FICUP
An InternationalConference on
Urban Physics
B. Beckers, T. Pico, S. Jimenez (Eds.)
Quito – Galápagos, Ecuador, 26– 30 September2016

A study of solar access in Bogotá: the Las Nieves neighborhood

R. Franco[1], P. Bright[1], J Benitez[1], and B. Beckers[2]

[1]Universidad de Bogotá Jorge Tadeo Lozano
address: Carrera 4 Nº 22-61, Bogotá - Colombia. http://www.utadeo.edu.co/es
e-mail: (ricardo.franco, p.bright, javier.benitezb)@utadeo.edu.co

[2] Université de Technologie de Compiègne-Sorbonne University
address: Rue Roger Couttolenc, CS 60319 60203 Compiègne – France. https://www.utc.fr/
e-mail: benoit.beckers@utc.fr

Keywords: *solar access, urban morphology, solar rights, energy and sun.*

Abstract. *It was during the 1970's that interest for searching and exploiting solar energy came up as a clean, safe and unlimited alternative source, as opposed to nuclear energy, coal, oil and its by-products and their environmental and speculative impact on markets. The concept of solar access was first used in the US as a way of legally protecting a building's present and future rights to sunlight availability and the collection and use of solar energy.*

This paper presents an on going research on solar access for the city of Bogotá, Colombia (4,38' North) applying the descriptive method, according to Knowles' concept of the solar envelope [Knowles 1999]. From this point of view the geometry and projection of shadows seek to establish the maximum height of buildings so that buildings access to sunlight is not obstructed.

Introduction

This article is the result of the on going research project at the Architecture Programme of the "Jorge Tadeo Lozano" University: "A study of solar access for the Las Nieves neighbourhood". Las Nieves is a traditional neighbourhood of the Colombian capital which has been object of a continuous process of urban transformation in the last 40 years, including building or renovating public space, renovation and reactivation of deteriorated areas. The consolidation of the cultural and educational uses as well as private investment have widened the commercial and real-estate offer, added to the pressure for taller buildings in order to increase density and the proposed urban renovation of this area of the city. These processes have brought, as a consequence, the construction of high rise towers of up to 60 stories in this traditional zone where the top heights were 5 stories within the neighbourhood and 20 stories on avenues as the Calle 19. The consequences of the construction of one of those new towers, the BD Bacatá, will be analysed in this article in terms of solar access (shadow projection, hours of sun, solar irradiation, and sky view factor).

Solar energy, more than any other type of renewable energy, has direct effects on shape, habitability, comfort and the volumetric planning of buildings, distance between buildings, their heights and recoils. Therefore, if a building has solar access, the energy received can be used and integrated in the building through active or passive systems with the goal of reducing CO2 emissions and its demand of energy; trying to keep a sustainable dimension in the architecture. The use of solar energy as a main source for the human life requires a space condition, the solar access, since without it, it is not possible to reach a dimension of the urban sustainability [Cárdenas 2012].

Background

Primitive use of sunlight: orientation and passive use

The idea of solar access is older than the research projects and laws passed in the previous century. Inhabitants in ancient China, Greece, Rome and Pre-Hispanic America (all localized in the northern hemisphere) used solar energy to heat spaces in winter and to avoid overheating in summer. The technique to obtain the best from solar energy consisted in understanding that sunlight changed according to seasons, and so they acted accordingly with proper building orientation and placing windows towards the south, as well as the proper use of materials and their thermal inertia.

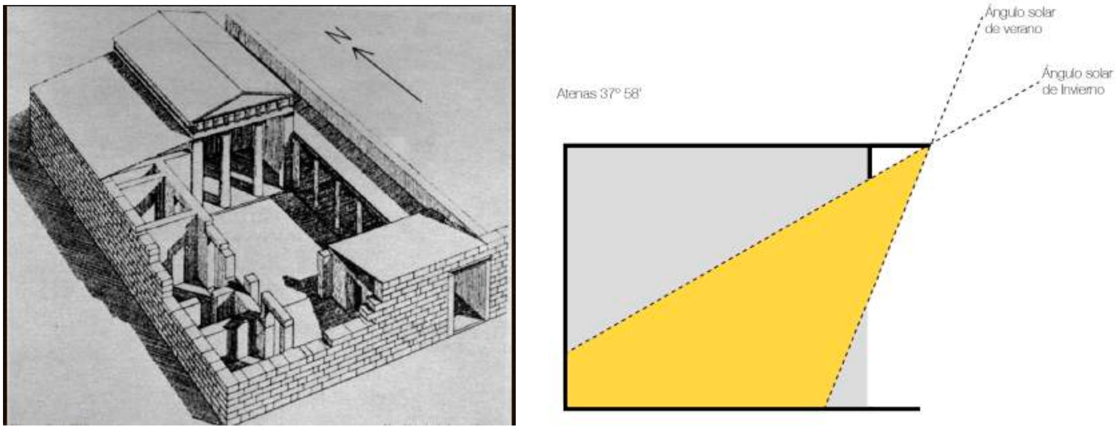


Figure 1: Greek house facing south (right) , taken from [Butti 1980], page 5.
(To the left) Bioclimatic control exercised by the portico for this latitude.

In ancient Greece, Socrates explained "In the houses that look toward the south, the sun penetrates the portico in winter, while in summer the path of the sun is right over our heads and above the roof so that there is the shade." [Butti 1980]

This Socratic principle of design served as a base for Greek architecture to gain advantage of solar resources in a passive manner, thanks to proper orientation and the effective disposition of rooms behind the portico which let the sun in during the winter while keeping the sun out in the summer.

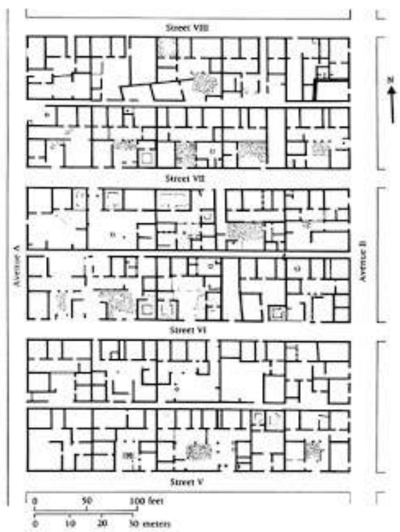


Figure 2: Plan of the city of Olynthus facing south, taken from [Butti 1980], page 6

The city of Olynthus is an example of how these principles were practiced in a dense community. Approximately 2500 people lived there with limited resources, wood for heating homes with fire was scarce and the Greeks had no glass in their windows, thus the necessity of gaining advantage with solar resources.

Solar access concept:
[McCann 2008] defines solar access as a building's continuous availability of direct sunlight without obstructions from other buildings, properties, trees, etc. Solar access is calculated using a solar path diagram for each building.

Solar access description:
According to [Muller 2009], in America every owner must have access to direct sunlight, with the right to install a device that turns solar energy into usable energy. In consequence, solar access is divided into two categories: the Solar Easement Law of 1976 concerning solar access and the Solar Rights Act of 1978 that concerns the right to install a solar energy system.

The link between urban form and solar access has not been addressed clearly or convincingly in urban standards and normativity for the design of Colombian cities. This paper seeks to address the issue of solar access and its importance for buildings and the well being of people everywhere.

Solar access study for the Las Nieves neighbourhood in Bogotá, Colombia (4º38' North)

The city of Bogotá is the capital of Colombia, located in the centre of the country on the eastern ramification of the Andes, located in 4º38' latitude North and 74º longitude West, and a height of 2650 metres above sea level (8694 ft).

Figure 3: Location of the Republic of Colombia and Bogotá city , taken from www.worldatlas.com

Bogotá has a moderately cold weather due mainly to the altitude, the average temperature is 14º C and there are no seasons or significant changes in climate. There are two periods of rain, from March to May and from September to November. The lowest temperatures happen in December and January, sometimes reaching -4º C before dawn and increasing up to 24º C at noon. With daily temperature variations of up to 12º C.

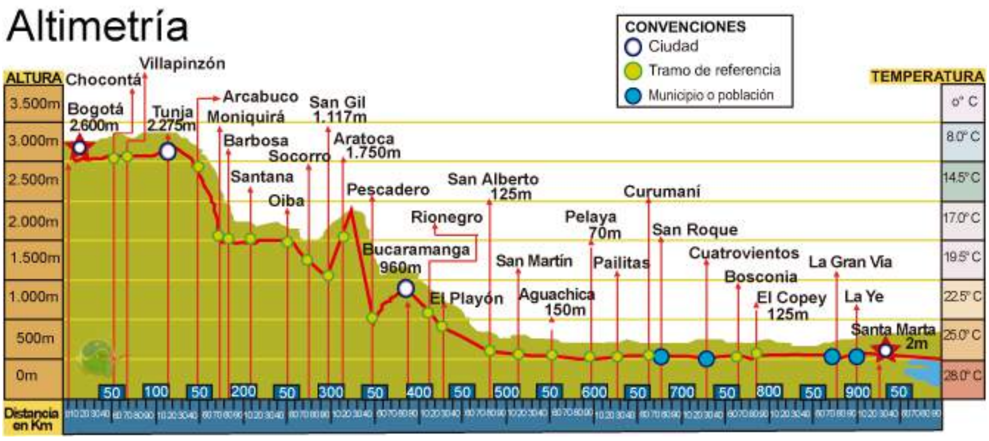


Figure 4: Altimetry Bogotá city, taken from www.destinosyplanes.com

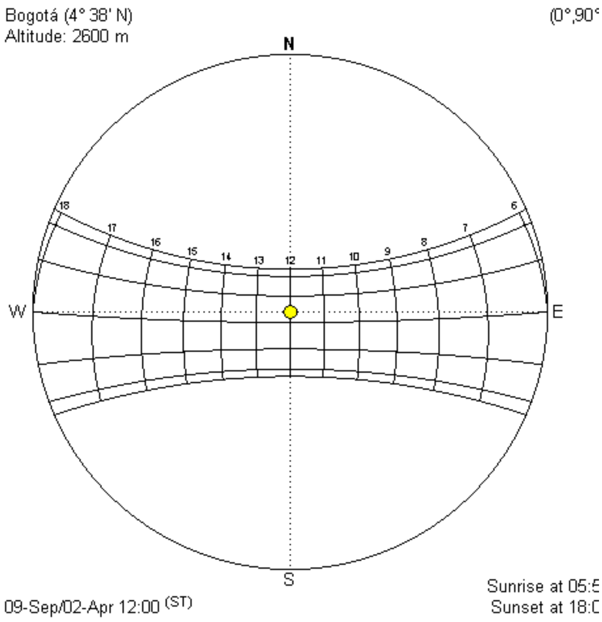


Figure 5: Solar Charter of Bogotá city, generated by the software Heliodon, [Beckers 2006]

The solar chart for Bogotá shows sunrise at 6:08 and sunset at 17:52. The height of the sun at noon is 62º, on December 21st. For the 21st of June sunrise is at 5:52, sunset at 18:08 and the sun's height is 71º at noon, establishing a 9º difference between December and June.

April 2nd and September 9th last the same, for those days the sun height is 90º. The difference between the longest day (June 21st) and the shortest (December 21st) is only 32 minutes.

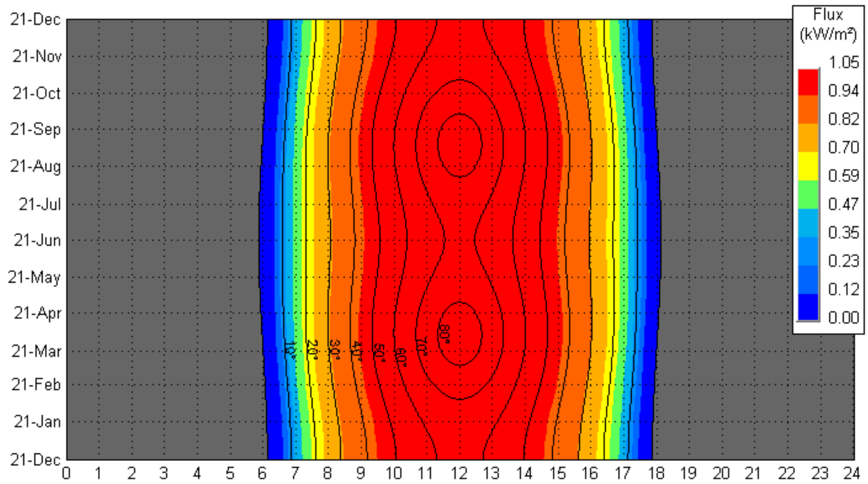


Figure 6: The isochronous projection for Bogotá, generated by the software Heliodon, [Beckers 2006]

The isochronous projection for Bogotá shows that the sun's height is above 40º during the whole year between 9:00 and 15:00. The direct solar flux exceeds 940 W/m2, reaching 1050 W/m2 at noon close to the equinoxes.

The need for sun and radiation in Bogotá

Givoni's higrothermic diagram for Bogotá recommends the use of passive gains in order to obtain energy within living spaces [Givoni 1969]. This extra energy can be exploited by architecture to increase inside temperature and so, without the use of other mechanisms, produce a better sensation of thermal comfort. This is particularly important due to the differences in temperature during the day.

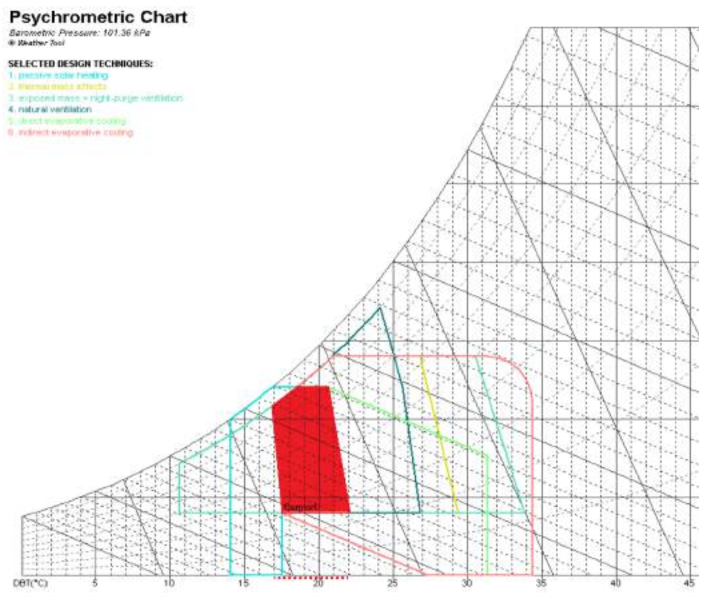


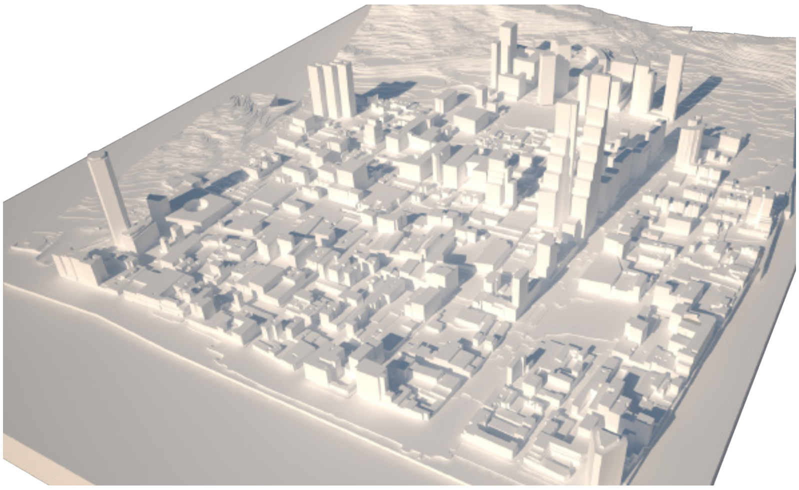
Figure 7: Givoni's higrothermic diagram for Bogotá, generated by the software Ecotect, versión 2011

According to [Knowles 1999], well-being and the joy of life are related to the sun and quality of life in our cities. The sun is an important determination in both physical and psychological comfort; it is important in architecture and can reduce public health issues.

Las Nieves

The Las Nieves Neighbourhood is linked to Bogotá's economic and cultural development. In 1598 Las Nieves was the northernmost Parish. Previously inhabited by natives, it grew since the XVII century thanks to civil and religious buildings. During the XVIII century artisans and industrial uses added to the area's religious character. In the XX century the neighbourhood was known for its cultural activity thanks to the appearance of several theatres and cinemas.

After 1970's the Las Nieves neighbourhood continues its transformation thanks to the appearance of other cultural centres and universities that keep the sector alive. New denser projects are being built now adding to the neighbourhood’s potential, hence the need to include high rise buildings.



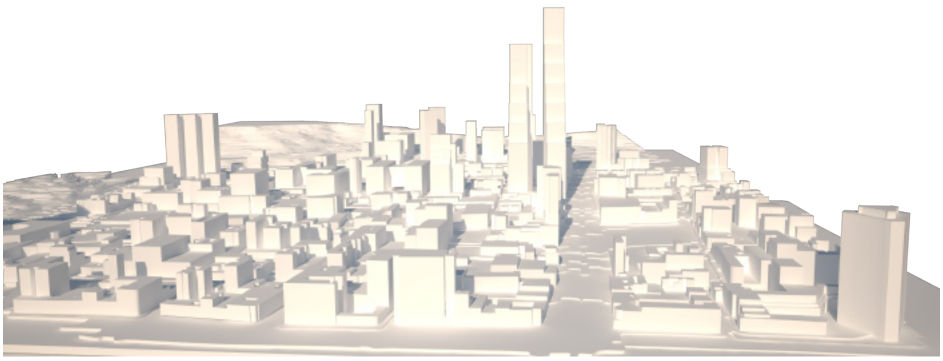


Figure 8: Images of the 3D model of the neighborhood Las Nieves

The model

These characteristics were taken into account in order to build the model

- Each floor is 3.00 metres height. There are no facade details or percentages of glass surfaces.
- Al roofs were assumed as flat.
- Projects being built or already designed were included
- The model includes the terrain and mountains to the east
- The model was constructed by students within the "Espacios temporales" workshop, at the Jorge Tadeo Lozano University.
- The model consists of 632814 triangles, 308658 points and measures 1537.6 x 1153.3 x 325.4 metres.

The solar access study

The analysis was made using the descriptive method because it is one of the most important points of view in the regulations as well as the concept of solar envelope by [Knowles 1999]. From this angle the geometry and projection of shadows seek to establish the maximum height of buildings so that they do not obstruct the access of sunlight to existing buildings [Franco 2014].

Section lines

Bogotá is located in the Torrid zone, therefore there are no seasons but rainy months. The model will be analysed with the lower sun angles and the extreme periods: on December and June 21st, from 9:00 to 15:00 (These time spans are consistent with US and Australian regulations).

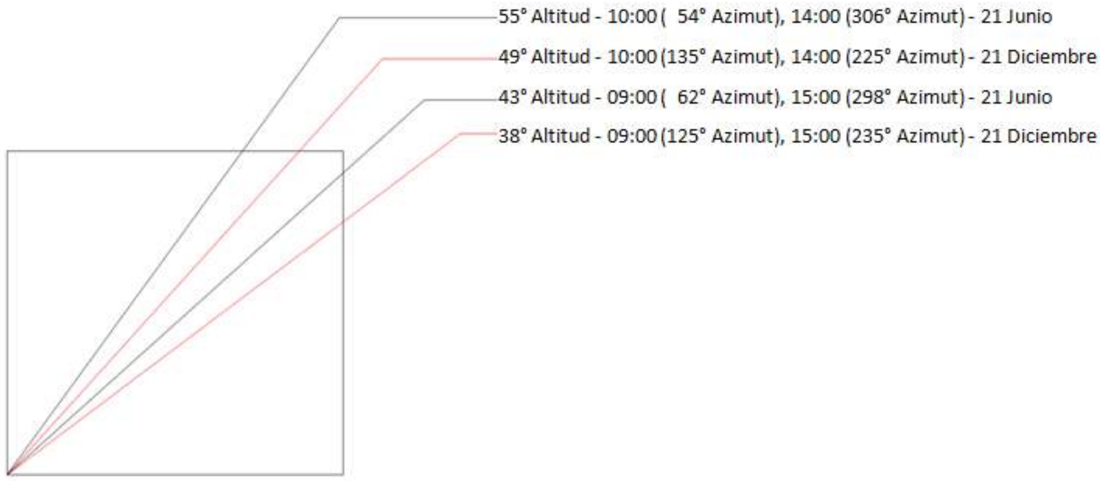


Figure 9: Section lines for Bogotá city

According to [Capeluto 2005] Section lines are used to:

- Determine solar access and rights by defining a base point in the lowest residential floor and use it to draw the section lines to limit the height of the building directly in front.
- Determine and uphold solar access and rights in public spaces: sidewalks, streets, squares and parks.

Case study: BD Bacatá Downtown Building

The BD Bacatá is being built in a lot previously occupied by the Bacatá Hotel, a 15 stories height building built by the architectural firm Meléndez Páez. The new building has multiple uses: hotel, housing, a commercial centre, office spaces and parking basements, designed by the Spanish Grupo Alonso Balaguer.

Figure 10: Plant location case study

The consequences of building a 67 floors (240 metres) building on the Calle 19 where no building is higher than 20 stories (60 metres) are shown in the following analysis. These consequences are exposed through graphic comparisons generated with the Heliodon software: shadow projection, hours of sunlight on facades and sidewalks, solar irradiation and the sky view factor taken on several points on the street.

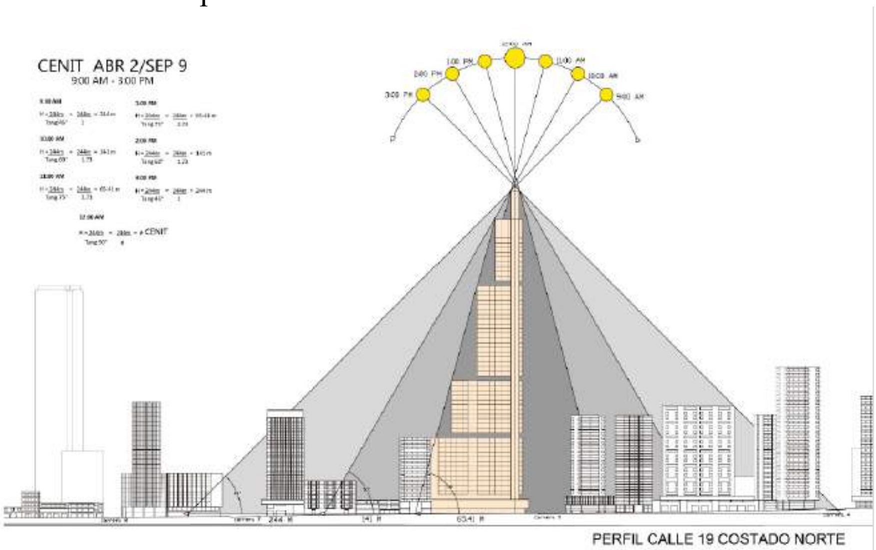


Figure 11: Shadow projection BD Bacatá Downtown on Calle 19 , April 2 , sun height 90. Graphic by students: Martín Diego, Martínez José y Riapira Steven

Shadow projection comparison on June 21st, at 9:00 a.m.

The graphs for the 21st of June at 9:00 a.m., show how the new BD Bacatá's shadow (below) is projected to the Southeast onto Calle 19 and some neighbouring buildings, even reaching the 7th avenue to the west. The projected shadow is approximately 260 metres in length. In the previous image the demolished hotel and its neighbours cast a uniform shadow onto Calle 19th, without affecting other buildings.

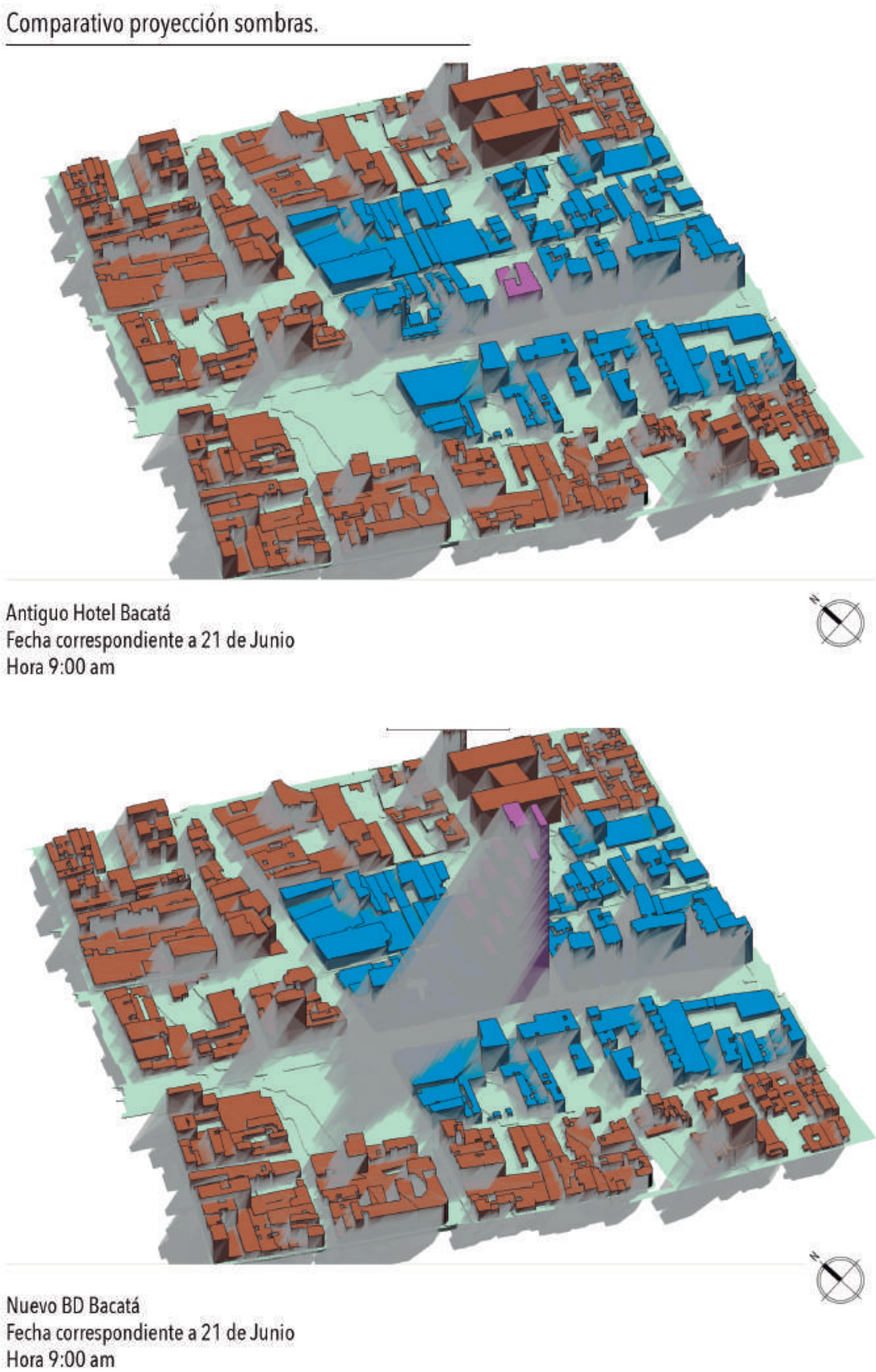


Figure 12: Comparison between shadow projections on June 21st, at 9:00 am

Shadow projection comparison on June 21st, at 3:00 p.m.

The graphs show the new BD Bacatá's shadow on Calle 19 to the Southeast reaching some of the neighbouring buildings. The previous hotel´s 48-metre shadow does no affect other buildings.

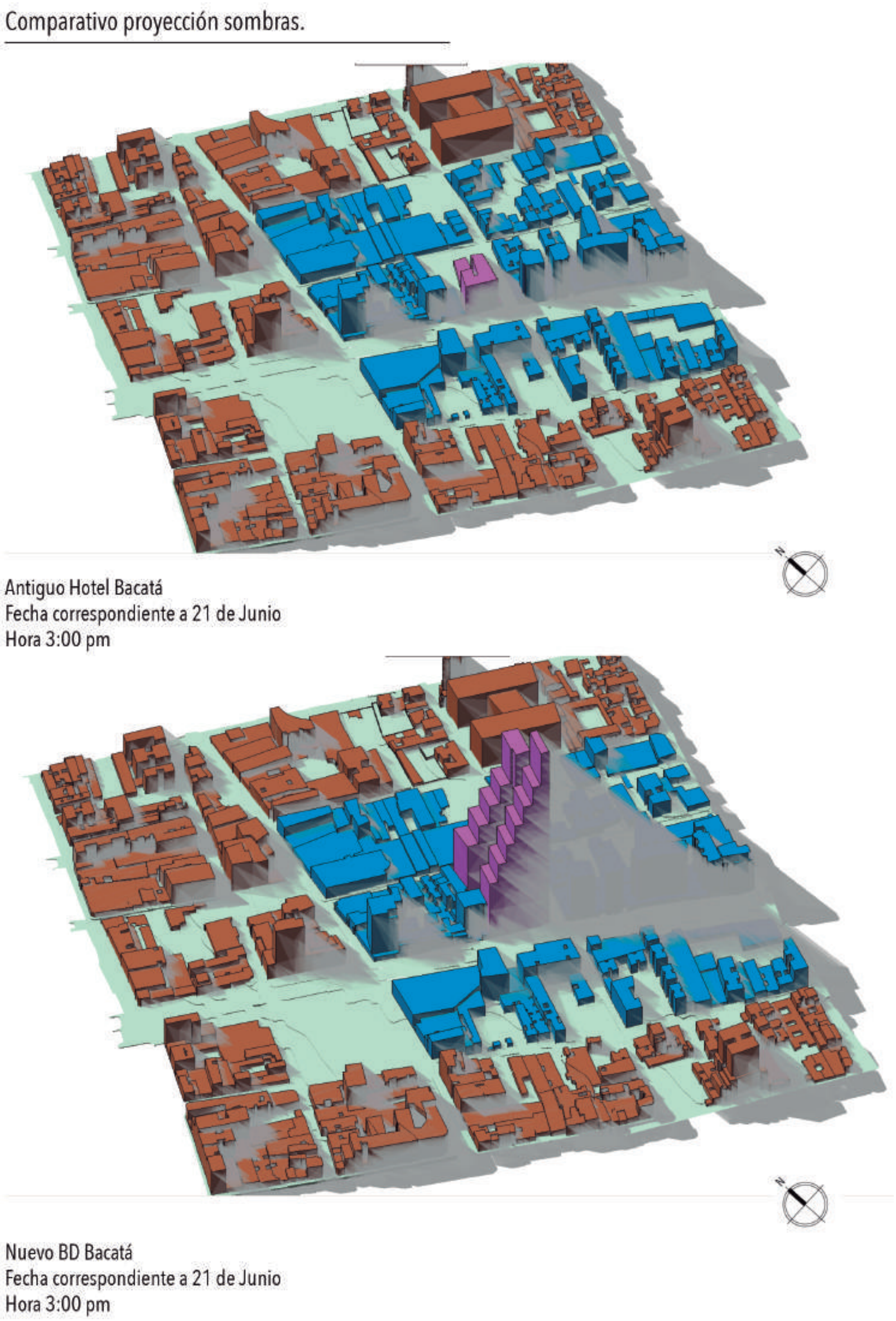


Figure 13: Comparison between shadow projections on June 21st, at 3:00 pm

Shadow projection comparison on December 21st, at 9:00 a.m.

The projected shadows of the BD Bacatá move to the Northwest affecting many of the neighbouring buildings, sidewalks and streets. The 307 metres extended shadow reaches Carrera 8a and 21st street. The previous building´s extended shadow was 57 metres long, reaching 20th street.

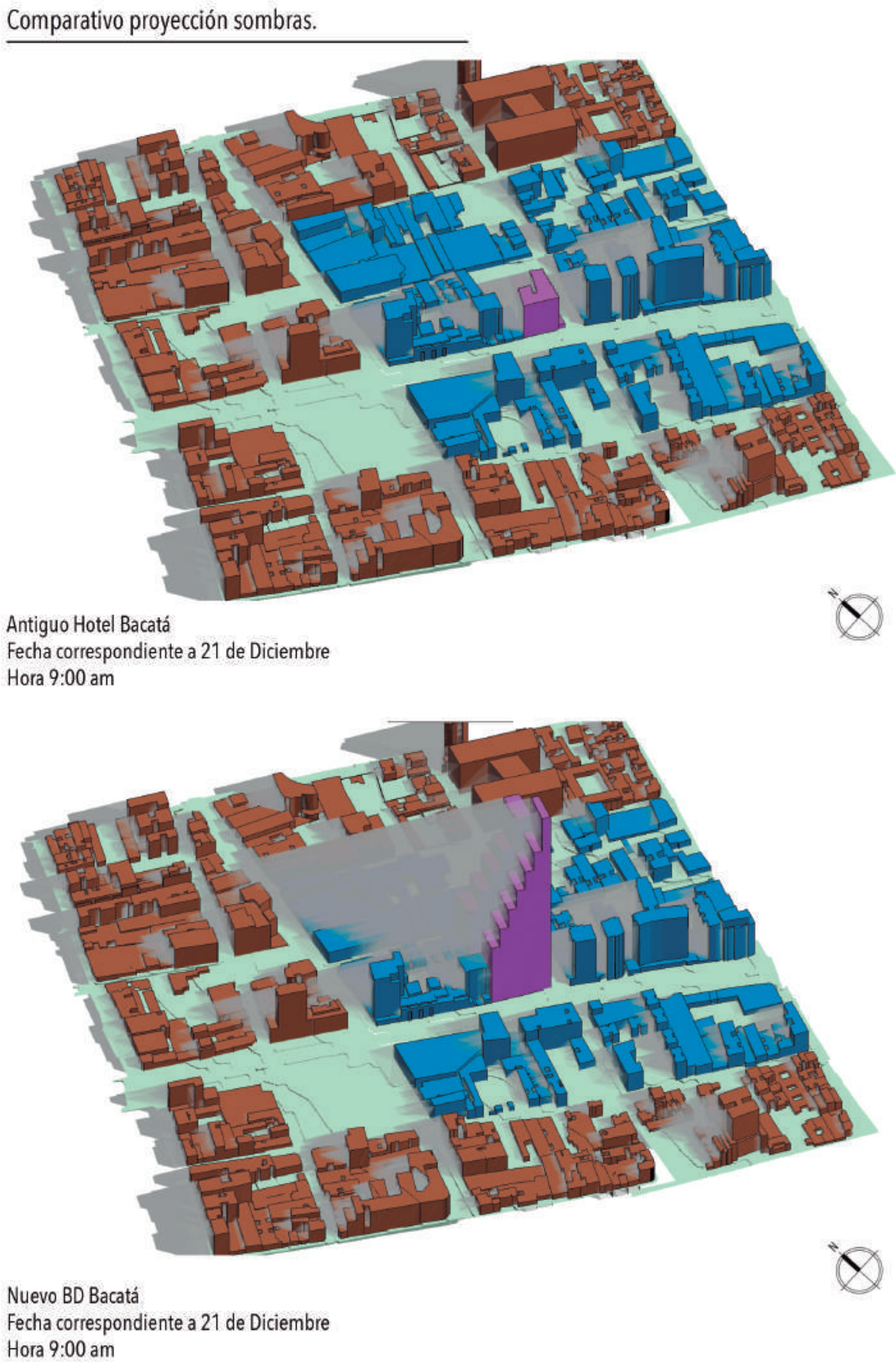


Figure 14: Comparison between shadow projections on December 21st , at 9:00 am

Shadow projection comparison on December 21st, at 3:00 p.m.

The 307 metres projected shadows of the BD Bacatá to the Northeast reach Carrera 3rd and Calle 21st. The old hotel's shadow reached up to Carrera 5a.

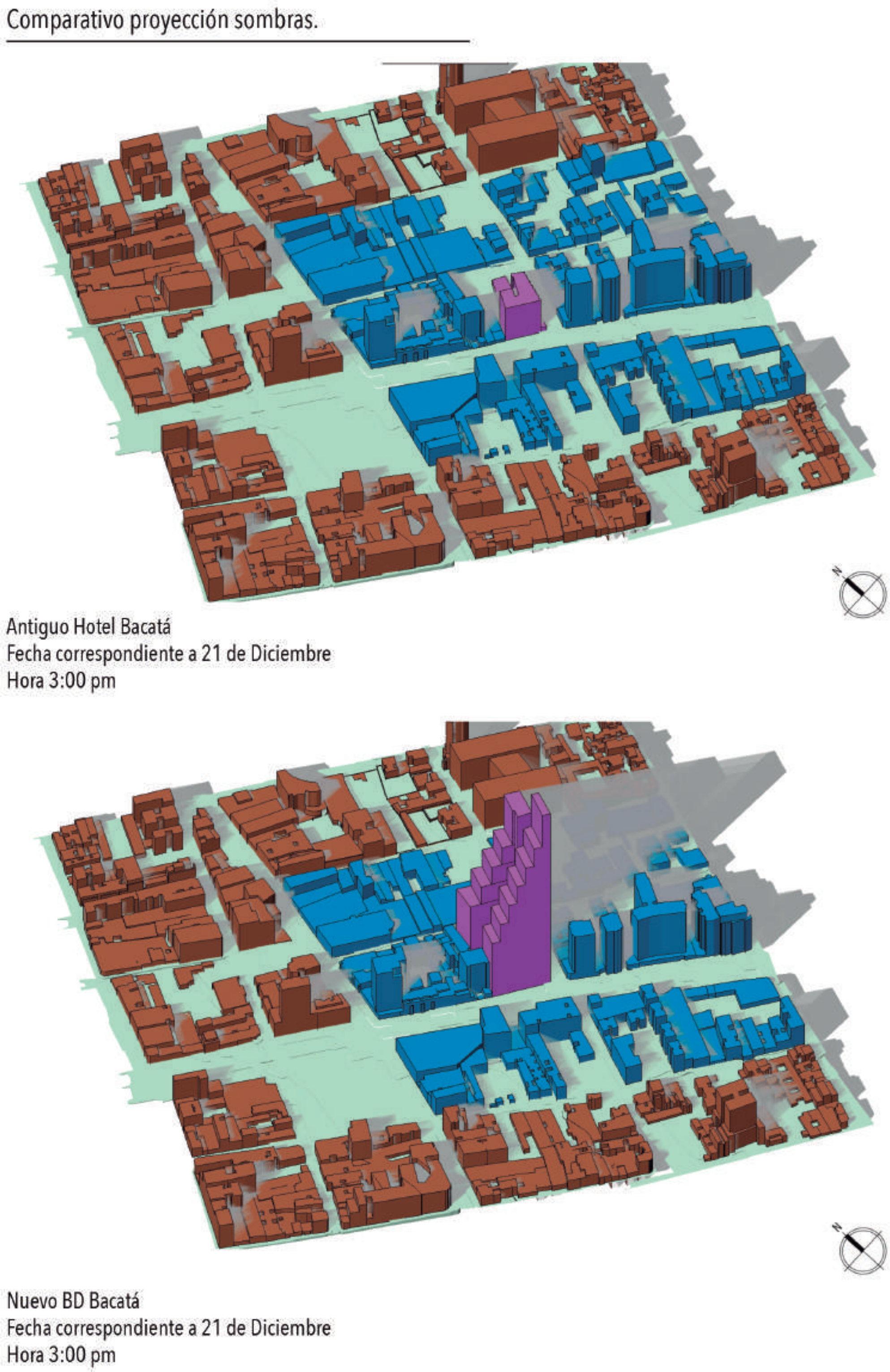


Figure 15: Comparison between shadow projections on December 21st, at15:00 pm

Comparison of hours of sun on surrounding facades and rooftops

The following graphs show the number of sunlight hours on facades and rooftops surrounding the case study. In June the demolished hotel the rooftops and north facades oriented to Calle 20 received between 10 and 12 hours of sun. With the BD Bacatá highrise the same rooftops and facades receive between 2.5 and 11 hours of sun, which means an average loss on 38.7%.

The situation for December is worse. The facades on Calle 19 receive between 6 to 11 hours of direct sun, a reduction of 17% compared to the demolished hotel. The facades on Carrera 5 receive between 0 to 5 hours of sun, compared to 2.6 to 6 in the previous situation. On average this means a loss of 71.3% in hours of direct sunlight, on December 21st.

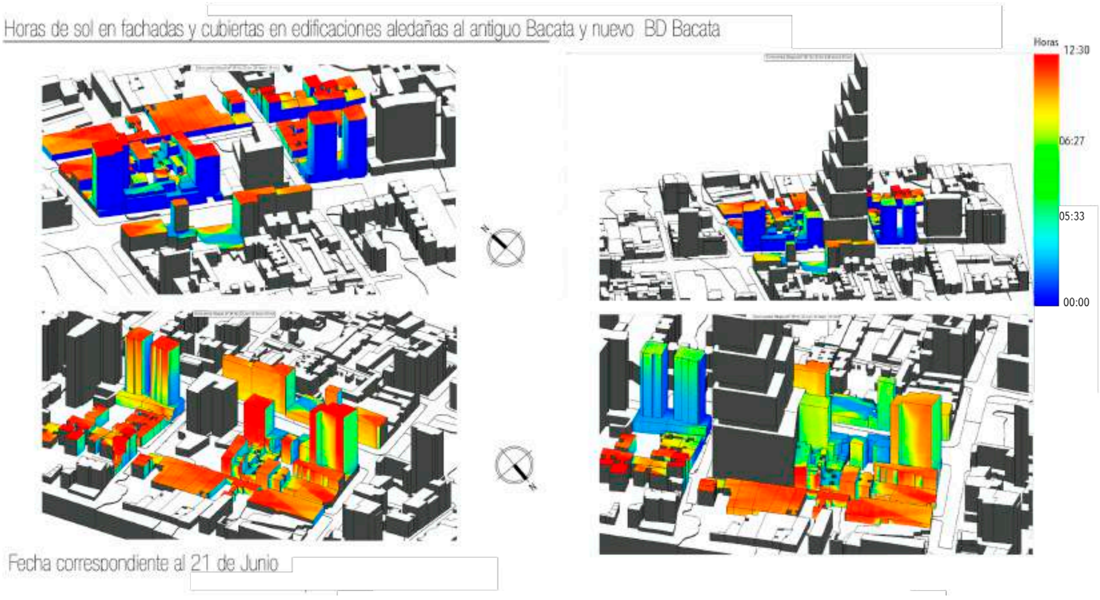


Figure 16: Comparison of hours of sun on surrounding facades and rooftops on June 21st

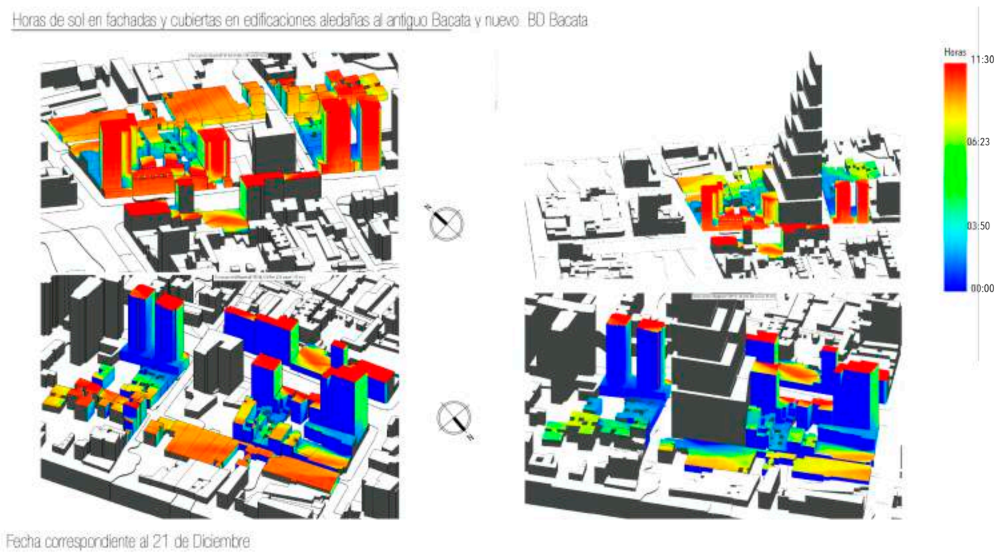


Figure 17: Comparison of hours of sun on surrounding facades and rooftops on December 21st

Solar irradiation comparison on surrounding facades and rooftops on June 21st

For this day the BD Bacatá affects the surrounding buildings, implying losses of up to 37% hours of sunlight and up to 50% in solar radiation. No evident losses occur on Carrera 5ta or Calle 20.

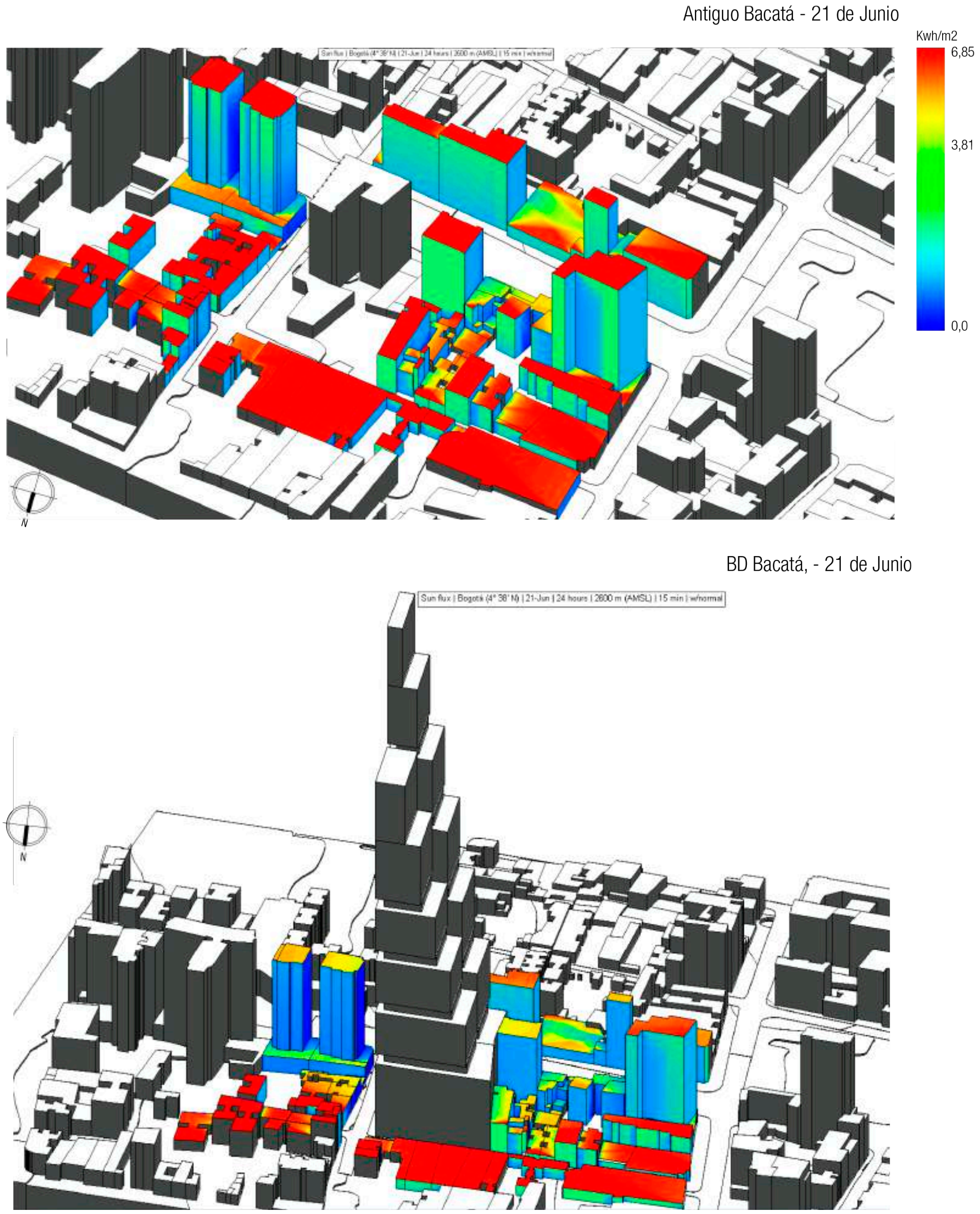
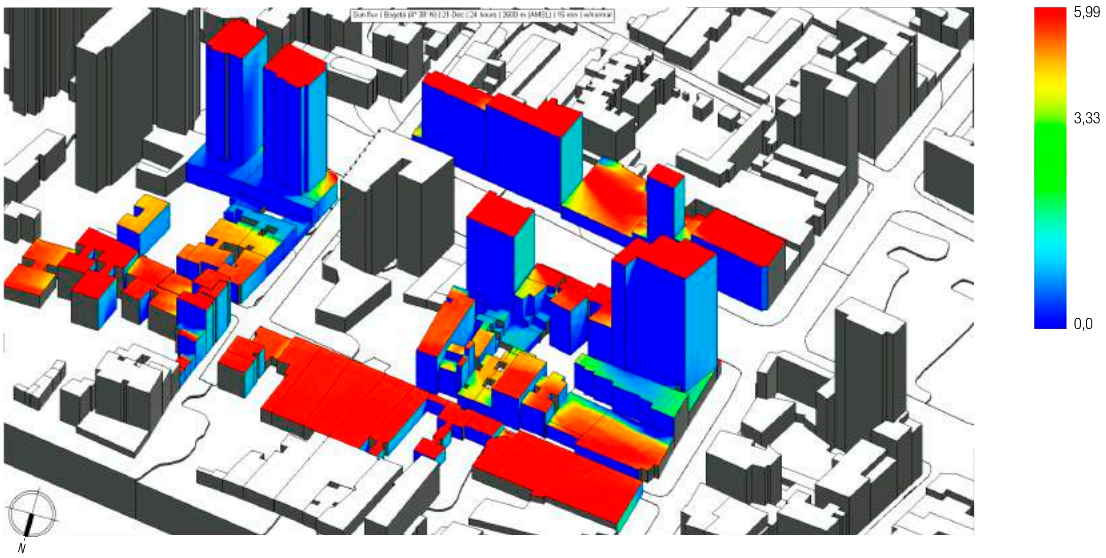


Figure 18. Solar irradiation comparison on surrounding facades and rooftops on June 21st

Solar irradiation comparison on surrounding facades and rooftops on December 21st

For this day the solar irradiation simulation results are contrasted, with less losses on neighbouring rooftops, between 10.5% reduction of sunlight and 33.6% radiation reduction. More losses occur then on Calle 20 where the rooftops receive up to 75% less energy, 32% less sunlight and 28% radiation. The worst situation occurs at the corner of Carrera 5ta and Calle 20 where the reductions in energy are 49.5% hours of sunlight and 50.5% in solar radiation.

Antiguo Bacatá - 21 de Diciembre



BD Bacatá, - 21 de Diciembre

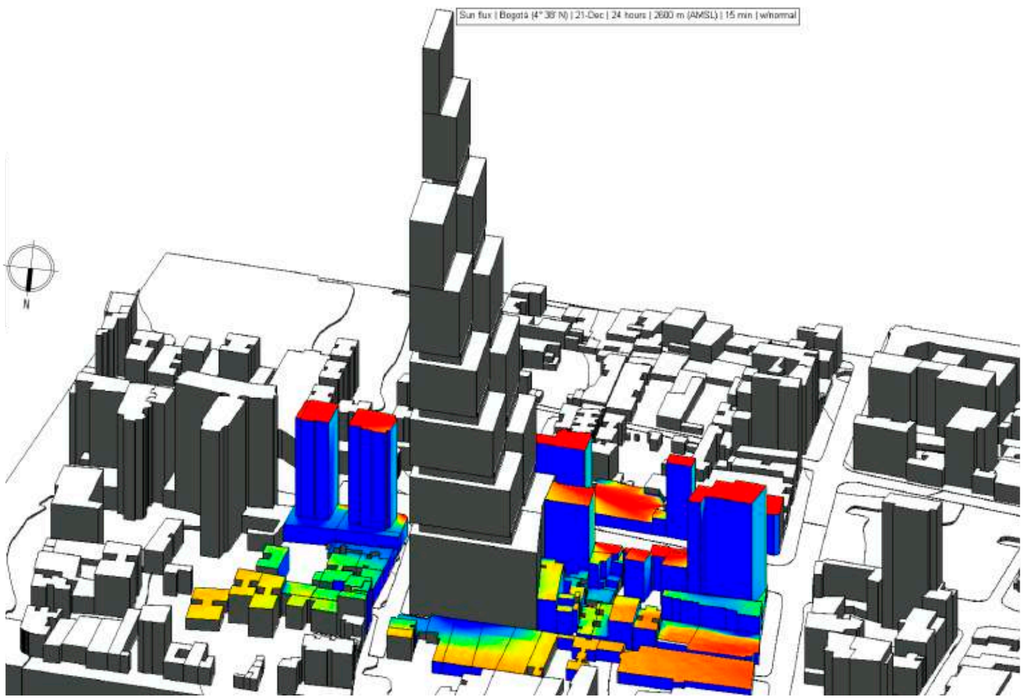


Figure 19. Solar irradiation comparison on surrounding facades and rooftops on December 21st

Comparison of sun hours on sidewalks

The building of the BD Bacatá skyscraper, in comparison to the demolished hotel, implies a reduction in hours of sun on sidewalks of 11.3% for the 21st of June. Stereograph 3 shows a reduction of sun on the sidewalk from 1 hour 45 minutes to zero. The problem is similar on December 21st, showing a reduction of 42.42% of sun reduction, as well a reduction from three and a half hours to zero in graph 2.

Figure 20: Comparison of sun hours on sidewalks on June 21st

Figure 21: Comparison of sun hours on sidewalks on December 21st

Sky view factor

These graphs show the comparison between the demolished hotel and the new BD Bacatá building and evidence a maximum reduction of 23.3% in sky view factor. The factor varies according to the relative distance to the new building.

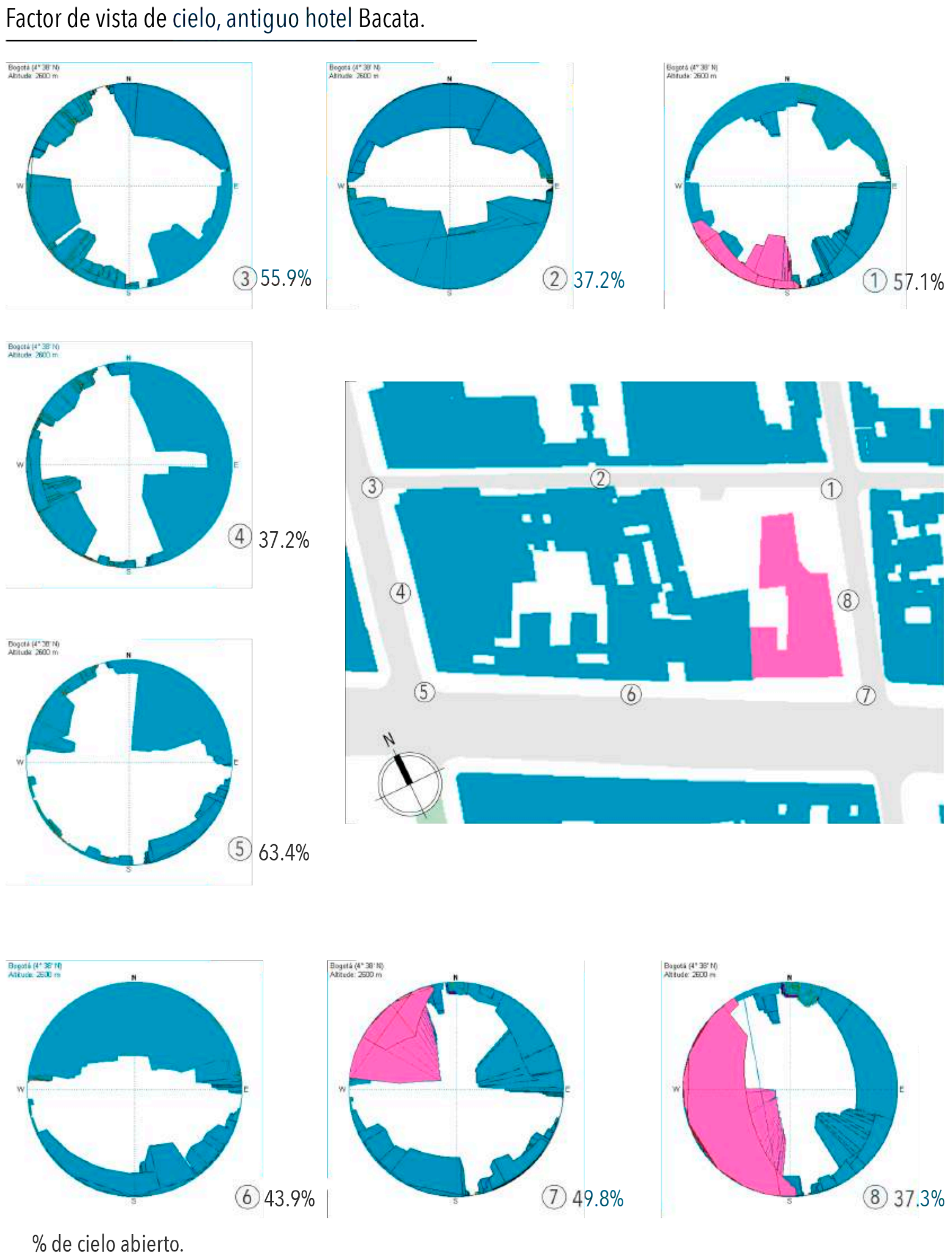
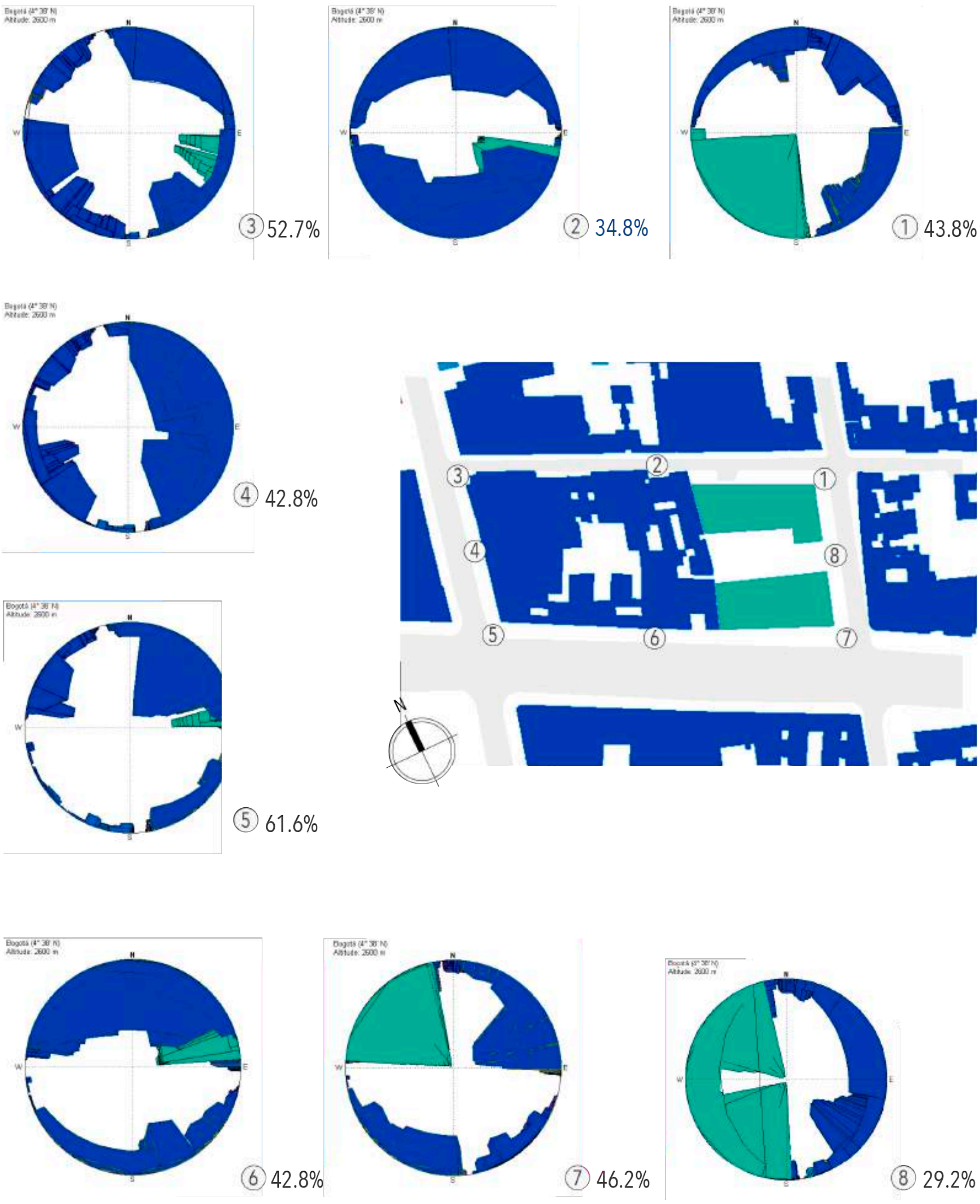


Figure 22: Sky view factor hotel Bacatá

Factor de vista de cielo, nuevo BD Bacata.



% de cielo abierto.

Figure 23: Sky view factor BD Bacatá

BD Bacatá Analysis of sunlight and irradiation hours on June 21st

On this day the BD Bacatá receives a maximum number of hours of sunlight, due the position of the sun for this period. The north facing facades and higher rooftop receive the highest amount of sunlight, the lower rooftops receive up to 50% less sunlight.

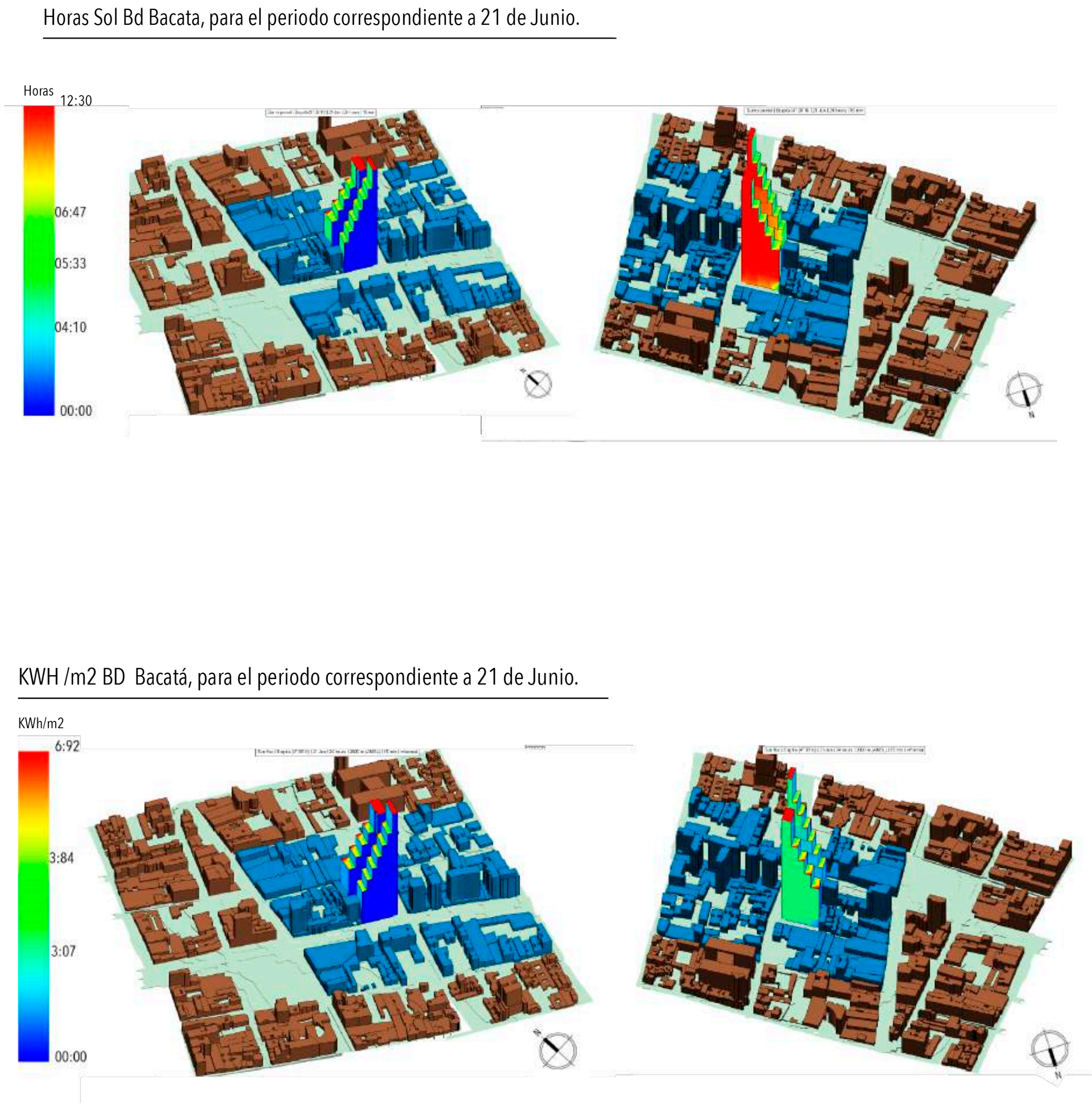
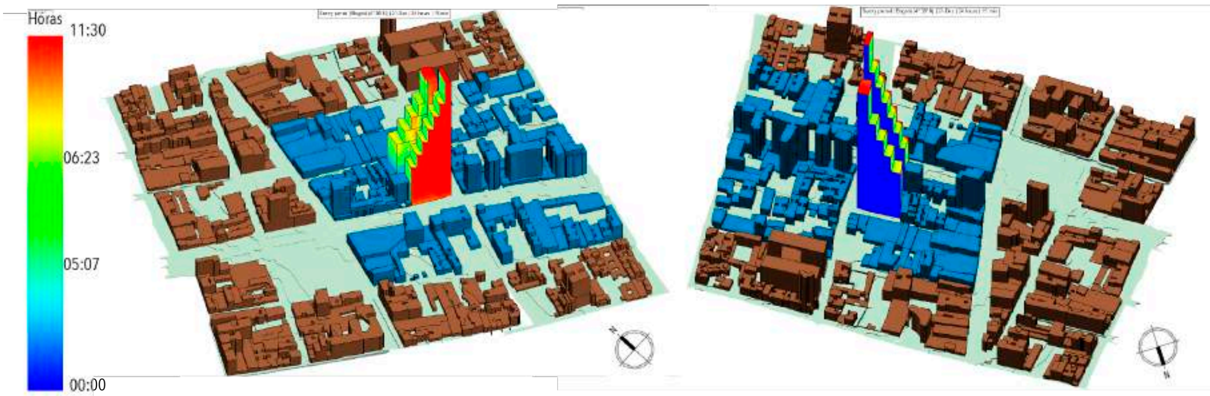


Figure 24: BD Bacatá sunlight and irradiation hours on June 21st

BD Bacatá Analysis of sunlight and irradiation hours on December 21st

On December 21st the buildings situation changes, although it is not absolutely inverse. Energy is concentrated on the southern facades and rooftops, with the same reduction in the lower rooftops.

Horas Sol Bd Bacata, para el periodo correspondiente a 21 de Diciembre.



KWH/m2 BD Bacatá, para el periodo correspondiente a 21 de Diciembre.

Figure 25: BD Bacatá sunlight and irradiation hours for the 21st of December

BD Bacatá Analysis of sunlight and irradiation hours during the whole year

According to the sunlight and irradiation analysis the BD Bacatá is a better solution as an architectural project than as an urban solution to existing energy conditions. The buildings largest facades oriented 120º North allow the building benefit from sunlight during the whole year, reaching an energy balance between the north and south facades.

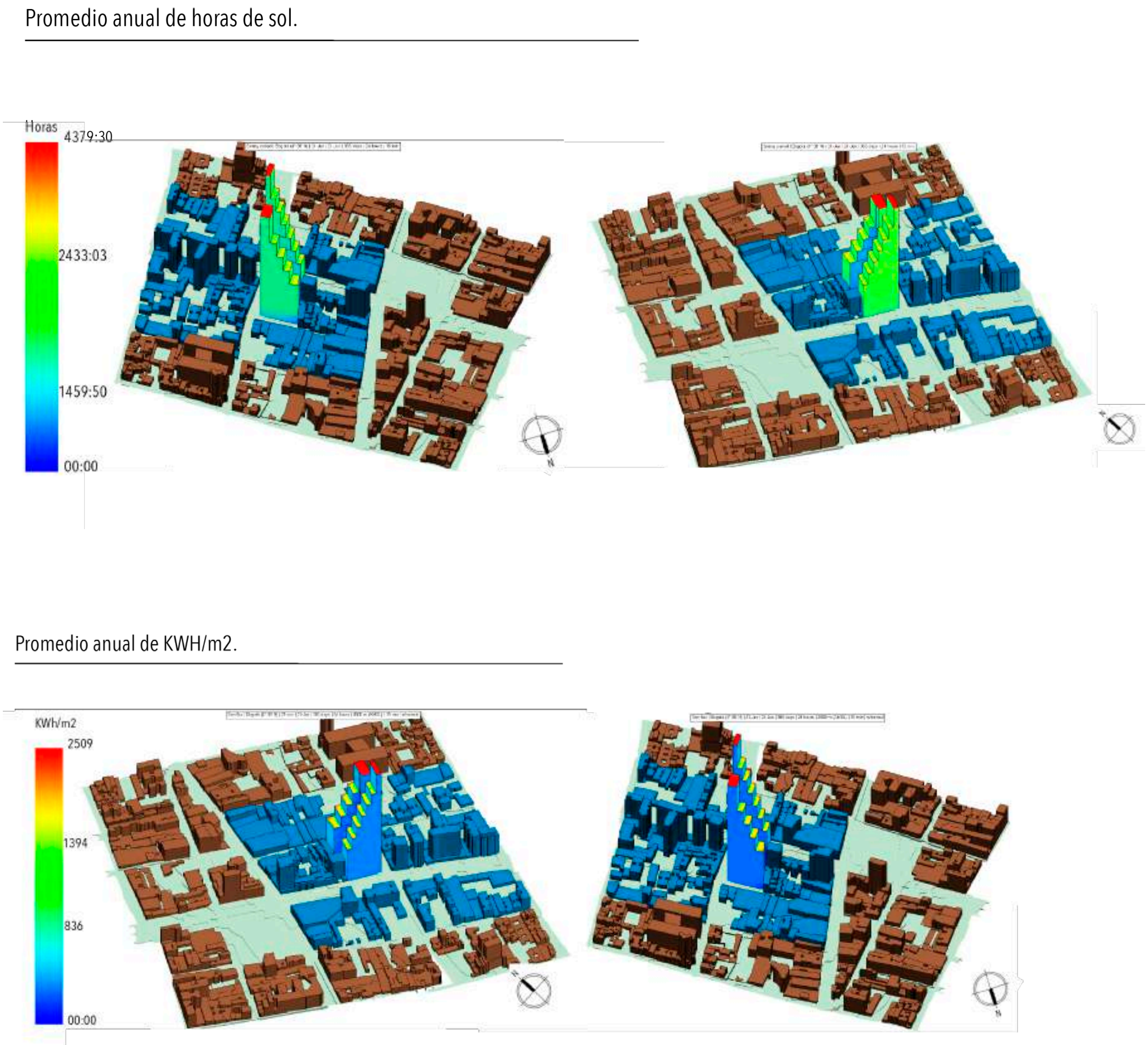


Figure 26: BD Bacatá sunlight and irradiation hours during the whole year

Conclusions

- According to the case study, the Las Nieves neighborhood, we can conclude that the building of the BD Bacatá has a negative effect on the surrounding urban fabric in key factors such as direct sunlight hours, sky view factor and solar irradiation.
- The new BD Bacatá building has a negative energetic impact on the surrounding urban fabric. The sky view factor from the sidewalks is reduced in 23.3%, its orientation and form affect the hours of sunlight on the facades and rooftops on Carrera 5 where the average loss of sunlight hours is of 71.3% on December 21st.
- The shadow projected by the new BD Bacatá during the year, specially during the cold days, prevents the passive solar gains required by the neighbouring buildings to increase their inside temperature, affecting social dynamics, comfort and health of the inhabitants.
- The buildings around the new BD Bacatá receive between 38.7% and 71.3% less hours of sun compared to the demolished Bacatá Hotel, designed on a platform and tower typology that permitted a higher solar access to the neighbouring buildings.
- The BD Bacatá's design consists of two towers facilitating shadows between them, decreasing possible sunlight and irradiation hours by 3.6% and 6% respectively. Under the same analysis, the building decreases sunlight by 6.8% and radiation by 7.4% in a radius close to 150 metres. It can be argued that the BD Bacatá is better as an architectural project than as an urban project in its response to existing energy conditions.
- The construction of the new building of BD Bacatá in Las Nieves neighborhood leads to at least two types of definitive reflections for growing and densification of the city; but this can be addressed in future articles. ¿What is the maximum possible height for new buildings in the Las Nieves Neighborhood according to US or Australian policies? ¿If high-rise buildings are permitted, how much free public space should be proposed below the buildings' projected shadow?
- As a final conclusion it can be said that taking into account the analysis above, the initial hypothesis is confirmed: The solar energy, more than any other type of renewable energy has direct effects on shape, habitability, comfort and the volumetric planning of our buildings, the distance between buildings, their heights and recoils. Therefore, if a building has solar access, the energy received can be used and integrated in the building through active or passive systems with the goal of reducing CO_2 emissions and its demand of energy; trying to keep a sustainable dimension in the architecture.

I would like to express my sincere gratitude to all of those have participated in the making of this article.

Dirección de Investigación, Creación y Extensión

Facultad de Artes y Diseño and Programa de Arquitectura de la Universidad de Bogotá Jorge Tadeo Lozano.

Javier Benitez , Omar Niño, Ángela Pachón research assistants

Student workshop Espacios temporales, period 2016-1:

ALVARADO CARRILLO, DANIELA
AMAYA SABOGAL, WILVER CAMILO
ARIAS LUQUE, NICOLÁS ALEJANDRO
BORDA RUEDA, ADRIANA MILENA
CAMACHO GARCÍA, JOHANNA ANDREA
CASTRO LATORRE, MARIO ADRÉS
CRUZ MUSUSU, MARÍA CAMILA
GARAVITO LÓPEZ, JONATHAN CAMILO
GARCÍA BETANCUR, PAULA ANDREA
GUZMÁN RAMÍREZ, LEONARDO ANTONIO
LUNA MOTATO, JOHANNA CAROLINA
MOSQUERA CASTELLANO, JORHELIS G.
OVALLE BARRERA, DANIEL ENRIQUE
PERDOMO BARBOSA, MARÍA CAMILA
PIÑEROS AGUDELO, ANDREA CATALINA
PRIETO ARÉVALO, KATHERINE JULIETTE
RAMÍREZ CÁRDENAS, ÁNGELA PATRICIA
RAMÍREZ RIAÑO, DANIELA
TERREROS PERDOMO, SEBASTIÁN E.
TORRES NARANJO, LAURA NATALIA
VILLALBA MORENO, JUAN DAVID
VITERI TORO, LUISA FERNANDA
ZULETA OLAYA, ANDRÉS FERNANDO

And finally students :

MARTÍN BUITRAGO, DIEGO ALBERTO
MARTÍNEZ MENESES, JOSÉ LUIS
RIAPIRA MORENO, LUDWIG STEVEN

References

[Beckers 2006] Benoit Beckers & LucMasset. *Heliodon2.* software and user's guide, www.heliodon.net. (2006)

[Butti 1980] Ken Butti. *A Golden thread : 2500 years of solar architecture and technology*. Palo Alto: Cheshire Books ; New York : Van Nostrand Reinhold. (1980)

[Cárdenas 2012] Luz Cárdenas & Paula Uribe. *Acceso solar a las edificaciones: El eslabón pendiente en la legislación urbanística chilena sobre la actividad proyectual.* Revista de Urbanismo, 14 (26), Pág. 21-42. doi:10.5354/0717-5051.2012.20922. (2012)

[Capeluto 2005] Capeluto, G., Yezioro, A., Bleiberg, T. &Shaviv, E. *From computer models to simple design tools: solar rights in the design of urban streets.* Cominiación presentada en: Ninth International IBPSA Conference. Montréal, Canada, (2005, Agosto).

[Franco 2014] Ricardo Franco. Tesina: Acceso solar: studio comparativo de acceso solar por el método descriptivo entre las ciudades: Jerusalén, Israel (31,8' Norte) y Bogotá, Colombia (4,38' Norte). Universidad Politécnica de Cataluña, Barcelona. (2014)

[Knowles 1999] Ralph Knowles. *The Solar Envelope.* California, USA. University of Southern California. [en línea][consulta: 19 mayo 2014] Disponible en: http://www-bcf.usc.edu/~rknowles/sol_env/sol_env.html. (1999).

[McCann 2008] ColleenMcCann.*A Comprehensive Review of Solar Access Law in the United States.*Florida. Ed.,Florida Solar Energy Research and Education Foundation. (2008).

[Muller 2009] Hannah Muller. "Solar Access: Recommendations for the City and County of Denver," U.S. Department of Energy**:** 5. (2009).