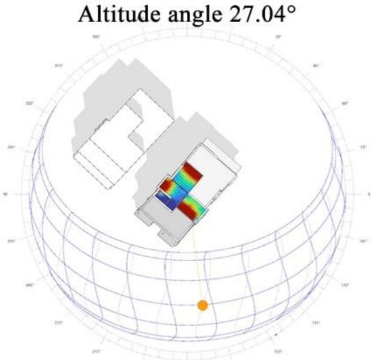
21 September 9:00
Azimuth angle 119.80°
Altitude angle 27.04°



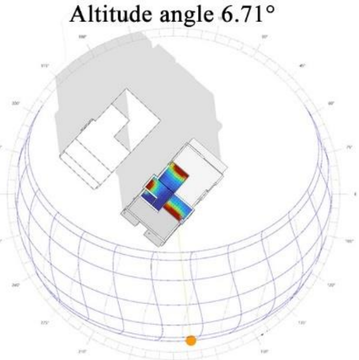
21 December 9:00
Azimuth angle 133.39°
Altitude angle 6.71°



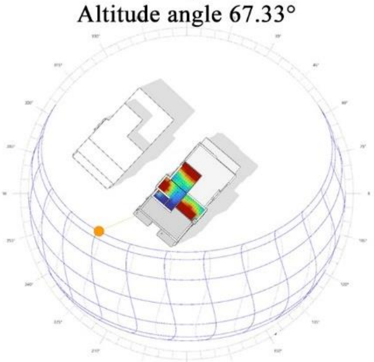
21 June 12:00
Azimuth angle 161.16°
Altitude angle 67.33°



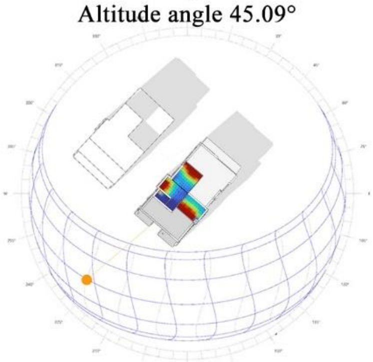
21 September 12:00
Azimuth angle 172.04°
Altitude angle 45.09°



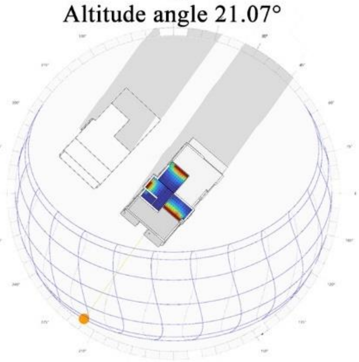
21 December 12:00
Azimuth angle 173.23°
Altitude angle 21.07°



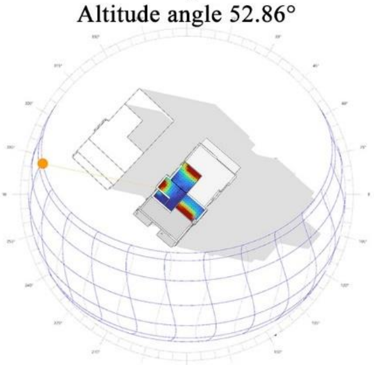
21 June 15:00
Azimuth angle 246.75°
Altitude angle 52.86°



21 September 15:00
Azimuth angle 229.51°
Altitude angle 33.42°

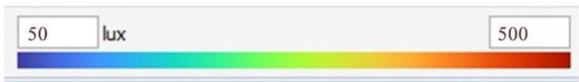


21 December 15:00
Azimuth angle 215.54°
Altitude angle 13.09°

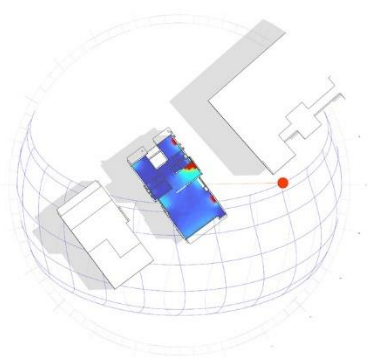


21 June 18:00
Azimuth angle 281.92°
Altitude angle 21.72°

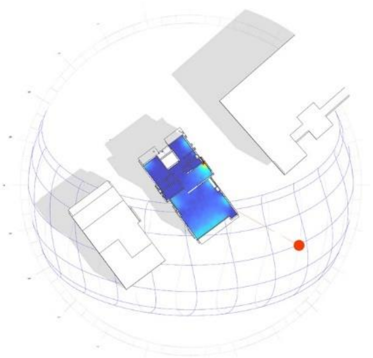
Location: Turin
Overcast sky
Ground albedo: 0.2
Glass type: Double glass
SHGC:0.31 TVIS:0.604 U-value:1.36



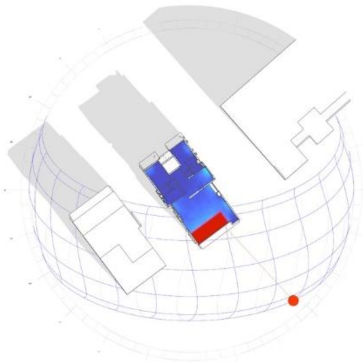
Case study 3 Ground floor 1:1000



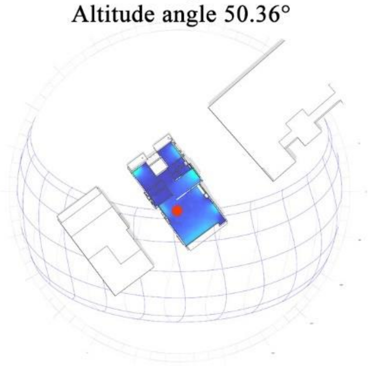
21 June 9:00
Azimuth angle 88.83°
Altitude angle 50.36°



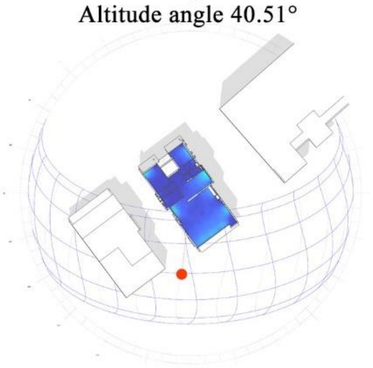
21 September 9:00
Azimuth angle 188.62°
Altitude angle 40.51°



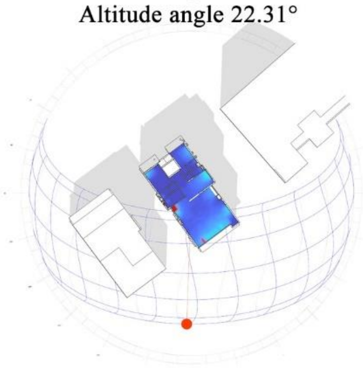
21 December 9:00
Azimuth angle 137.33°
Altitude angle 22.31°



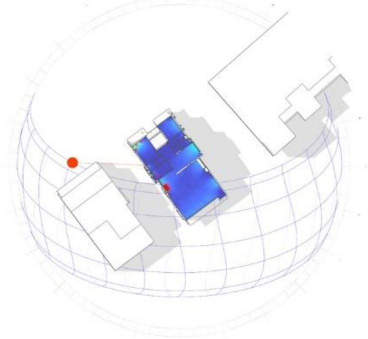
21 June 12:00
Azimuth angle 187.49°
Altitude angle 83.26°



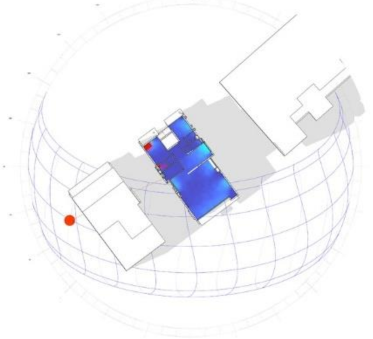
21 September 12:00
Azimuth angle 186.35°
Altitude angle 60.30°



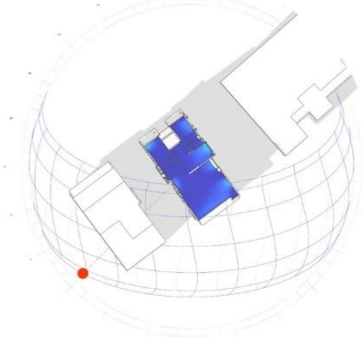
21 December 12:00
Azimuth angle 182.13°
Altitude angle 36.40°



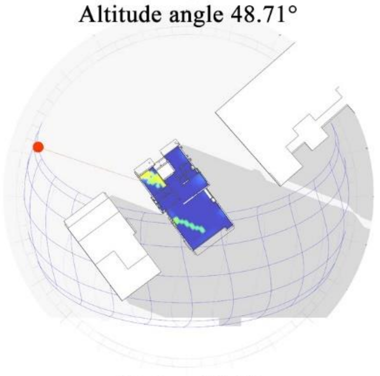
21 June 15:00
Azimuth angle 272.07°
Altitude angle 48.71°



21 September 15:00
Azimuth angle 246.31°
Altitude angle 35.57°



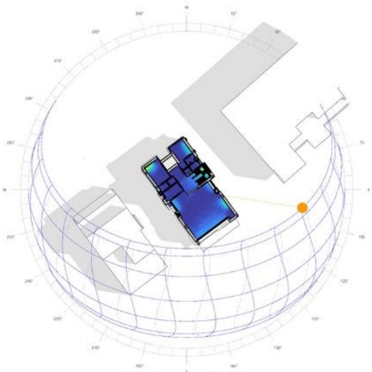
21 December 15:00
Azimuth angle 225.45°
Altitude angle 20.05°



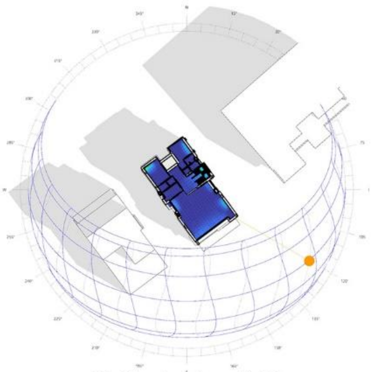
21 June 18:00
Azimuth angle 290.07°
Altitude angle 10.75°

Location: Cairo
Clear sky Ground albedo: 0.2
Glass type: Double glass 6.4 mm Stainless Steel Cover 30%
SHGC:0.15 TVIS:0.27 U-value:2.66

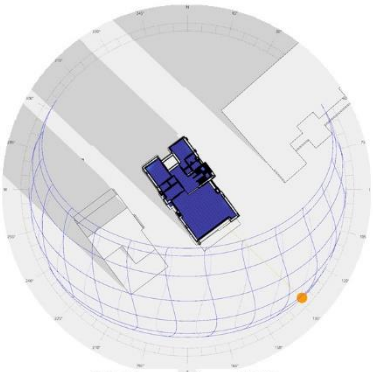
Case study 3 Ground floor 1:1000



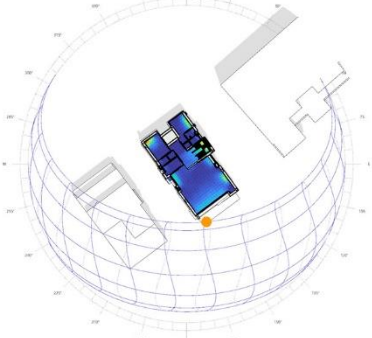
21 June 9:00
Azimuth angle 98.82°
Altitude angle 42.31°



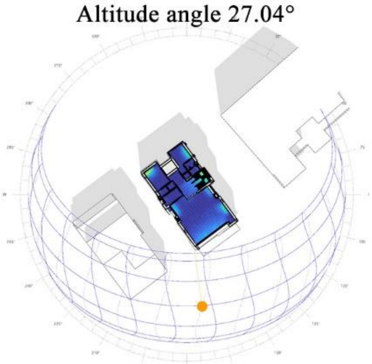
21 September 9:00
Azimuth angle 119.80°
Altitude angle 27.04°



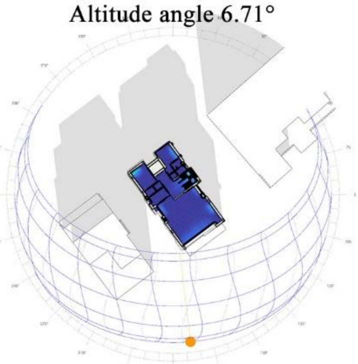
21 December 9:00
Azimuth angle 133.39°
Altitude angle 6.71°



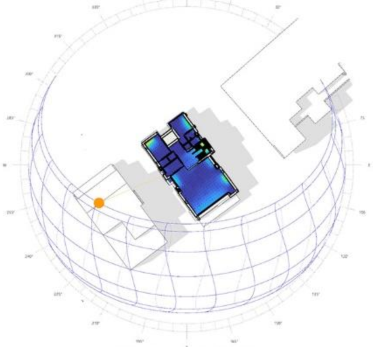
21 June 12:00
Azimuth angle 161.16°
Altitude angle 67.33°



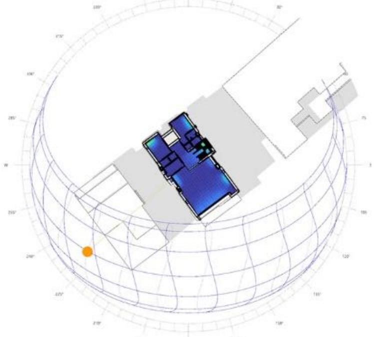
21 September 12:00
Azimuth angle 172.04°
Altitude angle 45.09°



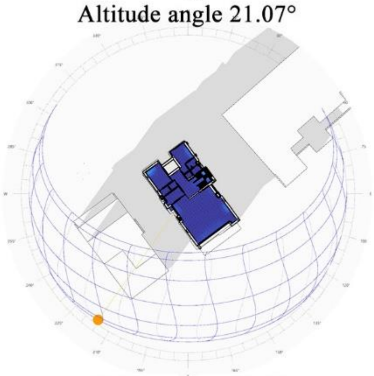
21 December 12:00
Azimuth angle 173.23°
Altitude angle 21.07°



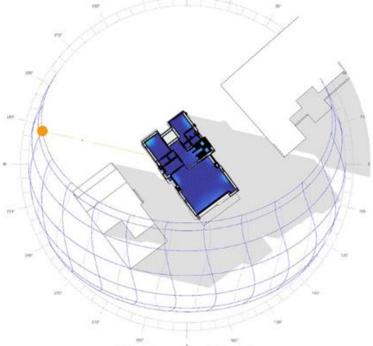
21 June 15:00
Azimuth angle 246.75°
Altitude angle 52.86°



21 September 15:00
Azimuth angle 229.51°
Altitude angle 33.42°



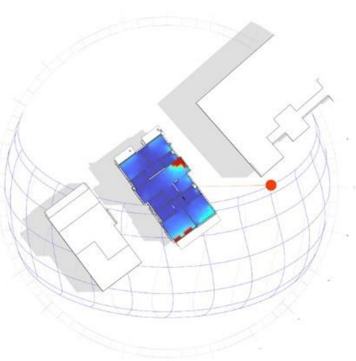
21 December 15:00
Azimuth angle 215.54°
Altitude angle 13.09°



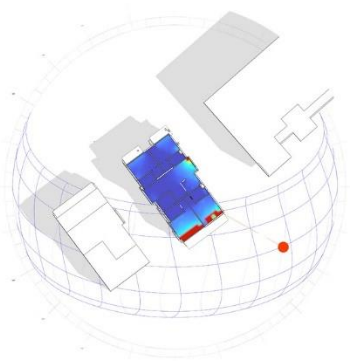
21 June 18:00
Azimuth angle 281.92°
Altitude angle 21.72°

Location: Turin
Overcast sky
Ground albedo: 0.2
Glass type: Double glass
SHGC:0.31 TVIS:0.604 U-value:1.36

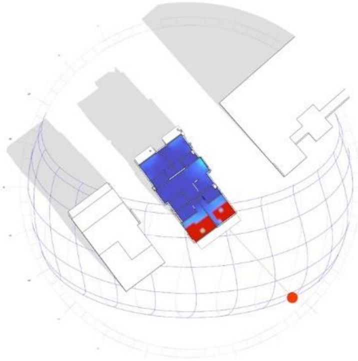
Case study 3 First floor1:1000



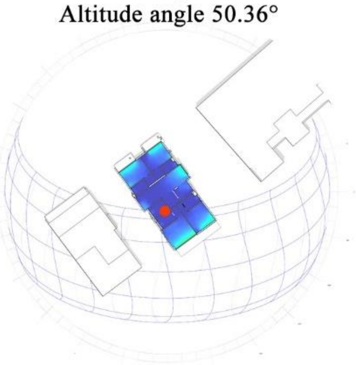
21 June 9:00
Azimuth angle 88.83°
Altitude angle 50.36°



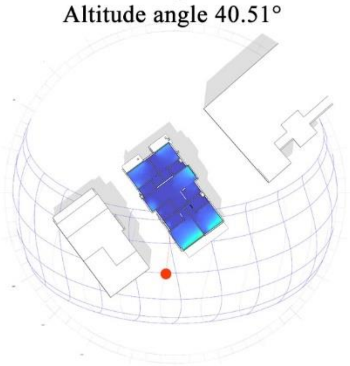
21 September 9:00
Azimuth angle 188.62°
Altitude angle 40.51°



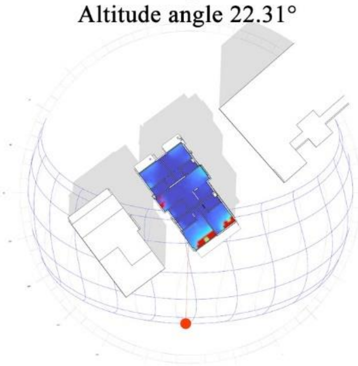
21 December 9:00
Azimuth angle 137.33°
Altitude angle 22.31°



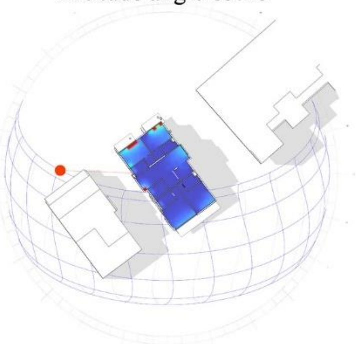
21 June 12:00
Azimuth angle 187.49°
Altitude angle 83.26°



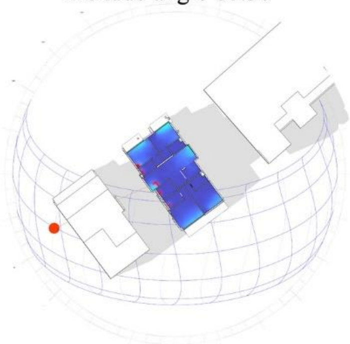
21 September 12:00
Azimuth angle 186.35°
Altitude angle 60.30°



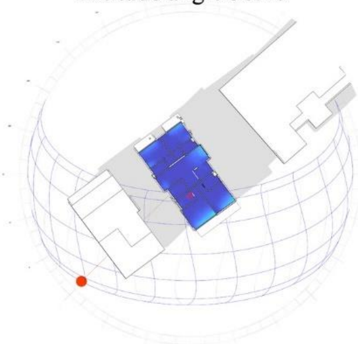
21 December 12:00
Azimuth angle 182.13°
Altitude angle 36.40°



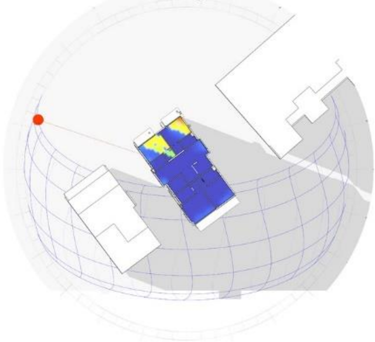
21 June 15:00
Azimuth angle 272.07°
Altitude angle 48.71°



21 September 15:00
Azimuth angle 246.31°
Altitude angle 35.57°



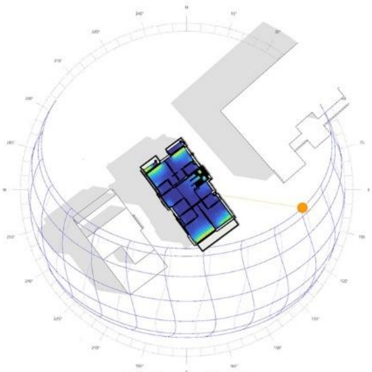
21 December 15:00
Azimuth angle 225.45°
Altitude angle 20.05°



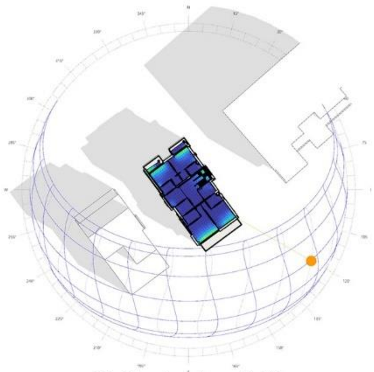
21 June 18:00
Azimuth angle 290.07°
Altitude angle 10.75°

Location: Cairo
Clear sky Ground albedo: 0.2
Glass type: Double glass 6.4 mm Stainless Steel Cover 30%
SHGC:0.15 TVIS:0.27 U-value:2.66

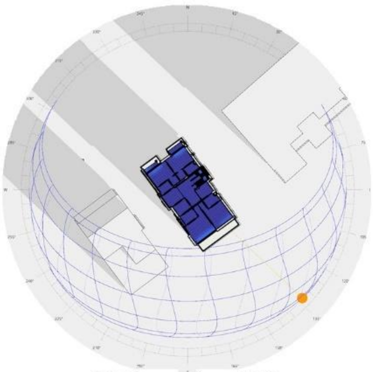
Case study 3 First floor 1:1000



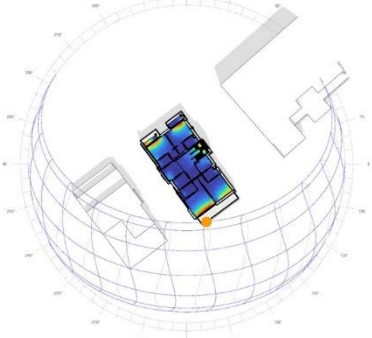
21 June 9:00
Azimuth angle 98.82°
Altitude angle 42.31°



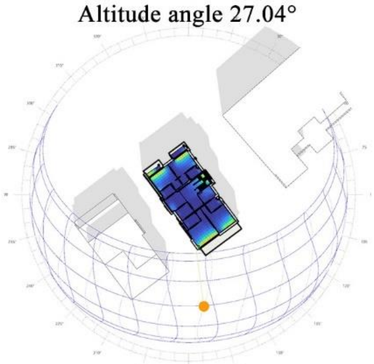
21 September 9:00
Azimuth angle 119.80°
Altitude angle 27.04°



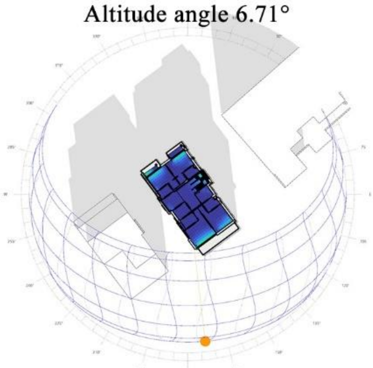
21 December 9:00
Azimuth angle 133.39°
Altitude angle 6.71°



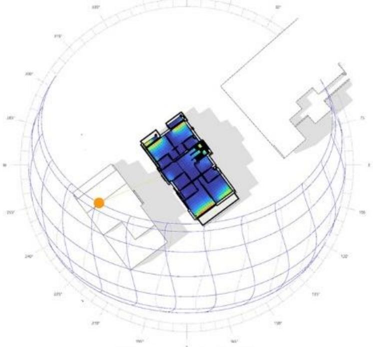
21 June 12:00
Azimuth angle 161.16°
Altitude angle 67.33°



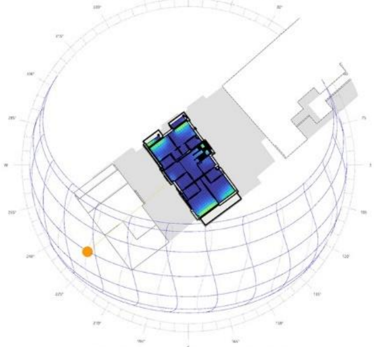
21 September 12:00
Azimuth angle 172.04°
Altitude angle 45.09°



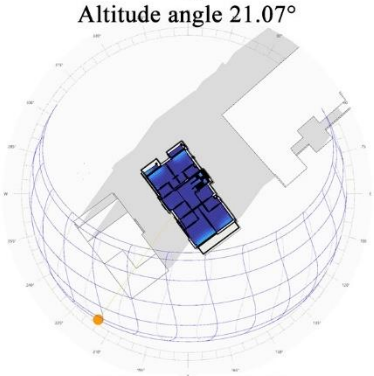
21 December 12:00
Azimuth angle 173.23°
Altitude angle 21.07°



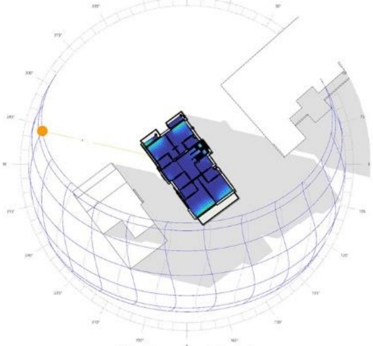
21 June 15:00
Azimuth angle 246.75°
Altitude angle 52.86°



21 September 15:00
Azimuth angle 229.51°
Altitude angle 33.42°

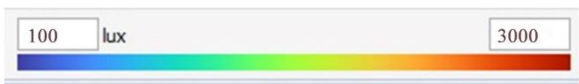


21 December 15:00
Azimuth angle 215.54°
Altitude angle 13.09°

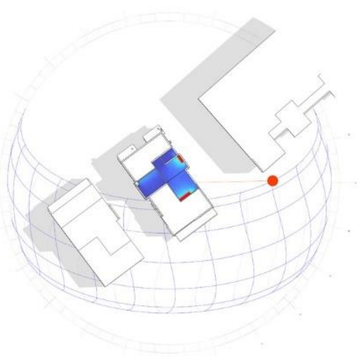


21 June 18:00
Azimuth angle 281.92°
Altitude angle 21.72°

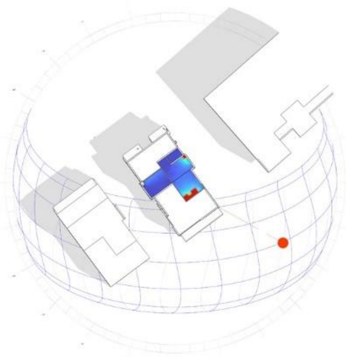
Location: Turin
Overcast sky
Ground albedo: 0.2
Glass type: Double glass
SHGC:0.31 TVIS:0.604 U-value:1.36



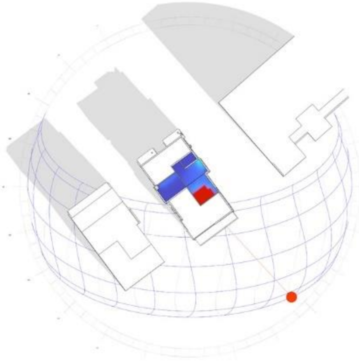
Case study 3 second floor 1:1000



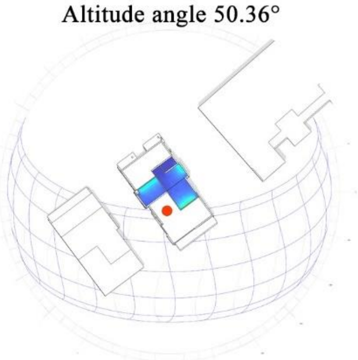
21 June 9:00
Azimuth angle 88.83°
Altitude angle 50.36°



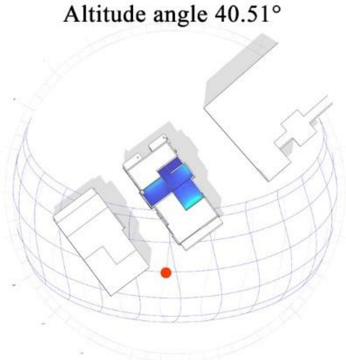
21 September 9:00
Azimuth angle 188.62°
Altitude angle 40.51°



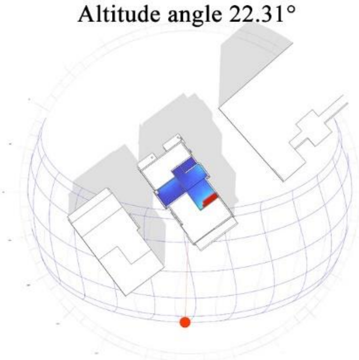
21 December 9:00
Azimuth angle 137.33°
Altitude angle 22.31°



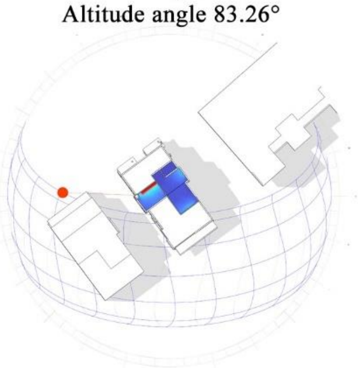
21 June 12:00
Azimuth angle 187.49°
Altitude angle 83.26°



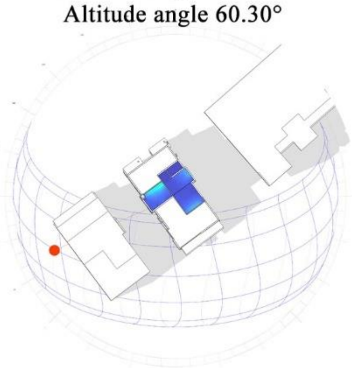
21 September 12:00
Azimuth angle 186.35°
Altitude angle 60.30°



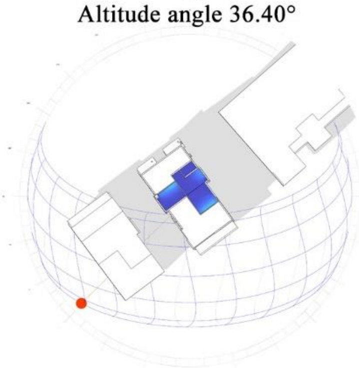
21 December 12:00
Azimuth angle 182.13°
Altitude angle 36.40°



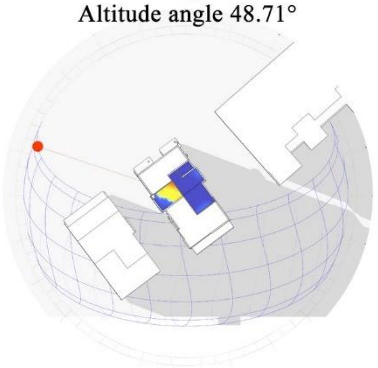
21 June 15:00
Azimuth angle 272.07°
Altitude angle 48.71°



21 September 15:00
Azimuth angle 246.31°
Altitude angle 35.57°

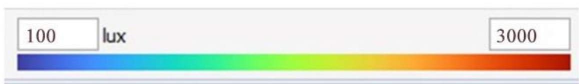


21 December 15:00
Azimuth angle 225.45°
Altitude angle 20.05°

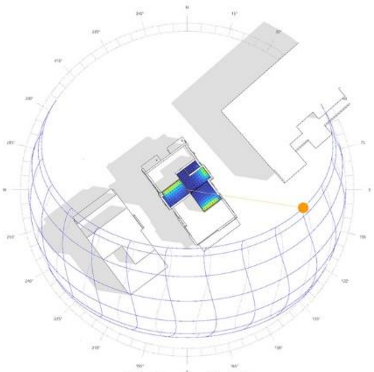


21 June 18:00
Azimuth angle 290.07°
Altitude angle 10.75°

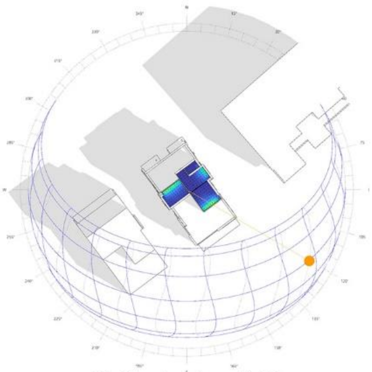
Location: Cairo
Clear sky Ground albedo: 0.2
Glass type: Double glass 6.4 mm Stainless Steel Cover 30%
SHGC:0.15 TVIS:0.27 U-value:2.66



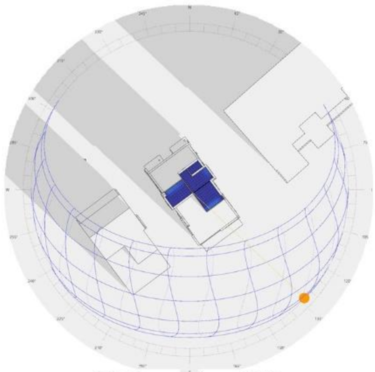
Case study 3 Second floor 1:1000



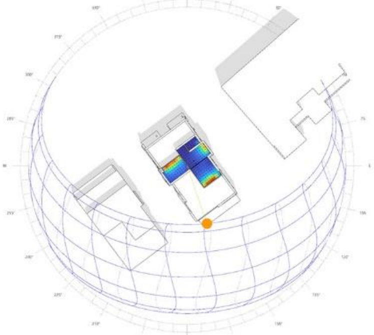
21 June 9:00
Azimuth angle 98.82°
Altitude angle 42.31°



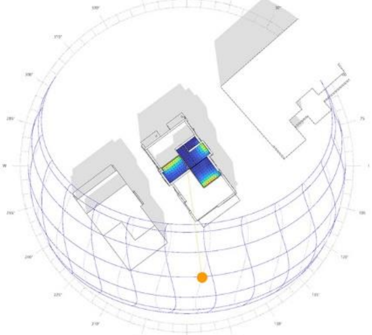
21 September 9:00
Azimuth angle 119.80°
Altitude angle 27.04°



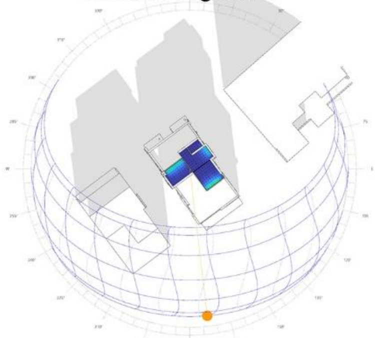
21 December 9:00
Azimuth angle 133.39°
Altitude angle 6.71°



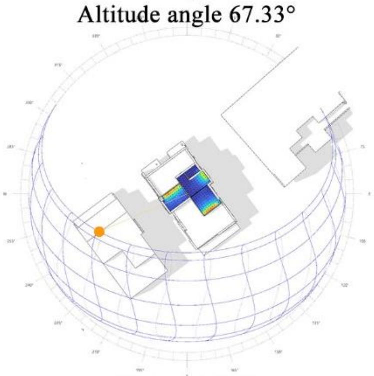
21 June 12:00
Azimuth angle 161.16°
Altitude angle 67.33°



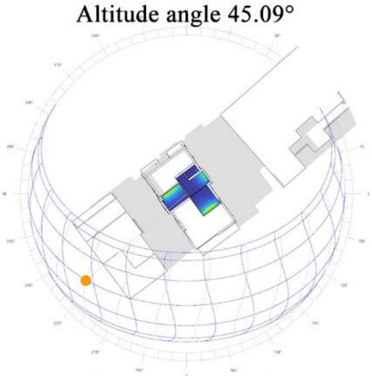
21 September 12:00
Azimuth angle 172.04°
Altitude angle 45.09°



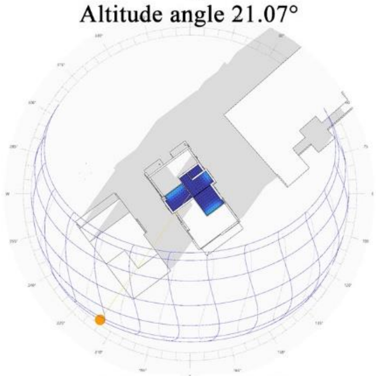
21 December 12:00
Azimuth angle 173.23°
Altitude angle 21.07°



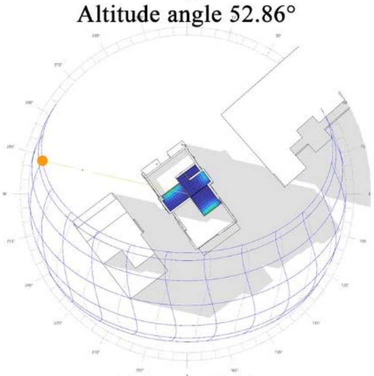
21 June 15:00
Azimuth angle 246.75°
Altitude angle 52.86°



21 September 15:00
Azimuth angle 229.51°
Altitude angle 33.42°



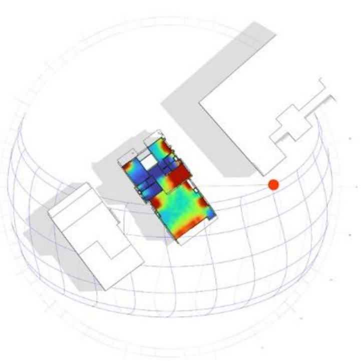
21 December 15:00
Azimuth angle 215.54°
Altitude angle 13.09°



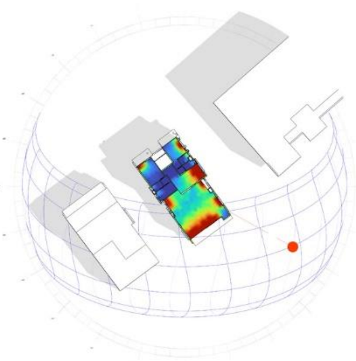
21 June 18:00
Azimuth angle 281.92°
Altitude angle 21.72°

Location: Turin
Overcast sky
Ground albedo: 0.2
Glass type: Double glass
SHGC:0.31 TVIS:0.604 U-value:1.36

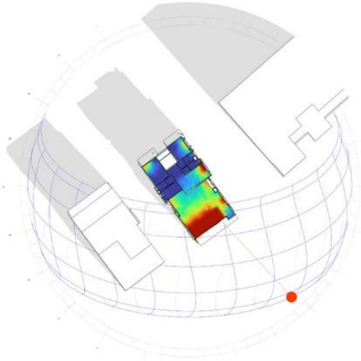
Case study 3 Ground floor 1:1000



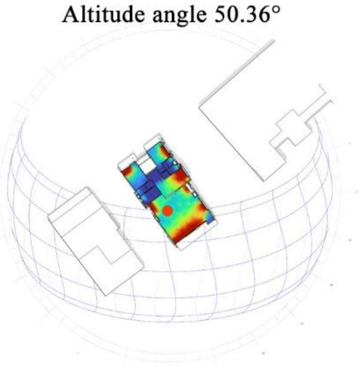
21 June 9:00
Azimuth angle 88.83°
Altitude angle 50.36°



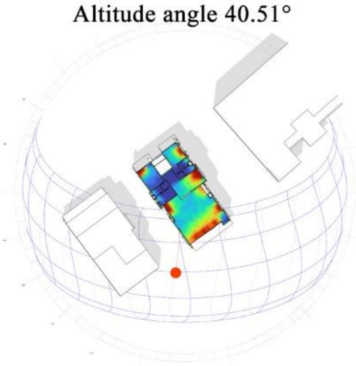
21 September 9:00
Azimuth angle 188.62°
Altitude angle 40.51°



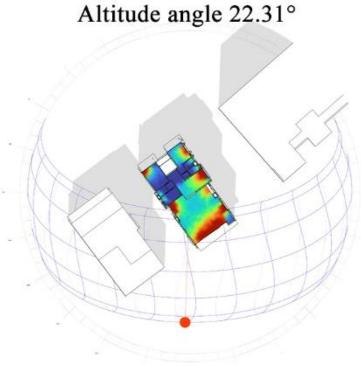
21 December 9:00
Azimuth angle 137.33°
Altitude angle 22.31°



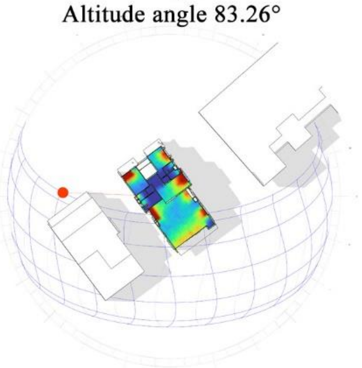
21 June 12:00
Azimuth angle 187.49°
Altitude angle 83.26°



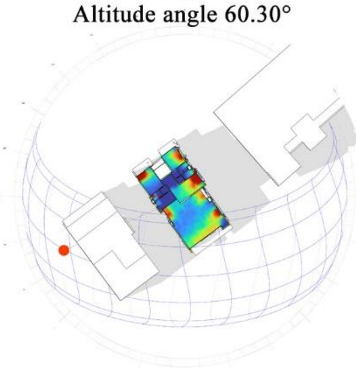
21 September 12:00
Azimuth angle 186.35°
Altitude angle 60.30°



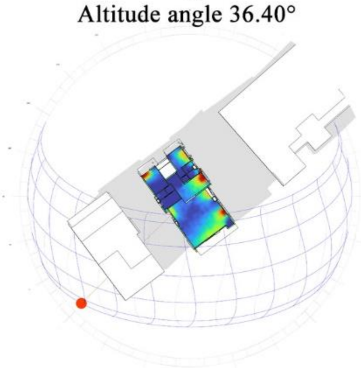
21 December 12:00
Azimuth angle 182.13°
Altitude angle 36.40°



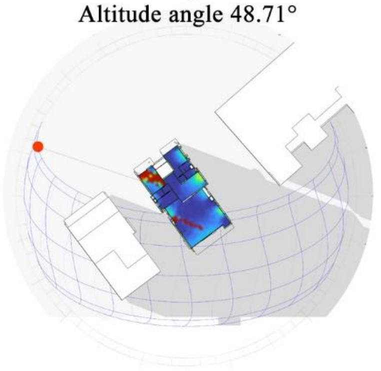
21 June 15:00
Azimuth angle 272.07°
Altitude angle 48.71°



21 September 15:00
Azimuth angle 246.31°
Altitude angle 35.57°



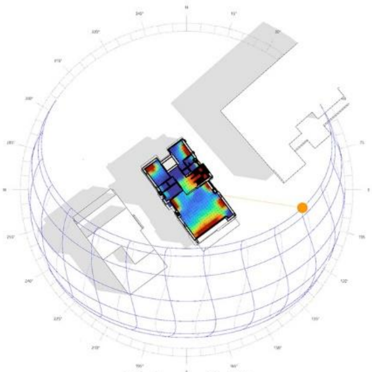
21 December 15:00
Azimuth angle 225.45°
Altitude angle 20.05°



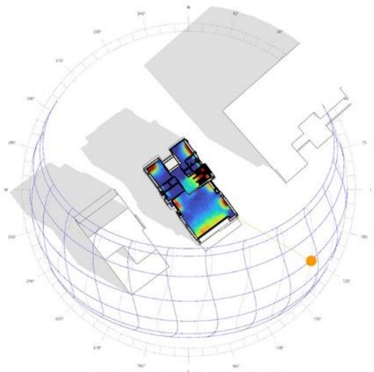
21 June 18:00
Azimuth angle 290.07°
Altitude angle 10.75°

Location: Cairo
Clear sky Ground albedo: 0.2
Glass type: Double glass 6.4 mm Stainless Steel Cover 30%
SHGC:0.15 TVIS:0.27 U-value:2.66

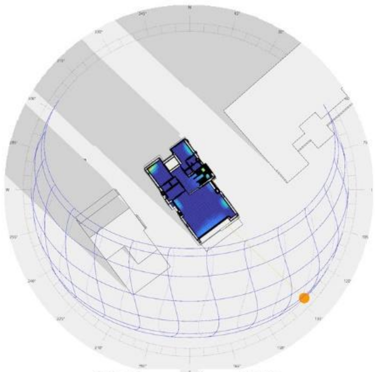
Case study 3 Ground floor 1:1000



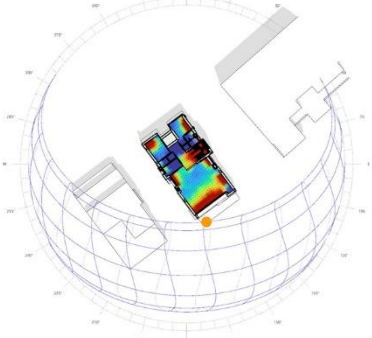
21 June 9:00
Azimuth angle 98.82°
Altitude angle 42.31°



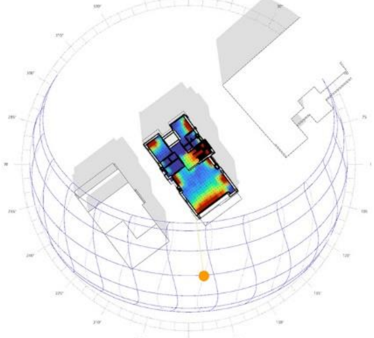
21 September 9:00
Azimuth angle 119.80°
Altitude angle 27.04°



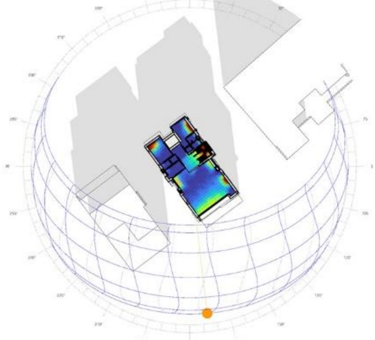
21 December 9:00
Azimuth angle 133.39°
Altitude angle 6.71°



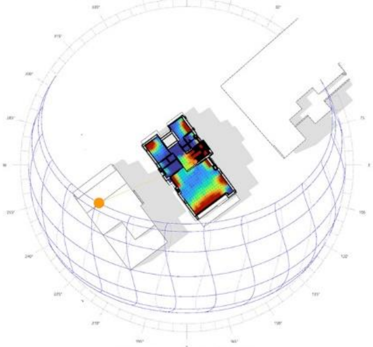
21 June 12:00
Azimuth angle 161.16°
Altitude angle 67.33°



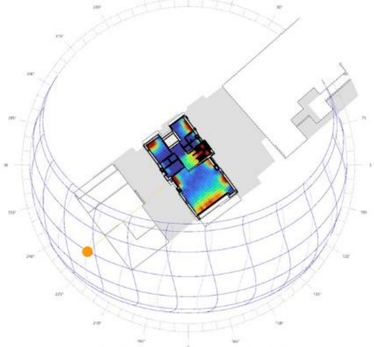
21 September 12:00
Azimuth angle 172.04°
Altitude angle 45.09°



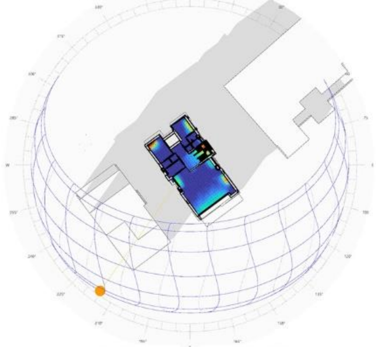
21 December 12:00
Azimuth angle 173.23°
Altitude angle 21.07°



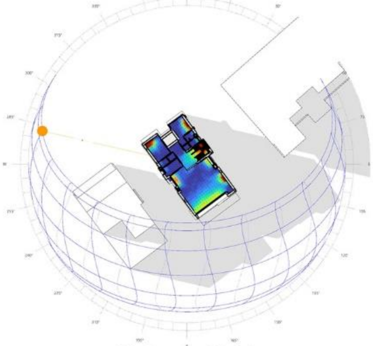
21 June 15:00
Azimuth angle 246.75°
Altitude angle 52.86°



21 September 15:00
Azimuth angle 229.51°
Altitude angle 33.42°

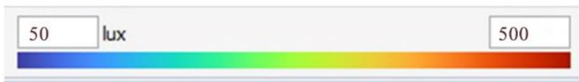


21 December 15:00
Azimuth angle 215.54°
Altitude angle 13.09°

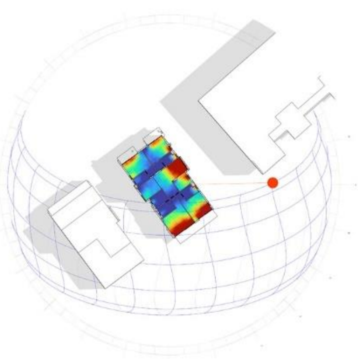


21 June 18:00
Azimuth angle 281.92°
Altitude angle 21.72°

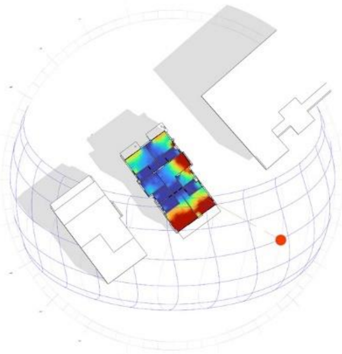
Location: Turin
Overcast sky
Ground albedo: 0.2
Glass type: Double glass
SHGC:0.31 TVIS:0.604 U-value:1.36



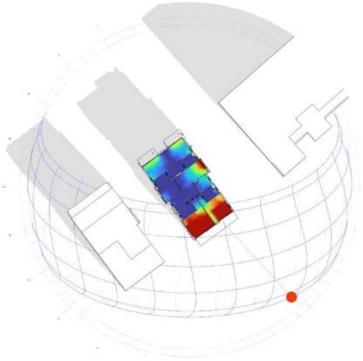
Case study 3 First floor1:1000



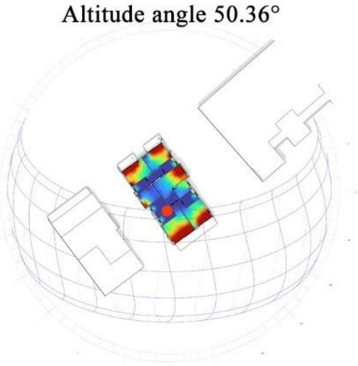
21 June 9:00
Azimuth angle 88.83°
Altitude angle 50.36°



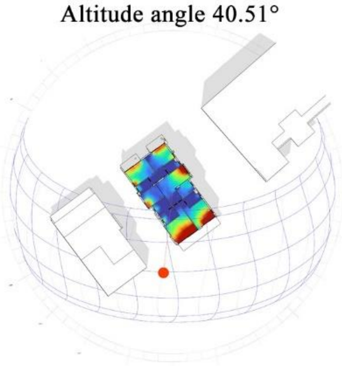
21 September 9:00
Azimuth angle 188.62°
Altitude angle 40.51°



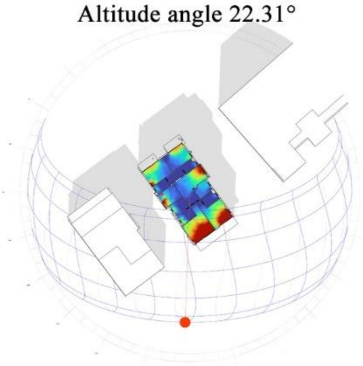
21 December 9:00
Azimuth angle 137.33°
Altitude angle 22.31°



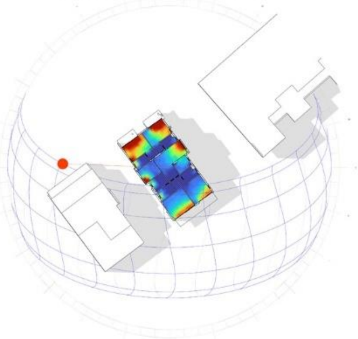
21 June 12:00
Azimuth angle 187.49°
Altitude angle 83.26°



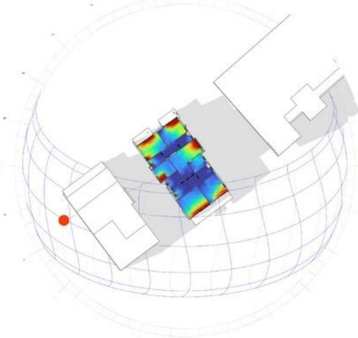
21 September 12:00
Azimuth angle 186.35°
Altitude angle 60.30°



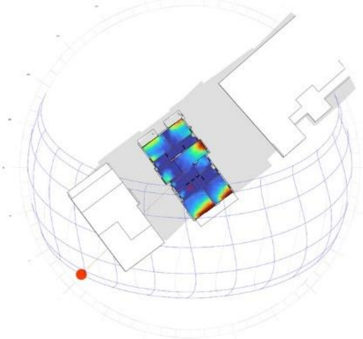
21 December 12:00
Azimuth angle 182.13°
Altitude angle 36.40°



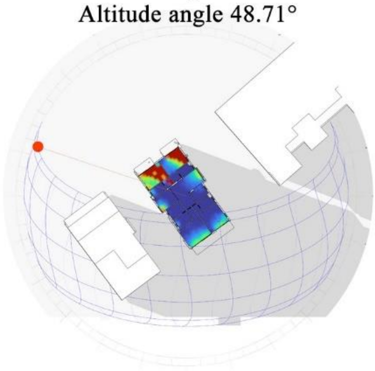
21 June 15:00
Azimuth angle 272.07°
Altitude angle 48.71°



21 September 15:00
Azimuth angle 246.31°
Altitude angle 35.57°

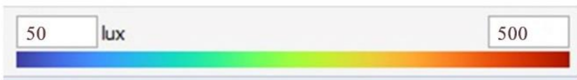


21 December 15:00
Azimuth angle 225.45°
Altitude angle 20.05°

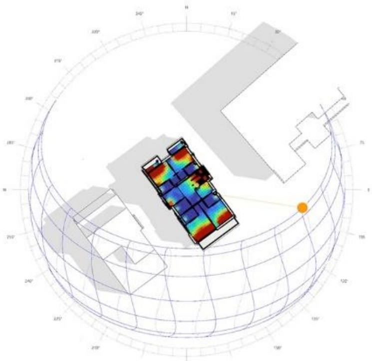


21 June 18:00
Azimuth angle 290.07°
Altitude angle 10.75°

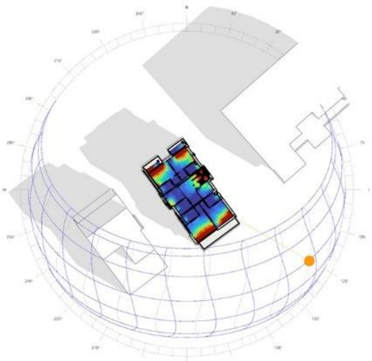
Location: Cairo
Clear sky
Ground albedo: 0.2
Glass type: Double glass 6.4 mm Stainless Steel Cover 30%
SHGC:0.15 TVIS:0.27 U-value:2.66



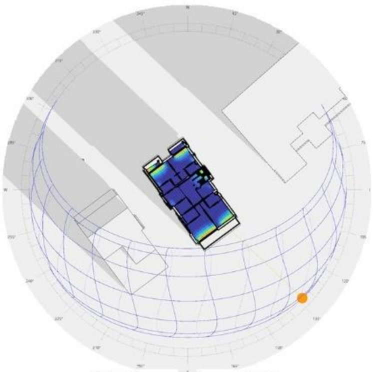
Case study 3 First floor 1:1000



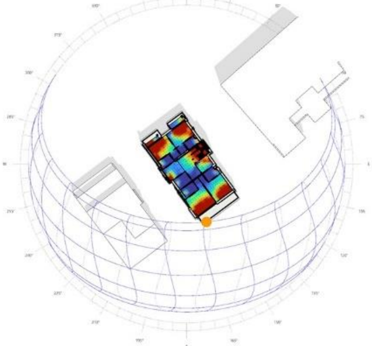
21 June 9:00
Azimuth angle 98.82°
Altitude angle 42.31°



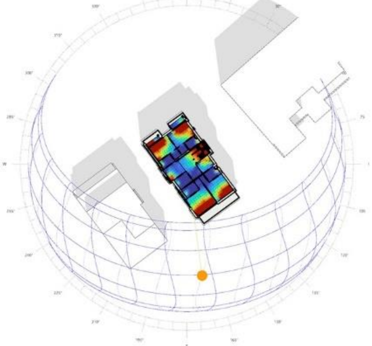
21 September 9:00
Azimuth angle 119.80°
Altitude angle 27.04°



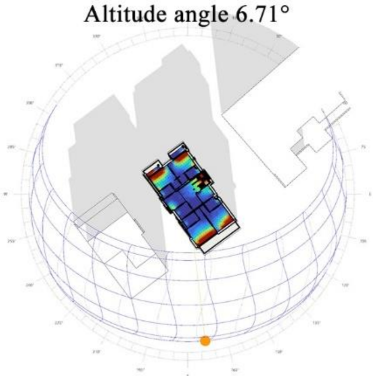
21 December 9:00
Azimuth angle 133.39°
Altitude angle 6.71°



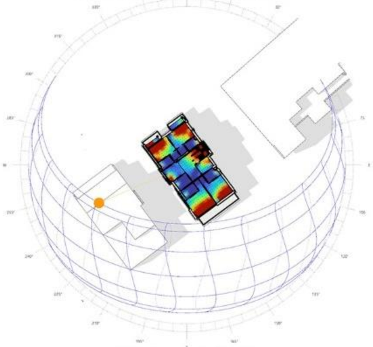
21 June 12:00
Azimuth angle 161.16°
Altitude angle 67.33°



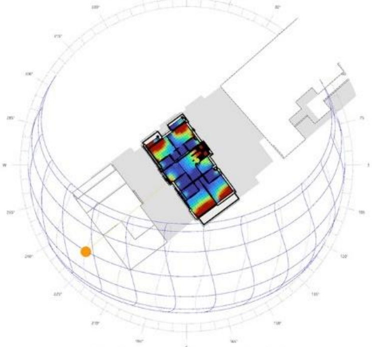
21 September 12:00
Azimuth angle 172.04°
Altitude angle 45.09°



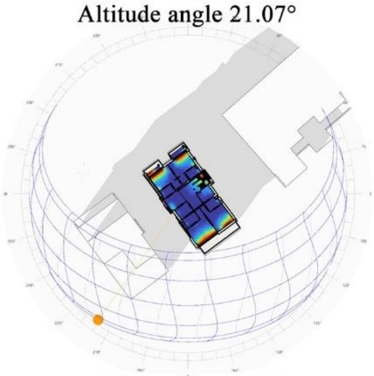
21 December 12:00
Azimuth angle 173.23°
Altitude angle 21.07°



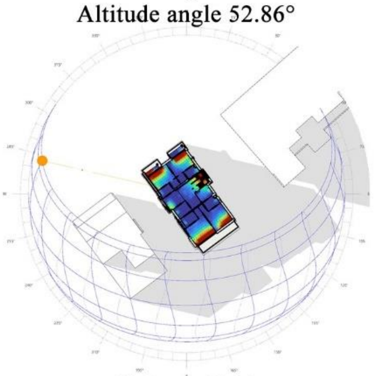
21 June 15:00
Azimuth angle 246.75°
Altitude angle 52.86°



21 September 15:00
Azimuth angle 229.51°
Altitude angle 33.42°



21 December 15:00
Azimuth angle 215.54°
Altitude angle 13.09°

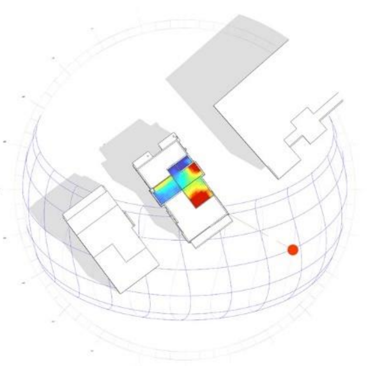


21 June 18:00
Azimuth angle 281.92°
Altitude angle 21.72°

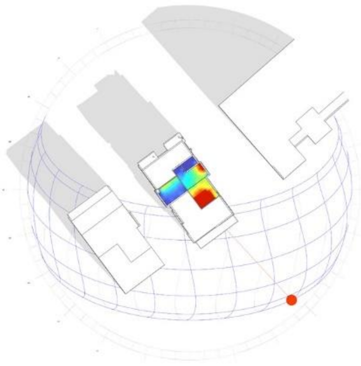
Location: Turin
Overcast sky
Ground albedo: 0.2
Glass type: Double glass
SHGC:0.31 TVIS:0.604 U-value:1.36

Case study 3 second floor 1:1000

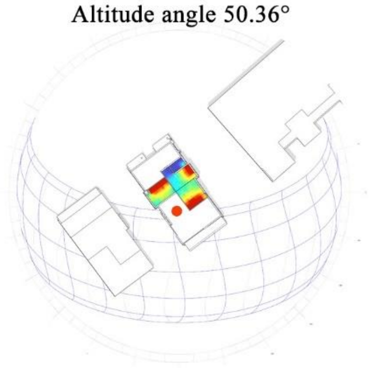
21 June 9:00
Azimuth angle 88.83°
Altitude angle 50.36°



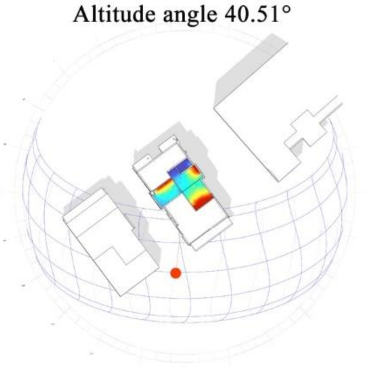
21 September 9:00
Azimuth angle 188.62°
Altitude angle 40.51°



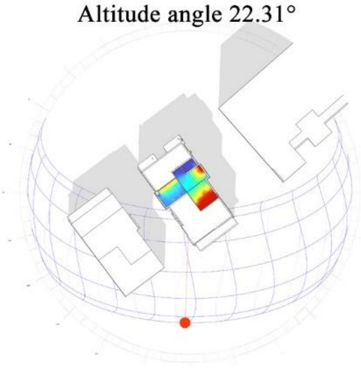
21 December 9:00
Azimuth angle 137.33°
Altitude angle 22.31°



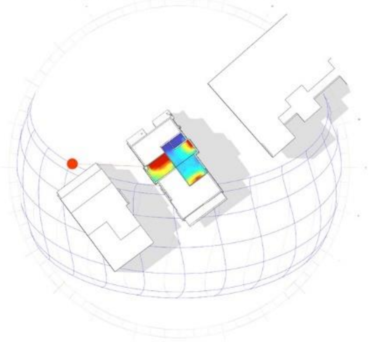
21 June 12:00
Azimuth angle 187.49°
Altitude angle 83.26°



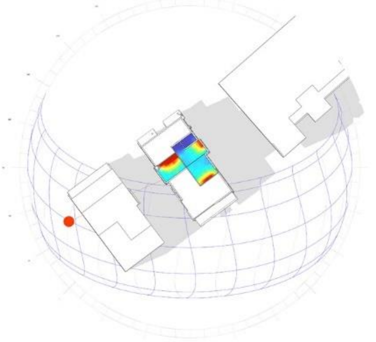
21 September 12:00
Azimuth angle 186.35°
Altitude angle 60.30°



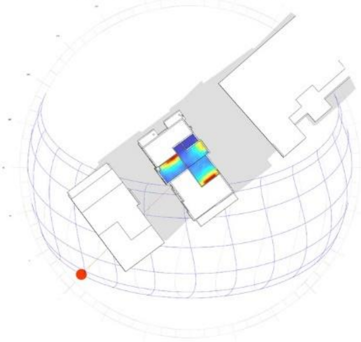
21 December 12:00
Azimuth angle 182.13°
Altitude angle 36.40°



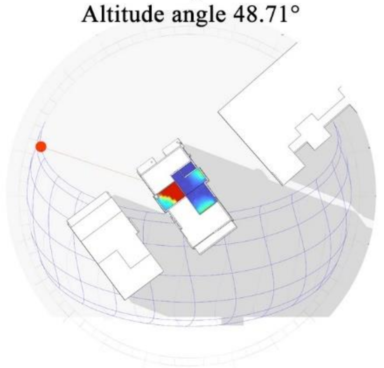
21 June 15:00
Azimuth angle 272.07°
Altitude angle 48.71°



21 September 15:00
Azimuth angle 246.31°
Altitude angle 35.57°

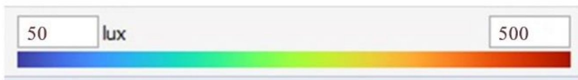


21 December 15:00
Azimuth angle 225.45°
Altitude angle 20.05°

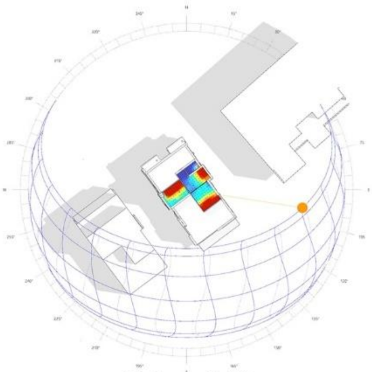


21 June 18:00
Azimuth angle 290.07°
Altitude angle 10.75°

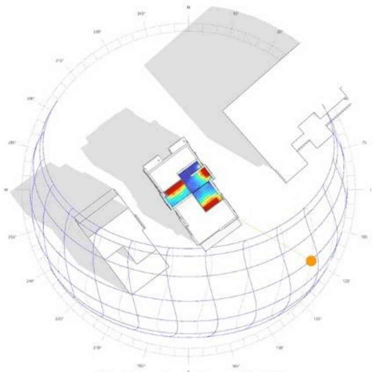
Location: Cairo
Clear sky   Ground albedo: 0.2
Glass type: Double glass 6.4 mm Stainless Steel Cover 30%
SHGC:0.15 TVIS:0.27 U-value:2.66



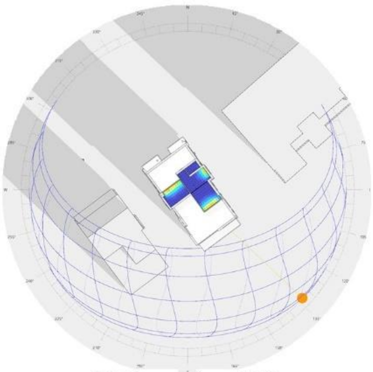
Case study 3 Second floor 1:1000



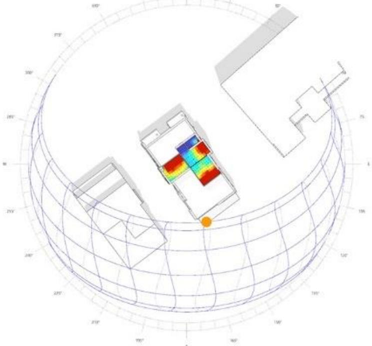
21 June 9:00
Azimuth angle 98.82°
Altitude angle 42.31°



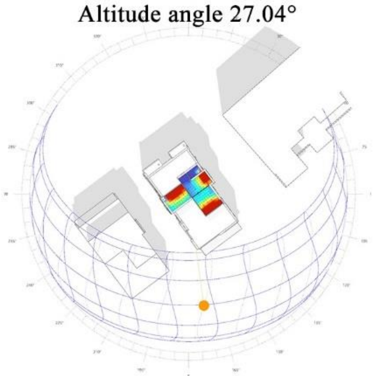
21 September 9:00
Azimuth angle 119.80°
Altitude angle 27.04°



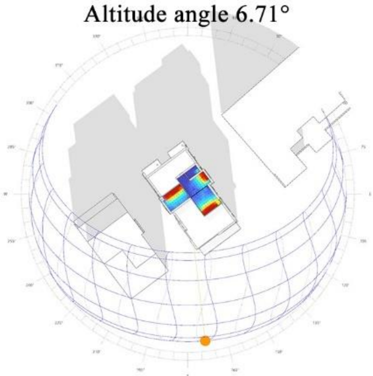
21 December 9:00
Azimuth angle 133.39°
Altitude angle 6.71°



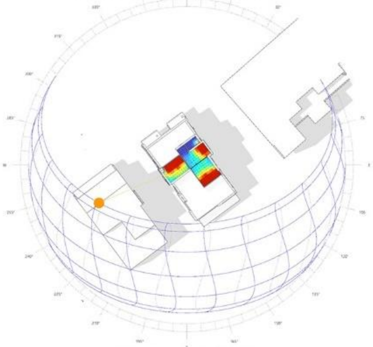
21 June 12:00
Azimuth angle 161.16°
Altitude angle 67.33°



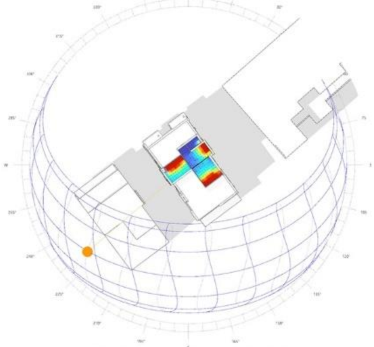
21 September 12:00
Azimuth angle 172.04°
Altitude angle 45.09°



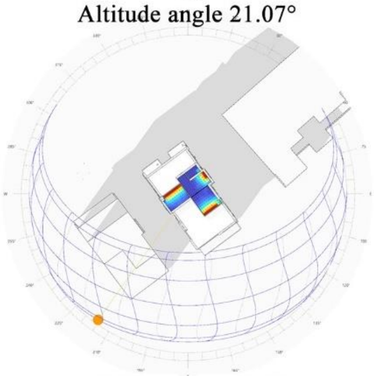
21 December 12:00
Azimuth angle 173.23°
Altitude angle 21.07°



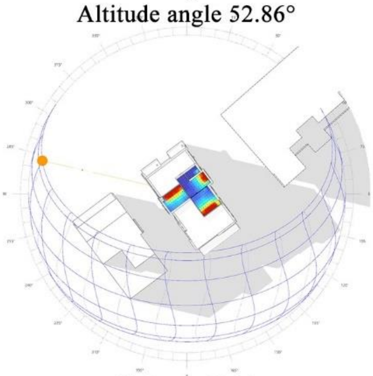
21 June 15:00
Azimuth angle 246.75°
Altitude angle 52.86°



21 September 15:00
Azimuth angle 229.51°
Altitude angle 33.42°



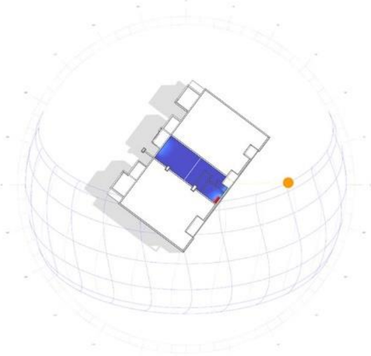
21 December 15:00
Azimuth angle 215.54°
Altitude angle 13.09°



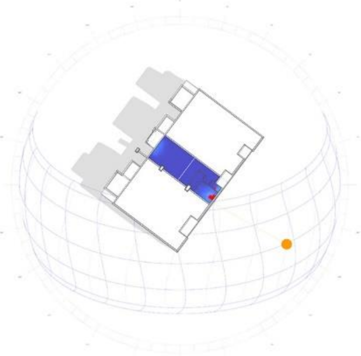
21 June 18:00
Azimuth angle 281.92°
Altitude angle 21.72°

Location: Turin
Overcast sky
Ground albedo: 0.2
Glass type: Double glass
SHGC:0.31 TVIS:0.604 U-value:1.36

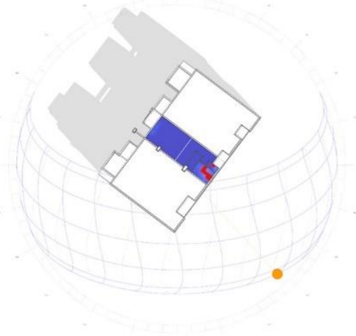
Case study 4 Ground floor 1:1000



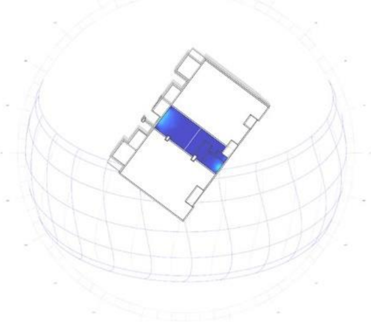
21 June 9:00
Azimuth angle 88.83°
Altitude angle 50.36°



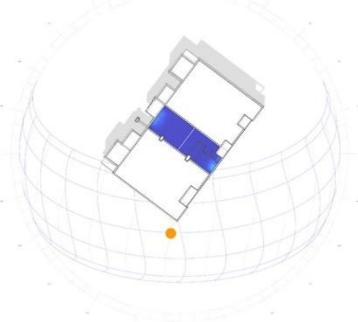
21 September 9:00
Azimuth angle 188.62°
Altitude angle 40.51°



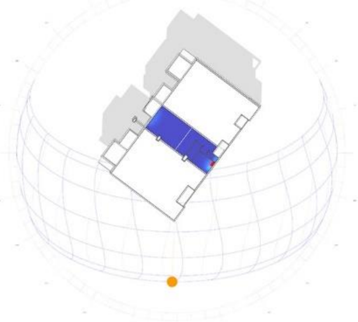
21 December 9:00
Azimuth angle 137.33°
Altitude angle 22.31°



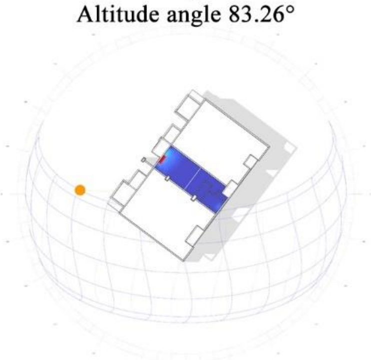
21 June 12:00
Azimuth angle 187.49°
Altitude angle 83.26°



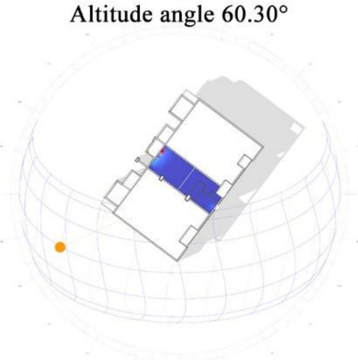
21 September 12:00
Azimuth angle 186.35°
Altitude angle 60.30°



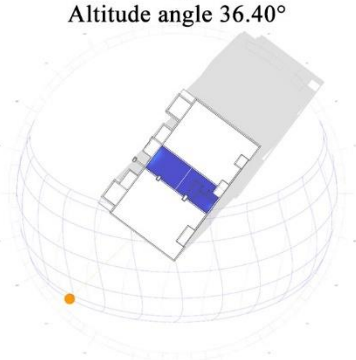
21 December 12:00
Azimuth angle 182.13°
Altitude angle 36.40°



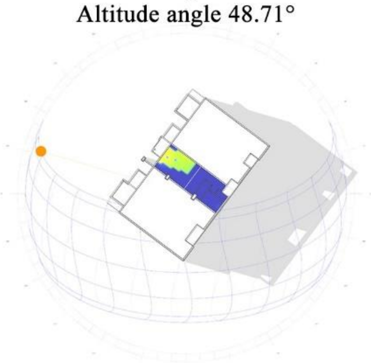
21 June 15:00
Azimuth angle 272.07°
Altitude angle 48.71°



21 September 15:00
Azimuth angle 246.31°
Altitude angle 35.57°



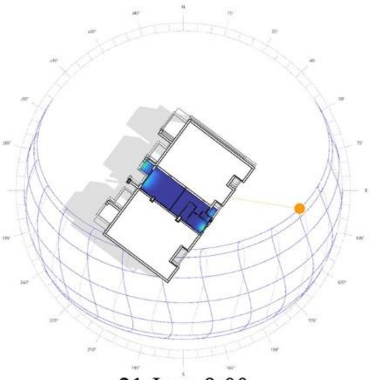
21 December 15:00
Azimuth angle 225.45°
Altitude angle 20.05°



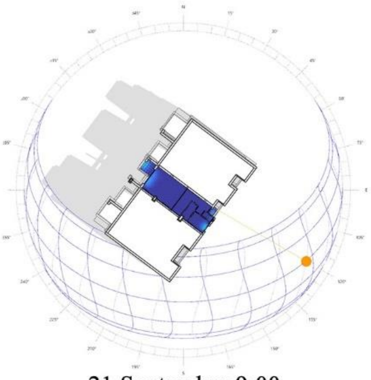
21 June 18:00
Azimuth angle 290.07°
Altitude angle 10.75°

Location: Cairo
Clear sky Ground albedo: 0.2
Glass type: Double glass 6.4 mm Stainless Steel Cover 30%
SHGC:0.15 TVIS:0.27 U-value:2.66

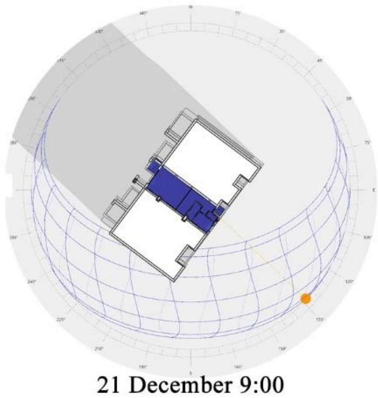
Case study 4 Ground floor 1:1000



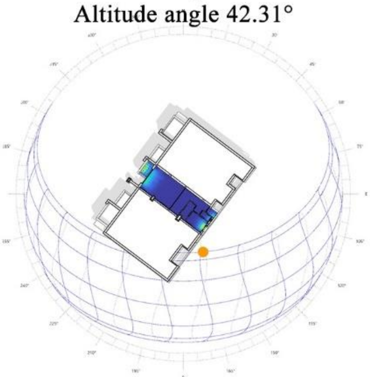
21 June 9:00
Azimuth angle 98.82°
Altitude angle 42.31°



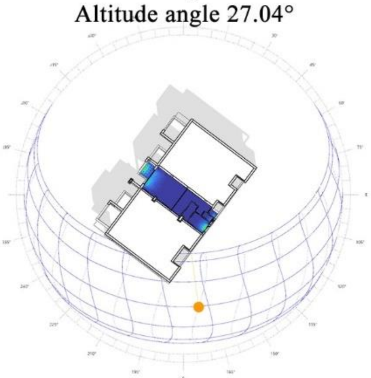
21 September 9:00
Azimuth angle 119.80°
Altitude angle 27.04°



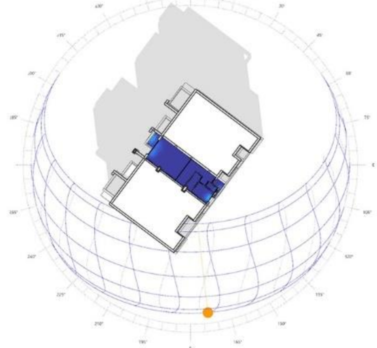
21 December 9:00
Azimuth angle 133.39°
Altitude angle 6.71°



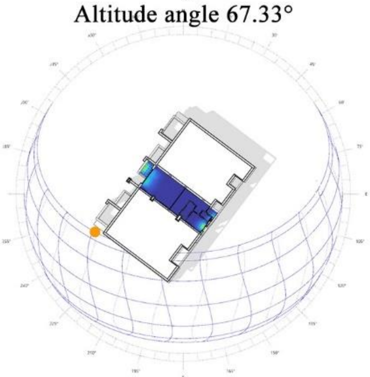
21 June 12:00
Azimuth angle 161.16°
Altitude angle 67.33°



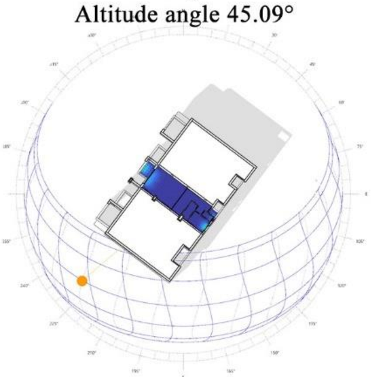
21 September 12:00
Azimuth angle 172.04°
Altitude angle 45.09°



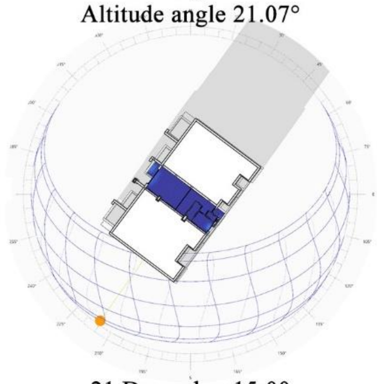
21 December 12:00
Azimuth angle 173.23°
Altitude angle 21.07°



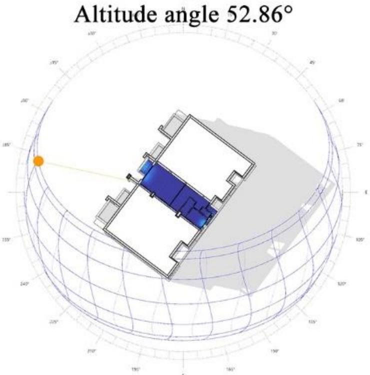
21 June 15:00
Azimuth angle 246.75°
Altitude angle 52.86°



21 September 15:00
Azimuth angle 229.51°
Altitude angle 33.42°



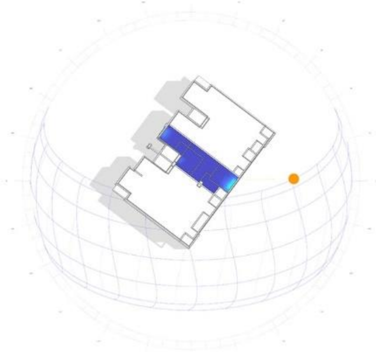
21 December 15:00
Azimuth angle 215.54°
Altitude angle 13.09°



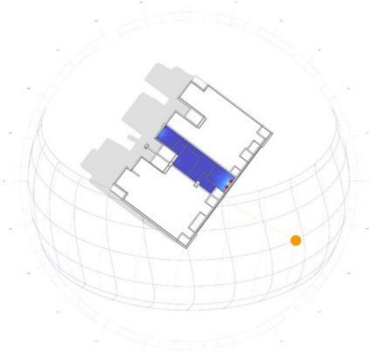
21 June 18:00
Azimuth angle 281.92°
Altitude angle 21.72°

Location: Turin
Overcast sky
Ground albedo: 0.2
Glass type: Double glass
SHGC:0.31 TVIS:0.604 U-value:1.36

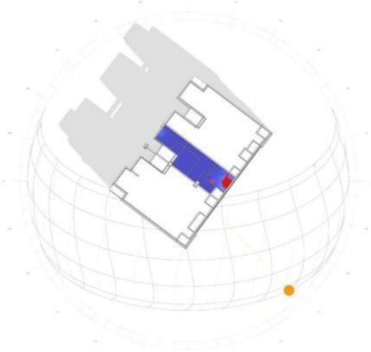
Case study 4 First floor 1:1000



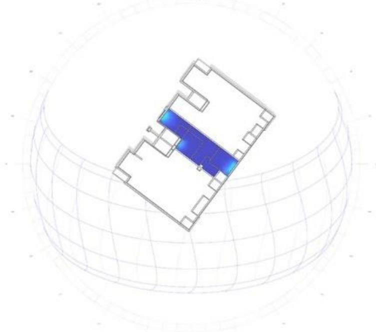
21 June 9:00
Azimuth angle 88.83°
Altitude angle 50.36°



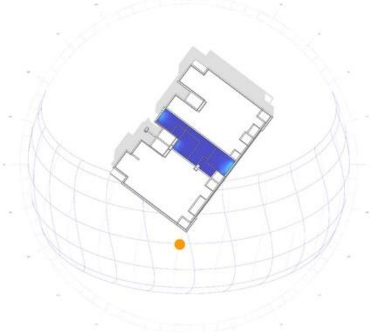
21 September 9:00
Azimuth angle 188.62°
Altitude angle 40.51°



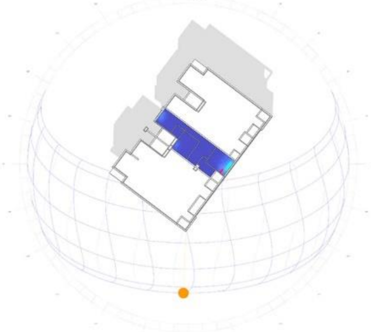
21 December 9:00
Azimuth angle 137.33°
Altitude angle 22.31°



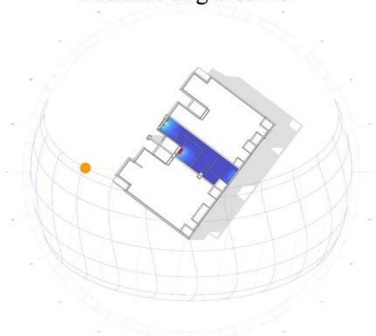
21 June 12:00
Azimuth angle 187.49°
Altitude angle 83.26°



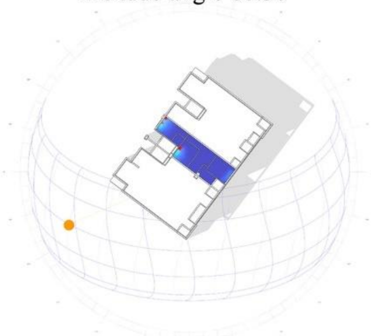
21 September 12:00
Azimuth angle 186.35°
Altitude angle 60.30°



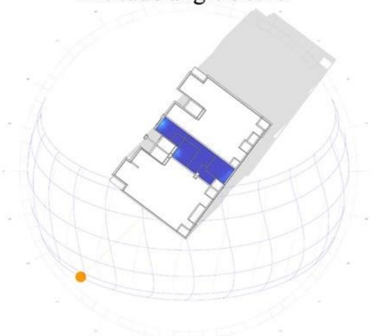
21 December 12:00
Azimuth angle 182.13°
Altitude angle 36.40°



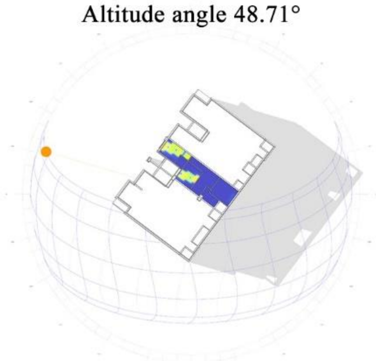
21 June 15:00
Azimuth angle 272.07°
Altitude angle 48.71°



21 September 15:00
Azimuth angle 246.31°
Altitude angle 35.57°



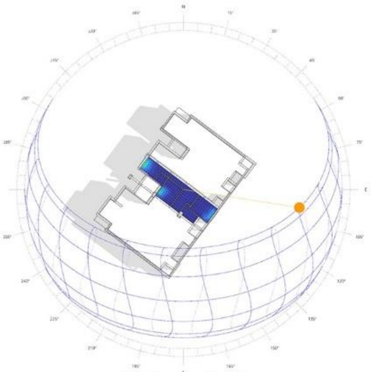
21 December 15:00
Azimuth angle 225.45°
Altitude angle 20.05°



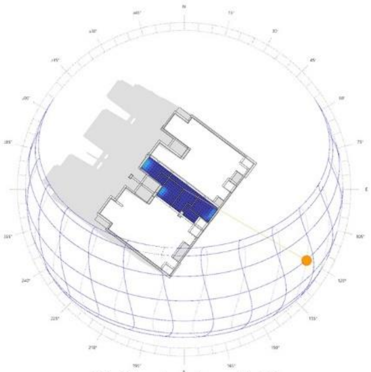
21 June 18:00
Azimuth angle 290.07°
Altitude angle 10.75°

Location: Cairo
Clear sky Ground albedo: 0.2
Glass type: Double glass 6.4 mm Stainless Steel Cover 30%
SHGC:0.15 TVIS:0.27 U-value:2.66

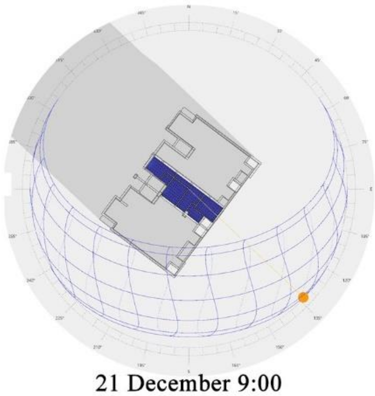
Case study 4 First floor 1:1000



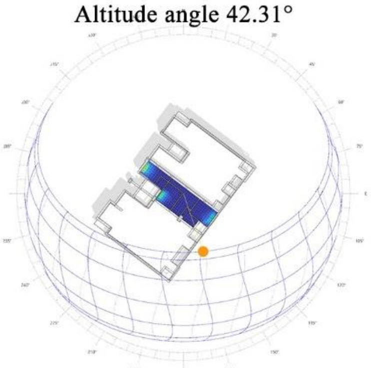
21 June 9:00
Azimuth angle 98.82°
Altitude angle 42.31°



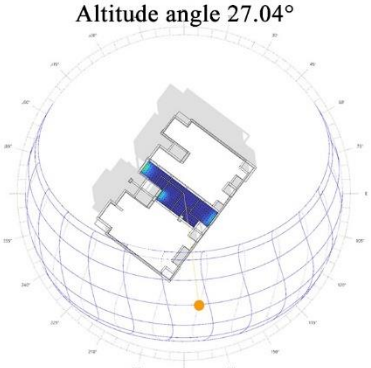
21 September 9:00
Azimuth angle 119.80°
Altitude angle 27.04°



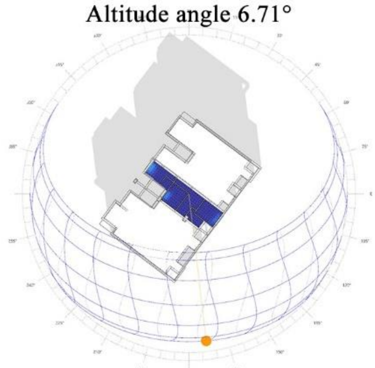
21 December 9:00
Azimuth angle 133.39°
Altitude angle 6.71°



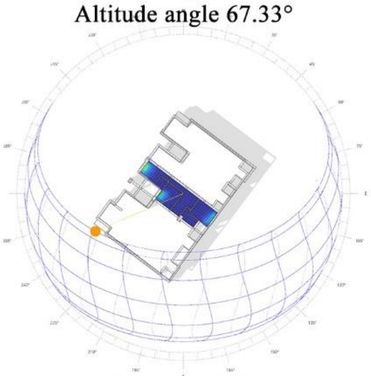
21 June 12:00
Azimuth angle 161.16°
Altitude angle 67.33°



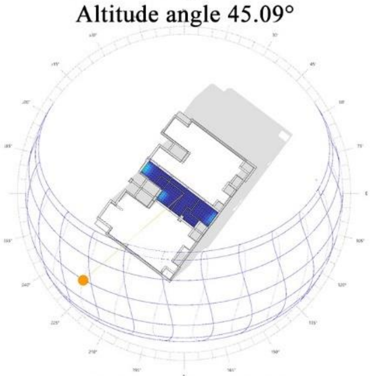
21 September 12:00
Azimuth angle 172.04°
Altitude angle 45.09°



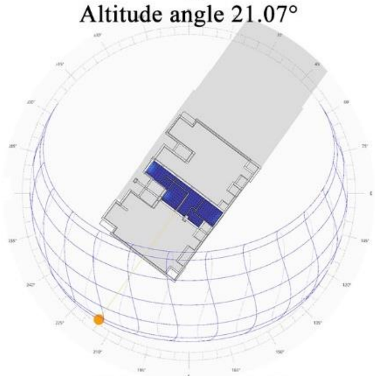
21 December 12:00
Azimuth angle 173.23°
Altitude angle 21.07°



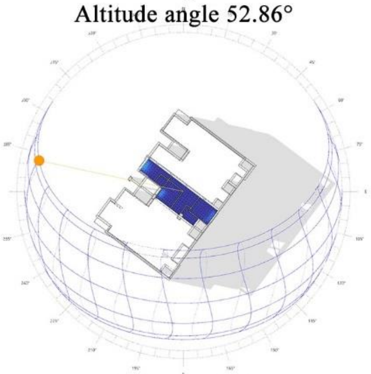
21 June 15:00
Azimuth angle 246.75°
Altitude angle 52.86°



21 September 15:00
Azimuth angle 229.51°
Altitude angle 33.42°



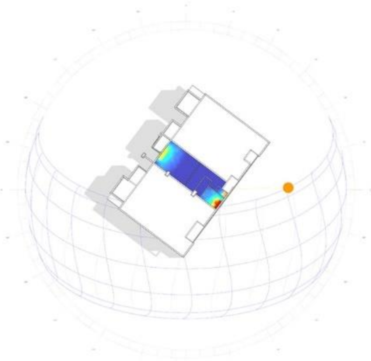
21 December 15:00
Azimuth angle 215.54°
Altitude angle 13.09°



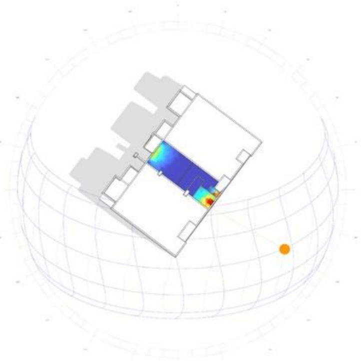
21 June 18:00
Azimuth angle 281.92°
Altitude angle 21.72°

Location: Turin
Overcast sky
Ground albedo: 0.2
Glass type: Double glass
SHGC:0.31 TVIS:0.604 U-value:1.36

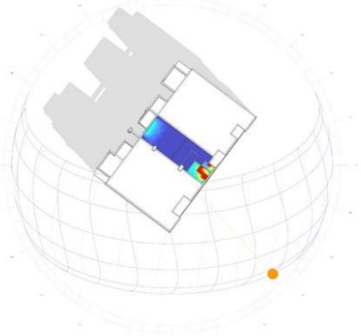
Case study 4 Ground floor 1:1000



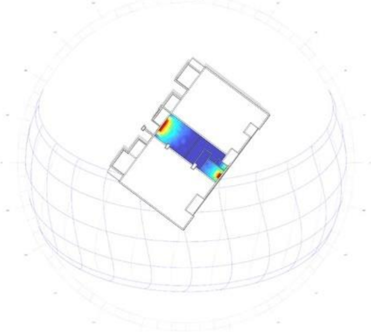
21 June 9:00
Azimuth angle 88.83°
Altitude angle 50.36°



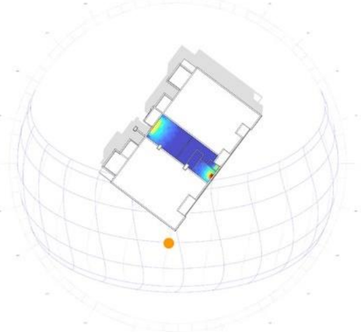
21 September 9:00
Azimuth angle 188.62°
Altitude angle 40.51°



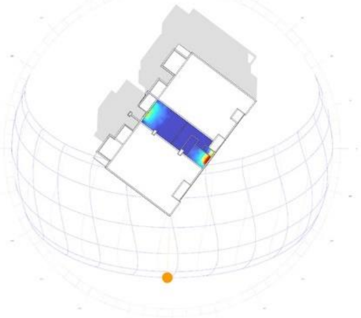
21 December 9:00
Azimuth angle 137.33°
Altitude angle 22.31°



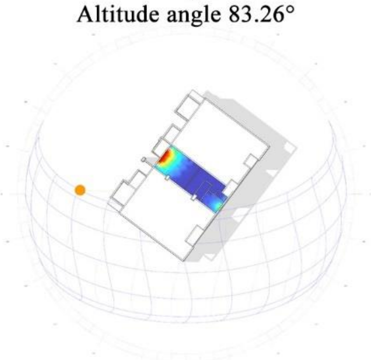
21 June 12:00
Azimuth angle 187.49°
Altitude angle 83.26°



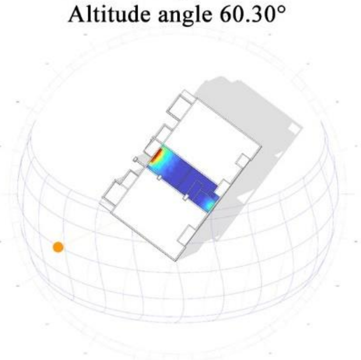
21 September 12:00
Azimuth angle 186.35°
Altitude angle 60.30°



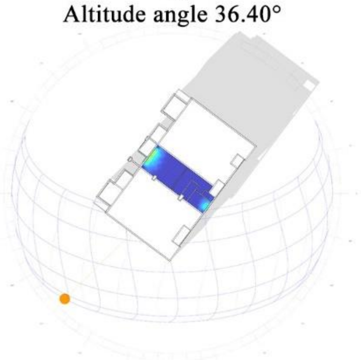
21 December 12:00
Azimuth angle 182.13°
Altitude angle 36.40°



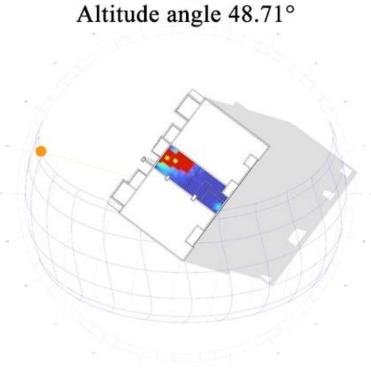
21 June 15:00
Azimuth angle 272.07°
Altitude angle 48.71°



21 September 15:00
Azimuth angle 246.31°
Altitude angle 35.57°

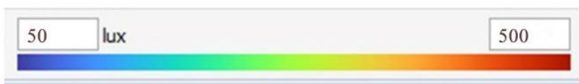


21 December 15:00
Azimuth angle 225.45°
Altitude angle 20.05°

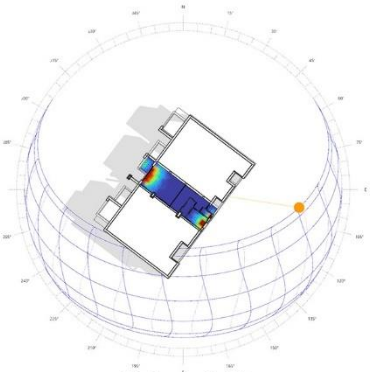


21 June 18:00
Azimuth angle 290.07°
Altitude angle 10.75°

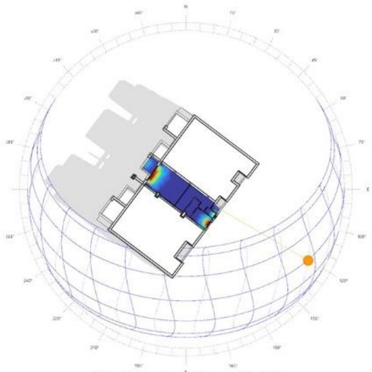
Location: Cairo
Clear sky   Ground albedo: 0.2
Glass type: Double glass 6.4 mm Stainless Steel Cover 30%
SHGC:0.15 TVIS:0.27 U-value:2.66



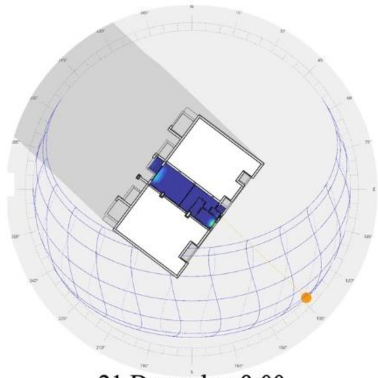
Case study 4 Ground floor 1:1000



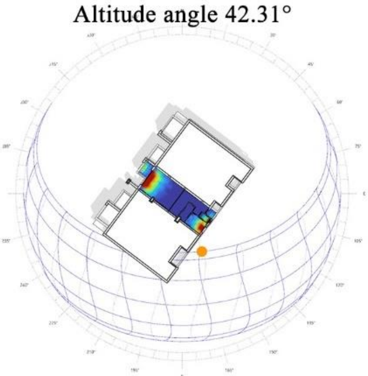
21 June 9:00
Azimuth angle 98.82°
Altitude angle 42.31°



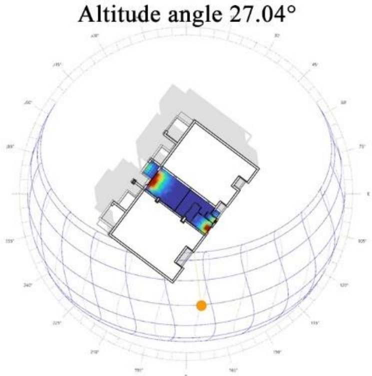
21 September 9:00
Azimuth angle 119.80°
Altitude angle 27.04°



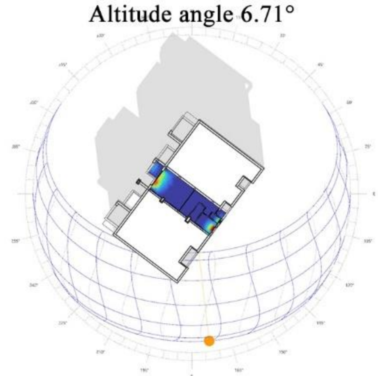
21 December 9:00
Azimuth angle 133.39°
Altitude angle 6.71°



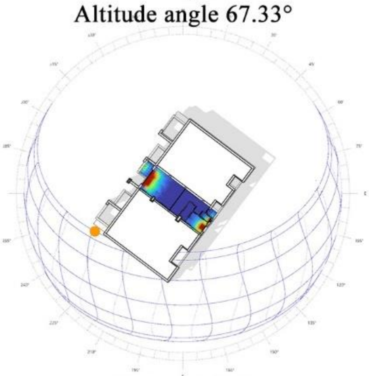
21 June 12:00
Azimuth angle 161.16°
Altitude angle 67.33°



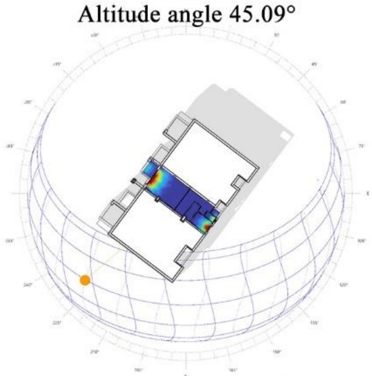
21 September 12:00
Azimuth angle 172.04°
Altitude angle 45.09°



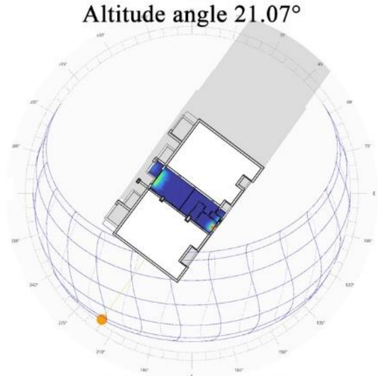
21 December 12:00
Azimuth angle 173.23°
Altitude angle 21.07°



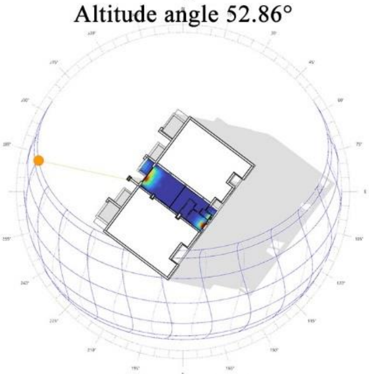
21 June 15:00
Azimuth angle 246.75°
Altitude angle 52.86°



21 September 15:00
Azimuth angle 229.51°
Altitude angle 33.42°



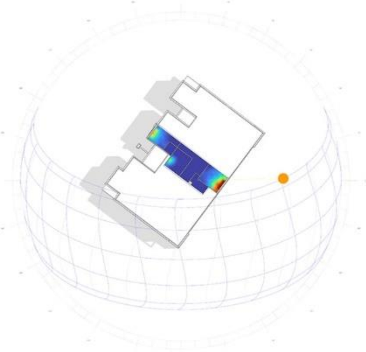
21 December 15:00
Azimuth angle 215.54°
Altitude angle 13.09°



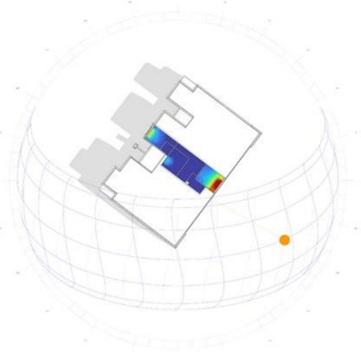
21 June 18:00
Azimuth angle 281.92°
Altitude angle 21.72°

Location: Turin
Overcast sky
Ground albedo: 0.2
Glass type: Double glass
SHGC:0.31 TVIS:0.604 U-value:1.36

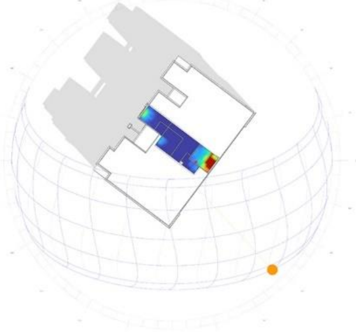
Case study 4 First floor 1:1000



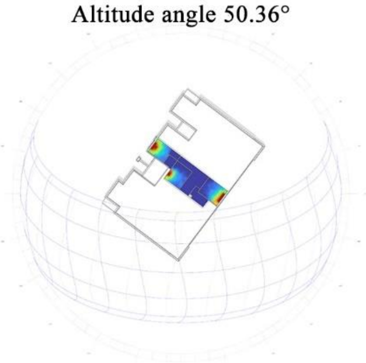
21 June 9:00
Azimuth angle 88.83°
Altitude angle 50.36°



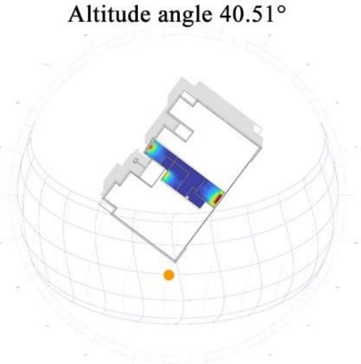
21 September 9:00
Azimuth angle 188.62°
Altitude angle 40.51°



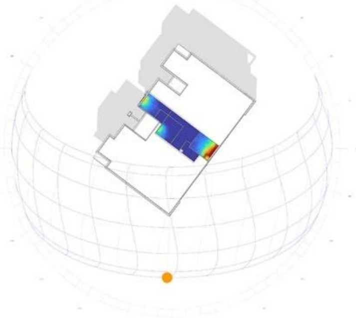
21 December 9:00
Azimuth angle 137.33°
Altitude angle 22.31°



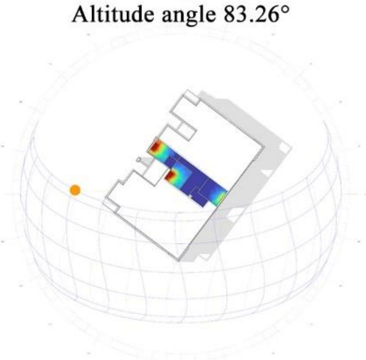
21 June 12:00
Azimuth angle 187.49°
Altitude angle 83.26°



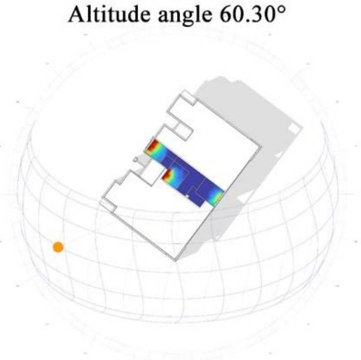
21 September 12:00
Azimuth angle 186.35°
Altitude angle 60.30°



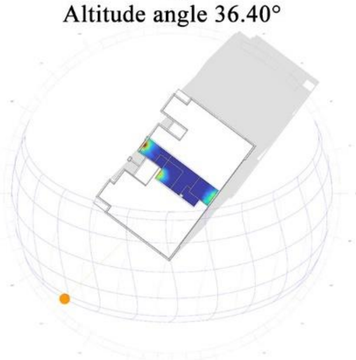
21 December 12:00
Azimuth angle 182.13°
Altitude angle 36.40°



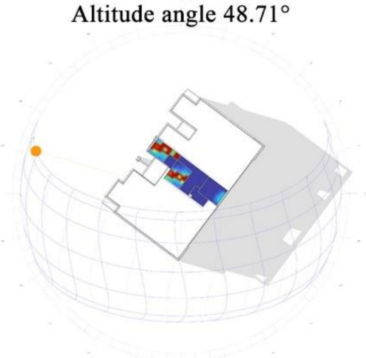
21 June 15:00
Azimuth angle 272.07°
Altitude angle 48.71°



21 September 15:00
Azimuth angle 246.31°
Altitude angle 35.57°

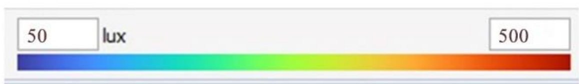


21 December 15:00
Azimuth angle 225.45°
Altitude angle 20.05°

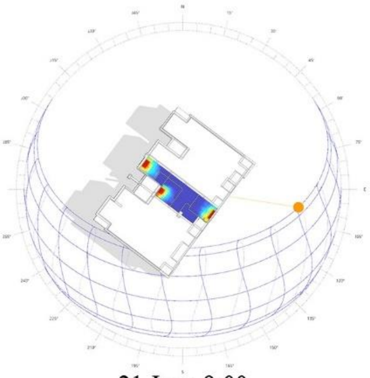


21 June 18:00
Azimuth angle 290.07°
Altitude angle 10.75°

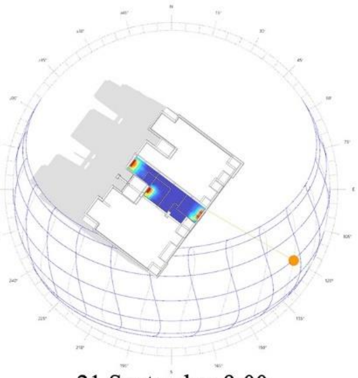
Location: Cairo
Clear sky Ground albedo: 0.2
Glass type: Double glass 6.4 mm Stainless Steel Cover 30%
SHGC:0.15 TVIS:0.27 U-value:2.66



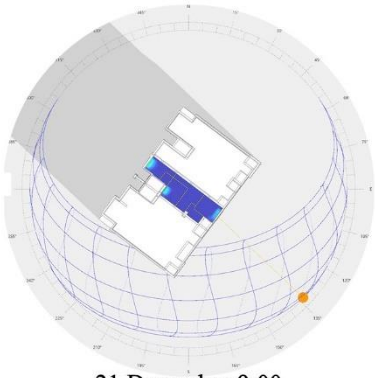
Case study 4 First floor 1:1000



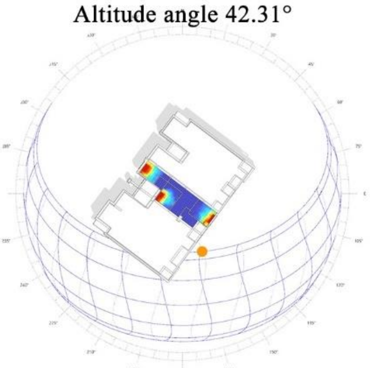
21 June 9:00
Azimuth angle 98.82°
Altitude angle 42.31°



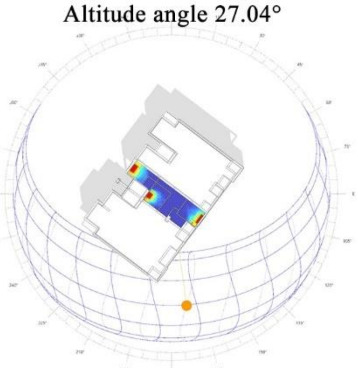
21 September 9:00
Azimuth angle 119.80°
Altitude angle 27.04°



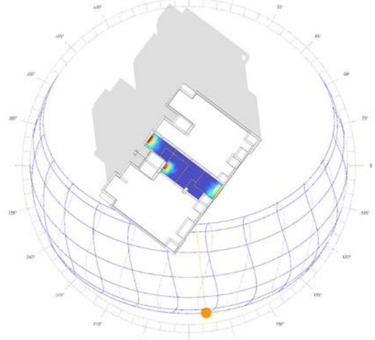
21 December 9:00
Azimuth angle 133.39°
Altitude angle 6.71°



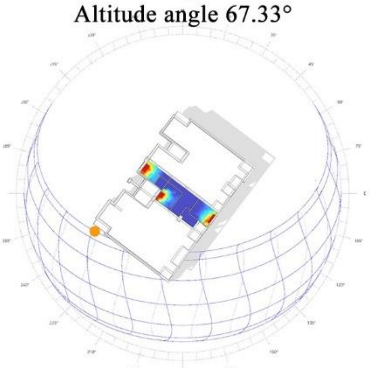
21 June 12:00
Azimuth angle 161.16°
Altitude angle 67.33°



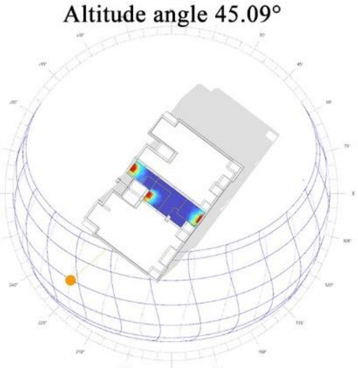
21 September 12:00
Azimuth angle 172.04°
Altitude angle 45.09°



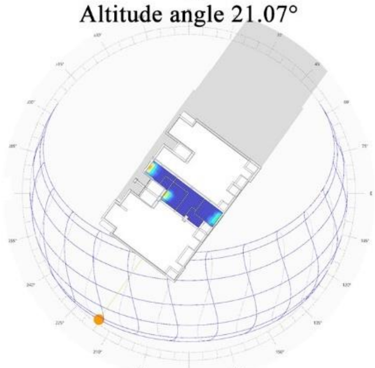
21 December 12:00
Azimuth angle 173.23°
Altitude angle 21.07°



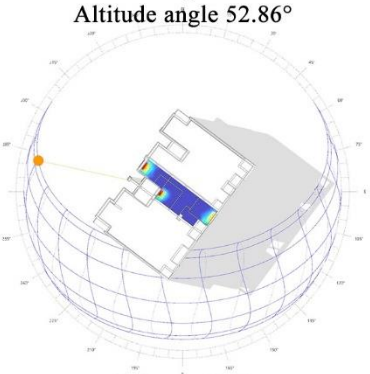
21 June 15:00
Azimuth angle 246.75°
Altitude angle 52.86°



21 September 15:00
Azimuth angle 229.51°
Altitude angle 33.42°

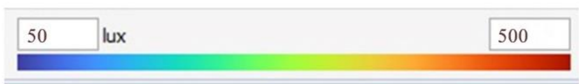


21 December 15:00
Azimuth angle 215.54°
Altitude angle 13.09°

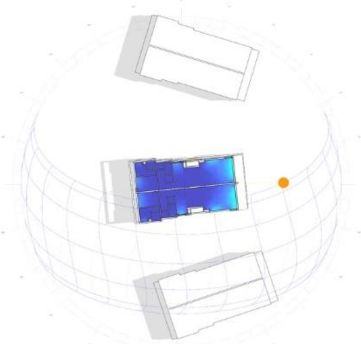


21 June 18:00
Azimuth angle 281.92°
Altitude angle 21.72°

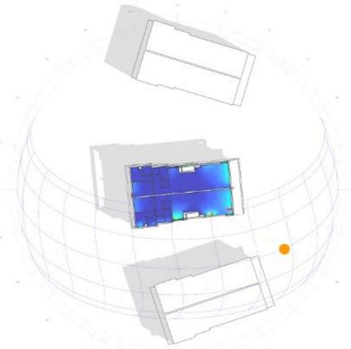
Location: Turin
Overcast sky
Ground albedo: 0.2
Glass type: Double glass
SHGC:0.31 TVIS:0.604 U-value:1.36



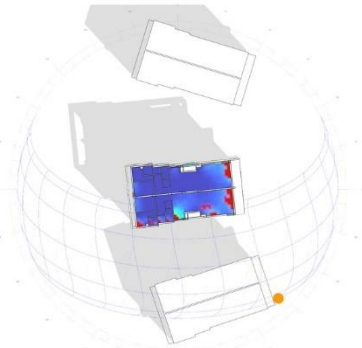
Case study 5 Ground floor 1:1000



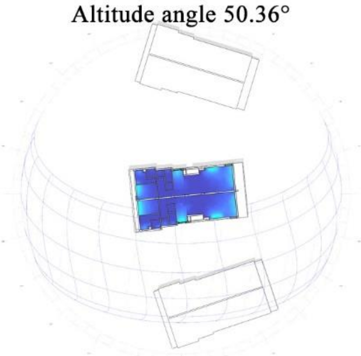
21 June 9:00
Azimuth angle 88.83°
Altitude angle 50.36°



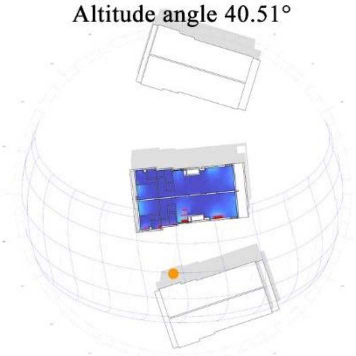
21 September 9:00
Azimuth angle 188.62°
Altitude angle 40.51°



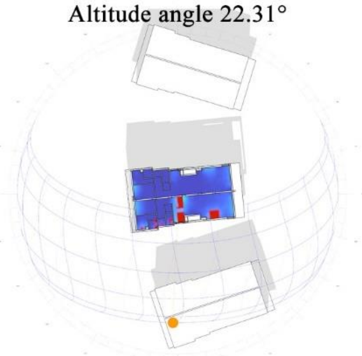
21 December 9:00
Azimuth angle 137.33°
Altitude angle 22.31°



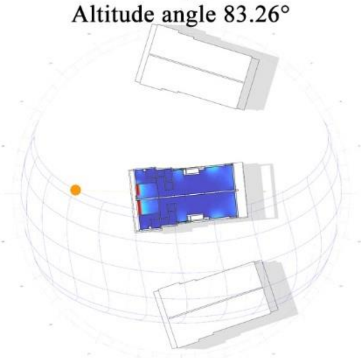
21 June 12:00
Azimuth angle 187.49°
Altitude angle 83.26°



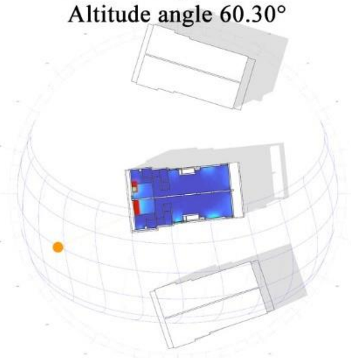
21 September 12:00
Azimuth angle 186.35°
Altitude angle 60.30°



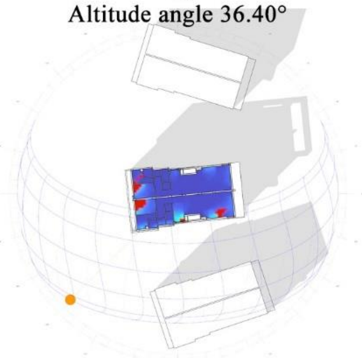
21 December 12:00
Azimuth angle 182.13°
Altitude angle 36.40°



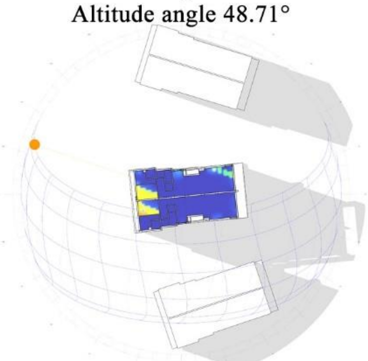
21 June 15:00
Azimuth angle 272.07°
Altitude angle 48.71°



21 September 15:00
Azimuth angle 246.31°
Altitude angle 35.57°



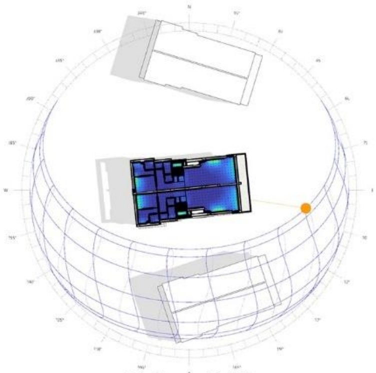
21 December 15:00
Azimuth angle 225.45°
Altitude angle 20.05°



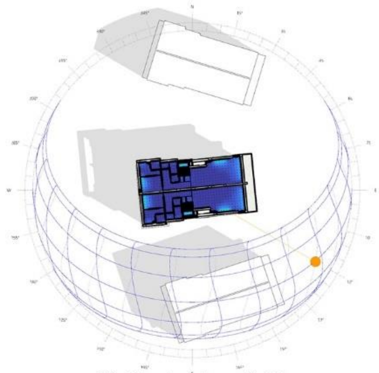
21 June 18:00
Azimuth angle 290.07°
Altitude angle 10.75°

Location: Cairo
Clear sky Ground albedo: 0.2
Glass type: Double glass 6.4 mm Stainless Steel Cover 30%
SHGC:0.15 TVIS:0.27 U-value:2.66

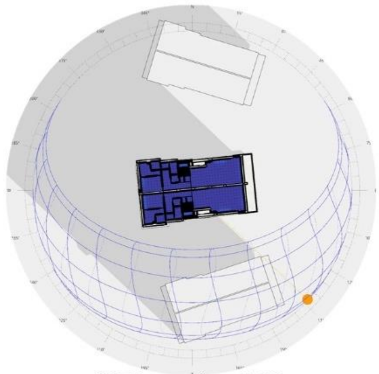
Case study 5 Ground floor 1:1000



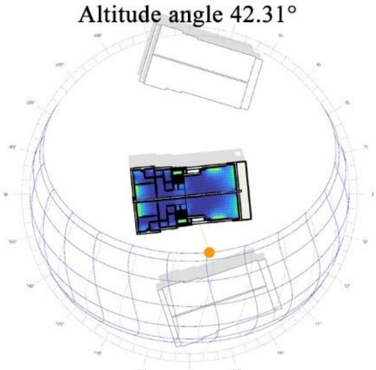
21 June 9:00
Azimuth angle 98.82°
Altitude angle 42.31°



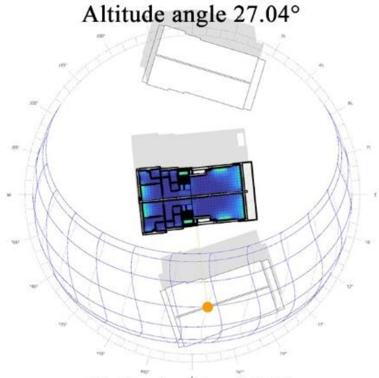
21 September 9:00
Azimuth angle 119.80°
Altitude angle 27.04°



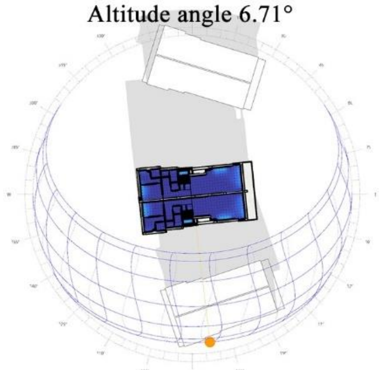
21 December 9:00
Azimuth angle 133.39°
Altitude angle 6.71°



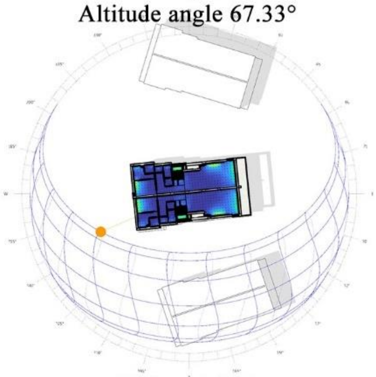
21 June 12:00
Azimuth angle 161.16°
Altitude angle 67.33°



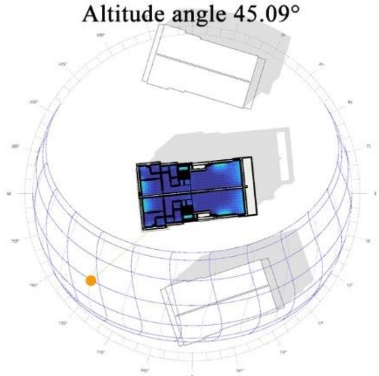
21 September 12:00
Azimuth angle 172.04°
Altitude angle 45.09°



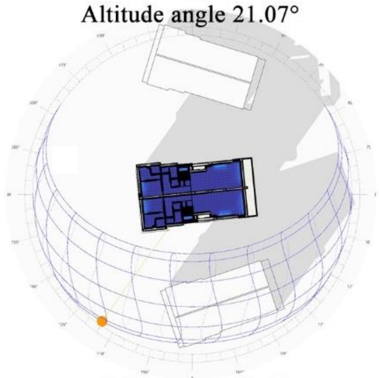
21 December 12:00
Azimuth angle 173.23°
Altitude angle 21.07°



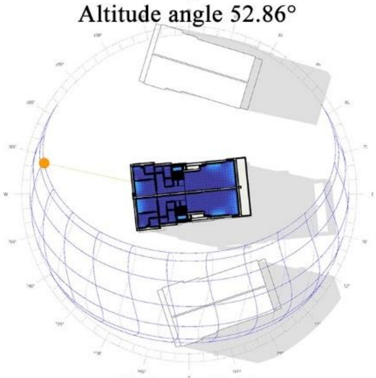
21 June 15:00
Azimuth angle 246.75°
Altitude angle 52.86°



21 September 15:00
Azimuth angle 229.51°
Altitude angle 33.42°

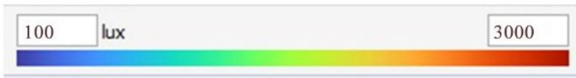


21 December 15:00
Azimuth angle 215.54°
Altitude angle 13.09°

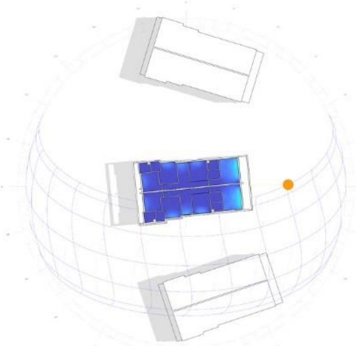


21 June 18:00
Azimuth angle 281.92°
Altitude angle 21.72°

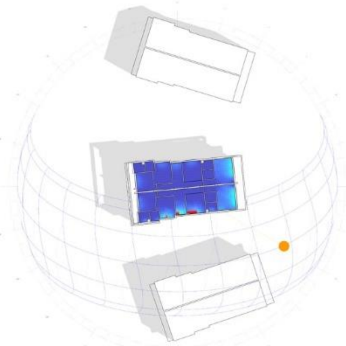
Location: Turin
Overcast sky
Ground albedo: 0.2
Glass type: Double glass
SHGC:0.31 TVIS:0.604 U-value:1.36



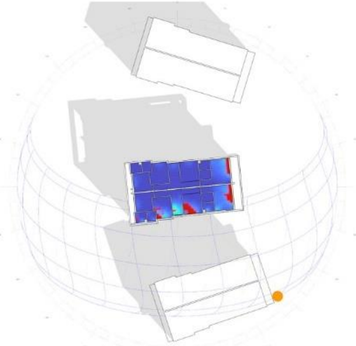
Case study 5 First floor 1:1000



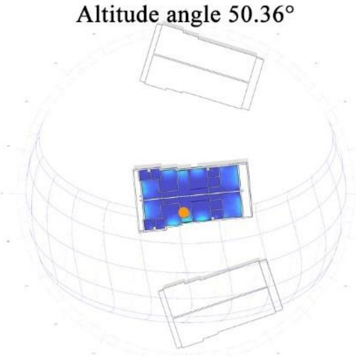
21 June 9:00
Azimuth angle 88.83°
Altitude angle 50.36°



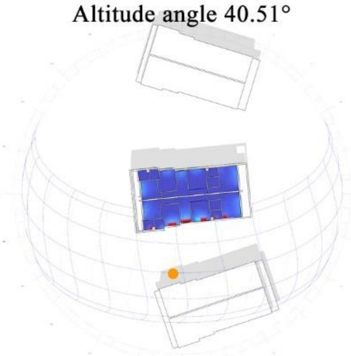
21 September 9:00
Azimuth angle 188.62°
Altitude angle 40.51°



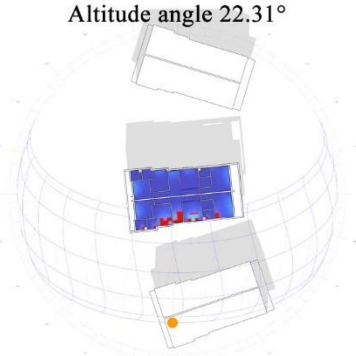
21 December 9:00
Azimuth angle 137.33°
Altitude angle 22.31°



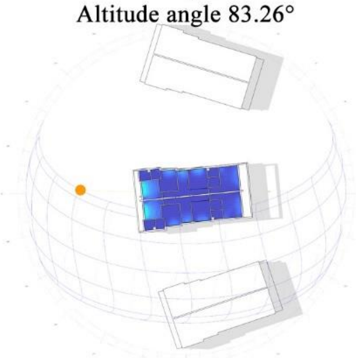
21 June 12:00
Azimuth angle 187.49°
Altitude angle 83.26°



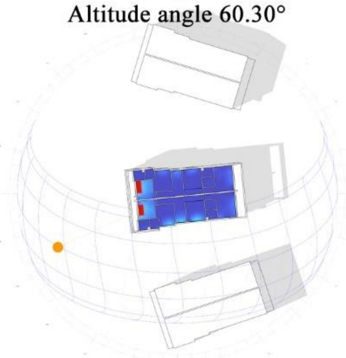
21 September 12:00
Azimuth angle 186.35°
Altitude angle 60.30°



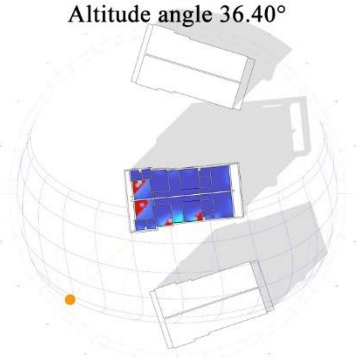
21 December 12:00
Azimuth angle 182.13°
Altitude angle 36.40°



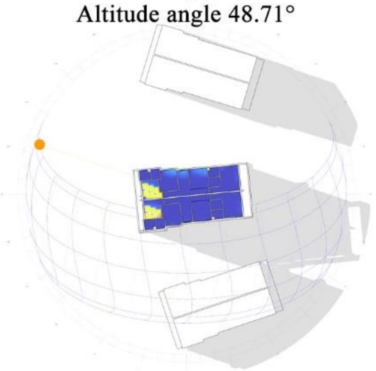
21 June 15:00
Azimuth angle 272.07°
Altitude angle 48.71°



21 September 15:00
Azimuth angle 246.31°
Altitude angle 35.57°

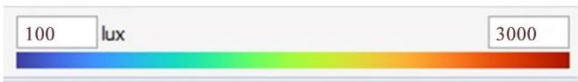


21 December 15:00
Azimuth angle 225.45°
Altitude angle 20.05°

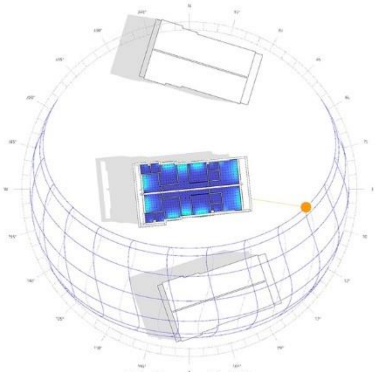


21 June 18:00
Azimuth angle 290.07°
Altitude angle 10.75°

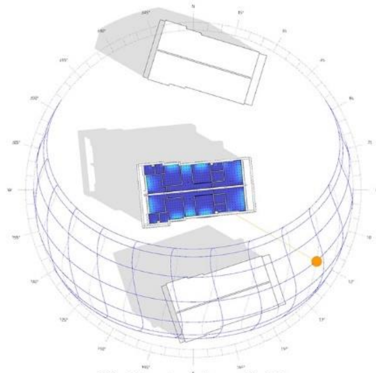
Location: Cairo
Clear sky Ground albedo: 0.2
Glass type: Double glass 6.4 mm Stainless Steel Cover 30%
SHGC:0.15 TVIS:0.27 U-value:2.66



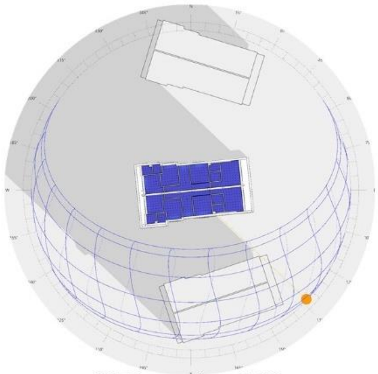
Case study 5 First floor 1:1000



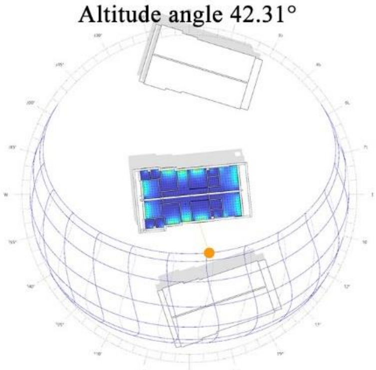
21 June 9:00
Azimuth angle 98.82°
Altitude angle 42.31°



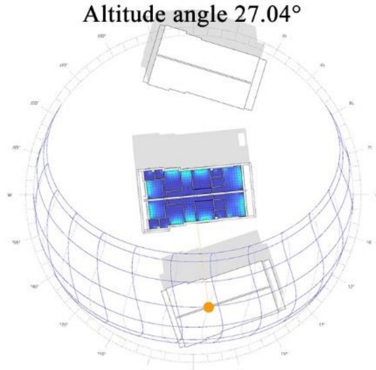
21 September 9:00
Azimuth angle 119.80°
Altitude angle 27.04°



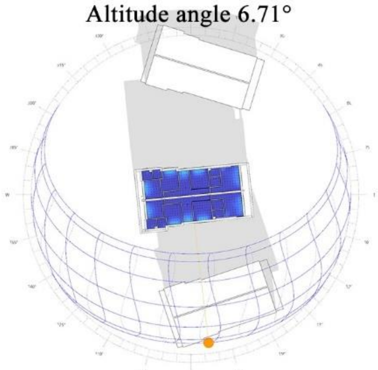
21 December 9:00
Azimuth angle 133.39°
Altitude angle 6.71°



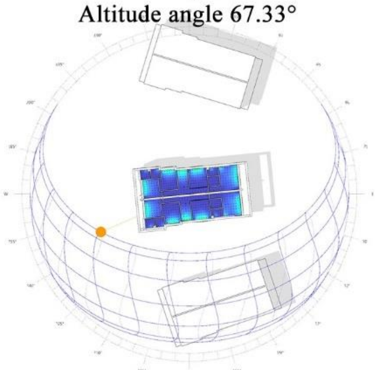
21 June 12:00
Azimuth angle 161.16°
Altitude angle 67.33°



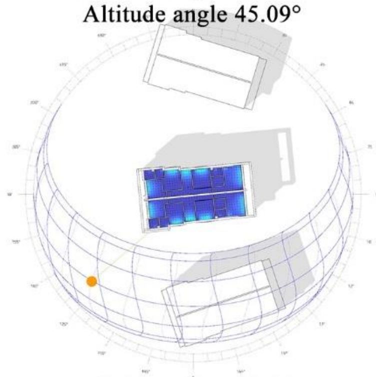
21 September 12:00
Azimuth angle 172.04°
Altitude angle 45.09°



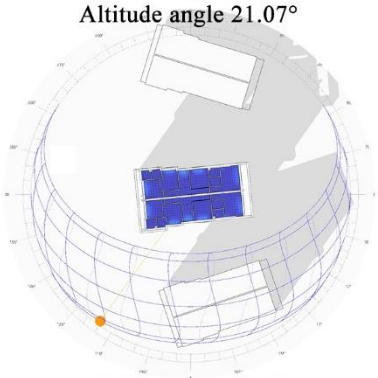
21 December 12:00
Azimuth angle 173.23°
Altitude angle 21.07°



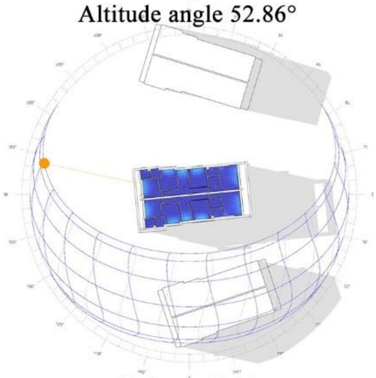
21 June 15:00
Azimuth angle 246.75°
Altitude angle 52.86°



21 September 15:00
Azimuth angle 229.51°
Altitude angle 33.42°



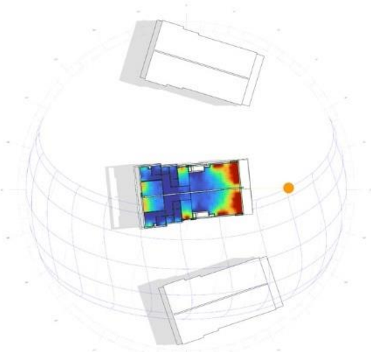
21 December 15:00
Azimuth angle 215.54°
Altitude angle 13.09°



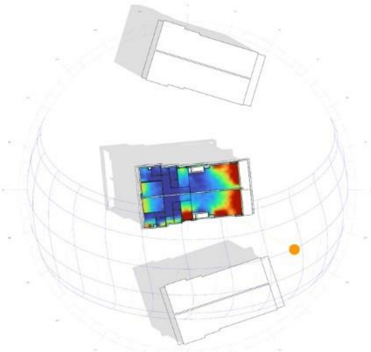
21 June 18:00
Azimuth angle 281.92°
Altitude angle 21.72°

Location: Turin
Overcast sky
Ground albedo: 0.2
Glass type: Double glass
SHGC:0.31 TVIS:0.604 U-value:1.36

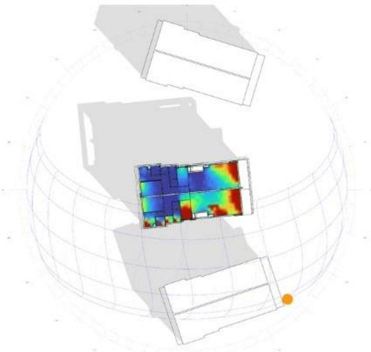
Case study 5 Ground floor 1:1000



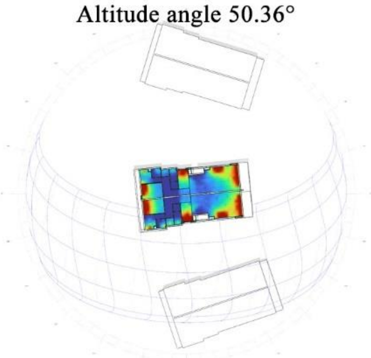
21 June 9:00
Azimuth angle 88.83°
Altitude angle 50.36°



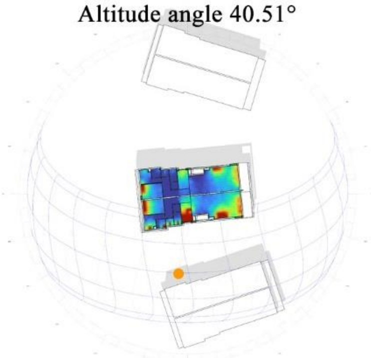
21 September 9:00
Azimuth angle 188.62°
Altitude angle 40.51°



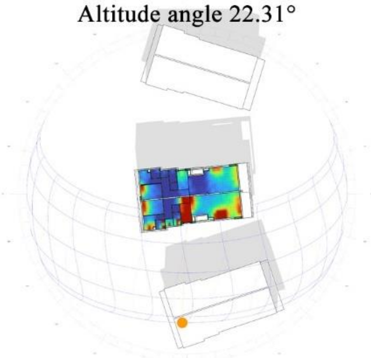
21 December 9:00
Azimuth angle 137.33°
Altitude angle 22.31°



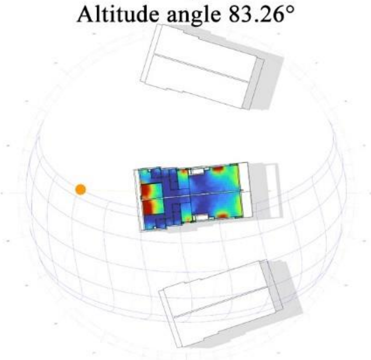
21 June 12:00
Azimuth angle 187.49°
Altitude angle 83.26°



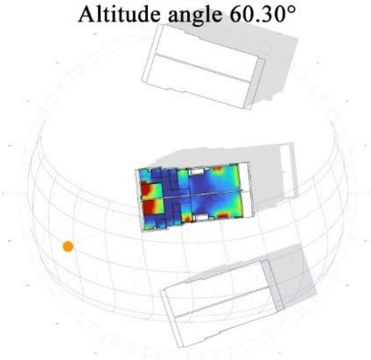
21 September 12:00
Azimuth angle 186.35°
Altitude angle 60.30°



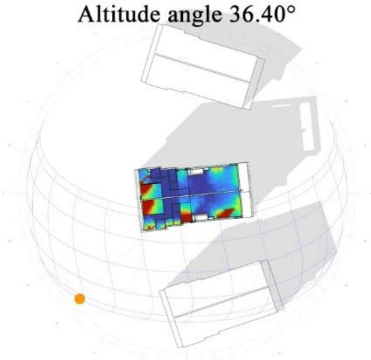
21 December 12:00
Azimuth angle 182.13°
Altitude angle 36.40°



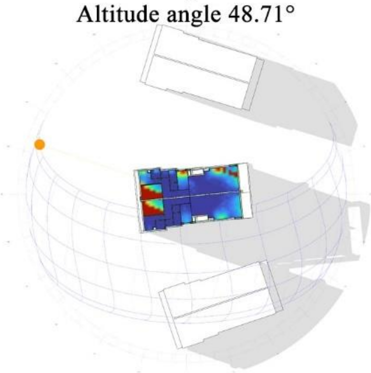
21 June 15:00
Azimuth angle 272.07°
Altitude angle 48.71°



21 September 15:00
Azimuth angle 246.31°
Altitude angle 35.57°

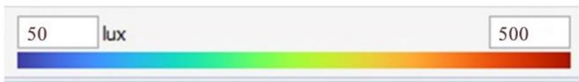


21 December 15:00
Azimuth angle 225.45°
Altitude angle 20.05°

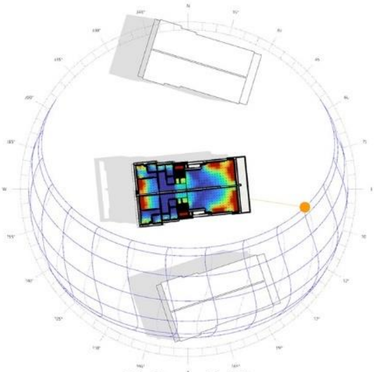


21 June 18:00
Azimuth angle 290.07°
Altitude angle 10.75°

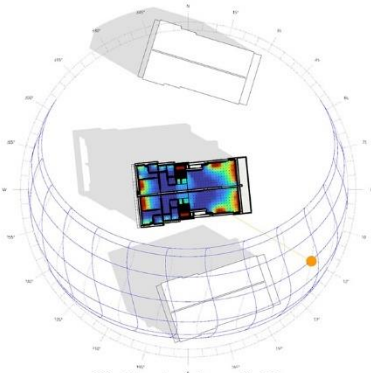
Location: Cairo
Clear sky Ground albedo: 0.2
Glass type: Double glass 6.4 mm Stainless Steel Cover 30%
SHGC:0.15 TVIS:0.27 U-value:2.66



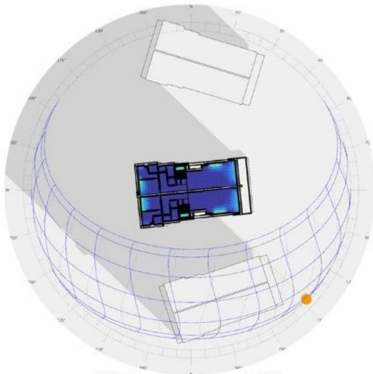
Case study 5 Ground floor 1:1000



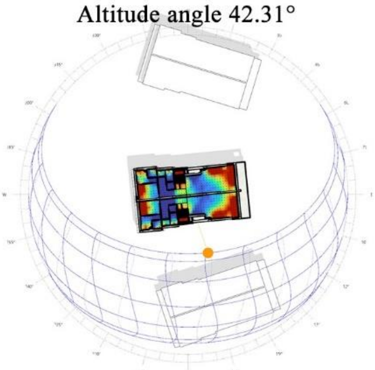
21 June 9:00
Azimuth angle 98.82°
Altitude angle 42.31°



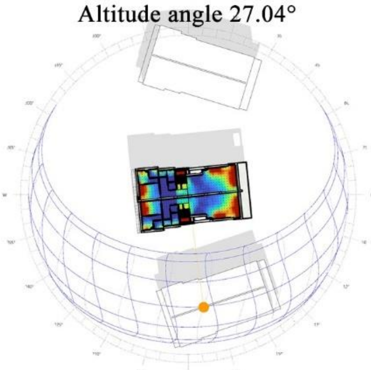
21 September 9:00
Azimuth angle 119.80°
Altitude angle 27.04°



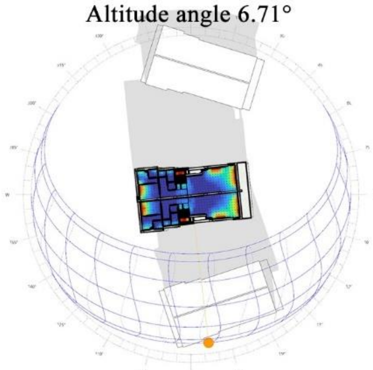
21 December 9:00
Azimuth angle 133.39°
Altitude angle 6.71°



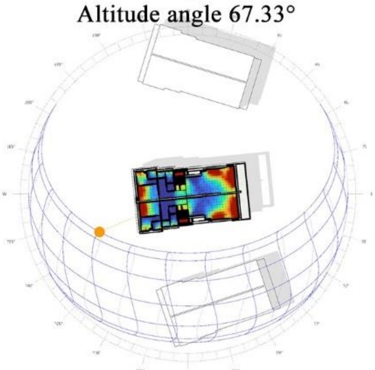
21 June 12:00
Azimuth angle 161.16°
Altitude angle 67.33°



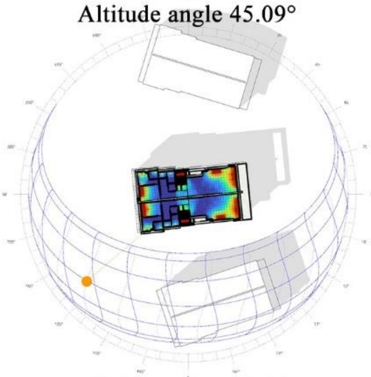
21 September 12:00
Azimuth angle 172.04°
Altitude angle 45.09°



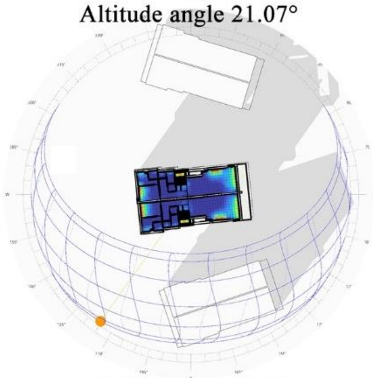
21 December 12:00
Azimuth angle 173.23°
Altitude angle 21.07°



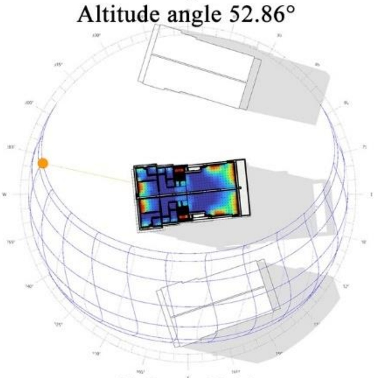
21 June 15:00
Azimuth angle 246.75°
Altitude angle 52.86°



21 September 15:00
Azimuth angle 229.51°
Altitude angle 33.42°

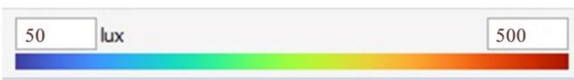


21 December 15:00
Azimuth angle 215.54°
Altitude angle 13.09°

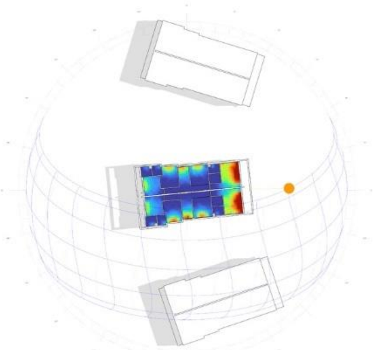


21 June 18:00
Azimuth angle 281.92°
Altitude angle 21.72°

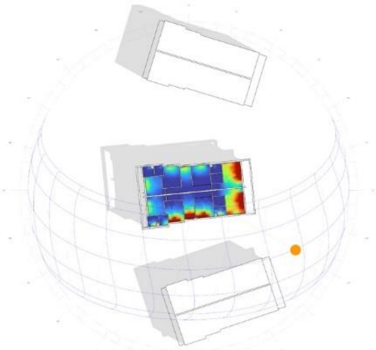
Location: Turin
Overcast sky
Ground albedo: 0.2
Glass type: Double glass
SHGC:0.31 TVIS:0.604 U-value:1.36



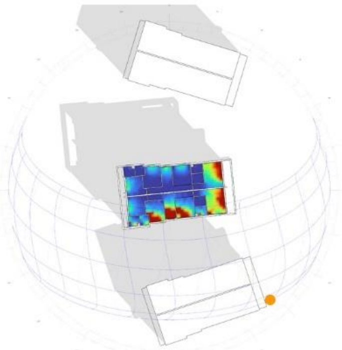
Case study 5 First floor 1:1000



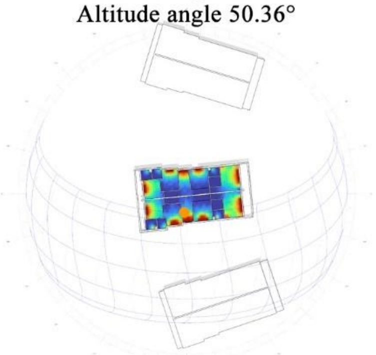
21 June 9:00
Azimuth angle 88.83°
Altitude angle 50.36°



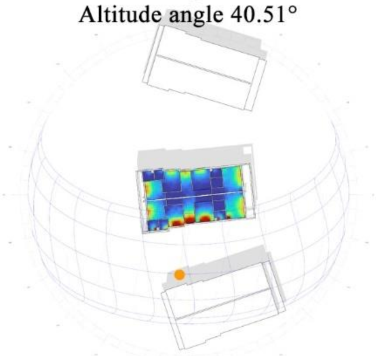
21 September 9:00
Azimuth angle 188.62°
Altitude angle 40.51°



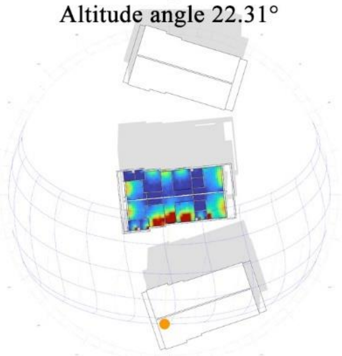
21 December 9:00
Azimuth angle 137.33°
Altitude angle 22.31°



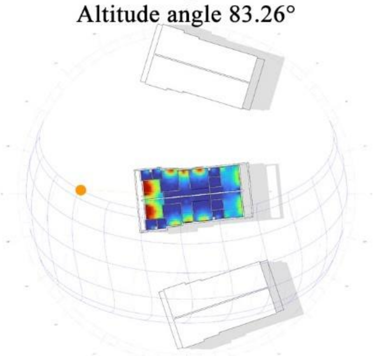
21 June 12:00
Azimuth angle 187.49°
Altitude angle 83.26°



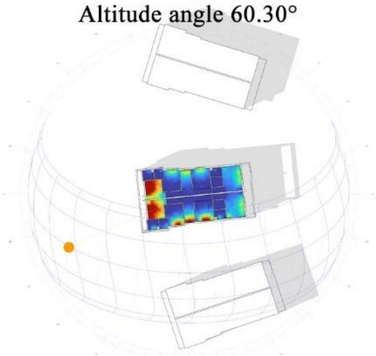
21 September 12:00
Azimuth angle 186.35°
Altitude angle 60.30°



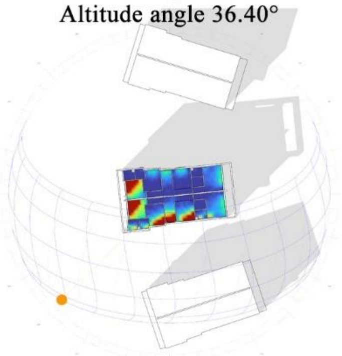
21 December 12:00
Azimuth angle 182.13°
Altitude angle 36.40°



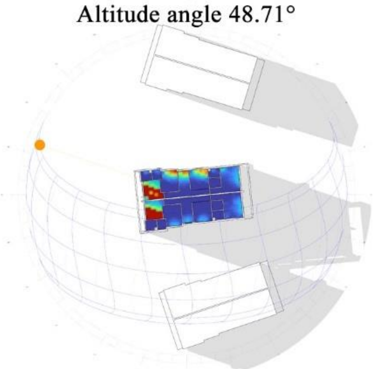
21 June 15:00
Azimuth angle 272.07°
Altitude angle 48.71°



21 September 15:00
Azimuth angle 246.31°
Altitude angle 35.57°

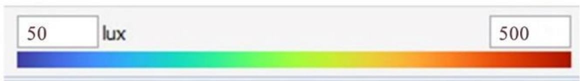


21 December 15:00
Azimuth angle 225.45°
Altitude angle 20.05°

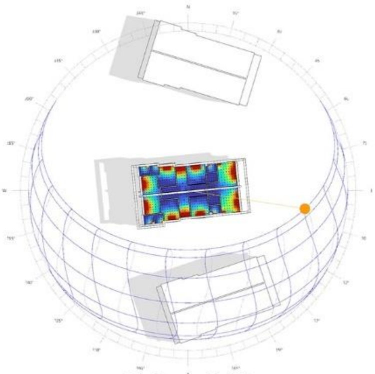


21 June 18:00
Azimuth angle 290.07°
Altitude angle 10.75°

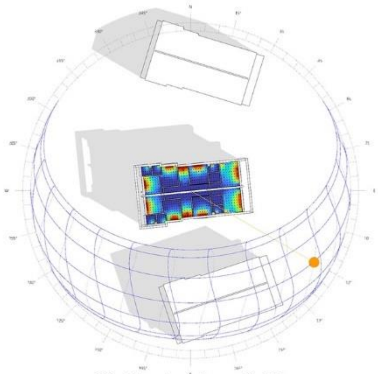
Location: Cairo
Clear sky Ground albedo: 0.2
Glass type: Double glass 6.4 mm Stainless Steel Cover 30%
SHGC:0.15 TVIS:0.27 U-value:2.66



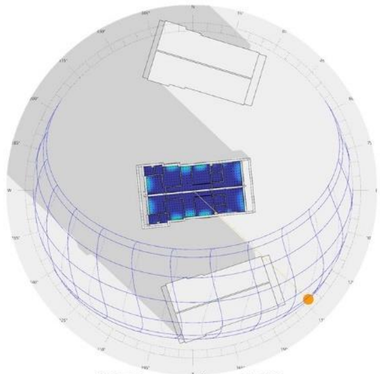
Case study 5 First floor 1:1000



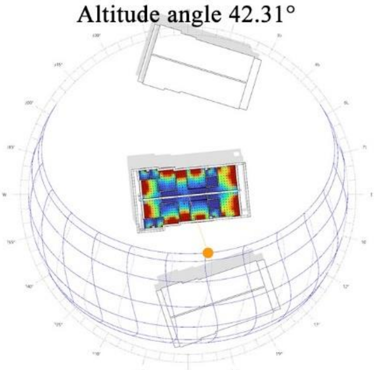
21 June 9:00
Azimuth angle 98.82°
Altitude angle 42.31°



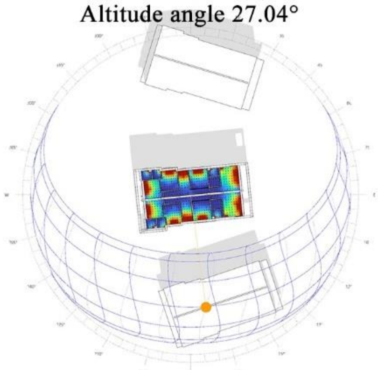
21 September 9:00
Azimuth angle 119.80°
Altitude angle 27.04°



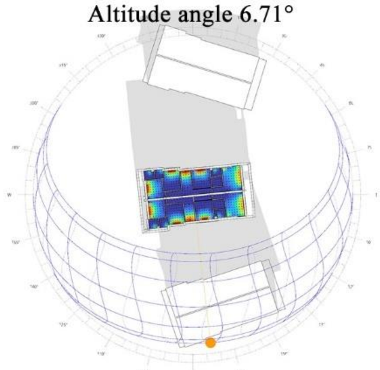
21 December 9:00
Azimuth angle 133.39°
Altitude angle 6.71°



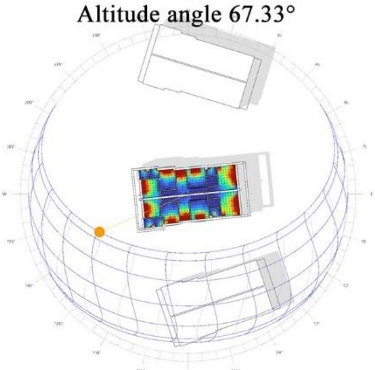
21 June 12:00
Azimuth angle 161.16°
Altitude angle 67.33°



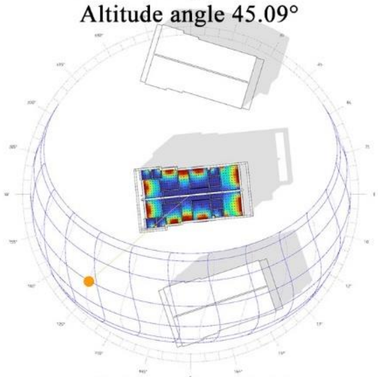
21 September 12:00
Azimuth angle 172.04°
Altitude angle 45.09°



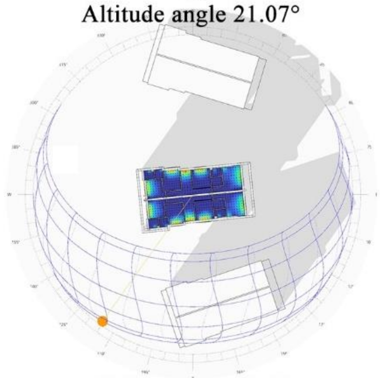
21 December 12:00
Azimuth angle 173.23°
Altitude angle 21.07°



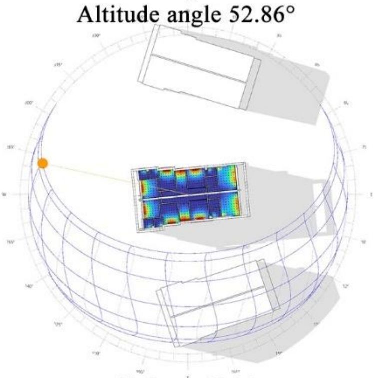
21 June 15:00
Azimuth angle 246.75°
Altitude angle 52.86°



21 September 15:00
Azimuth angle 229.51°
Altitude angle 33.42°



21 December 15:00
Azimuth angle 215.54°
Altitude angle 13.09°

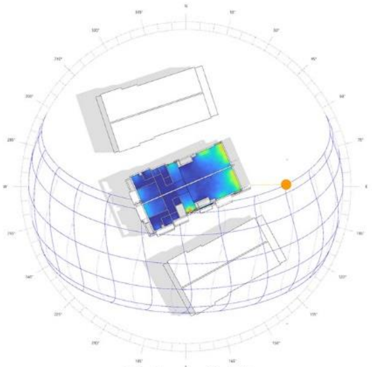


21 June 18:00
Azimuth angle 281.92°
Altitude angle 21.72°

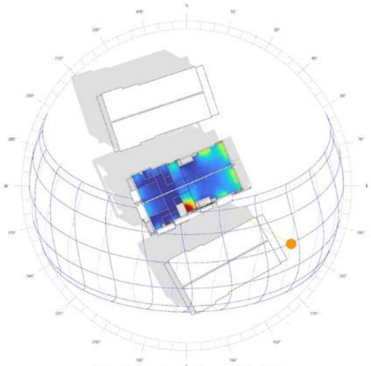
Location: Turin
Overcast sky Ground albedo: 0.2
Glass type: Double glass
SHGC:0.31 TVIS:0.604 U-value:1.36

Annex B

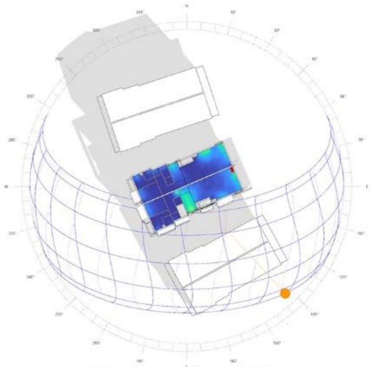
Case study 1 Ground floor 1:1000



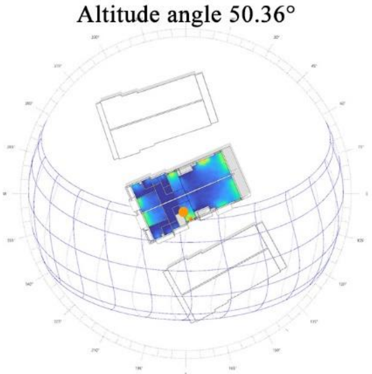
21 June 9:00
Azimuth angle 88.83°
Altitude angle 50.36°



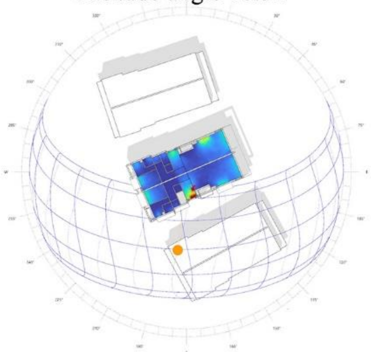
21 September 9:00
Azimuth angle 188.62°
Altitude angle 40.51°



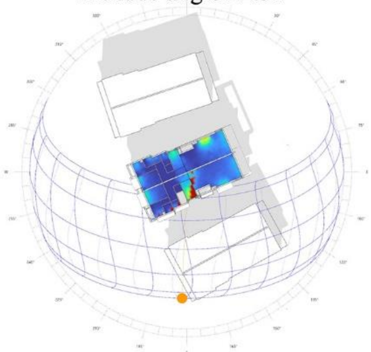
21 December 9:00
Azimuth angle 137.33°
Altitude angle 22.31°



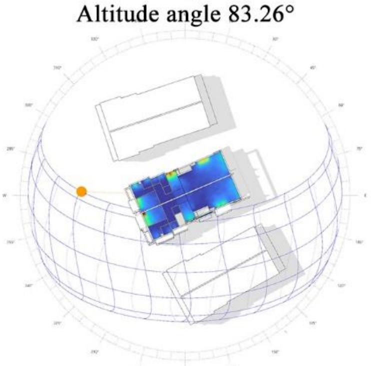
21 June 12:00
Azimuth angle 187.49°
Altitude angle 83.26°



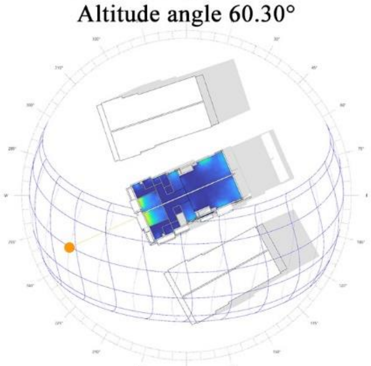
21 September 12:00
Azimuth angle 186.35°
Altitude angle 60.30°



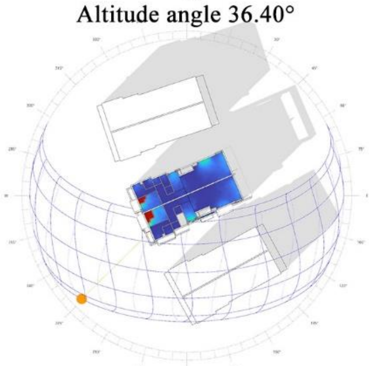
21 December 12:00
Azimuth angle 182.13°
Altitude angle 36.40°



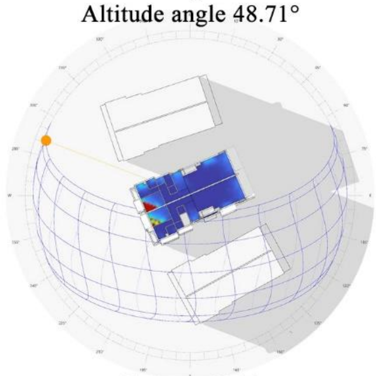
21 June 15:00
Azimuth angle 272.07°
Altitude angle 48.71°



21 September 15:00
Azimuth angle 246.31°
Altitude angle 35.57°

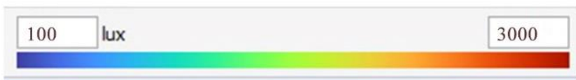


21 December 15:00
Azimuth angle 225.45°
Altitude angle 20.05°

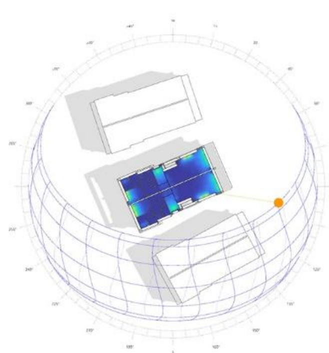


21 June 18:00
Azimuth angle 290.07°
Altitude angle 10.75°

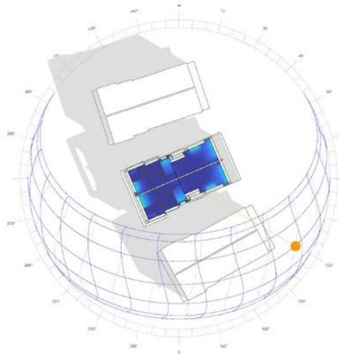
Location: Cairo
Clear sky
Ground albedo: 0.2
Glass type: Double glass
SHGC:0.277 TVIS:0.68 U-value:1.62



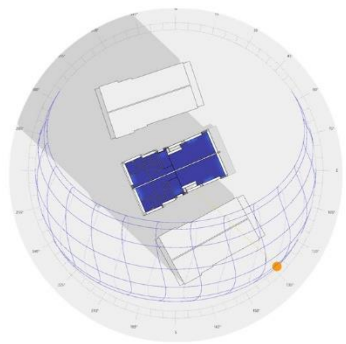
Case study 1 ground floor 1:1000



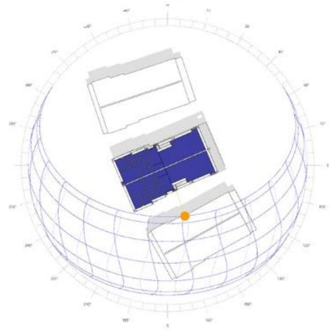
21 June 9:00
Azimuth angle 98.82°
Altitude angle 42.31°



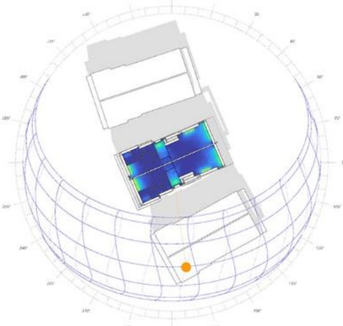
21 September 9:00
Azimuth angle 119.80°
Altitude angle 27.04°



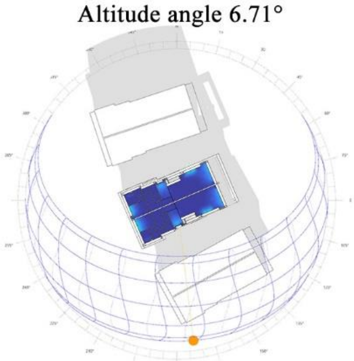
21 December 9:00
Azimuth angle 133.39°
Altitude angle 6.71°



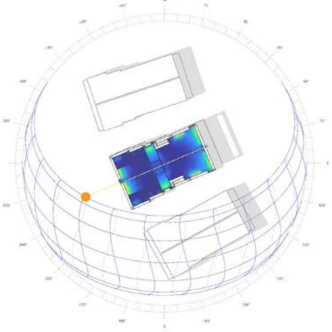
21 June 12:00
Azimuth angle 161.16°
Altitude angle 67.33°



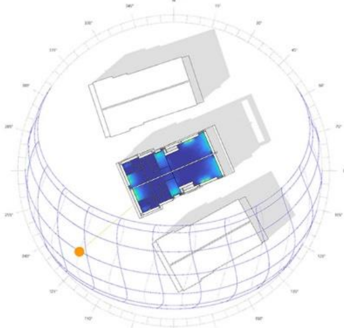
21 September 12:00
Azimuth angle 172.04°
Altitude angle 45.09°



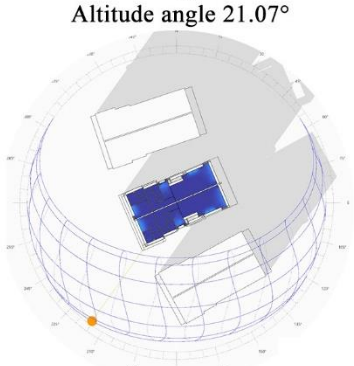
21 December 12:00
Azimuth angle 173.23°
Altitude angle 21.07°



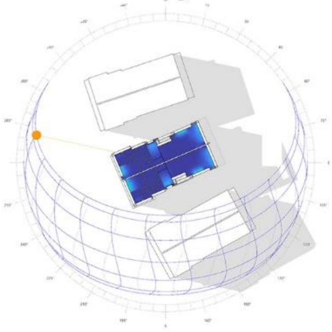
21 June 15:00
Azimuth angle 246.75°
Altitude angle 52.86°



21 September 15:00
Azimuth angle 229.51°
Altitude angle 33.42°

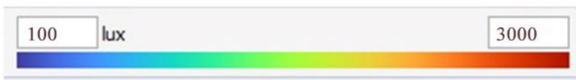


21 December 15:00
Azimuth angle 215.54°
Altitude angle 13.09°

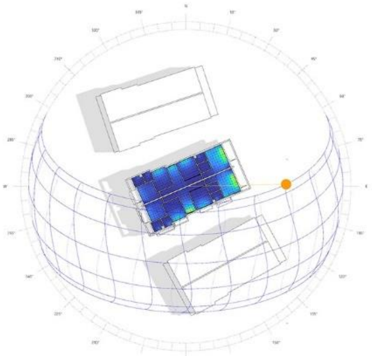


21 June 18:00
Azimuth angle 281.92°
Altitude angle 21.72°

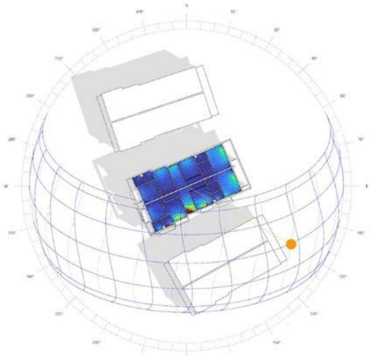
Location: Turin
Overcast sky
Ground albedo: 0.2
Glass type: Double glass
SHGC:0.678 TVIS:0.804 U-value:1.45



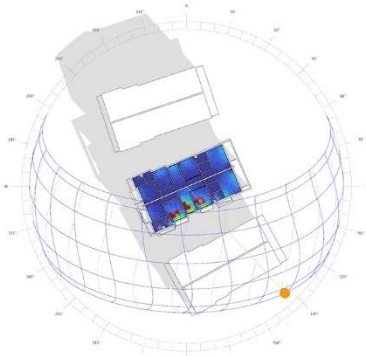
Case study 1 first floor 1:1000



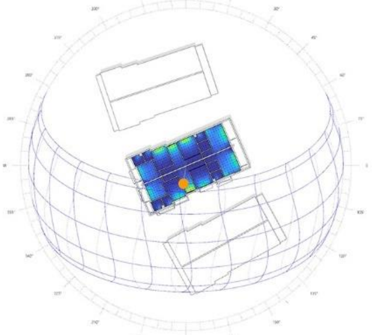
21 June 9:00
Azimuth angle 88.83°
Altitude angle 50.36°



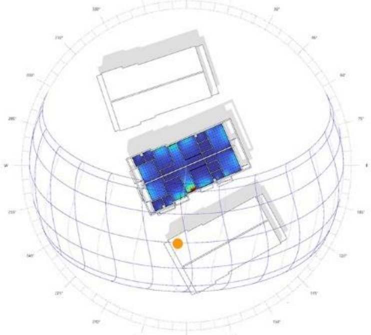
21 September 9:00
Azimuth angle 188.62°
Altitude angle 40.51°



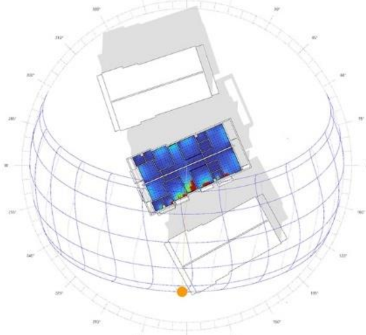
21 December 9:00
Azimuth angle 137.33°
Altitude angle 22.31°



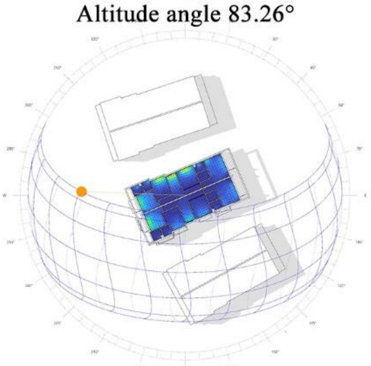
21 June 12:00
Azimuth angle 187.49°
Altitude angle 83.26°



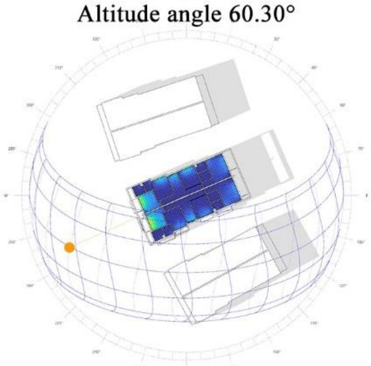
21 September 12:00
Azimuth angle 186.35°
Altitude angle 60.30°



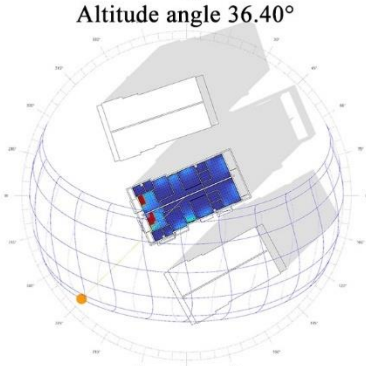
21 December 12:00
Azimuth angle 182.13°
Altitude angle 36.40°



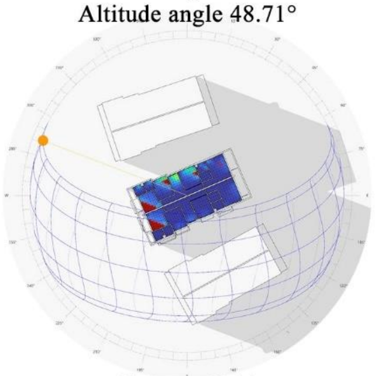
21 June 15:00
Azimuth angle 272.07°
Altitude angle 48.71°



21 September 15:00
Azimuth angle 246.31°
Altitude angle 35.57°

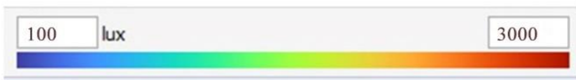


21 December 15:00
Azimuth angle 225.45°
Altitude angle 20.05°

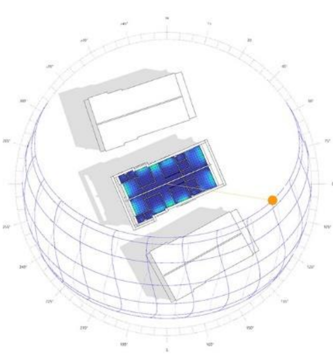


21 June 18:00
Azimuth angle 290.07°
Altitude angle 10.75°

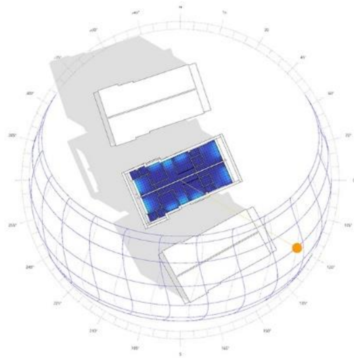
Location: Cairo
Clear sky
Ground albedo: 0.2
Glass type: Double glass
SHGC:0.277 TVIS:0.68 U-value:1.62



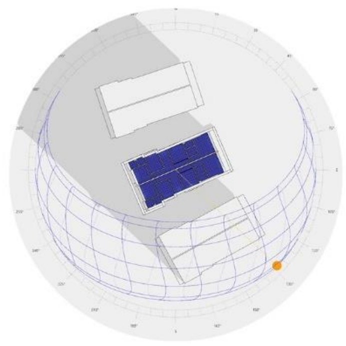
Case study 1 first floor 1:1000



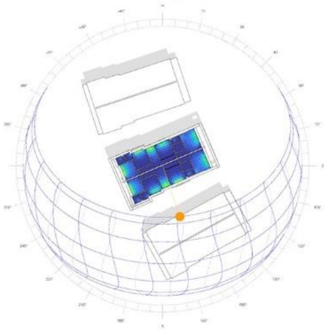
21 June 9:00
Azimuth angle 98.82°
Altitude angle 42.31°



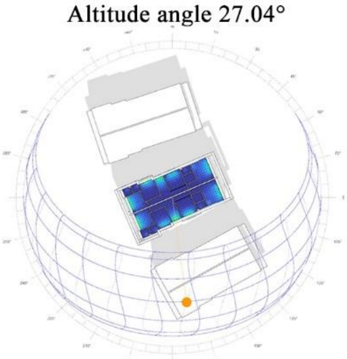
21 September 9:00
Azimuth angle 119.80°
Altitude angle 27.04°



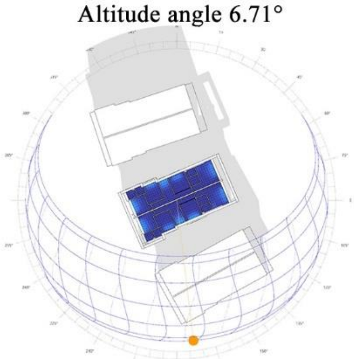
21 December 9:00
Azimuth angle 133.39°
Altitude angle 6.71°



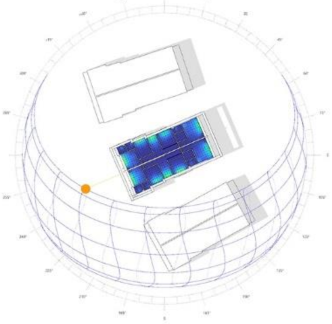
21 June 12:00
Azimuth angle 161.16°
Altitude angle 67.33°



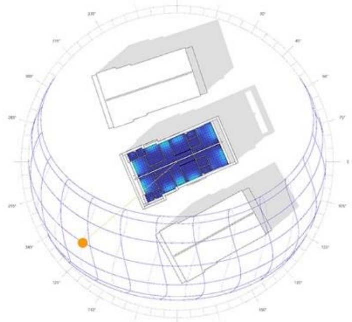
21 September 12:00
Azimuth angle 172.04°
Altitude angle 45.09°



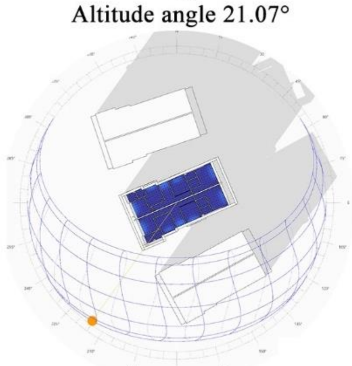
21 December 12:00
Azimuth angle 173.23°
Altitude angle 21.07°



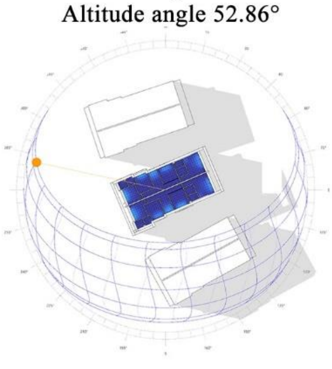
21 June 15:00
Azimuth angle 246.75°
Altitude angle 52.86°



21 September 15:00
Azimuth angle 229.51°
Altitude angle 33.42°

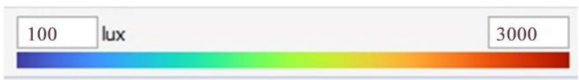


21 December 15:00
Azimuth angle 215.54°
Altitude angle 13.09°

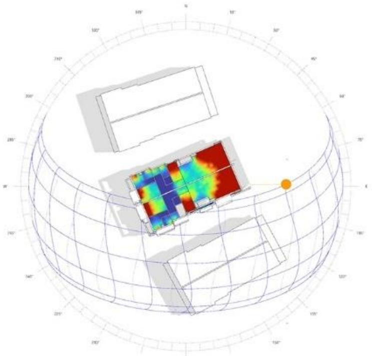


21 June 18:00
Azimuth angle 281.92°
Altitude angle 21.72°

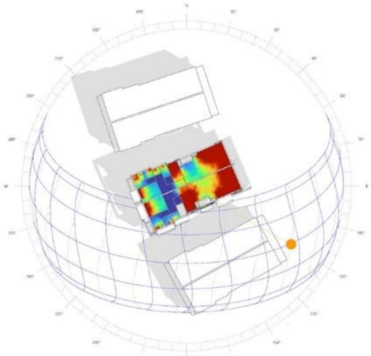
Location: Turin
Overcast sky
Ground albedo: 0.2
Glass type: Double glass
SHGC:0.678 TVIS:0.804 U-value:1.45



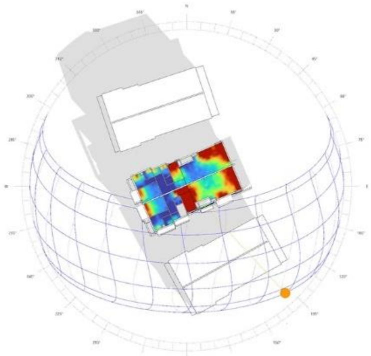
Case study 1 Ground floor 1:1000



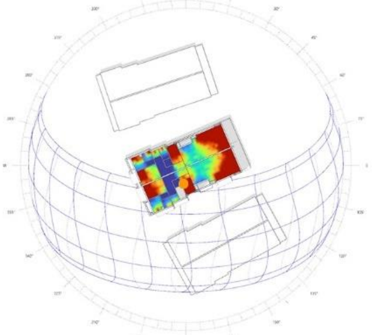
21 June 9:00
Azimuth angle 88.83°
Altitude angle 50.36°



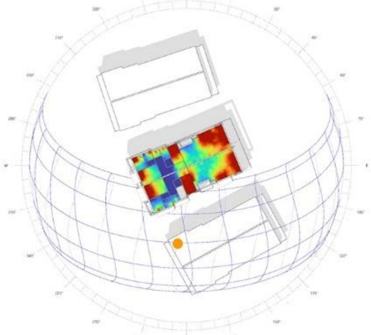
21 September 9:00
Azimuth angle 188.62°
Altitude angle 40.51°



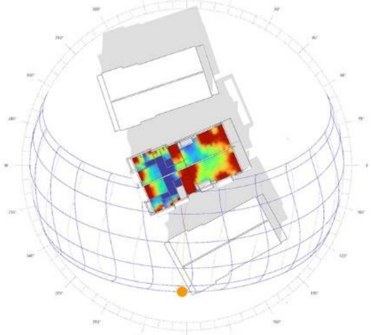
21 December 9:00
Azimuth angle 137.33°
Altitude angle 22.31°



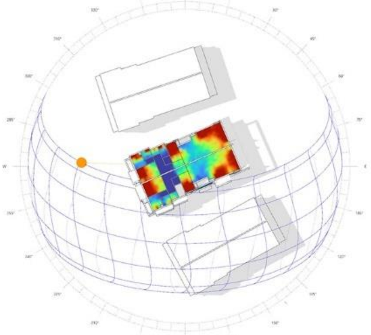
21 June 12:00
Azimuth angle 187.49°
Altitude angle 83.26°



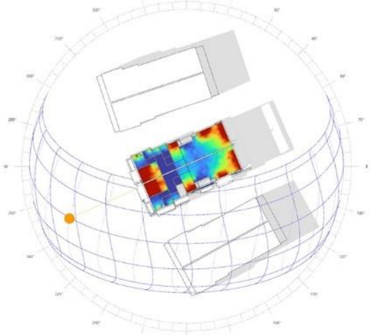
21 September 12:00
Azimuth angle 186.35°
Altitude angle 60.30°



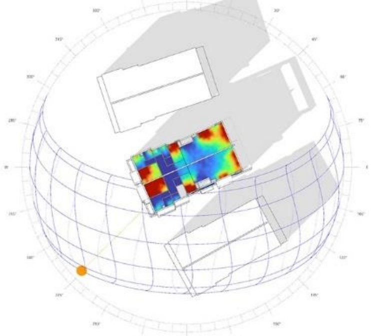
21 December 12:00
Azimuth angle 182.13°
Altitude angle 36.40°



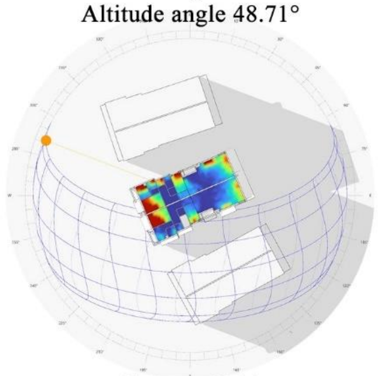
21 June 15:00
Azimuth angle 272.07°
Altitude angle 48.71°



21 September 15:00
Azimuth angle 246.31°
Altitude angle 35.57°

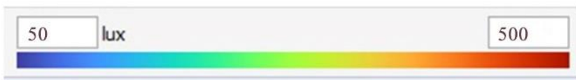


21 December 15:00
Azimuth angle 225.45°
Altitude angle 20.05°

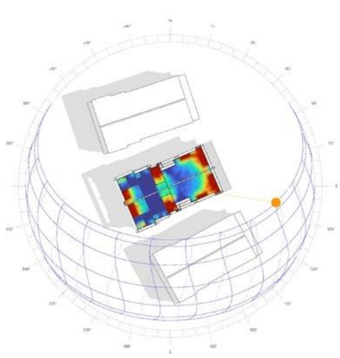


21 June 18:00
Azimuth angle 290.07°
Altitude angle 10.75°

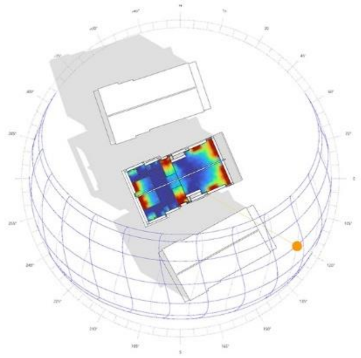
Location: Cairo
Clear sky
Ground albedo: 0.2
Glass type: Double glass
SHGC:0.277 TVIS:0.68 U-value:1.62



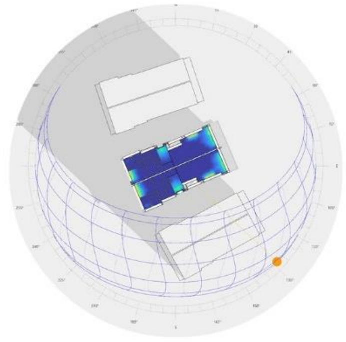
Case study 1 ground floor 1:1000



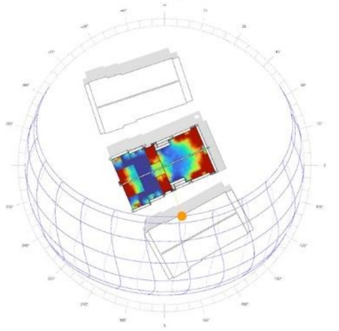
21 June 9:00
Azimuth angle 98.82°
Altitude angle 42.31°



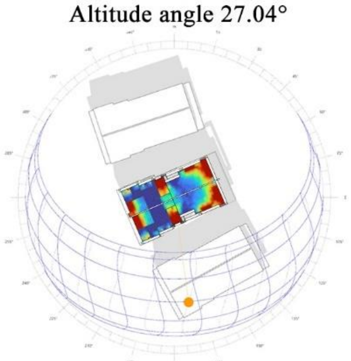
21 September 9:00
Azimuth angle 119.80°
Altitude angle 27.04°



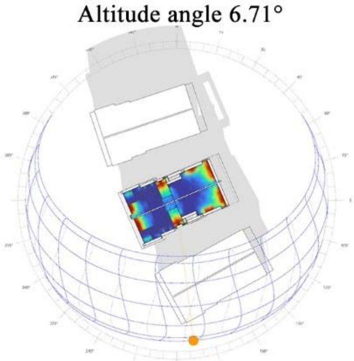
21 December 9:00
Azimuth angle 133.39°
Altitude angle 6.71°



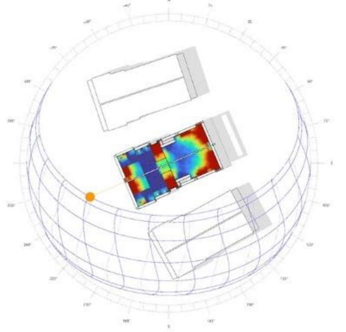
21 June 12:00
Azimuth angle 161.16°
Altitude angle 67.33°



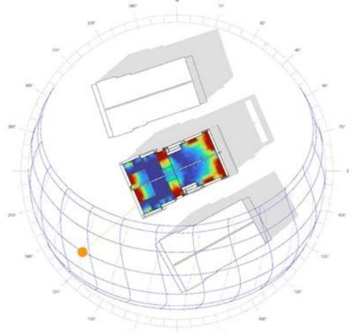
21 September 12:00
Azimuth angle 172.04°
Altitude angle 45.09°



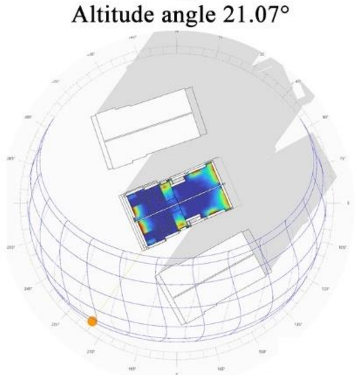
21 December 12:00
Azimuth angle 173.23°
Altitude angle 21.07°



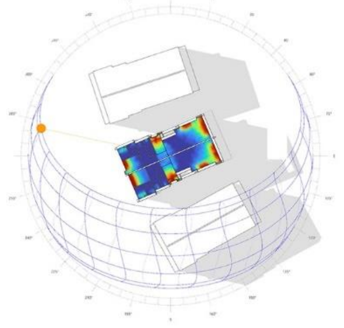
21 June 15:00
Azimuth angle 246.75°
Altitude angle 52.86°



21 September 15:00
Azimuth angle 229.51°
Altitude angle 33.42°

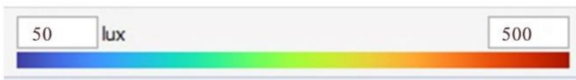


21 December 15:00
Azimuth angle 215.54°
Altitude angle 13.09°

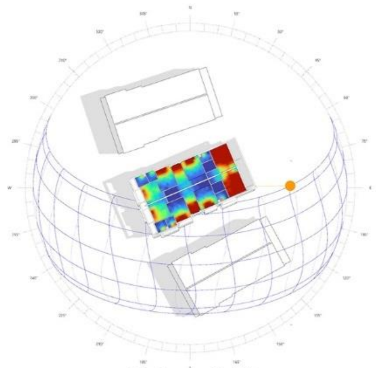


21 June 18:00
Azimuth angle 281.92°
Altitude angle 21.72°

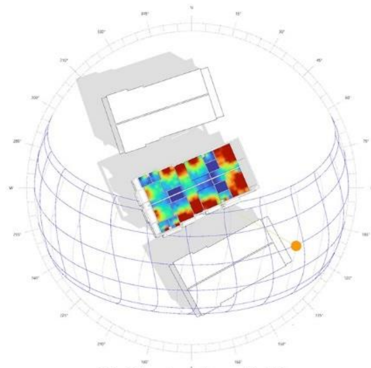
Location: Turin
Overcast sky
Ground albedo: 0.2
Glass type: Double glass
SHGC:0.678 TVIS:0.804 U-value:1.45



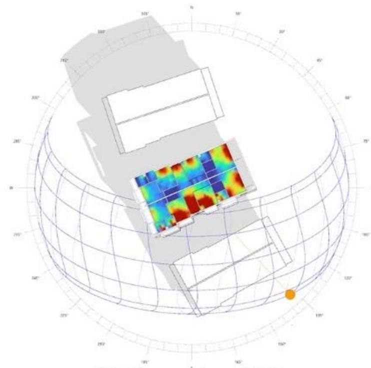
Case study 1 First floor 1:1000



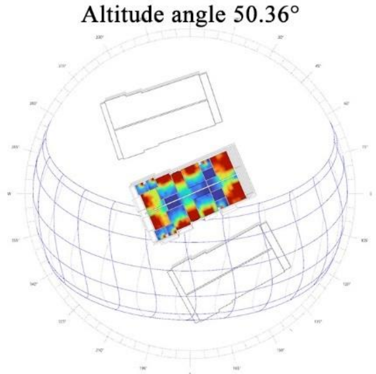
21 June 9:00
Azimuth angle 88.83°
Altitude angle 50.36°



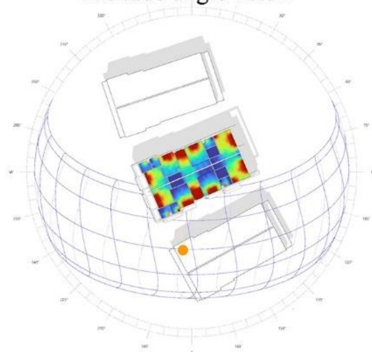
21 September 9:00
Azimuth angle 188.62°
Altitude angle 40.51°



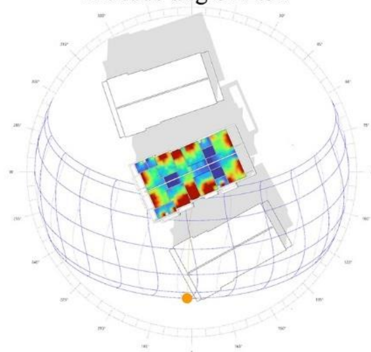
21 December 9:00
Azimuth angle 137.33°
Altitude angle 22.31°



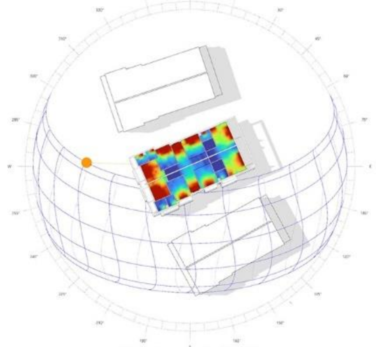
21 June 12:00
Azimuth angle 187.49°
Altitude angle 83.26°



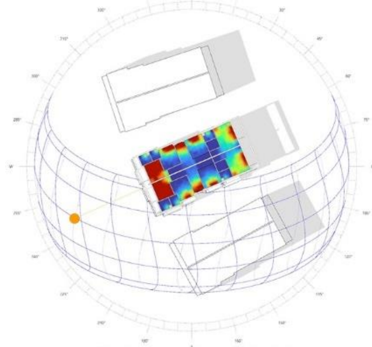
21 September 12:00
Azimuth angle 186.35°
Altitude angle 60.30°



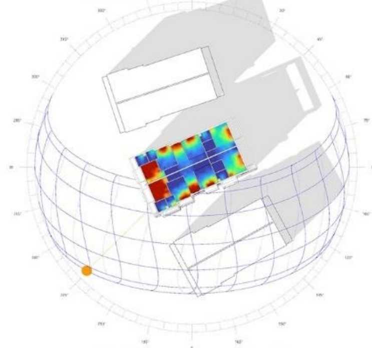
21 December 12:00
Azimuth angle 182.13°
Altitude angle 36.40°



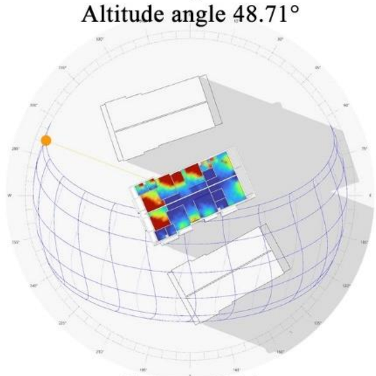
21 June 15:00
Azimuth angle 272.07°
Altitude angle 48.71°



21 September 15:00
Azimuth angle 246.31°
Altitude angle 35.57°

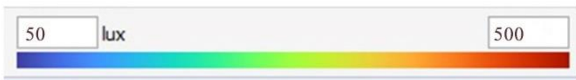


21 December 15:00
Azimuth angle 225.45°
Altitude angle 20.05°

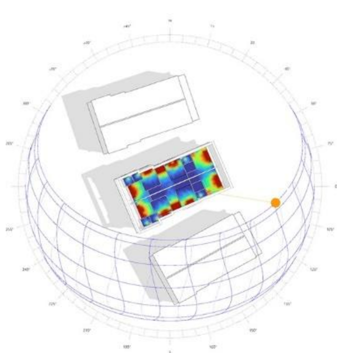


21 June 18:00
Azimuth angle 290.07°
Altitude angle 10.75°

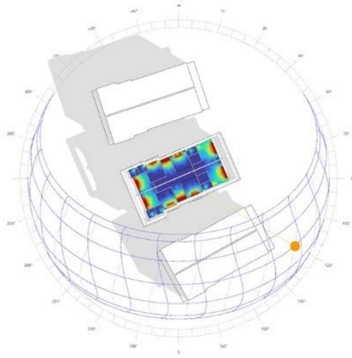
Location: Cairo
Clear sky
Ground albedo: 0.2
Glass type: Double glass
SHGC:0.277 TVIS:0.68 U-value:1.62



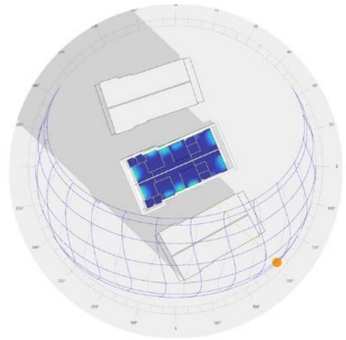
Case study 1 first floor 1:1000



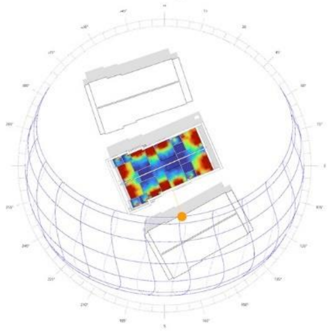
21 June 9:00
Azimuth angle 98.82°
Altitude angle 42.31°



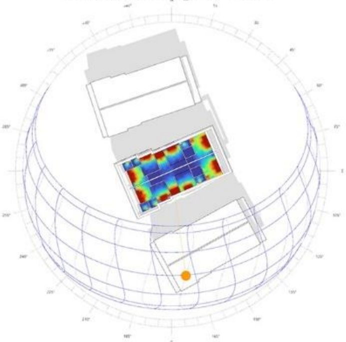
21 September 9:00
Azimuth angle 119.80°
Altitude angle 27.04°



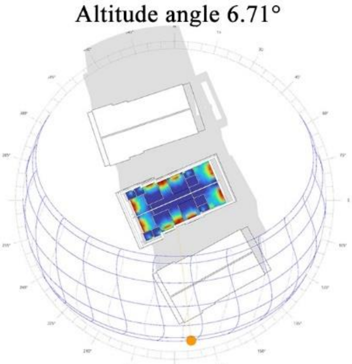
21 December 9:00
Azimuth angle 133.39°
Altitude angle 6.71°



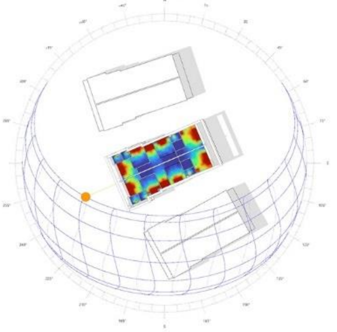
21 June 12:00
Azimuth angle 161.16°
Altitude angle 67.33°



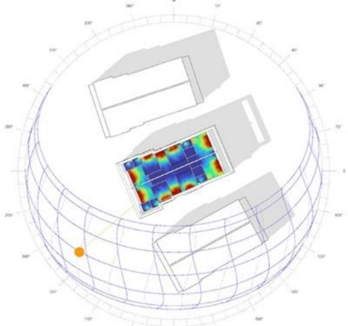
21 September 12:00
Azimuth angle 172.04°
Altitude angle 45.09°



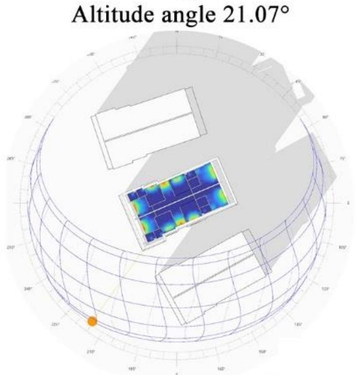
21 December 12:00
Azimuth angle 173.23°
Altitude angle 21.07°



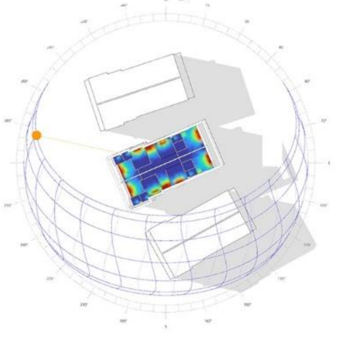
21 June 15:00
Azimuth angle 246.75°
Altitude angle 52.86°



21 September 15:00
Azimuth angle 229.51°
Altitude angle 33.42°



21 December 15:00
Azimuth angle 215.54°
Altitude angle 13.09°



21 June 18:00
Azimuth angle 281.92°
Altitude angle 21.72°

Location: Turin
Overcast sky
Ground albedo: 0.2
Glass type: Double glass
SHGC:0.678 TVIS:0.804 U-value:1.45