Educational facilities for energy autonomy in the Colombian Pacific region

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Politecnico di Torino

Corso di Laurea Magistrale in Architettura per la Sostenibilità
A.a. 2023/2024
Sessione di Laurea Febbraio 2024

Tesi di Laurea Magistrale

Educational facilities for energy autonomy in the Colombian Pacific region

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1. Abstract

The Colombian Pacific is a region of great cultural and environmental richness, where traditional architecture works in balance with the natural environment, the landscape, and the cultural identity of its inhabitants. It is also one of the regions with the highest percentage of people without access to electricity (non-interconnected areas), in addition to other problems related to unmet primary and secondary needs. Due to its difficult access from centralized systems, energy self-sufficiency solutions such as solar photovoltaic energy are the most efficient for this region. This research seeks to recognize the characteristics of traditional architecture to highlight its potential as sustainability strategies and apply them to a prototype of an educational center focused on the energy independence of its users. To this aim, an investigation is proposed on bioclimatic strategies of architecture in the Colombian Pacific and strategies for energy efficiency for solar energy production. A prototype of educational equipment is proposed in which these strategies are applied, to define their scope and effectiveness for the region.

Colombian Pacific, vernacular architecture, bioclimatic, energy efficiency

2. Glossary

2.1 Energy efficiency concepts:

Energy efficiency

is the ratio of useful energy output to the total energy input in a system, indicating how effectively energy is utilized

↓

Energy consumption + **Energy production** → **Energy balance**

Energy consumption: the amount of energy used or consumed in a system during a specific period of time.

Energy production: generation of electricity from sunlight using photovoltaic cells

Energy balance

- Net Zero: Equal production and consumption.
- **Positive: the system produces more energy than it consumes**

2.2 Photovoltaic system concepts:

- Solar Panels (Photovoltaic Modules): Solar panels, or photovoltaic modules, are the most visible part of the system. They are composed of solar cells that convert sunlight into electricity through the photovoltaic effect.
- Inverter: The inverter is an essential component that converts the direct current (DC) generated by the solar panels into alternating current (AC), which is the form of electricity used in homes and businesses.
- Structural Mounting: Structural mounting supports and positions the solar panels to maximize exposure to the sun. It can take the form of ground structures, roof mounts, or even solar tracking systems that adjust the orientation of the panels throughout the day.
- Batteries: Some photovoltaic systems include batteries to store excess electricity generated during the day for use during the night or on cloudy days. This allows for the creation of solar systems independent of the electrical grid.
- Bi-Directional Meter: In grid-connected systems, a bi-directional meter may be used to measure both generated and consumed electricity. In some cases, excess electricity can be fed back into the grid, and the system owner may receive credits.
- Charge Controller: If batteries are used, a charge controller regulates the flow of electricity between the solar panels and the batteries to protect them and optimize their performance.
- Monitoring System: Some systems include a monitoring system that allows owners to track the performance of the system in real-time and over time.

2.3 Non-interconnected zones concepts:

- Non-interconnected zones (ZNI): ZNI refers to municipalities, districts, localities, hamlets, etc., not connected to the National Interconnected System (SIN) (Article Law 855-2003).
- Telemetry: Telemetry is a technology that enables remote measurement of electrical energy and the subsequent transmission of this information to a centralized monitoring system. The telemetry system consists of two fundamental components: an energy measurement system and a communication system (communication devices and interfaces) that allow the remote recording and transmission of electrical energy and variable registration information.
- Localities with Telemetry Systems: These are localities where the provision of electrical energy supply is monitored using a telemetry or remote measurement system, which allows remote measurement of electrical energy and the subsequent transmission of this information to the National Monitoring Center.
- Localities without Telemetry Systems: These are localities where the provision of electrical energy supply is monitored through telephone contact, email, or other digital communication means (Contact Center), using interviews or surveys with users and/or local operators.
- Service Provision Hours (h): The monthly average of daily service provision hours for electrical energy in localities of Non-Interconnected Zones (ZNI).
- Service Provision Energy (W): The monthly average of daily service provision total electrical energy in localities of Non-Interconnected Zones (ZNI).

2.4 Colombian pacific vernacular architecture concepts:

- Palafitos (Stilt Houses): Houses built on stilts or piles, typically elevated above water or wet ground to mitigate the effects of flooding or tidal variations.
- Mangrove Forest: A coastal ecosystem consisting of salt-tolerant trees and shrubs, known as mangroves, which thrive in brackish water and provide valuable habitats for various species.
- Pilings: Vertical structural elements, often made of wood, bamboo, or concrete, driven into the seabed or soil to provide stability and support for elevated structures.
- Water Adaptation: Design considerations and features that account for and respond to the dynamic nature of water, such as tides and water levels.
- Platform: flat and elevated surface extending from a stilt structure, providing additional space and facilitating different activities.
- Community Construction: The collaborative effort of multiple families or community members in the construction and maintenance of structures, fostering a sense of shared responsibility and community engagement.

3.Introduction

3.1 Thesis overview: Identity and Autonomy

The Colombian Pacific is one of the regions with the largest number of non-interconnected areas in Colombia, which means, areas where there is no electricity supply from the country's centralized system (Agencia de Renovación del territorio, 2021, p. 29). This condition hinders the development of the region and exacerbates social and economic inequality. Solar photovoltaic energy systems are proving to be the most effective and appropriate solution for the region, due to their high efficiency in the local climate conditions, their adaptability and sustainability. These proposals are promoted and financed by the Rural Energy Planning of the Fund for Renewable Energy Sources (FENOGE) and the Institute for Energy Solutions Planning and Promotion for non-interconnected areas of Colombia (IPSE).

On the other hand, the Colombian Pacific is a region characterized by the richness of its ecosystems and the adaptability of its inhabitants to the natural environment respectfully and coherently. The traditional architecture of the region consists mainly of palafite buildings, which are designed according to the cultural, economic, and social activities of the communities, which also prove to be strategic for climatic conditions.

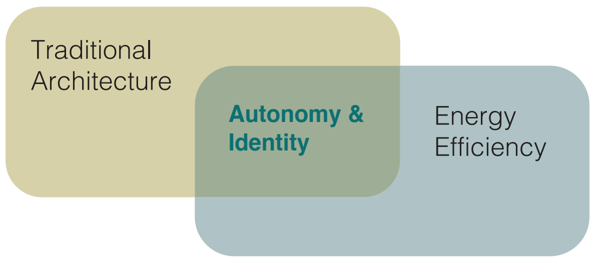
Learning about the vernacular techniques implemented promotes the development of the sustainable architecture of the region, preserving its tradition, culture, history, and environmental values. This academical work proposes to recognize the sustainability strategies of traditional architecture in the Colombian Pacific to achieve educational facilities with integrated photovoltaic energy production systems.

For this purpose, the research phase focuses on a a review about the energy transition in Colombia and the non-interconnected areas. The Colombian Pacific area is chosen to be studied because of its largest number of non-interconnected areas. The region is studied through a historical, territorial and demographic review. Vernacular architecture and the social development planning are also studied. This was followed by a review of the implementation of the energy proposals in the region. In this chapter is also included the importance of the architecture that integrates energy efficiency strategies and its climate change impact.

Afterward, an analysis of two case studies is conducted based on personal experience in both projects. The first, *Minga House*, a winning proposal for the *Solar Decathlon 2019* competition, draws from my personal involvement as the team leader. In this project, passive and active strategies from the traditional architecture of the Pacific region are implemented. The second reference is *Hallenbad Zuffenhausen*, designed by *Behnisch Architekten*, based on my professional internship experience. This building applies high-efficiency energy strategies to become the first public 'EnergyPlus' provider in the region of Stuttgart, Germany.

After conducting the research, the focus shifts to proposing a prototype of an energy solution as an educational institution in the Colombian Pacific region. It begins with the analysis of the city where it will be carried out. Then, a design methodology grounded in region-specific bioclimatic strategies shapes the following architectural proposal. This section anchors the architectural design in the bioclimatic studies. Afterwards, the proposal focuses on the dimensioning of the photovoltaic system, emphasizing the energy autonomy capacity.

It concludes by evaluating the results on two topics: traditional architecture and energy efficiency. Through this methodology, it is proposed to evaluate the possibility of creating educational facilities that provide electricity through photovoltaic production to replace other fossil fuels in currently use.



3.2 Justification

The proposal of this research is justified by the importance of acknowledge, respecting, and promoting sustainable and autonomous development of the Colombian Pacific region. This has historically been rejected and ignored by the state, which exacerbates the need to identify the needs of the communities, assess their cultural and environmental potential, and strengthen their development.

One of the ways is through the implementation of rural facilities that encourage the consolidation of communities and facilitate access to educational and development opportunities, in addition to encouraging the autonomous production of photovoltaic energy.

The strengthening of the region recognize its autonomous development, respecting and valuing constructive traditions. At the same time engaging these proposals should develop integrated renewable energy sources into architecture.

In this way, **the research proposes to value vernacular architecture and demonstrate its efficiency by applying its concepts to a prototype of educational equipment that fulfills the function of being a source of photovoltaic solar energy.**

The viability of energy solutions is also justified by their use and application. Public educational facilities have a consumption profile that facilitates the energy efficiency of a photovoltaic system. On the other hand, there is a lack of such facilities in the region, and territorial planning programs promote the construction of such facilities to meet the development needs of the region.

It is expected to establish a range of energy production that will determine the efficiency of the bioclimatic strategies of the constructive traditions of the Colombian Pacific. This academic work seeks to give importance to vernacular forms of construction to create a futuristic view of energy transformation based on tradition and cultural identity.

Problem

The energy dependence of non-interconnected areas in the Colombian Pacific region and the lack of architectural solutions that integrate sustainability strategies of traditional buildings in the region in addition to the lack of education facilities in the region.

Background:

1. High rate of non-interconnected areas in the Colombian Pacific due to the difficulty of connecting to the main power grid for their geographical conditions.

2. Lack of recognition of the value of traditional Pacific architecture for implementation in projects of social value.

Causes:

1. Lack of study of traditional construction methods and their potential as sustainability strategies.

2. Disconnection between the territory, the State entities responsible for in-vestments in the territory, and academia.

Effects:

1. Deficient investments in projects that are inappropriate for the social, cultural, and environmental context of the region and temporary power supply solutions that generate long dependance on centralized systems.

2. Abandonment of the territory due to lack of educational opportunities and imposed development ideas incoherent with the cultural context of the territory.

3.3 Research objectives

Aim

To value the Colombian Pacific architecture for its sustainable performance in high energy efficiency buildings

Specific objectives

1. Recognize strategies of vernacular architecture in terms of adaptation to climate change, coherence with the territory, and thermal comfort.

2. Identify strategies for achieving energy-efficient buildings that allow the building to be supplied with electricity and establish an energy source range for other users.

3. Demonstrate the effectiveness of bioclimatic strategies through a prototype of educational equipment, based on comfort and energy efficiency simulations.

Research question

How can photovoltaic generation solutions be integrated into the traditional architecture of the Colombian Pacific Region?

Additional questions:

What is the effectiveness of the vernacular architecture of the territory in terms of energy efficiency, adaptability, and thermal comfort?

How can a traditional architecture prototype building become a replicable and feasible proposal for energy autonomy buildings?

How can architecture develope technological development and at the same time respect and maintain the values and traditions of vernacular constructions?

3.4 Methodology

The methodology to be followed in this research is:

1. Review of the energy transition in Colombia to non-conventional sources of renewable energy and study of the situation of non-interconnected areas in the country.

2. The Colombian Pacific area is chosen because it is the region with the largest number of non-interconnected areas in Colombia. A historical, biogeographical review, vernacular architecture and planning with a territorial focus is carried out.

3. Consideration is given to the application of energy solutions for the non-interconnected areas of the Pacific region. It reviews the importance of the architecture that integrates energy efficiency and analyses the impact of climate change for this case.

4. Reference case studies are carried out in two categories: projects that integrate traditional Pacific architecture and projects that achieve high energy efficiency and autonomy.

5. A proposal for a prototype for the region is made. It begins with the analysis of the city where it will be carried out. A design methodology based on the bioclimatic strategies needed in the region is carried out. An architectural proposal is proposed and a proposal for the dimensioning of the photovoltaic system is proposed.

6. It concludes by evaluating the results on two themes: architecture and energy efficiency.

4. Context: Energy transition in Colombia

4.1 Renewable energy sources
4.2 Photovoltaic generation
4.3 Non-interconected zones

Figure 1 Colombia's territory map   Source: Self-created, 2023.

4.1 Renewable energy sources

Within the framework of the climate crisis, Colombia has great potential to take the role of reference in sustainability strategies, especially those related to the energy crisis. The accelerated growth of the economic model increases the world energy demand and thus the market of fossil fuels (oil, gas, and coal), which still today has great importance over the geopolitical control of the territories where they are abundant. With the development of renewable energy technologies, it could be demonstrated that international could replace the use of fossil fuels with clean energy sources. (Corredor, 2018, p. 109) Currently, 85.5% of global energy consumption comes from fossil fuels, while 4.5% comes from nuclear power, 6.9% from hydroelectricity, and only 3.2% from unconventional renewables (BP, 2017).

Many countries are exploring ways to change their energy matrix and replace conventional sources with clean energy. To reduce the impact of climate change, all these actions must be carried out with urgent political agendas and all sectors involved must be consistent with this need. It should be clarified that the management of the energy crisis involves not only the use of renewable energies but also, equally important, the drastic reduction of energy consumption.

The energy matrix in Colombia is different from that of most countries due to its great wealth of water bodies, which makes hydroelectricity the largest resource within the range of renewable energies. However, the level of total energy consumption, in the country is highly dependent on conventional sources such as oil and gas (Corredor, 2018, p. 116). Hydroelectric power is not yet a source on which the country can rely completely because of the climate variability on which it depends. On the other hand, they always correspond to a centralized system that is difficult to distribute in a complex geography. There are mostly large and medium-sized hydropower plants, which in different cases show a negative impact on ecosystems because of their construction and operation.

Colombia's power system consists of an interconnected grid (the National Interconnected System, SIN in its Spanish abbreviation), covering 97% of the total electricity demand, and the non-interconnected zones, which are supplied by local small electricity generation plants, running mainly on liquid fuels, such as diesel (IMF, 2019).

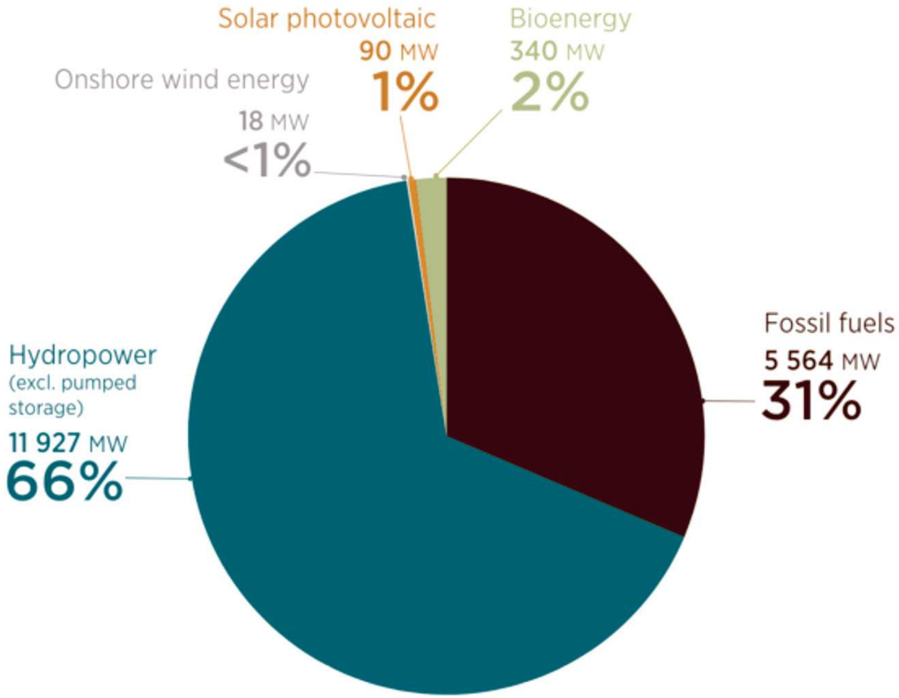


Figure 2 Colombia's generation capacity in MW and % in 2019 Source: IRENA, 2020

Energy demand growth in Colombia is estimated at 2% of the annual average. At COP28, Colombia presented a net zero target and an ambitious Nationally Determined Contribution (NDC), aiming at a 51% reduction in greenhouse gas (GHG) emissions by 2030. These ambitions are reflected in the long-term strategy, the E2050 Strategy, the Energy Transition Law and the Climate Action Law. To implement its targets, Colombia uses a robust system of climate change management plans across government with targets assigned to each sector, including for energy. (International Energy Agency, 2023, p. 18)

In addition to the fact that the environmental crisis is one of the most important reasons for a transition to clean energy in Colombia, it is important to note that this transition also represents an investment of great social impact.

Alternative energy sources are systems that could allow the decentralization of electric energy and could make it possible to achieve the goal of providing all citizens with this service. The energy transition in Colombia requires not only a replacement at the source of existing systems but also a transformation from a centralized system to a more equitable, efficient, and socially oriented one.

On the other hand, the construction industry has a great impact on the energy crisis, from the extraction of raw materials, the energy used for construction, consumption per use of buildings, and the demolition of these. Full cycle consumption accounts for 20% of global energy consumption and also contributes 40% of direct and indirect greenhouse gas emissions. According to studies, such is the impact that sustainable building practices can lead to a 35% reduction in CO_2 emissions, a 30-50% reduction in water and energy consumption, and a reduction in solid waste disposal costs of up to 90 percent (WorldGBC, 2008).

The importance of recognizing the effectiveness of sustainability strategies in construction promotes policies that encourage these practices and sustain a change in the environmental impact of this industry.

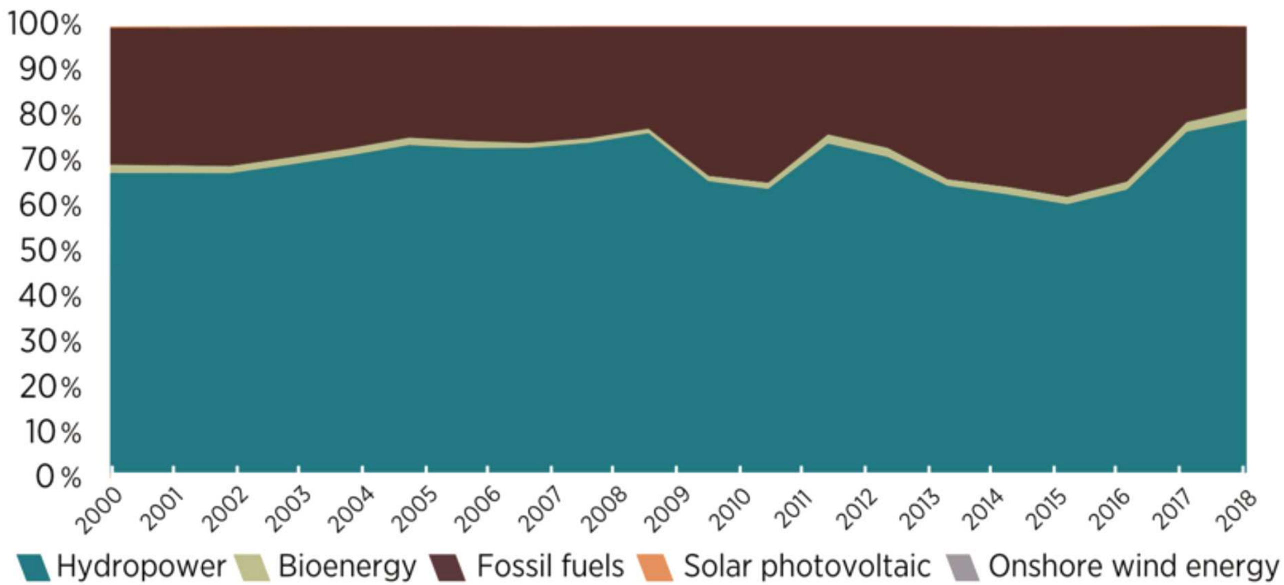


Figure 3 Colombia's generation share by technology, 1990-2018. Source: IRENA, 2020.

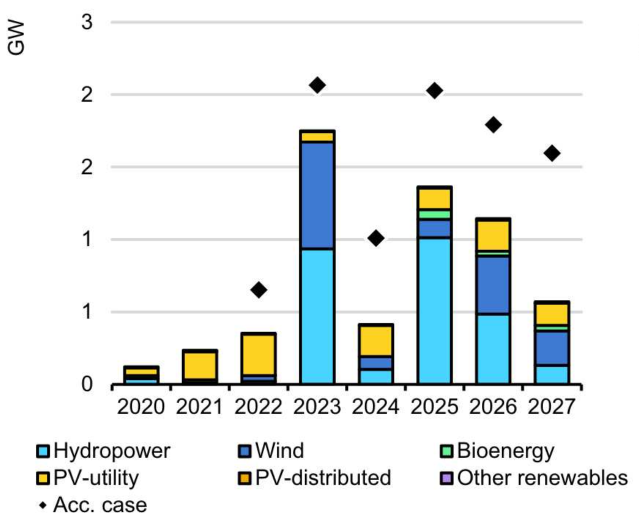


Figure 4. Colombia's renewable capacity addition, 2020-2027. Source: UPME, 2022.

The proposals that Colombia is presenting to COP 28 revolve around financing, adaptation and mitigation to climate change, especially because of the urgency of avoiding aggravating the current situation of the planet.

Colombia's proposals are grouped into discussions on fuel transition, financing, mitigation and adaptation to climate change. In this regard, Colombia will bet on a portfolio for the Socio-Ecological Transition and adherence to the call for a treaty on the non-proliferation of fossil fuels.

World Balance: Colombia will propose the need to rethink global economic models, along with an Energy Transition, communities and the progressive elimination of fossil fuels.

Investment portfolio: $34 billion in investment projects presented by Colombia to mitigate the climate crisis and enable the Energy Transition.

Fossil Fuels: Colombia becomes the 10th country and the largest oil-dependent to ask the world for a treaty to curb the exploitation of fossil fuels.

Commission of Experts on Debt for Climate Action: Colombia proposes the establishment of a technical panel of experts to review the reforms needed to ensure debt sustainability for developing countries.

Loss and Damage Fund: Colombia led the structuring of the Fund, which will allow access to resources to vulnerable countries, to repair the ravages of climate change. (Ministry of Environment and Sustainable Development. (2023). COP28. Retrieved from https://www.minambiente.gov.co/cop28/)

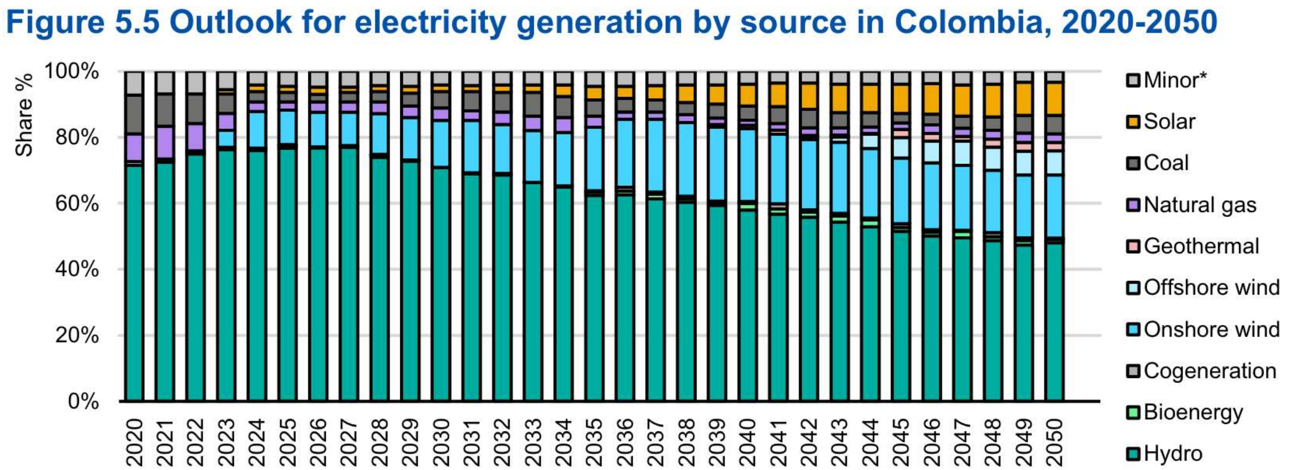


Figure 5. Outlook for electricity generation by source in Colombia 2020-2050. Source: UPME, 2022.

4.2 Photovoltaic generation

Solar photovoltaic energy is one of the alternatives that, according to studies, brings the greatest advantages in countries such as Colombia. Some general advantages are ease of installation system, modularity and adaptability in buildings, independence from a centralized system, balance of production and consumption on small and controllable scales, and adaptability in architecture (Vivas, p. 1).

Colombia has an installed generation capacity of 90 MW produced by photovoltaic solar energy, representing only 1% among other sources of its total energy capacity. Compared to other countries, its capacity is too low, especially considering the solar radiation potential that it has on its territory. (Ovalle, et al., 2020, p. 15)

"Renewable energy sources, especially solar and wind power, dominate the expansion of electricity supply globally. In 2022, they accounted for 88% of global renewable energy additions. Between 2010 and 2021 their prices have fallen drastically: 89% for solar and more than 60% for wind" ("Diagnóstico - Base para la transición energética justa.", p. 56)

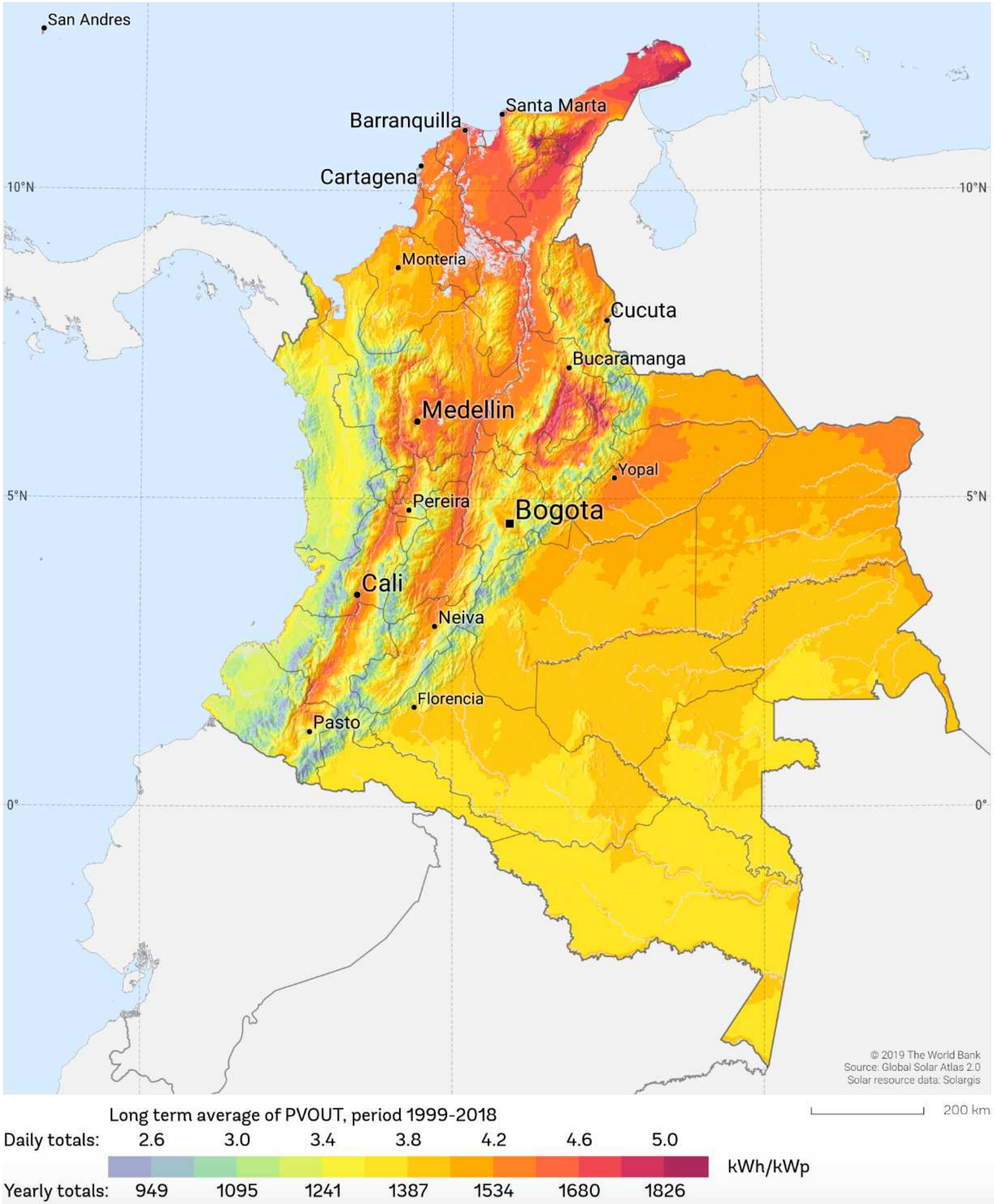


Figure 6. Colombia's global radiation map Source: Global Solar Atlas, 2019.

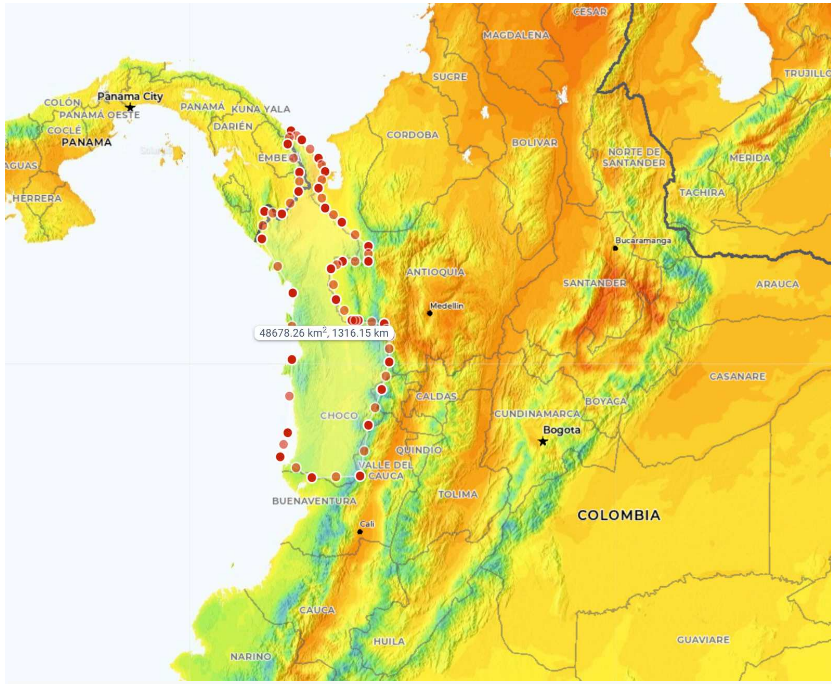


Figure 7 Choco's global radiation map.   Source: Global Solar Atlas, 2019.

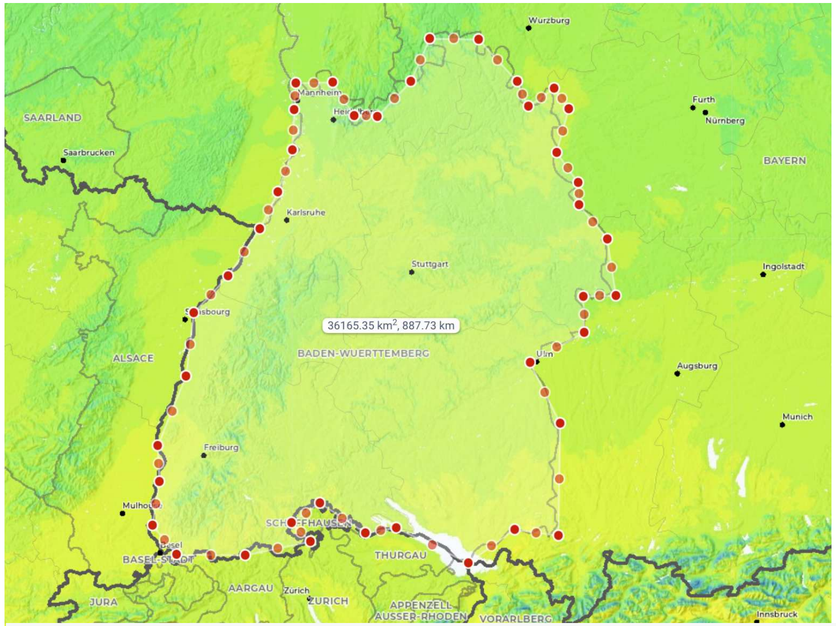


Figure 8. Baden Wurtenberg's global radiation map.   Source: Global Solar Atlas, 2019.

Chocó, Colombia:

Global horizontal irradiation:
4.73 kWh/m2-day

Diffuse horizontal irradiation:
2.63 kWh/m2-day

Direct normal irradiaton:
2.90 kWh/m2-day

Optimum tilt of PV panels:
2-9º

Air temperature:
21.9º-27.0º

Baden-Württenberg, Germany:

Global horizontal radiation:
3.36 kWh/m2

Diffuse horizontal irradiation:
1.60 kWh/m2-day

Direct normal irradiaton:
3.24 kWh/m2-day

Optimum tilt of PV panels:
35-38º

Air temperature:
7.6º-11.3º

Global horizontal irradiation comparison:

Colombia has a photovoltaic solar energy potential between 2.67 kWh/KWp to 4.8 kWh/kWp. This means that on average in Colombia a photovoltaic system with an installed capacity of 1 kWp generates 3.88 kWh of electricity in a year. While the average potential in Germany is 2.98, the production of photovoltaic power exceeded 60.8 terawatts per hour in 2022 (Energy Institute - Statistical Review of World Energy (2023); Smil (2017) – major processing by Our World in Data). The comparison between both countries' potential shows that Colombia has the opportunity to generate 45% more production capacity than Germany. This comparison is only made concerning the terms of production potential, which is calculated with predetermined values (Global Solar Atlas 2.0).

In the Colombian Pacific region, specifically in the department of Chocó, global solar radiation is not as high as in other regions of Colombia. However, it is good enough to justify the efficiency of these systems in the region.

Analyses of installed capacity and photovoltaic power generation potential show a great opportunity for the energy transition in Colombia. In addition to public policies for energy distribution, the political agenda also provides tax incentives to facilitate the importation of solar panels into Colombia. However, this modality continues to represent a major investment that still needs a lot of development and confidence to distribute photovoltaic power generation capacity on smaller commercial scales and promote its use. (Ovalle, et al., 2020, p. 20)

4.3 Non-interconnected zones

The complex geography of Colombia, the history of settlements in rural areas, and the centralization of national systems have been the main reasons for the existence of approximately 1,710 rural localities where it is estimated that 128,587 people only access the service between four and twelve hours a day. (Vivas, p. 1).

Non-interconnected areas in Colombia (ZNI) are those regions that do not receive public electricity through the Colombian national grid, also known as the National Interconnected System (SIN). They cover 52% of the country's territory and have an estimated total population of 1,900,000 inhabitants, giving a population density of 3 inhabitants/km².” (Mora-Guarda, 2020, p. 1)

This problem has been studied to generate different temporary solutions while discussing the connectivity of the country's centralized network. Given the enormous potential of renewable energies to cover this type of territory isolated from urban areas, 96% of the power generation in these territories is produced by diesel generators (based on fossil fuels), which leads to high levels of pollution and dependence on fuel (Mora-Guarda, 2020, p. 1).

Energy is a fundamental resource, to meet some basic needs and others related to human well-being, such as heating, cooling, lighting, mobility and the operation of a wide variety of devices (Aristizábal, 2017; Strantzali and Aravossis, 2016; To and Lee, 2017).

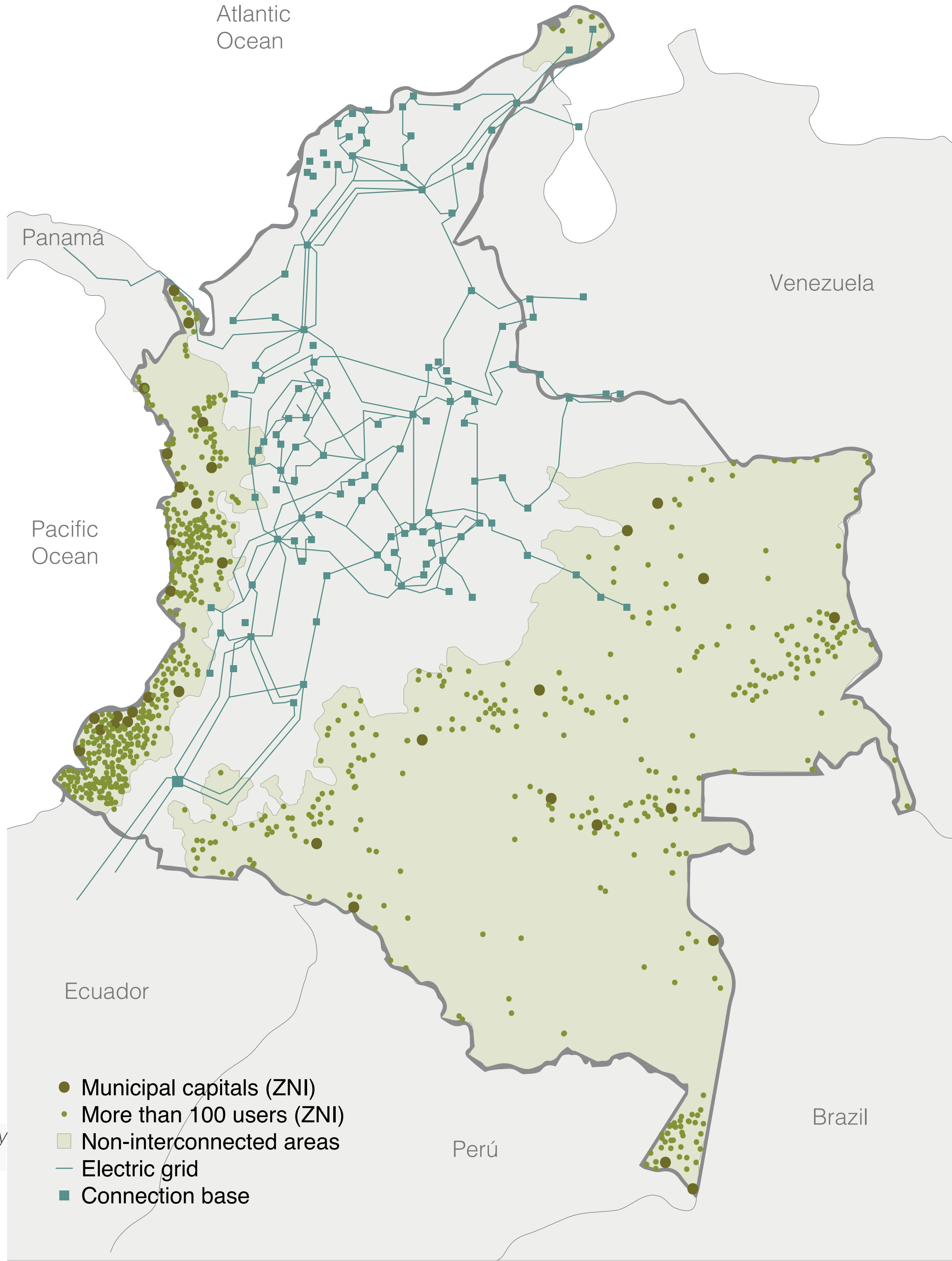


Figure 9 Non interconnected zones in Colombia and energy characterization. Source: IPSE, 2023.

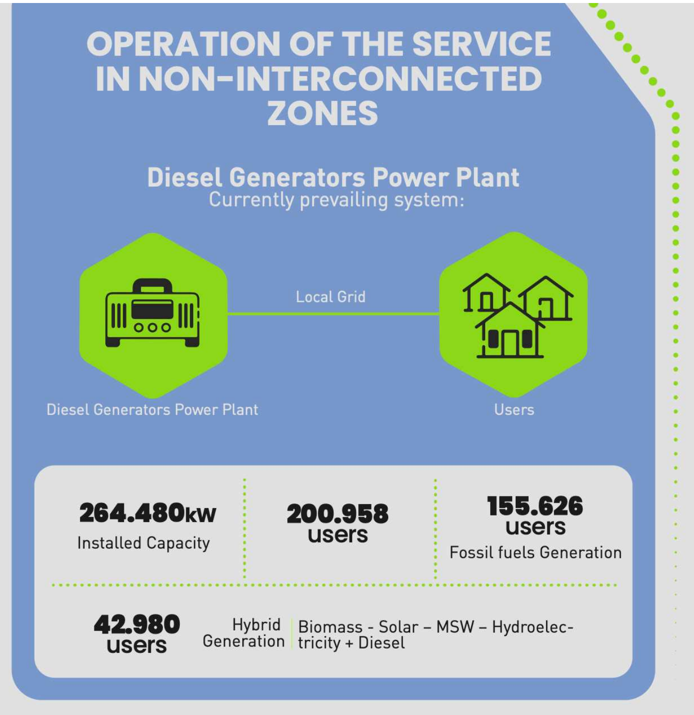


Figure 10 Diesel Operation service. Source: IPSE, 2023.

The intern solutions of fuel-based generators have become permanent conditions, which also record recurrent technical failures and administrative problems in municipalities with telemetry records. These solutions have been insufficient and inadequate because they rely on a centralized system or resources such as fuel and the recurrent distribution of generators in hard-to-reach areas. In addition, being the only source providing the electric power service, the localities that use this type of system become dependent on these and the maintenance of an external entity on these generators. Considering the complex geography of the non-interconected zones and the limited network of roads for land access, decentralization of electricity sources is the most sustainable alternative for these cases.

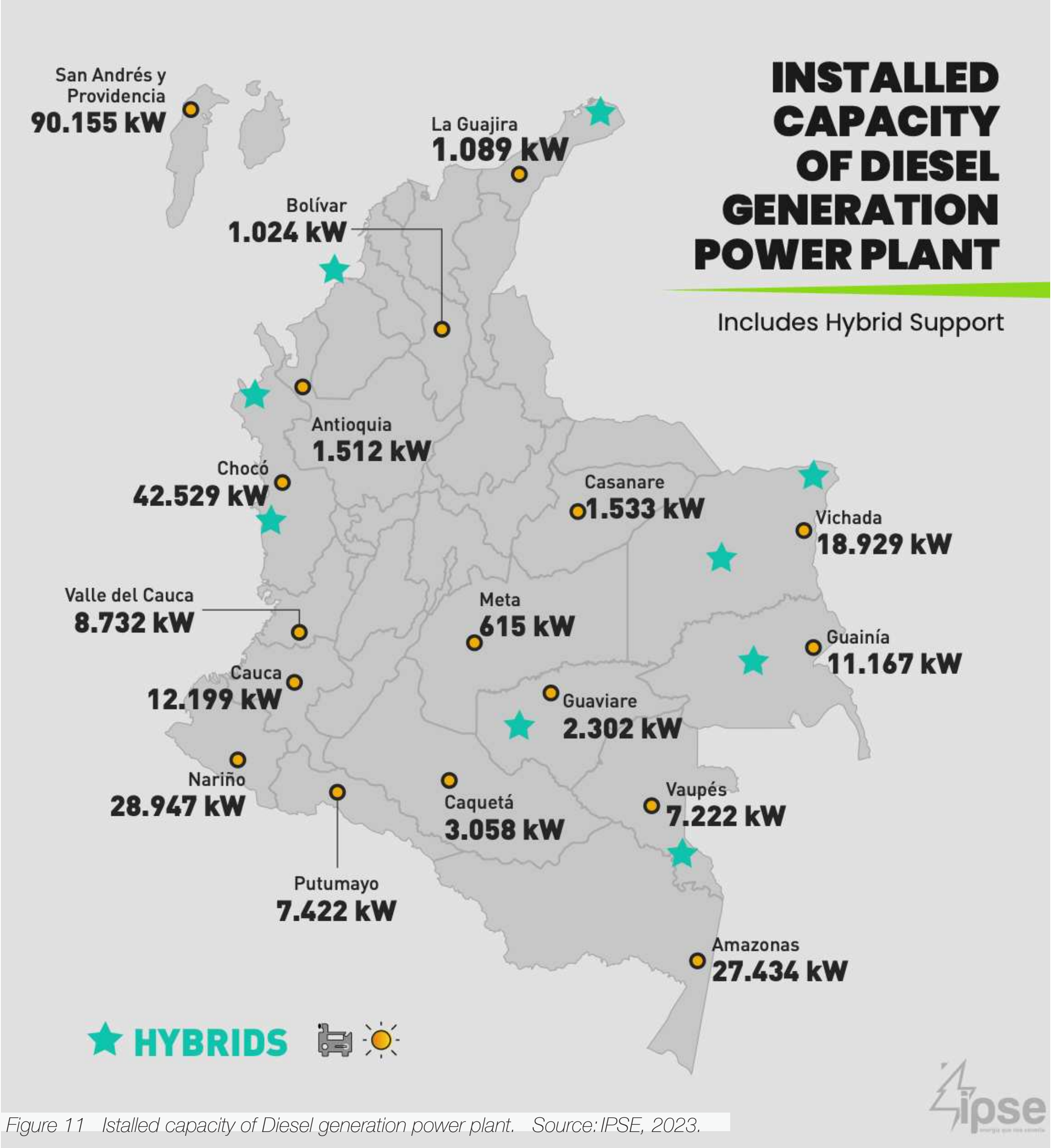


Figure 11 Istalled capacity of Diesel generation power plant. Source: IPSE, 2023.

In addition, many of these solutions provide these populations with only a few hours of electricity per day. The Secretary of Government of Sipí, a municipality that is not interconnected to the department of Chocó, states that to keep a single power generator in operation it is necessary to invest 360,000 COP of ASPM per day, representing a high unsustainable and irrecoverable cost for the municipality (Vivas, p. 1).

Most of the non-interconnected areas are in the departments of Nariño (600 areas) and Chocó (509). Most of these areas are small towns or hamlets, with low population density and in hard-to-reach locations.

In this way, future solutions for non-interconnected areas must shift their focus towards alternatives such as solar photovoltaic energy, to promote the autonomous use of the region's resources. The independent electric power service ensures the region's connectivity with the rest of the country, providing intercommunications, internet service, parity for economic development, educational resources, and many other basic conditions that the region needs.

These types of solutions for the non-interconnected areas of the Colombian Pacific guarantee the sustainable development of the region with the responsible use of natural resources, as long as they are models that include communities in their participation in these areas. (Agencia de Renovación del territorio, 2021, p. 29).

"For the energy supply, diesel-powered generation plants are mostly used. Diesel power plants offer multiple advantages, including: easy market access, low costs per kW, easy maintenance, an extensive network of component and service providers, and acceptable operating and maintenance costs. However, when these plants are operated in remote areas, transportation difficulties arise, resulting in high fuel, operation and maintenance costs. This is reflected in the cost of power service per kW/h." (Ovalle et al., 2020, p. 18)

Figure 12. Diesel generations systems trasportation through rivers. Source: Vivas, 2022.

The Institute for Planning and Promotion of Energy Solutions (IPSE) structures and promotes projects based on energy solutions compatible with the natural environment, which at the same time guarantee the active participation of the community and the proper management of natural resources, as well as respect for ethnic and cultural diversity. In this way, solar photovoltaic energy is considered a viable solution from the technical, socio-economic, and environmental point of view for the most remote localities or communities in the country, characterized by their low ability to pay, high percentage of unmet basic needs and low coverage of public services, such as electricity. ("Documento de Manejo Ambiental Proyectos con sistemas fotovoltaicos.", 2019, p. 2)

Renewable energies are an efficient alternative for increasing access to electricity in remote areas and reducing energy poverty. According to the Sustainable Development Goals, affordable and clean energy must be provided for all. With an average radiation of 4.5 kWh/m2, photovoltaic energy production in Colombia has great potential for efficiency (Acuna et al., 2021, p. 1).

On the other hand, the Environmental Management Document for Projects with Photovoltaic Systems also highlights the importance of providing a very good energy service for the education sector. This increasingly requires digital resources and technology for school and vocational training updated to a globalized world. Likewise, the health system requires the provision of continuous quality service in all sectors of the country through the use of equipment and treatment in health centers.

Non-interconnected zones are an opportunity for **decentralized and autonomous photovoltaic systems**

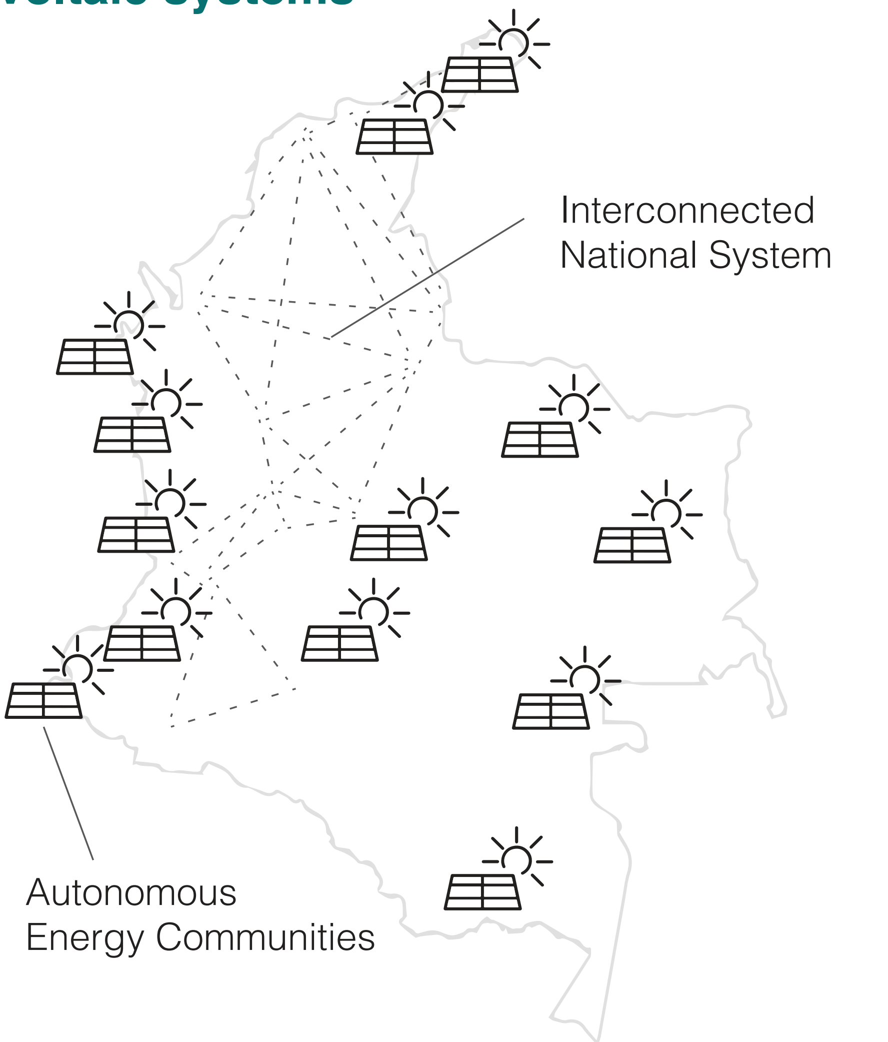


Figure 13. Decentralized systems diagram. Source: Self-created, 2023.

Photovoltaic installed generation capacity 262.433 kW - 84% of all ZNI

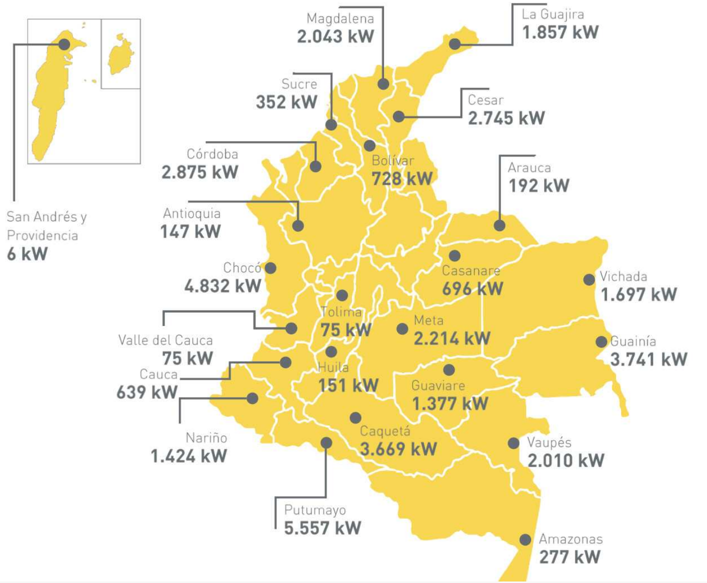


Figure 14. Photovoltaic installed generation capacity Source: IPSE, 2021.

DIESEL installed generation capacity 49.006 kW - 16% of all ZNI

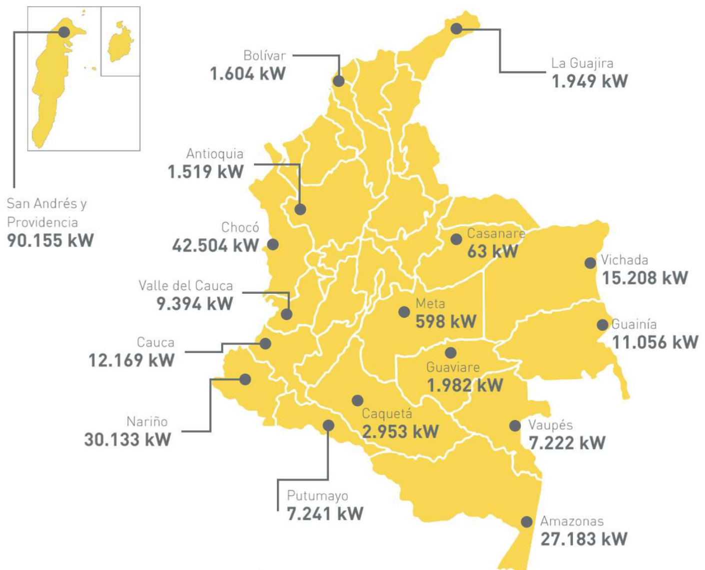


Figure 15. Diesel installed generation capacity. Source: IPSE, 2021.

The non-interconnected areas were recognized under Law 1715 of 2014, as were the implementation plans for them. As a strategic measure, the plan for the measurement system for these areas, known as the telemetry system, was presented. Currently, there are 1,750 localities recognized as non-interconnected areas throughout the country, of which 134 have telemetry systems to monitor projects that bring energy to them.

The monitoring system records consumption, energy provision hours and any faults that may occur in the systems. In many of these localities the local electricity grid already exists independently and many other localities do not yet have an electricity grid.

Thirty-four per cent of non-interconnected zones have a 24-hour power supply, 41 per cent between 5-10 hours and 25 per cent receive less than 5 hours a day.

The remaining non-interconnected areas without telemetry account for 89% of the total, being these 1,559 localities. Different systems of diesel generators are installed in each of them, in some cases hydroelectric sources and in others solar photovoltaic energy. However, the main use is for diesel generators and that is why future proposals look for ways to replace them.

5.Problem: Challenges in the Colombian Pacific

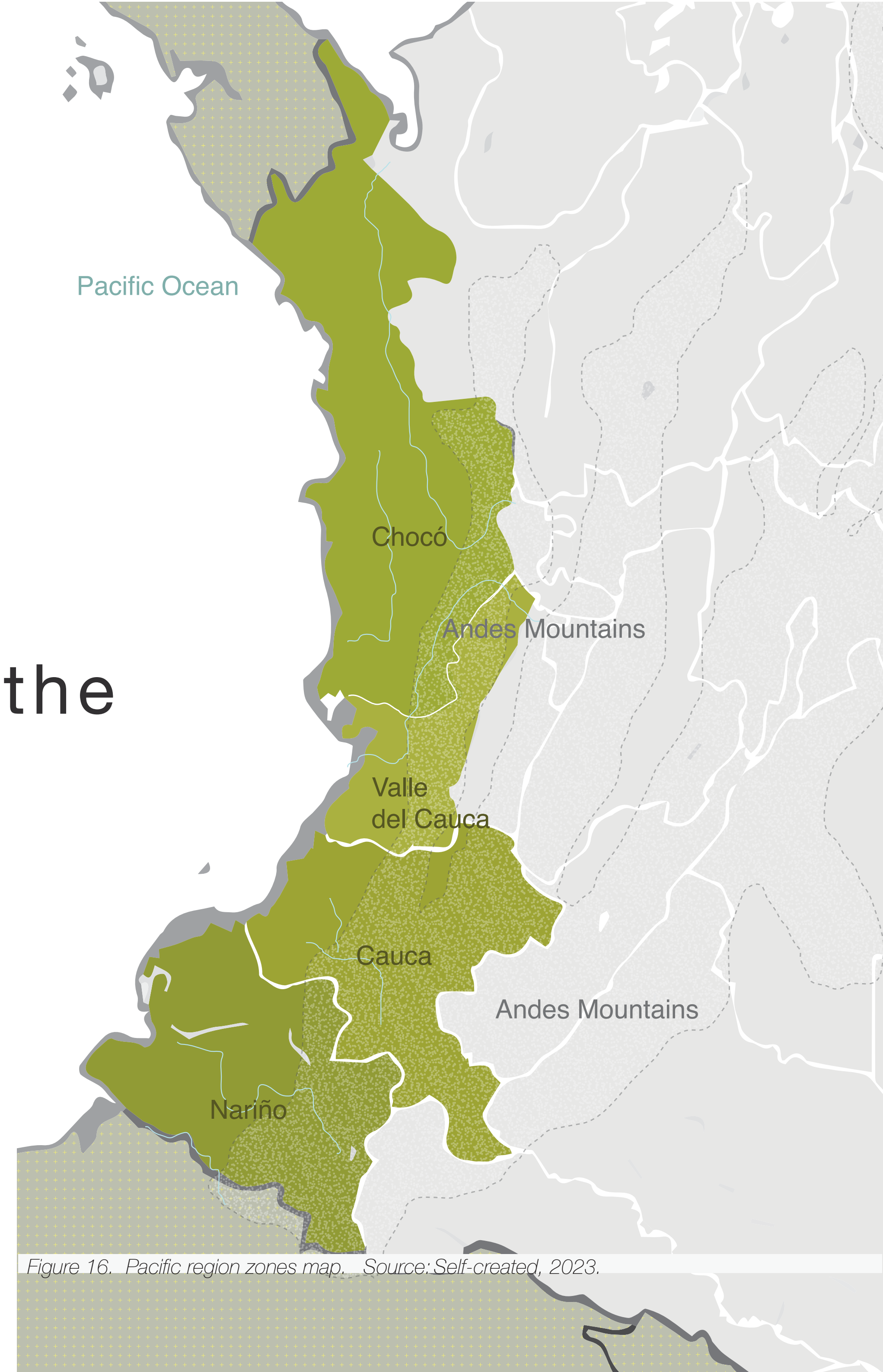


Figure 16. Pacific region zones map. Source: Self-created, 2023.

5.1 History

The Colombian Pacific is a natural region of Colombia that extends along the entire coast of the Pacific Ocean. It is bordered by Panama to the north, Ecuador to the south, and the western mountain range of the Colombian Andes to the east. The region is made up of the departments of Chocó, El Valle del Cauca, Cauca, and Nariño. The Colombian Pacific is part of the biogeographical Chocó region, which also includes the coastal zone of Ecuador and southern Panama. However, the region's political boundaries do not provide a clear definition of the territory. Therefore, it is necessary to review the historical cartographic studies, scientific studies, expeditions, and different views on the territory to understand it better.

This region has been understood and interpreted in different ways since the first cartographic records made from exploratory expeditions, during the Spanish colony. **Even though access to the region is much wider, many views on the territory are still based on the utilitarian perceptions of the colonizers who explored this region.** The name "Chocó biogeográfico" (in english "biogeographical Chocó") refers to the tracing of history that has changed according to the interest in its resources, until finally reaching a fairer definition, that is inclusive and with a multidimensional approach.

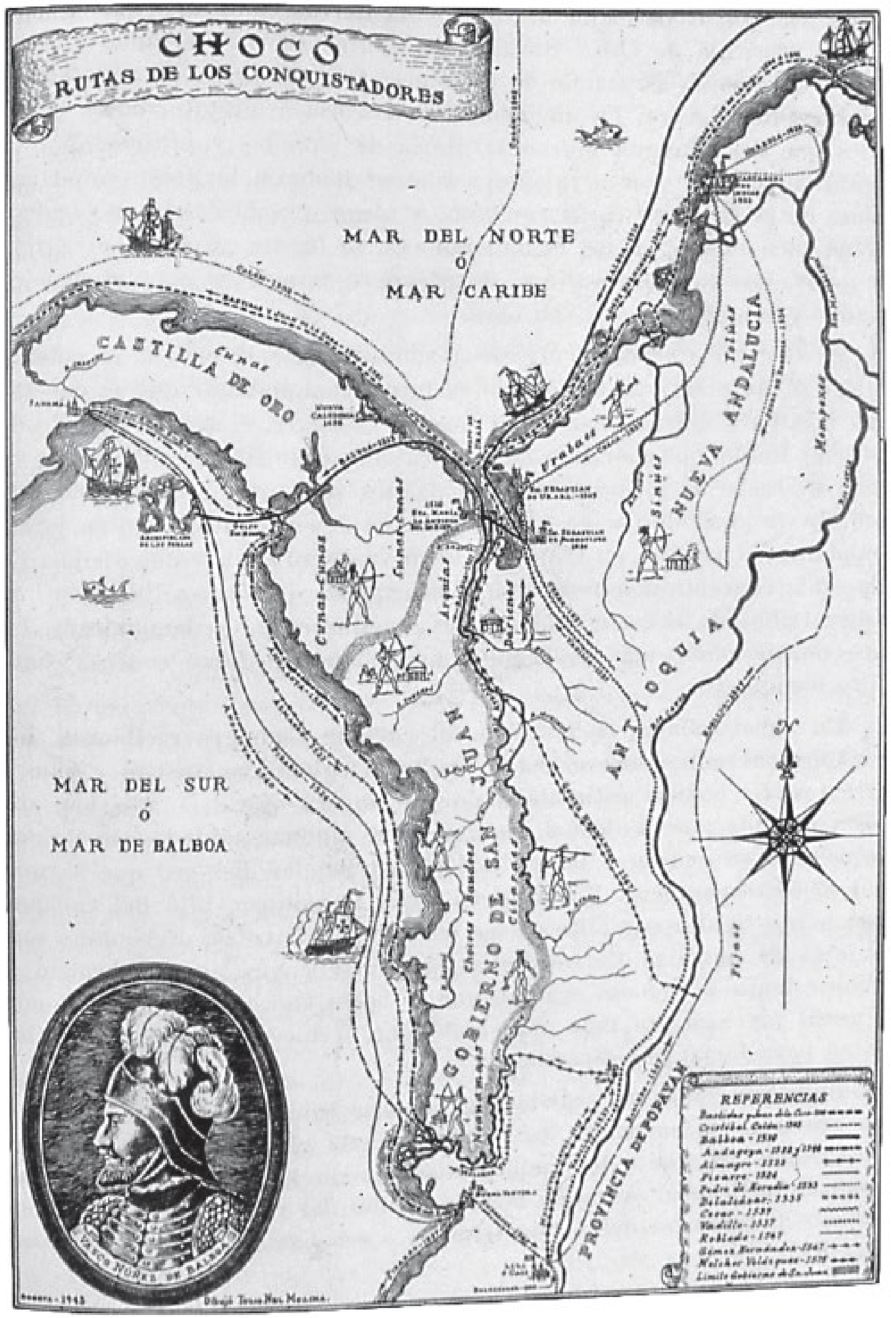


Figure 17. Colonization routs in the pacific region. Source: Boletín cultural y biografico,2018.

The imaginatinary of the region was built based on expedition routes, which had as their sole purpose the exploration to find mining sites. This is how the understanding of this region, even without a name, was born from the limits that determined the military frontiers of the Spanish colony. (Boletín Cultural y Bibliográfico, s. f.)

This territory belonged to various indigenous cultures, such as the Embera Nation and the Noanamaes, Tule, and other allied communities before Spanish colonization. **During the colony, the region was surrounded by military borders which, due to the difficulty of transiting the territory, slowly occupied the exploration routes with Spanish settlements. However, many areas of indigenous communities, protected by the same geographical complexity of the territory, remained on the margins of Spanish military objectives.** (Boletín Cultural y Bibliográfico, p.11")

Many other regions were not recognized until the arrival of African slave communities fleeing for protection in the tropical forests. Migratory movements increased in 1851 with the African Slave Liberation Act, developing their settlements and ways of life on the territory. These occupations of displaced Afro-Colombian migrants and indigenous people, fleeing the military occupations of the Spanish colony, developed communities that since then have lived in an adaptive way to the territory and share a worldview of respect for it. New ways of inhabiting the territories developed as the groups dispersed near the riverbeds, adopting different types of economy according to their proximity to the coast.

"In Latin America, there was independence but not decolonization. The Afro and indigenous communities were left with the same racist narrative imposed by the Spanish Crown."
Diana Uribe Podcast.

Figure18. Illustration of exploration routes. Source: Boletín cultural y geografico, 2018.

Despite the end of the Spanish colony, colonizing and exploiting interests in this region continued, now by new interested actors. The mining wealth of the territory and its geographical complexity were the motivation for many new exploration routes. “Alexander von Humboldt defined the region by its mining wealth, its geographical conditions and rainfall, and even gave his opinion about its development and condemned slavery as being counterproductive to the economy” (Boletín Cultural y Bibliográfico, p.22).

It is important to note that the history of the territory is created from the colonial views on it. The imposing rainforest, the way of inhabiting it, and the culture and traditions of its inhabitants are subjects that did not come into the interest of the explorers who created the imagination of the region for foreign governments and even the local government itself.

The racist conception of territories for commercial and modernist use did not allow true environmental and cultural value to be found in them.

At the beginning of the 20th century, when interest in mining required more detailed studies of the region, researchers began demonstrating its great environmental value and justifying the importance of the conservation and protection of the Colombian Pacific. Research on flora and fauna in the 70s and 80s showed the great biodiversity of the geographical Choco and the endemic endangered species. The concept of environmental protection of conservation areas is being developed for the Pacific region and its importance is recognized at the global level.

The region is becoming an area of great concern for the conservation of the planet’s biodiversity and is considered to be a very significant part of the world’s biodiversity capital, especially because of the endemic species. **This change of perspective led to the definition of “biogeographic” and began to include the recognition of the cultural richness of the region.** However, the struggle to recognize the knowledge, traditions, culture, and ways of living of Pacific communities remains a struggle today.

In addition to the injustices that have been experienced in the Colombian Pacific as a result of colonization and systematic discrimination from the interior of the country, the region has been one of the most affected by the armed conflict in Colombia. Since the 1960s, Colombia has been immersed in armed conflict involving guerrilla groups, paramilitaries, military and civilian forces. The conflict has left hundreds of thousands of people dead and displaced and has affected the country’s economy and society. Losada et al. (2019) mention that the armed conflict has affected a large part of the population, especially the ethnic groups living in the Colombian Pacific area.

According to figures from the National Information Network, from 1965 to 2019, the departments of the Pacific region, Chocó (447,739), Valle del Cauca (420,239), Cauca (445,901), and Nariño (486,363) have reported 1,800,230 victims of the armed conflict, which is equivalent to 21.2% of the national total. Various actors have disputed the territory within the framework of the armed conflict, due to the presence of paramilitary and guerrilla groups, in addition to the limited presence of the State in the region.

The conflict has led to forced displacement, sexual violence, killings, kidnappings, and missing persons. The struggle for territorial control has led to the forced displacement of Pacific communities to the main cities of the interior of the country from the 1970s to the present day. According to the Semi-Annual Report on Forced Displacement 2022-1 for the city of Cali published by the Unidad de Víctimas, 67,144 victims of forced displacement were registered, of which 98.2% were from the Pacific region. Of these, 26% identify themselves as black, Afro-Colombian, Raizal, and Palenqueros, and 5% as indigenous.

The Peace Agreement between the National Government and the Revolutionary Armed Forces of Colombia (FARC) and the agencies created from it have focused on conflict resolution and reparation for victims, focusing on the most affected territories, including the Pacific region.

The Peace Agreement is an important milestone for repairing the effects of the war in the Pacific because it recognizes the abandonment of the national government over the territory.

On the other hand, cultural traditions, gastronomy, music, and worldview have been positioned due to the representation of these communities in new national and international settings. From the point of view of architecture, the ways of living, the urban systems about the geographical context, the buildings adapted to the ecosystem, and the constructive practices are recognized as heritage and legacy of Colombia.

5.2 Biogeographical Chocó Region

Geography y biodiversity of Chocó

The Colombian Pacific is a natural region covering 83.170 km2, which represents 7% of the national territory. This region is characterized by tropical forest vegetation and watersheds on wide, floodable valleys, and sometimes swampy areas. In the department of Chocó stands out the Serranía de Baudó, while in the departments of Cauca and Nariño is the mountain range of the Andes. The region is located to the west of Colombia, and extends from the Gulf of Urabá, over the Caribbean Sea, to the border with Panama, and from the Cordillera Occidental to the coast of the Pacific Ocean. (Romero, 2009, p. 7)

The geography of the region can be characterized by four prominent elements. **(1) the presence of the sea, (2) the Andean relief of the Western Cordillera, which creates difficulties in connection with other regions of the country, (3) the hydrographic richness of rivers, basins, and bodies of water, and (4) the climate, very particular to the region,** which is characterized by high relative humidity and the highest rainfall in the world. (Romero, 2009, p. 7)

The coast of the Pacific Ocean is divided into two areas of the territory, separated by Cabo Corrientes, a reef near the municipality of Bajo Baudó, Chocó. The north coast is characterized by rocky cliffs, bays, and inlets, while to the south lies the floodplain, composed of mangrove forests and estuaries. This is an important differentiation that influences the economic and cultural activities of its inhabitants.

Figure 19. Chocó municipalities. Source: Self-created, 2023

Towards the interior of the continent, the topography of the mountain system of the Western Cordillera is the most irregular in the country, being this one of the least cultivated and populated areas. Precipitation in the north and south of the Pacific region is more variable and varies between dry and wet periods, while in the center of the region, moisture is always present. However, it is consistent that the frequency of rainfall is greater during the night (Romero, 2009, p. 8).

The Biogeographical Choco region has Protected Areas under SINAP Decree 2372 of 2010 and defines different environmental categories in these areas. However, only 199,437.51 ha fall under this category and represent only 7% of the region's total area (Territorial Renewal Agency, 2021, p. 26).

The biodiversity of the territory is one of its great environmental assets. **The Colombian Pacific region is the largest reserve of natural resources in the country, after the Amazon.** The great diversity of habitats in the territory gives rise to a large number of endemic and unique species in Colombia (Peña Salamanca and Palacios Peñaranda, 2015, p. 38).

The ecosystems in the region have many dense forests, flowing rivers, and the largest mangroves of South America, the most biodiverse on the planet. These have at least 2000 species of endemic fauna and flora, which means that are only found in this region of the world. It has more than 5400 species of plants (17% of all that exist in Colombia). Also 192 species of mammals, 778 species of birds, 188 species of reptiles, 139 species of amphibians, and 196 species of fish, among others (Belokurov et al., p. 1).

Figure 20. Colombia's geography map. Source: Territorial Renewal Agency, 2021.

Climate

According to the Köppen classification, **the predominant climate type is tropical humid forest, which is characterized by high relative humidity, precipitation, and average temperatures between 26ºC and 29ºC throughout the year.** The following figures show the graphs of the climatic data of the Quibdó meteorological station, in the department of Chocó, analyzing dry temperature, relative humidity, horizontal global solar radiation, and precipitation.

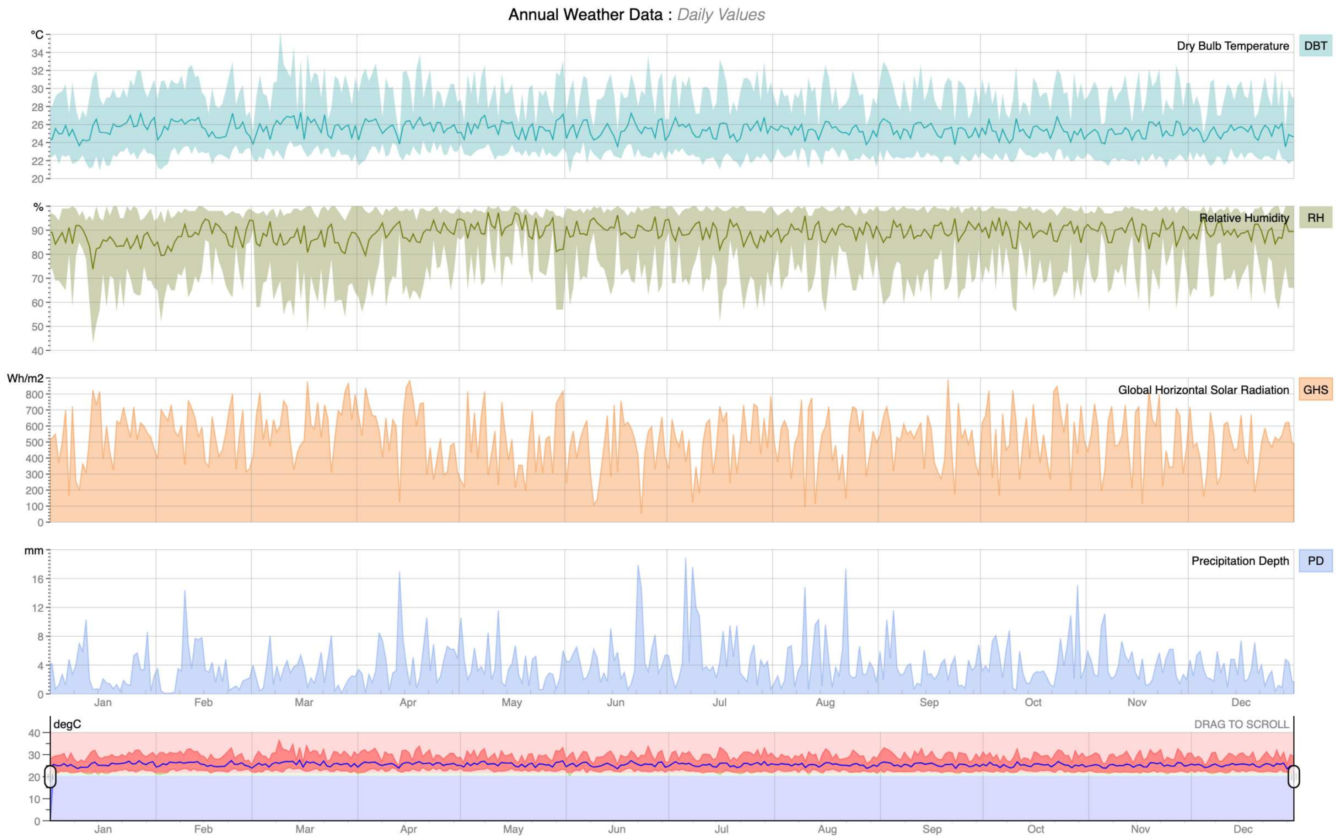


Figure 21. Dry bulb temperature, relative humidity, global horizontal radiation and precipitation Depth of Quibdo Weather Climate Data processed in Climate Analysis Software by andrewmarsch.com. Source: Self-created, 2023.

The dry temperature shows variations between 21ºC and in some cases extremes 34ºC, with an annual average between 24ºC and 27ºC. The analysis of temperature variability on an average day shows a difference of almost 10ºC between the highest and lowest temperatures.

The relative humidity shows a high percentage throughout the year reaching values of 98% up to drier periods of 60%. The variation during an average day shows a curve inversely proportional to the dry temperature, as it drops during the hours of the highest temperature and increases at night when the temperature drops.

Horizontal global solar radiation is important in this analysis because it also defines the degree of cloud cover that typically occurs in the tropical rainforest. There is a variation between 800 Wh/m2 and 100 Wh/m2.

Rainfall is proving to be an abundant and constant condition. They can reach up to 16mm per day and for very few periods it is below 4mm per day. This represents high precipitation and, on some peaks, the large amount of rainfall that can occur in the humid rainforest.

Demography

The Pacific region has a very high disparity between the port of Buenaventura, in Valle del Cauca, which mobilizes 50% of the national cargo. Despite its economic capital, this potential is not represented in the social indicators of the inhabitants of the city and the region and therefore is excluded of the socio-economic indicators of the region.

According to the 2005 General Census, approximately 8.37% of the Colombian population live in the department of Chocó. **The historical-colonial legacy of the region is still visible in social indicators such as the Unmet Basic Needs Index (UBN) of 79%, the highest in the country. This means that 352,257 inhabitants are considered in the categories of poverty and extreme poverty.** ("Economías del Pacífico colombiano", 2008, p. 44).

Despite government assistance to the region, the results and indicators have not changed over the decades. In many cases, corruption and other types of fraud have been detected in the budgets allocated to the region, as well as in the internal management of the departmental government. (Viloria de la Hoz, 2008, p. 51)

The department of Chocó has one of the lowest population growth rates in the country, and at the same time a low population density. West (1957,p.136) describes four characteristics associated with the low population density of the region compared to others in the country: (1) the scarcity of agricultural land; (2) the isolation of populations; (3) the lack of transport systems and road infrastructure; (4) diseases.

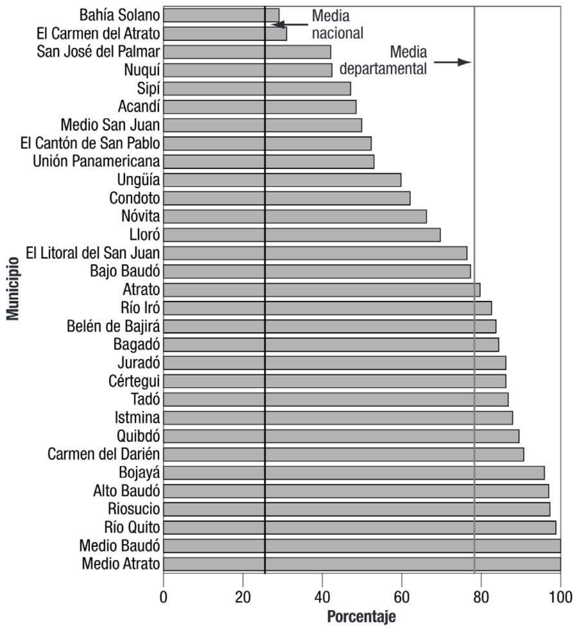


Figure 22 . Percentage of people with basic unmet needs in Chocó municipalities in 2005. Source: Villoria de la Oz, 2008.

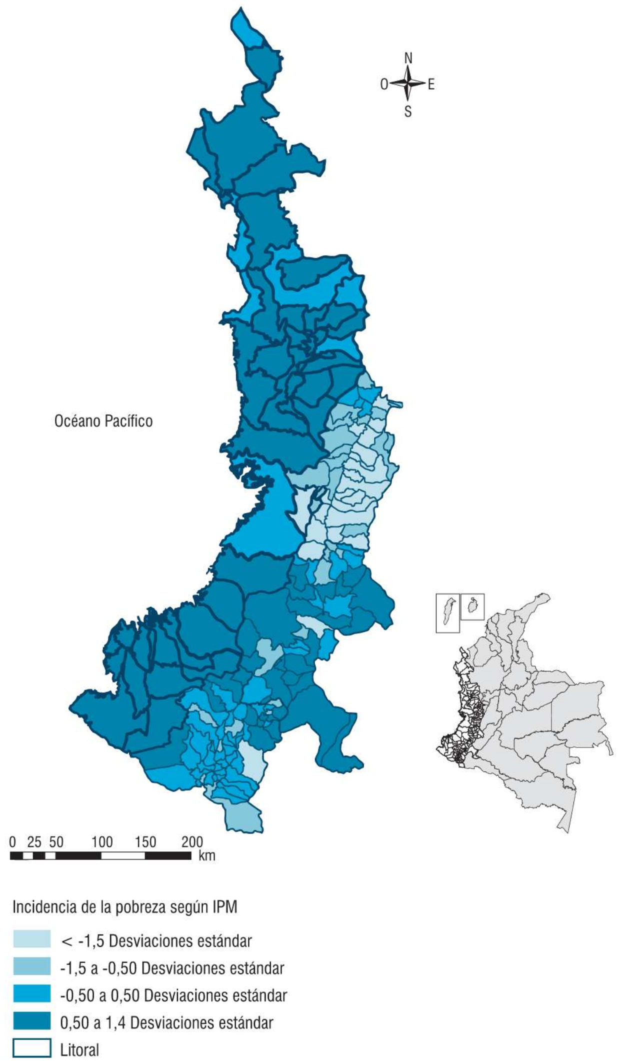


Figure 23. Poverty index distributon in the pacific region. Source: Villoria de la Oz, 2018.

"Designing for life is about giving direction rather than specifying endpoints."
(Escobar, 2018)

5.3 Vernacular architecture

The essence of vernacular architecture lies in the intrinsic connection to the traditional language of each culture, preserving materials and construction systems passed down through generations. It emerges as a response to the act of dwelling, a harmonious adaptation to the environment.

As Esteve (p. 29) states, vernacular architecture embodies a cultural construction specific to a place and its climate, reflecting a society finely attuned to its surroundings through experimentation and profound knowledge. To be coherent, to adapt rather than confront the environment becomes a guiding principle. The wisdom encapsulated in vernacular architecture transcends mere aesthetics; it is a cultural heritage, a technology of the environment applied to construction and comfort. Esteve (p. 23) emphasizes that bioclimatic design is nothing more than the practical application of this accumulated knowledge—a synergy between traditional wisdom and modern sustainability, seamlessly blending the past with the present.

In contemporary contexts, the concept of 'vernacular' transcends rigid traditionalism, evolving into a realm of possibility that aligns with creative endeavors. As Escobar (2018, p. 37) notes, it becomes a dynamic space that can be woven into innovative projects, seamlessly blending vernacular forms, concrete locales, landscapes, ecological restoration, and advancements in environmental and digital technologies. This integration serves as a response to pressing issues affecting livelihoods, offering a means to reinvigorate communities. Beyond conventional design paradigms, Escobar (2018, p. 184) emphasizes that community-driven design is essentially a self-inquiry or learning system. In this collaborative process, designers transition into co-researchers, actively engaging with the community to understand its intricacies and needs, fostering a more participatory and holistic approach to design.

The vernacular architecture is the materialization of ancient wisdom, distilled from the knowledge that the people have accumulated about their environment, the climate, and the supply of materials of the place. Through the elevation of traditional construction practices—acknowledging their technological, environmental, and economic merits, and valuing their aesthetic qualities—vernacular architecture becomes a profound wellspring of alternatives in the continual exploration of shaping genuinely sustainable architectural solutions. It represents a conscientious and considerate reaction to our integral connection with nature, as well as a response to the social and cultural contexts of those who inhabit the built environments. (Anzellini, 2016, p. 11)

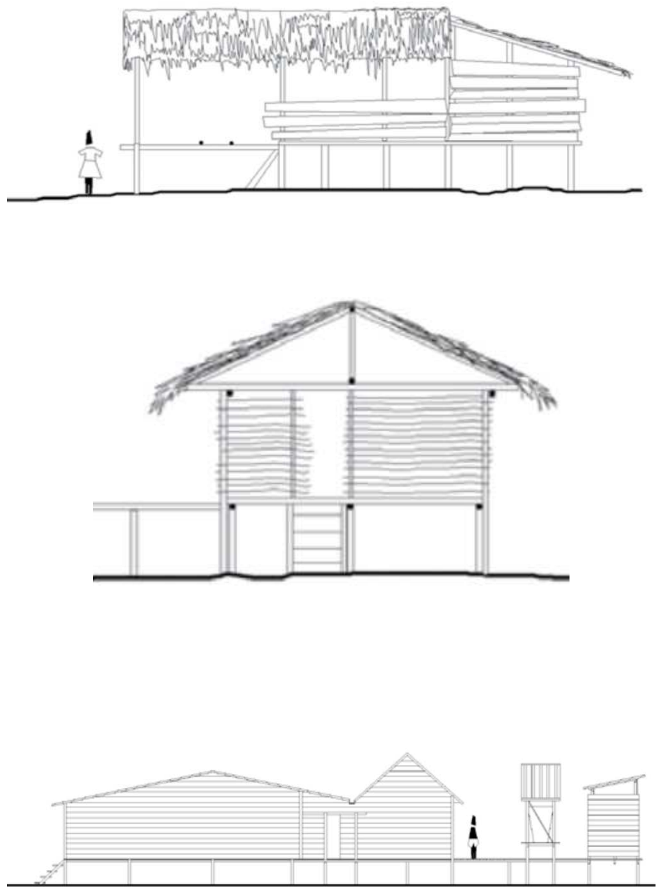


Figure 24. Palafitic housing typologies illustration Source: Mosquera, 2014.

Rural habitat

According to the 2018 Census, 66.2% live in rural areas and 33.8% in urban areas (Territorial Renewal Agency, 2021, p. 21). As described in the historical overview, rural settlements are mainly composed of indigenous and Afro-descendant communities.

Despite the extensive existence of the sea, most communities did not settle only on the coasts, but strategically close to rivers. In response to changes in the level of the waterways, their flood seasons, and the protection of other animals, the settlements are laid out on stilts. These are constructions based on pillars buried underground that raise living platforms above the water level to adapt to changes in the water level and at the same time maintain the link with the water.

As the authors describe, “palafitic constructions have a symbiotic relationship of support with the natural resources of the aquatic environments that support them.” (Rodríguez Zambrano y Robledo, 2020, p. 14)

The palafitic constructions are born from a way of inhabiting and adapting to a territory and are developed in dwellings of rural settlements. However, it also becomes a cultural characterization, scaling this constructive form to other architectural uses and applications in urban areas.

The palafitic constructions create among themselves a web of connections of platforms or elevations between them, direct access to houses or small communal harbors.

The architect Andrés García, researcher of the Faculty of Architecture of the University of Zulia of Venezuela: “The first habitats are linked to water. The right answer to the harsh sun and the need for protection at night from the harassment of wild animals, vermin, or simply the plague of mosquitoes. There the man isolated himself and raised his posts on the grooves of the canals, rivers, or lagoons, to receive the tempered breeze that ripples through their channels. (Rodríguez Zambrano y Robledo, 2020, p. 15)

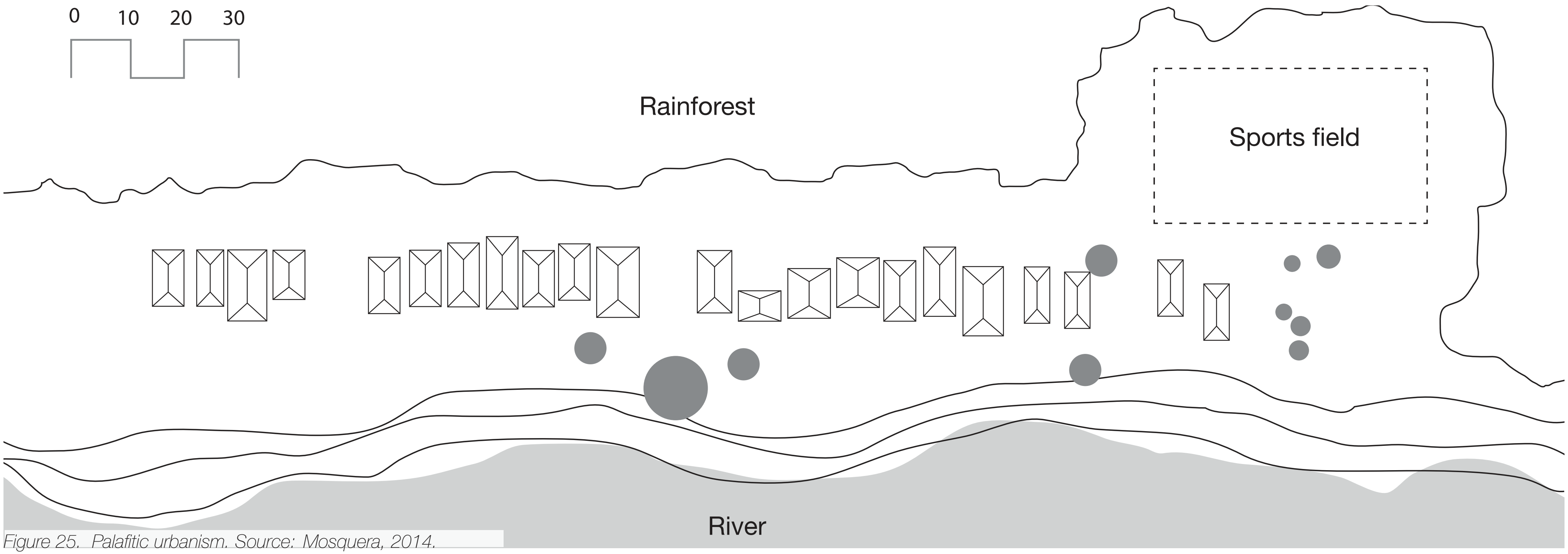


Figure 25. Palafitic urbanism. Source: Mosquera, 2014.

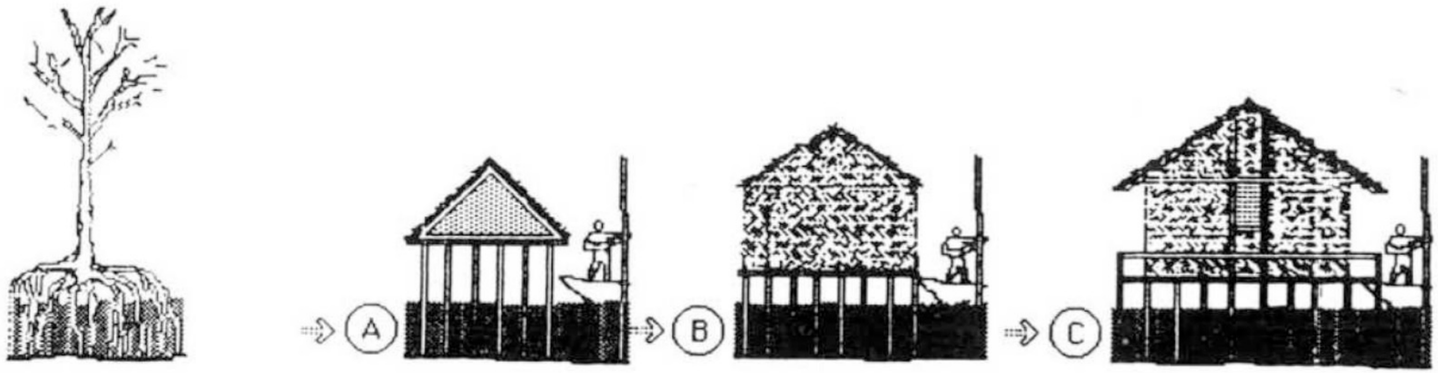


Figure 26. Mangrooves and palafitic housing comparison illustration. Source: Mosquera, 2014.

Like mangroves, palafite dwellings allow a way of life in constant relationship with water. They adapt to the levels of rivers and tides, making it possible to sustain economic and cultural activities related to water, such as fishing, boat and canoe transport, etc. Palafite dwellings are a type of self-construction of lightweight structures and resistant to changes in the environment. The settlements create among themselves a network of pedestrian bridges that prioritize access to water for each dwelling and at the same time a connection between them.

In this way, palafite settlements create urban morphologies adapted to the riverbeds, the conditions of the forest, and other characteristics of the territory, which are completely different from the imposed colonial settlements. Central squares with churches and government buildings do not fall into this context. In some populations, urban development has been based on the true traditions of the settlements and it can be distinguished that public spaces such as docks, markets, laundries, and toilets, among other spaces of social interaction, arise from the direct relationship with water. However, in many cases a mixture of both morphologies can be detected, co-existing between a colonial past and a tendency to continue the practices that communities need and have been able to solve.

Figure 27. Palafitic housing in the pacific rural areas. Source: Mosquera, 2014.

Settlements in coastal areas near rivers are different from those near the sea. They are stronger and built at a higher elevation, making them less prone to flooding. Additionally, they have a higher vegetation layer that can be used for crops. These settlements are established due to the availability of abundant natural resources such as vegetation and the possibility of growing different crops. (Castaño, p. 32)

In the Colombian Pacific region, about 40% of the population lives in rural areas. Despite some deficiencies in road infrastructure and aqueducts, the development of rural settlements represents a model of adaptation and sustainable construction with the environment (Peña Salamanca and Palacios Peñaranda, 2015, p. 39). This is why these types of settlements stand out for their adaptability and resilience, and instead of considering them as an urban problem, they should be a conceptual basis for developing structures that value the culture and traditions of the region.

Unfortunately, there is no regulation of this type of settlement. Both academia and governmental entities have the responsibility to study these settlements and assess their potential for adaptation and sustainability for urban development based on these principles.

"The rural landscape is a collective construction that, to preserve or restore it, requires the cooperation, commitment, and sensitivity of specialists, civil servants and residents, men and women of all ages; as well as methodologies that bring technical knowledge closer to local knowledge, to guarantee not only greater relevance and assertiveness of decisions, but, perhaps more importantly, the legitimacy of interventions." (García-Reyes Röthlisberger y Fajardo, 2019, p. 45)

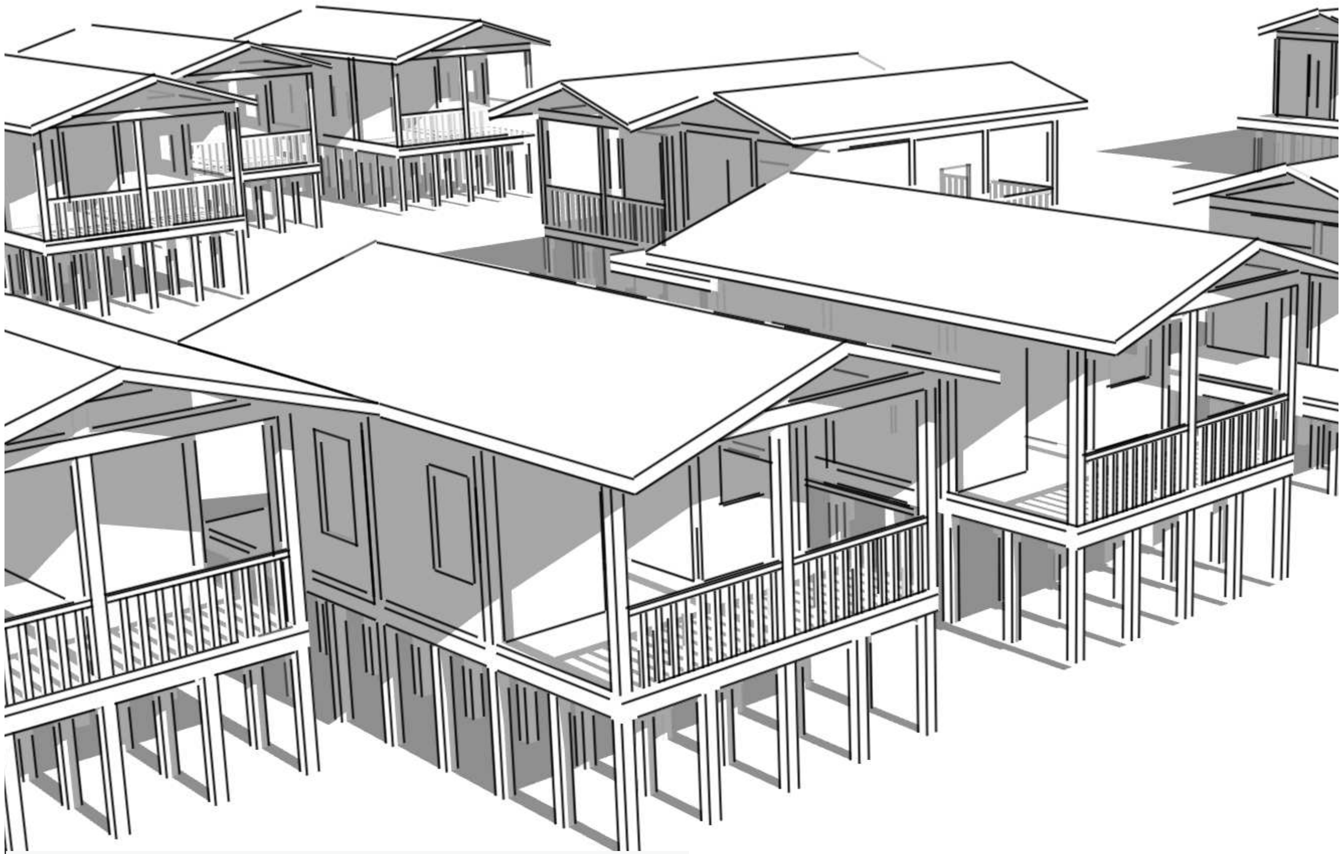


Figure 28. Palafitic housing illustration. Source: Self-created, 2023.

Palafitic housing

The buildings on stilts are arranged mainly for the dwellings of the inhabitants. It adopts the same principles of adaptation as the mangrove forests of the Pacific coast, such as adaptation to the water level, protection of predatory animals, and materials resistant to changes in humidity and temperature.

Unlike the landscape of the imaginary Spanish colony, the palafitic dwellings do not interrupt the landscape but are a continuity of it. (Garcés, p. 23).

These structures are light and flexible, thanks to the choice of mainly vegetable materials according to each of the elements. Starting with the structural foundations of the house, the pillars or "hileros" form the structure, on which the rest of the house rises. The number of these depends on the size of the building. On these, they find embedded and nailed with steel tips wooden blocks, commonly called "madres", which fulfill the function of beams for mooring the floor of the house. Over these, wooden blocks of lesser thickness called "chanclones" or "durmientes" are anchored, which is where the wooden boards of the floor are supported. The floorboards usually go in the opposite direction to the "chanclones" and are usually 1-inch x 10-inch x 3 m long. This creates the platform of the house, which is elevated above the water level or flood zone.

There is no defined height of the platform concerning this level, but it is always ensuring the airflow below the platform to reduce the internal temperature.

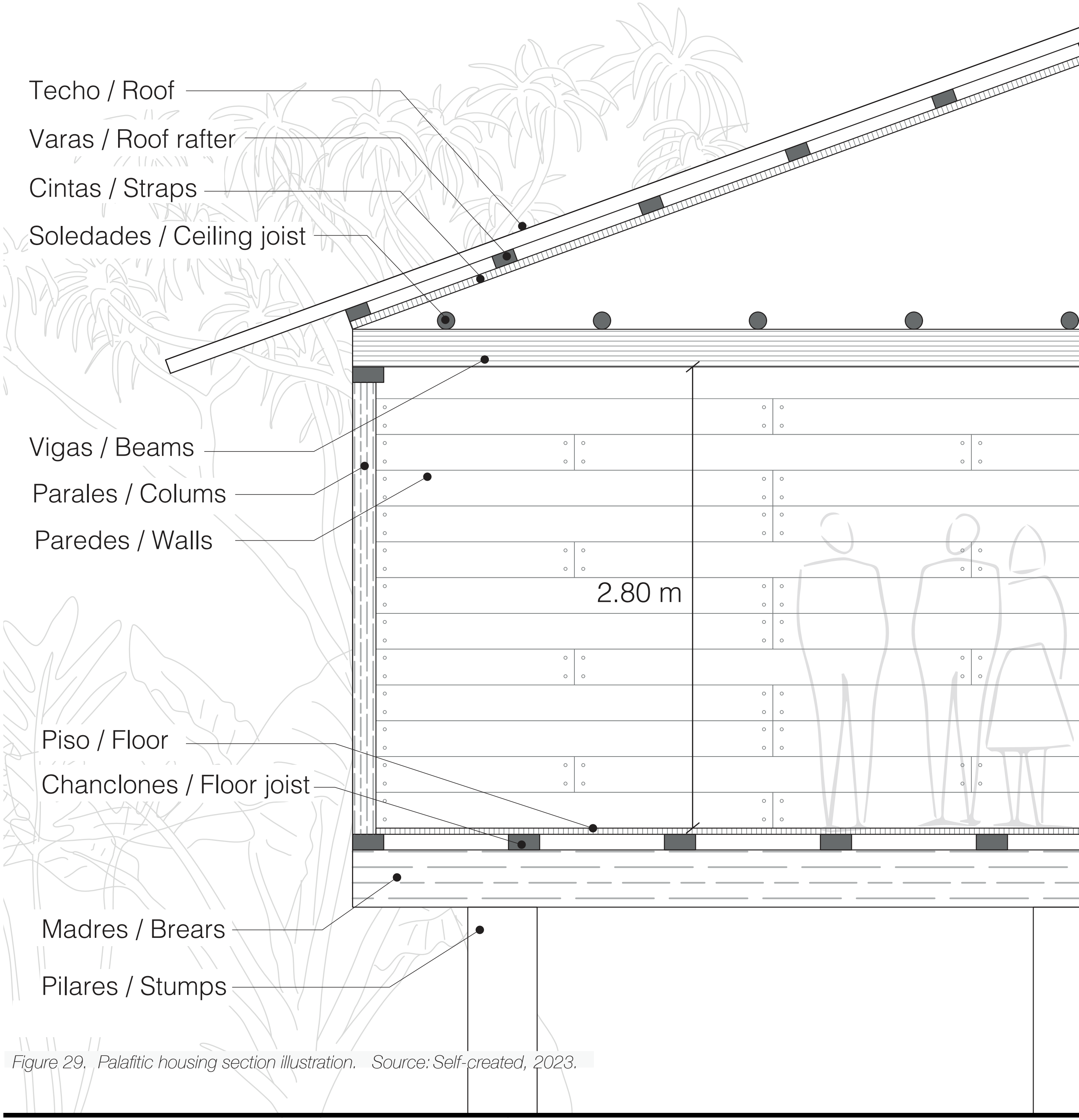


Figure 29. Palafitic housing section illustration. Source: Self-created, 2023.

On the “madres” of the floor and the roof beams, there are the vertical pillars, called portals, which support the structure of the roof and at the same time serve as columns of the walls of the dwelling. Indigenous and Afro-descendant dwellings differ in their interior spatial distribution with the use of walls, doors, and windows that make up the relationship with the exterior. Indigenous dwellings consist of larger interior spaces with fewer divisions and do not normally build a ceiling, allowing greater interior ventilation and a direct relationship with the landscape. In contrast, the housing of Afro-descendants has more divisions, smaller spaces, and ceilings, which creates higher temperatures environments.

The social area, located according to the access to water, is the only open and completely ventilated space. The balconies are important for the social activities of the inhabitants. (Garcés, p. 26)

The exterior walls are usually built with wooden planks that are horizontally superimposed, creating a shading pattern among each other. These boards have normally standardized dimensions of 3⁄4-inch-thick x 10-inch-wide x 3 m long. The interior walls are usually built with two prefabricated wooden combs or with the same boards placed horizontally joined by wooden slats and steel tips.

The structure of the roof is formed by the beams supported on the portals, as the perimeter of the dwelling. On these beams are supported the secondary beams also called “soledades” that serve as a base for the “varas” that make up the shape of the roof. On the “varas” are the “cintas”, in charge of supporting the materials of the roof, which may be straw braids, Eternit panels, tejalit or zinc sheets.

Figure 30. Palafitic housing in Ladrilleros, Buenaventura. Source: Self-created, 2022.

Figure 31. Palafitic bay in Ladrilleros, Buenaventura. Source: Self-created, 2022.

Figure 32. Palafitic housing in Vigia, Nariño. Source: Vivas, 2022.

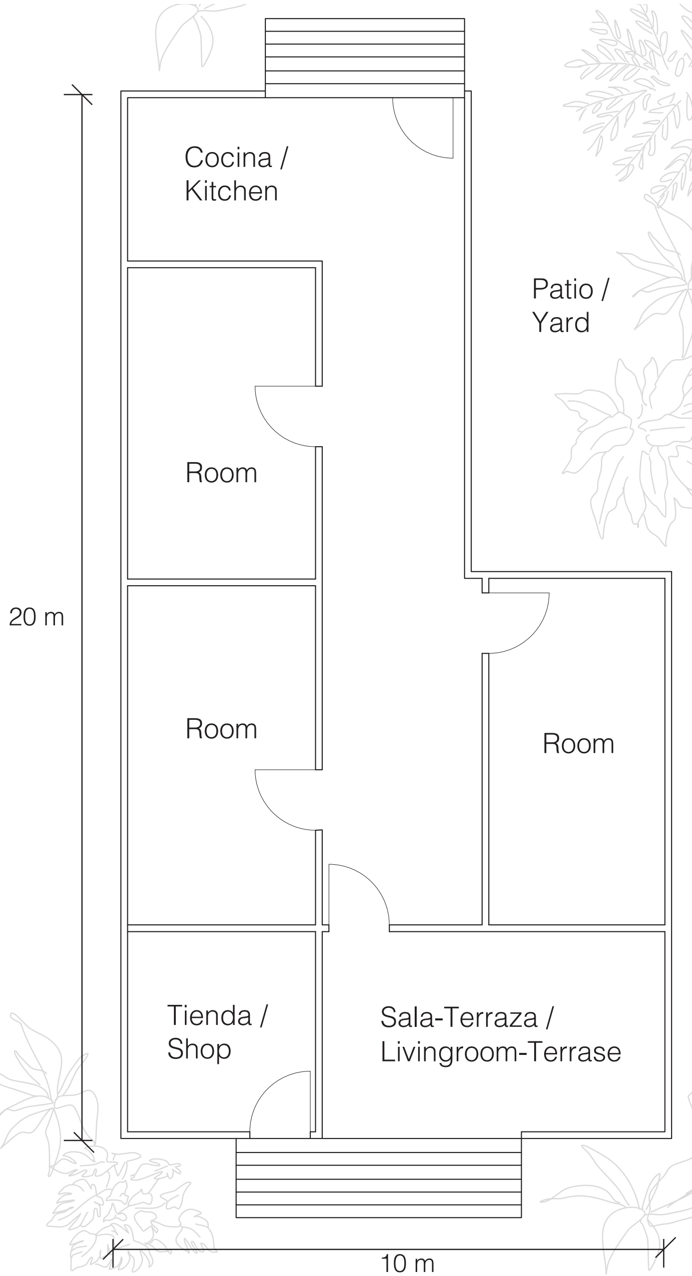


Figure 33. Palafitic housing typology plan. Source: Self-created, 2023.

The material of the roof has great importance for the climatic conditions inside the house. Straw, unlike Eternit or zinc sheets, creates a lower temperature condition. (Garcés, p. 27). In the homes of Afro-descendants, balconies stand out because they are spaces with direct connection to other homes, the exterior, or direct access to the river.

In most palafite dwellings, the predominant material is wood, and depending on each structural piece the type and type of wood to be used is chosen according to accessibility in the area and characteristics such as structural strength, durability, texture, weight, or hardness. (Garcés, p. 28)

Despite how compact and defined housing units appear to be, the concept of a house extends to the community in which it exists. Usually, the bathrooms are shared outside the houses, the kitchens are visually connected to the outside, the common areas are shared between different families, and the balconies become elevated platforms and have direct access to the water. So many other forms of interaction blur the boundaries of each housing unit, building a community system that integrates with its landscape.

Thus, the main place of the dwelling is the social area, which is usually recognized as a balcony because it has no exterior walls and is covered. This is located at the front of the houses, allowing the social and commercial interactions of each family. This is the space with better ventilation and more spaciousness of the house. It can serve as a family room, a place to watch television, the space before a family business as a grocery store, or a small pier for fishing if you have direct access to the river or sea. It has a semi-public character since the shared use with people who do not live in the house can access it without invading the privacy of the inhabitants. (Garcés, p. 37)

According to the family composition of the residents, the house usually has two or three rooms which are usually used only in the evening. These are the smallest, darkest, and least ventilated spaces of the house. Kitchens are spaces that have changed rapidly according to the type of technology used for cooking. Some kitchens that have gas stoves are more enclosed spaces than those that cook with wood stoves. In either case, the kitchen has a direct connection to the outside for access to food stored in back balconies or vegetable gardens. In the homes with bathrooms, the kitchens are located close to this to facilitate the plumbing and sanitary facilities.

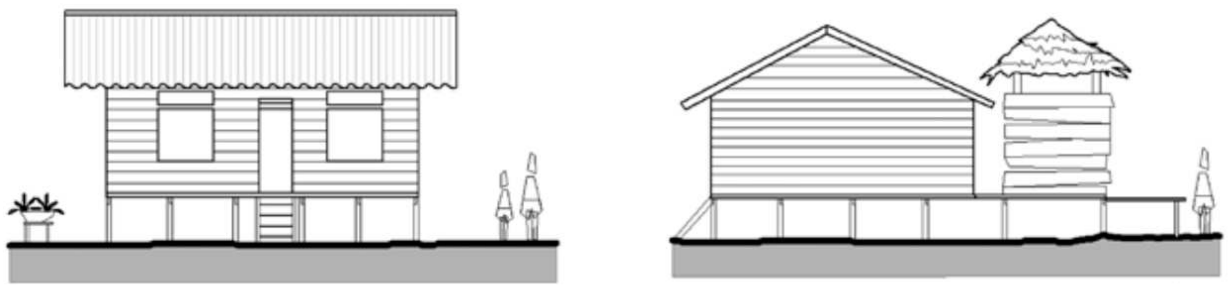


Figure 34. Palafitic housing in the pacific rural areas. Source: Mosquera, 2014.

Figure 35. Palafitic housing in the pacific rural areas. Source: Mosquera, 2014.

"Sustainability is a cultural process rather than an expert one" (Escobar, 2018, p. 5)

The layout, construction, and materials of the housing build an architecture coherent with the landscape and the needs of the communities in addition to responding to good climatic conditions inside. However, by external governmental initiatives or by the initiative of the inhabitants themselves, the materials originally used are in many cases replaced by industrialized materials that come to the settlements as technological trends. The more original materials of each element that make up a house are replaced, the more the indoor climate can deteriorate. One of the changes that can most affect the home is the replacement of wood in the parts that come into contact with water. Wood is characterized by being an ideal material in humid areas because it does not retain moisture and dries easily, avoiding the creation of fungi and mud. Other industrialized materials such as concrete, zinc sheets, and steel do not have this intrinsic ease as wood and high-tech quality are needed to withstand the climate conditions of the tropical rainforest.

The palafito construction not only is successful because of the constructive efficiency, and high levels of thermal comfort, but they also represent the identity of their inhabitants. The typologies are formed from the social values of community, social cohesion, and respect for nature. The constructive tradition represents an identity of resistance of Afro-descendent and indigenous peoples who, despite their colonial past, demonstrate a coexistence between their habitat and culture. From a Western point of view, the configurations of the palafito dwellings lack public spaces, equipment, and certain services.

Most of the formal processes of construction have not been able to be brought into line with the vernacular dynamics. The author describes that bureaucratic forms for large-scale projects are not adaptable to the variability of informal processes. There are two main reasons why informal building processes fail to be regulated: (1) risk mitigation of natural phenomena, and (2) the sanitarily of bathrooms and kitchens due to their ventilation conditions.

However, the view from academia and government agencies must be adjusted by our constructive regulations and include these types of housing in manuals of sustainable construction and spatial planning plans. Co-inheritance with the territory must take place through its study, beyond the imposition of rules carried out outside our territories. The missing elements in these typologies to comply with a normativity should not be a limiting factor for inclusion in the legality but rather should be considered as a deficiency in the studies and development of the construction industry in Colombia.

5.4 Social development

After a review of the history and current context of the territory and its characteristics, some questions arise: What is the future of this region? Can a past of imposition and injustice be repaired? Is it possible to build a vision of the future of a territory? What is the concept of development for this territory? What is the best way to contribute to a territory while being an external entity to it? What is the role of architecture in this?

These and many other questions have also been questioned and elaborated on in past decades, there are different ways of covering planning and the future of the territory. This chapter highlights the approaches of the Hoja de Ruta del Programa de Desarrollo con Enfoque Territorial (PDET) for the Chocó subregion and the views of some experts on the territory and sustainable development.

The PDET was created from Decree 893 of 2017, as part of the programs of the Peace Agreement of 2016, in which regions and municipalities were selected according to the criteria of prioritization of this decree, as a planning and management tool for the economy and social development of the most affected areas by the internal armed conflict. (Agencia de Renovación del territorio, 2021, p. 19)

It emphasizes that the idea of development must be rethought and reconstructed according to the inhabitants and emphasizes specific goals for the territory. Since this program was born from studies of armed conflict and peacebuilding in Colombia, it recognizes the territory from a symbolic dimension and the inherent values of its inhabitants. The program has been carried out directly with the communities affected by the violence and is based on long-term work with these communities.


Figure 36. Post-conflict participatory meetings. Source: Agencia de Renovación del territorio, 2021.

The PDET sets as its main goal that by 2033, Chocó will be a subregion that actively participates in the process of designing and implementing public policy, whose economic model is based on harmony with the different worldviews of the territory and the sustainable use of natural resources. This economic and social model will be based on ethnic and cultural diversity as an engine of development, promoting respect for others and reconciliation. The Chocó wishes to represent itself as an emblematic space of reconciliation serving as an example for other processes of reconstruction of the social structure. (Agencia de Renovación del territorio, 2021, p. 28).

One of the main goals is to create a suitable infrastructure that allows for interconnection and promotes the learning processes of inhabitants. This should take into consideration the need for improved housing conditions and an inclusive ethno-educational model. One of the main challenges is to stabilize the social conditions of its population, ensure basic services to all its inhabitants, and improve the quality of life.

Basic services are defined as guaranty of economic development and education. After the COVID-19 pandemic, the Internet service became more relevant to guarantee access to health services and schooling. Connectivity is a prerequisite for boosting economic recovery in the region. (Agencia de Renovación del territorio, 2021, p. 53)

Another important goal is to improve the educational levels of the population. To this aim, the following objectives are defined: (1) improving the quality of education to enable young people to occupy more competitive positions; (2) expanding coverage to prevent absenteeism and dropout, particularly among rural children and young people; (3) implementing ethno-educational approaches; (4) expanding the coverage, quality, and relevance of technical, technological and university education in rural areas; and (5) including adult education programs. (Agencia de Renovación del territorio, 2021, p. 42).

These goals coincide with the demographic studies of the lack of community facilities inside the palafite settlements. There is recognition of the lack of these spaces that offer community services, education, health, and encounters for the social cohesion of the communities. (Rodríguez Zambrano y Robledo, 2020, p. 133)

On the other hand, some experts in the study of the region have highlighted the issue of sustainable development for the Colombian Pacific. The natural wealth of the territory is under constant threat and the deterioration of natural resources continues to be the result of the interests of the extractive economy. The authors Peña and Palacios (2013) emphasize that any type of development should be based on the protection of the biodiversity of the territory as a tool to ensure sustainability in the territory.

The complexity approach of natural systems calls for understanding territories as a system of ecosystems interconnected with the social structures that inhabit them at different spatial and temporal scales (Baptiste & Franco 2009). The challenges of sustainable development are based on understanding biodiversity and implementing more ambitious conservation strategies with social relevance, explicitly on issues of quality of life, human well-being, and environmental security. This entails developing knowledge on how to guarantee social equity and maintain a harmonious coexistence with the nature in which one lives.

In this way, understanding the region and its ways of life becomes a study of sustainable development for them. The relationship with water of the palafitic constructions is a clear example of the interventions that do not interrupt the natural cycles, but are molded to them.

Strengths

- Sustainble and coherent construction tradition.
- Climate change adaptability: temperature and sea leavel rise adaptable architecture.
- Cultural and environmental value of the communities.

Opportunities

- Favorable weather conditions for the efficiency of photovoltaic systems.
- Energy communities of IPSE government programs for independent energy systems.

Weaknesses

- Areas without access to electricity national systems because of geographical complex locations.
- Conditions of social vulnerability and territorial abandonment.

Threats

- Sea level and temperature rise due to climate change.
- Inefficient and polluting temporary solutions based on fosil fuels.

Figure 37. Palafitic housing and rivers correlation. Source: Agencia de Renovación del territorio, 2021.

5.5 Educational facilities

The demographics of the region show a need to focus on the development of educational institutions for the region.

The region shows a non-attendance of the school-age population (5 % to 17 years old) in the territories delimited by the Hoja de Ruta del Programa de Desarrollo con Enfoque Territorial (Development Program with Territorial Focus).

In the entire department of Chocó, it is estimated that 10% of children of Afro-descent between the ages of 6 and 10 do not have access to education, which is 27 % higher than that of mixed-race (mestizos) children.

In addition, it is estimated that 27 % of children and adolescents between the ages of 15 and 16 are out of secondary education. (Rodríguez Zambrano y Robledo, 2020, p. 27)

The level of education offered by institutions in the region. It is highlighted that 70% of these offer levels of Primary School.

Only 16% of institutions offer full-level education. The *Hoja de Ruta del Programa de Desarrollo con Enfoque Territorial* aims to provide coverage for all levels of education or to strengthen the secondary and higher levels to prevent the population of schooling age from moving to other localities or their low level of non-attendance.

It is important to recognize the lack of educational facilities for higher education for territorial planning and social development in the region. The lack of these is the cause of the displacement of young people to cities or in other cases, which leads to a lack of job opportunities for young people in this region. The department of Chocó is the region with the fewest years of schooling in Colombia (Viloria de la Hoz, 2008, p. 47).

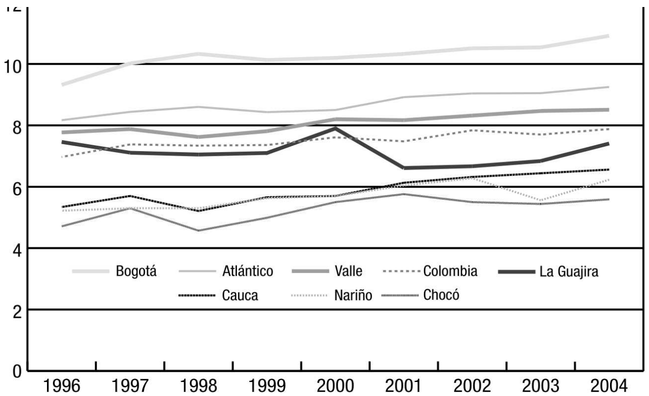


Figure 38. Years of schooling by region in Colombia.
Source: Viloria de la Oz, 2008.

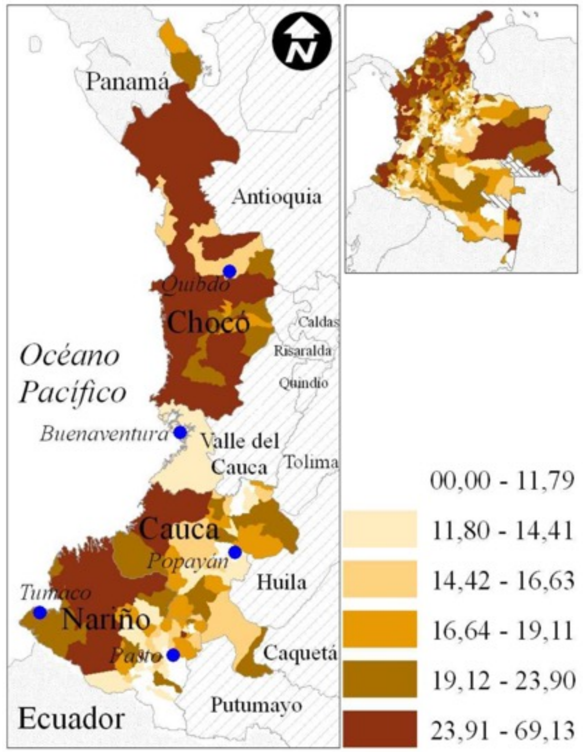


Figure 39. Analphatebism in the pacific region.
Source: Romero, 2009.

6.Application: Energizing in the Colombian Pacific

6.1 Climate change impact
6.2 Energy solutions for the region
6.3 Energy efficiencient architecture

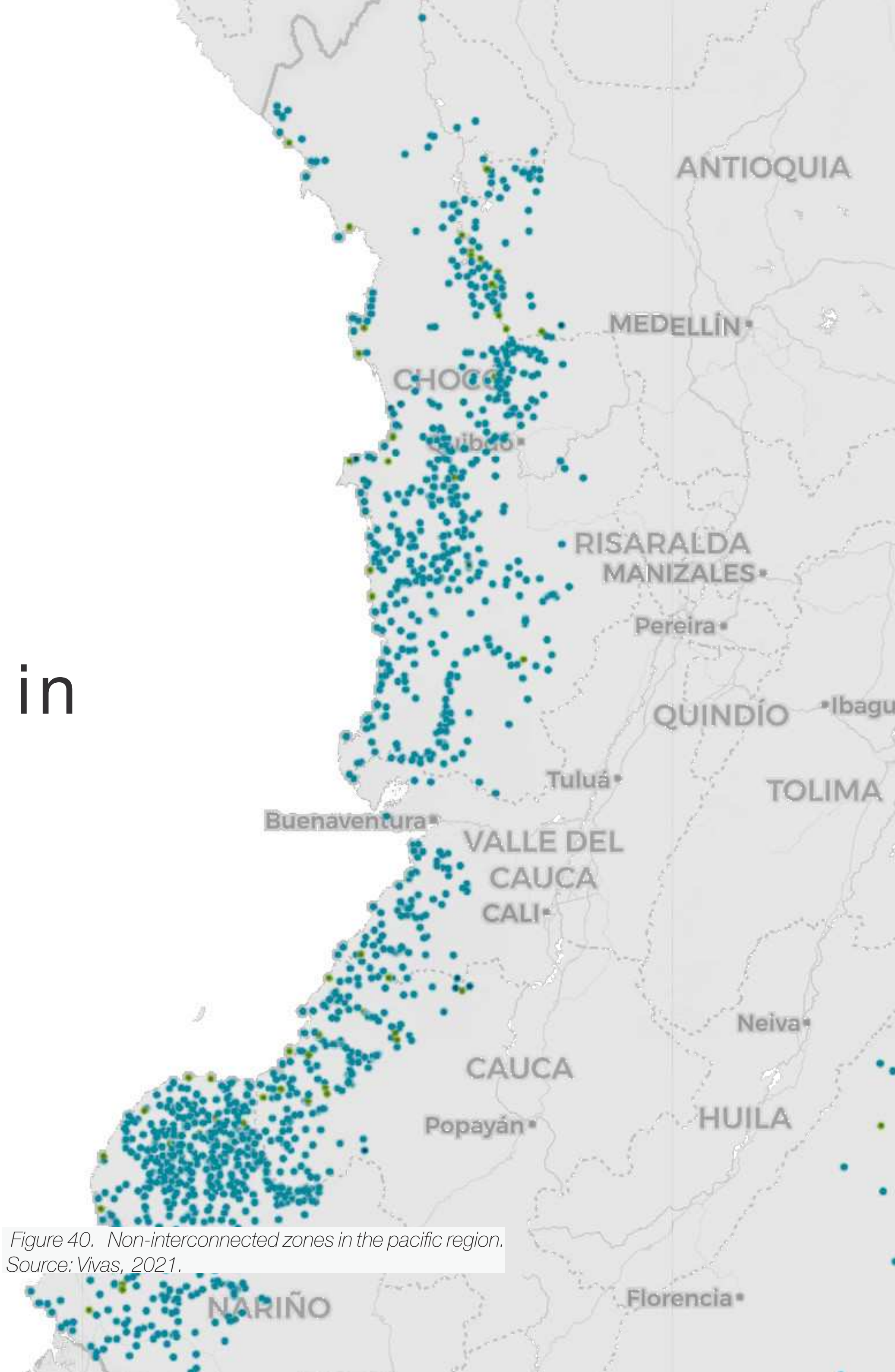


Figure 40. Non-interconnected zones in the pacific region. Source: Vivas, 2021.

6.1 Climate Change Impact

Climate change is a term used to describe the long-term changes in temperature and climate patterns. It is caused by human activities, mainly by the burning of fossil fuels like coal, oil, and gas, which generate greenhouse gas emissions. These emissions create a layer in the Earth's atmosphere that traps the sun's heat, leading to a global temperature rise. The two main greenhouse gas emissions that contribute to climate change are carbon dioxide and methane gas.

Since the 1970s, the global temperature has increased by approximately 1ºC compared to previous climate variations. The rise in global temperature has serious consequences for life on the planet and the equilibrium of ecosystems. Some of these changes include droughts, water scarcity, forest fires, rising sea levels, flooding, melting of the poles, and the threat to biodiversity (Corredor, 2018, p. 109).
The global temperature rise also has serious consequences for human life, such as the increase in malaria cases, as climatic conditions are more favorable to the spread of transmitting mosquitoes. In warm climates, exposure to heat can seriously affect human health through the incidence of other diseases. Vulnerable individuals such as children and the elderly are at risk of hazardous conditions that are exacerbated by the increasing global temperatures.

The Colombian Pacific region is facing significant threats due to climate change. The increase in temperature poses high risks to both human health and ecosystems in the region. Additionally, the rise in sea level is a major concern as it can cause damage to structures that are not designed to adapt to the change in level.

The rise in global temperatures can lead to discomfort, prompting the need for air conditioning and ventilation to maintain human health. The use of these strategies is unavoidable and energy consumption must be considered necessary for the human health of the inhabitants of the region.

However, the proper use of active and passive systems can compensate for the energy consumption of these systems and ensure responsible energy consumption as well as thermal comfort conditions for human health.

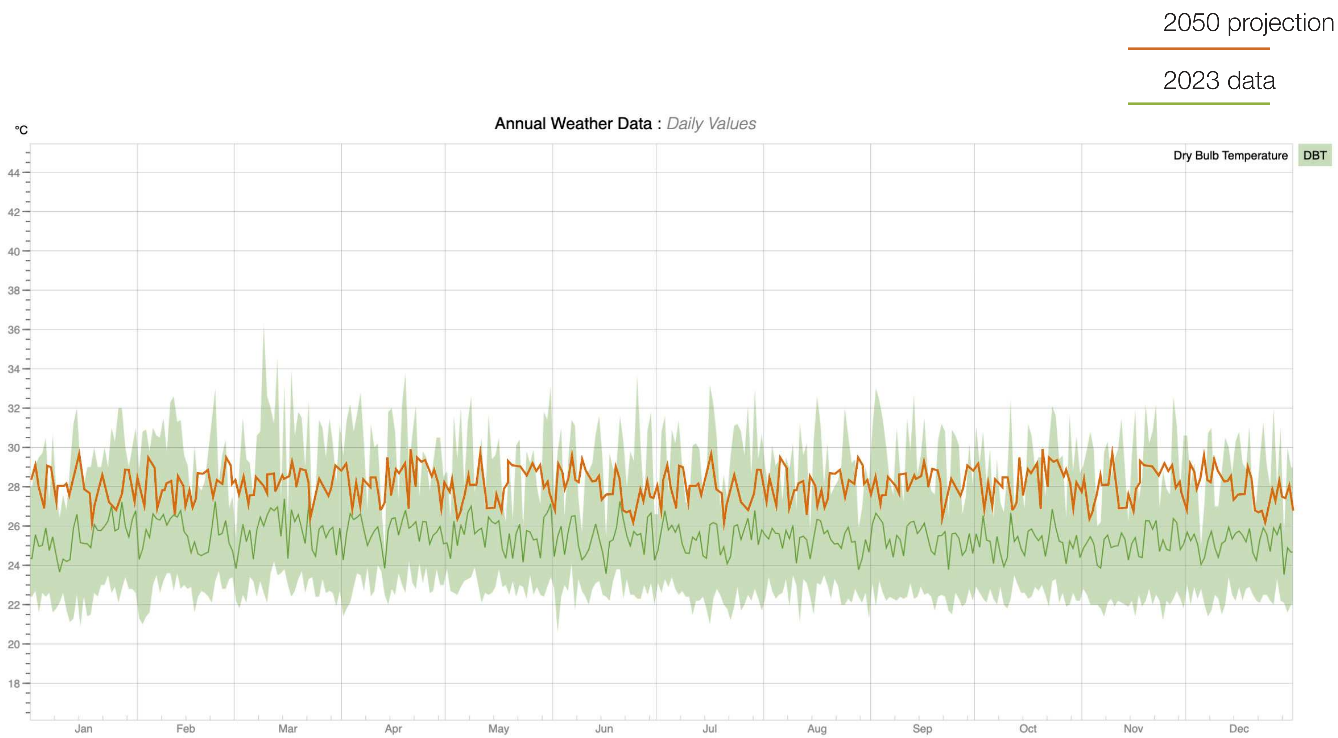


Figure 41. Dry bulb temperature analysis of Quibdo Weather file in 2023 and 2050 prediction.Source: Self-created, 2023.

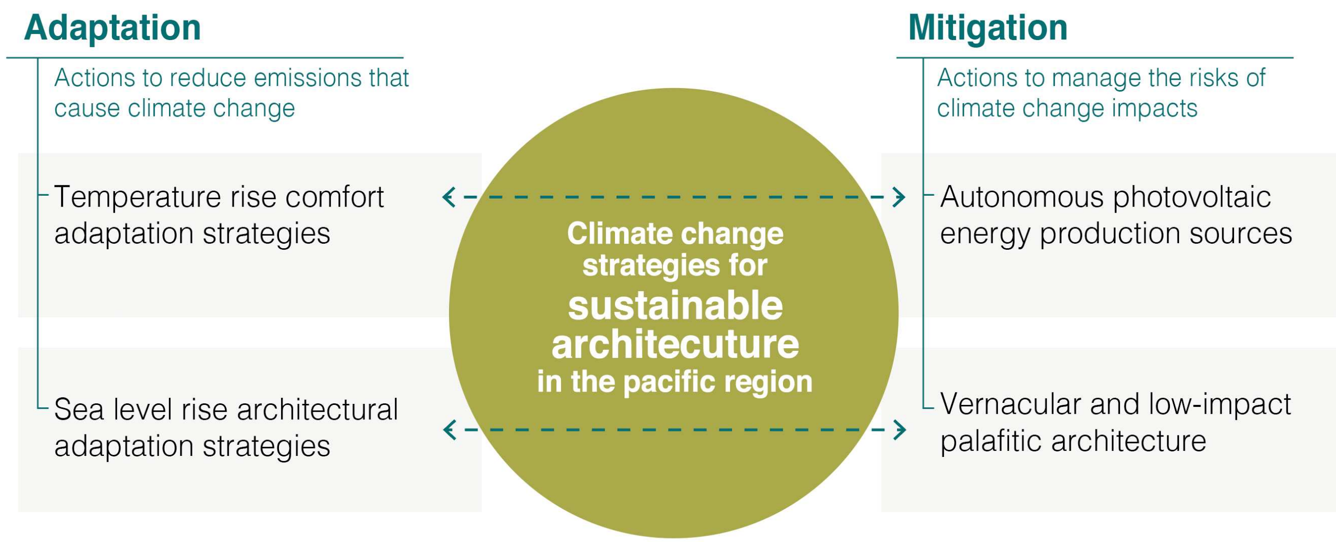


Figure 42. Sustainability strategies for the pacific region projects. Source: Self-created, 2023.

The Colombian Pacific, being an area of great importance for the biodiversity of the planet, requires great care in the interventions to be carried out there. Autonomous systems prevent infrastructure that is not coherent with the territory and the ecosystem. The projects to be carried out should consider the small and large-scale impact on biodiversity and pollution in the territory.

The irreversible effects of climate change include many of the climatic conditions that affect human health on the planet, and steps must be taken to reduce the risks.

These strategies fall into two types: adaptation and mitigation. Adaptation strategies are based on the premise that climate change is reversible and lifestyles must adapt to its consequences. These make it possible to mitigate the risks of climate change to human life. For example, adaptation to high temperatures, rainfall phenomena, resource scarcity and sea-level rise.

Mitigation strategies are those that seek to reduce the effects of climate change through strategies such as reducing impacts or conserving resources. These measures justify the use of clean energy to avoid the production of greenhouse gases produced by fossil fuel-based energy.

Climate change responsable actions in the colombian pacific region:

- Responsible use of local materials and with environmental responsibility certifications.
- Design consistent with the natural landscape and respectful of existing ecosystems.
- Reduction of energy consumption at buildings construction and use phases.
- Planning of energy consumption during the life of the building, especially for the reduction of greenhouse gases.
- Consistency with regional cultural practices and social values.
- Adaptation to climate change, climatic phenomena and risk management.

6.2 Energy solutions for the region

The department of Chocó has 3,210 kW of installed capacity thanks to the implementation plans in rural areas for areas not interconnected with the national electricity system.

According to data from the Institute for Planning and Promotion of Energy Solutions for Non-Interconnected Zones (IPSE), there are 1,710 rural localities in Colombia where it is estimated that 128,587 people only access the service between four and twelve hours a day. (Vivas, p. 1) The transition to clean energy sources must also comply with harnessing decentralized energy systems to have an impact on social development in an environmentally sustainable manner.

In the participatory tables of the Pacific Regional Strategic Plan 2020-2040, it was recognized that dispersed peoples should be energized with isolated alternative systems. They declare that the traditional system is unviable in a region such as the Pacific because of the scale and complexity of its forests and very dispersed and small communities (Becerra, p. 42).

However, participants concluded that renewable energies such as photovoltaics can have a good implementation but that in some cases where they are already used, the problem is management and scaling. (Becerra, p. 42).

1.3.2 Act No. 1715 of 2014 This Act promotes the inclusion of Unconventional Energy Sources (FNCE) as a mechanism for the diversification of technologies for the electrification of Non-Interconnected Zones and the reorientation of the design and strategies that guide rural energy plans; it creates the Unconventional Energy and Efficient Energy Management Fund (FENOGE) to finance programmes for the generation and efficient management of energy from unconventional sources. (Ovalle et al., 2020, p. 21)

Figure 43. Urban non interconnected zones in Choco region and service provision hours. Source: Vivas, 2021.

IPSE Energy Communities

Figure 44. Energy communities illustration. Source: Colciencias, 2015.

Various projects are currently on progress for the non-interconnected areas of the country, grouped by geographical region. For the Colombian Pacific, priority is given to the implementation of photovoltaic systems through education and training programs on solar energy. These programmes seek to replace systems that rely on fuel-based generators with solar photovoltaic energy. The replacement of these systems is envisaged progressively, recognizing the difficulties and limitations of the programmes.

The IPSE structures and advocates for energy solutions that are environmentally compatible, reliable, and sustainable. This ensures active community participation and proper management of natural resources, as well as respect for ethnic and cultural diversity. In this context, the exploration and utilization of Non-Conventional Energy Sources (NCES) such as photovoltaic solar energy emerge as a technically, socio-economically, and environmentally viable solution for remote localities or communities in the country. These areas are characterized by low-paying capacity, a high percentage of unmet basic needs, and limited coverage of public services, including energy. ("Documento de Manejo Ambiental Proyectos con sistemas fotovoltaicos.", 2019, p. 2)

It is very important to recognize that the procedure for implementing these projects is called "Energy Communities", which include training programs for the autonomous maintenance of new photovoltaic systems.

Energy programs in the Colombian Pacific seek to provide and replace fuel-based electric generators with photovoltaic systems or other types of renewable energy according to climatic conditions.

Solar photovoltaic energy can be installed in different ways and at different scales. The IPSE classifies projects into four categories:

1. Individual Solar Photovoltaic System (SISFV): Photovoltaic modules with less than 5 kW

2. Nanon-networks: Energy solution consisting of an individual generation system of 5 kW with weather station compatible with the monitoring system.

3. Micro-grids: Energy solution consisting of an individual generation system of 10 kW, with weather station compatible with the monitoring system.

4. Mini-networks: Energy solution consisting of an individual generation system superior 10 kW, with weather station compatible with the monitoring system.

These proposals may be submitted individually by the same inhabitants of non-interconnected areas or by state organizations. Some projects have been submitted for community services such as common refrigerators for restaurants and businesses or for electric motorboat mobility.

IPSE promotes that proposals for energy communities can come from any user who submits a project for energy purposes in non-interconnected areas. For this purpose, it has on its website a budget simulator for photovoltaic systems to facilitate the approach of the proposal to other interested parties.

Figure 45. Micro-grid project Source: IPSE, 2022.


Figure 46. Individual system. Source: Colciencias, 2015.


Figure 47. Individual system installation. Source: Colciencias, 2015.

Micro-Grids Modules

Currently, the projects installed in the Colombian Pacific region are small solar panel installations disintegrated from the traditional architecture of the users. There are also small modules with solar panels on deck and batteries for storage that are built in isolation and disconnected from the architectural context. This type of implementation can be disadvantageous for energy transition projects because they are disconnected from the constructive tradition of the populations and are not included in the ways of inhabiting the place.

The *Miichi Ka'i* module (which means "Solar House" in *wayuu* language) is a modular project proposed for the Guajira region, on the Atlantic coast of Colombia. It is proposed with a photovoltaic generator of 10 kW and a battery bank inside the module. It is planned that this module will be installed in all non-interconnected areas of the country. The Colombian Pacific region, being the area with the largest number of non-interconnected areas, needs to adapt this type of module to its social and environmental context.

As has been shown, there are different ways to integrate photovoltaic systems into architecture, so as not to damage rural landscapes. Integrating photovoltaic systems into the traditional architecture of the region (BIPV) may be an initiative to adapt solar energy to future traditional Pacific buildings.

Figure 48. Miichi' Kai Micro-Grid Module. Source: IPSE, 2023.

Figure 49. Miichi' Kai Micro-Grid Module. Source: IPSE, 2023.

6.3 Energy efficient architecture

Climate comfort strategies

In the pursuit of sustainable architecture, various studies propose contrasting solutions, some favoring advanced technologies, while others advocate for simpler, low-tech approaches. While high-tech methodologies in architecture offer the allure of enhanced control, comfort, and accessibility, the sustainability of low-tech approaches, as observed in many vernacular structures, lies in their minimal impact on a building's energy input and output throughout construction and operation. It is worth noting that each approach carries its unique advantages and challenges.

Strategies for achieving climatic comfort are defined according to the climatic standards of temperature, humidity, lighting, reverberation, and amount of carbon dioxide in an indoor or outdoor space. There are passive strategies, which do not require mechanical or electrical systems that consume energy, and active strategies, which refer to the use of equipment such as air conditioners, fans, and heaters. Bioclimatic architecture includes all design decisions related to climate and territory, to reduce energy consumption and achieve indoor thermal comfort, in addition to the use of renewable energy sources (Esteve, p. 31).

Climatic comfort is very important for the health and well-being of the inhabitants, in addition to determining the impact of the building's energy consumption. Comfort conditions determine the spatial quality of a building and function in direct relation to the climate in which they are located.

Bioclimatic strategies are divided into two types of intervention: strategies associated with climate conditions and those to energy efficiency. Climate determines decisions on orientation, ventilation, lighting, and solar exposure. Simultaneously, the energy efficiency of the building is shaped by considerations such as its form, thermal insulation, inertia, system efficiency, choice of fuels, and the effective utilization of the building (Esteve, p. 31).

The psychometric chart of the climate data of Quibdó, the capital city of the Chocó region in Colombia, shows the temperature and humidity records for every hour of the year. In this diagram, the comfort zone is marked in the green area to show if the temperature and humidity are within these ranges and the corresponding bioclimatic strategies for each marked data. The graph shows very few hours inside the comfort zone and the need for natural ventilation for most annual data.

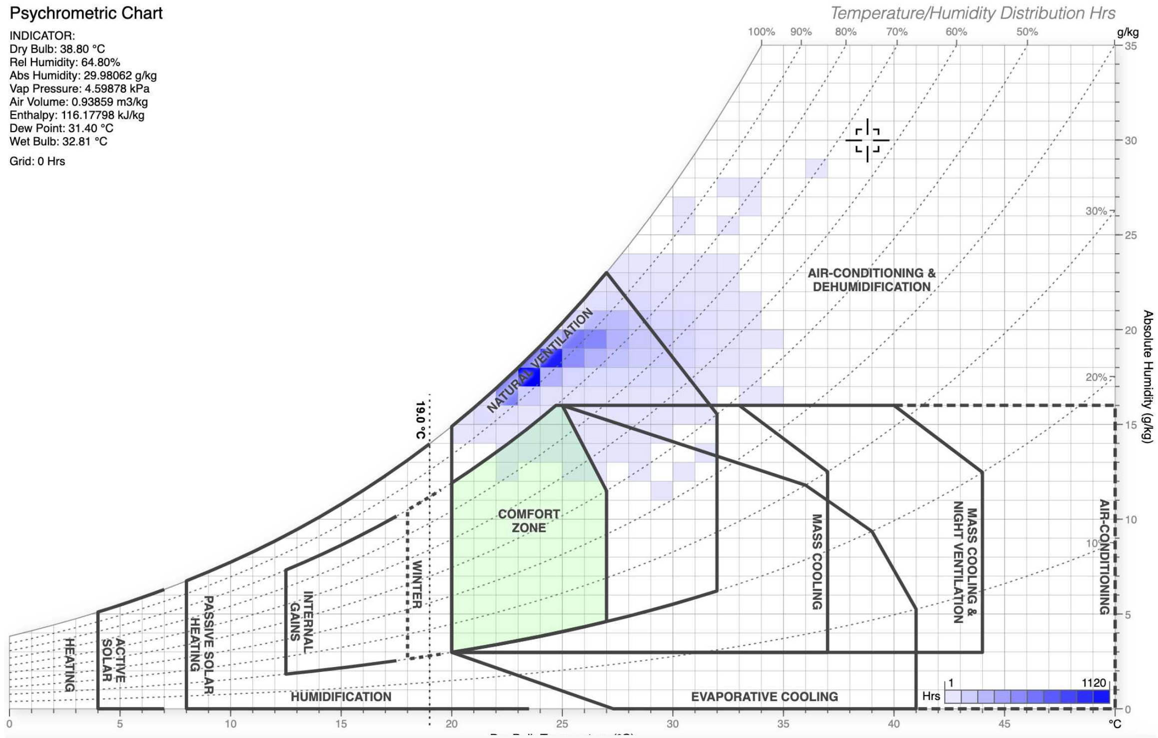


Figure 50. Quibdo weather file psycometric chart processed by climate analysis Source: Andrewmarsh.com, 2023.

Due to the increase in global temperature, considering the combination of both active and passive comfort strategies is a way of mitigation and adaptation to climate change.

Traditional building materials are very effective in maintaining an indoor thermal comfort environment thereby reducing external energy consumption. Coupled with solar passive techniques vernacular materials are sustainable resources and passively provide comfortable interiors. The incorporation of these principles helps in reducing the dependency on artificial means for achieving thermal comfort.

Currently, there are many ways to evaluate thermal comfort in indoor spaces, adopted by international standards such as the ANSI/ ASHRAE-55 and the adaptive model, which works on the assumption that indoor comfort mainly depends on the relationship between indoor operative temperature and outdoor temperature.

Climate projections for 2050 show that climate comfort conditions will be very difficult to achieve with passive strategies. This is why it is necessary to consider the climate projection on the psychometric chart and to address passive cooling strategies more efficiently.

Pasive strategies

Based on architectural features with no energy consumption

- Natural ventilation
- Sun protection
- Gain of solar radiation
- Thermal insulation
- Natural lighting
- Guidance
- Thermal mass

Active strategies

Based on electrical devices with energy consumption

- Air conditioning
- Fans
- Extractors
- Dehumidifiers
- Heating
- Artificial lighting
- Humidifiers

Figure 51. Bioclimatic strategies for the pacific region. Source: Self-created, 2023.

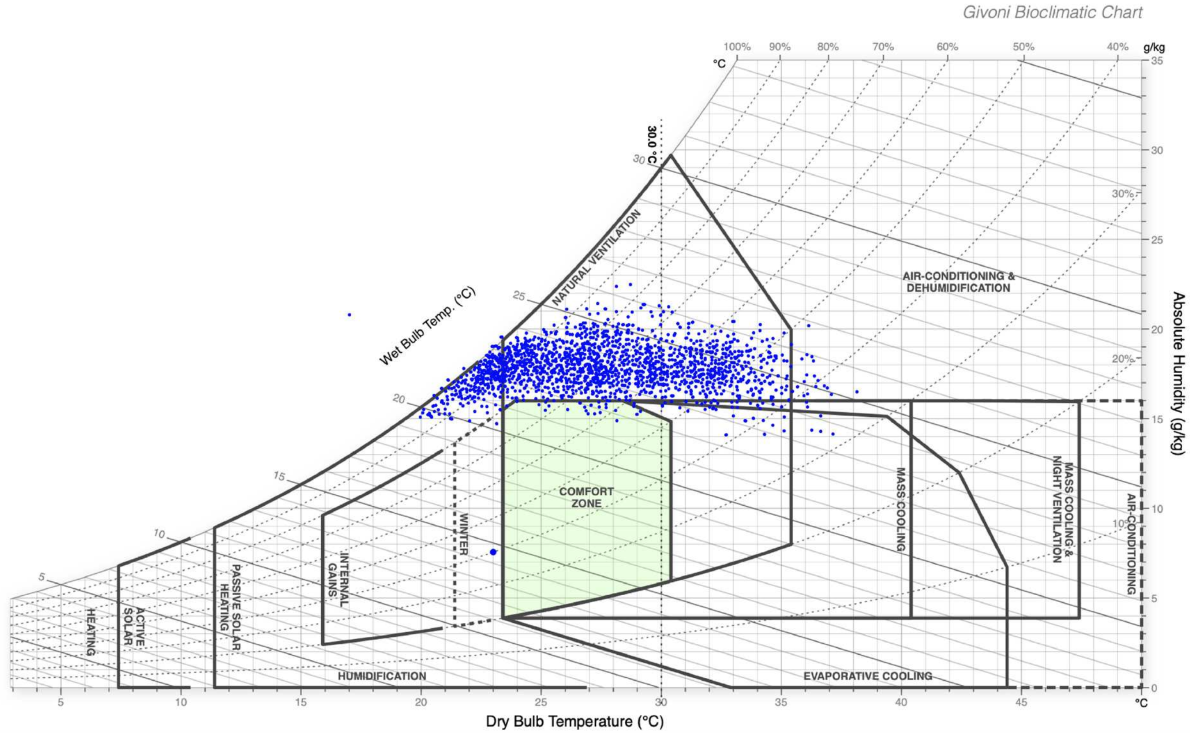


Figure 52. Quibdo's weather file psycometric chart projection for 2050. Source: Self-created, 2023.

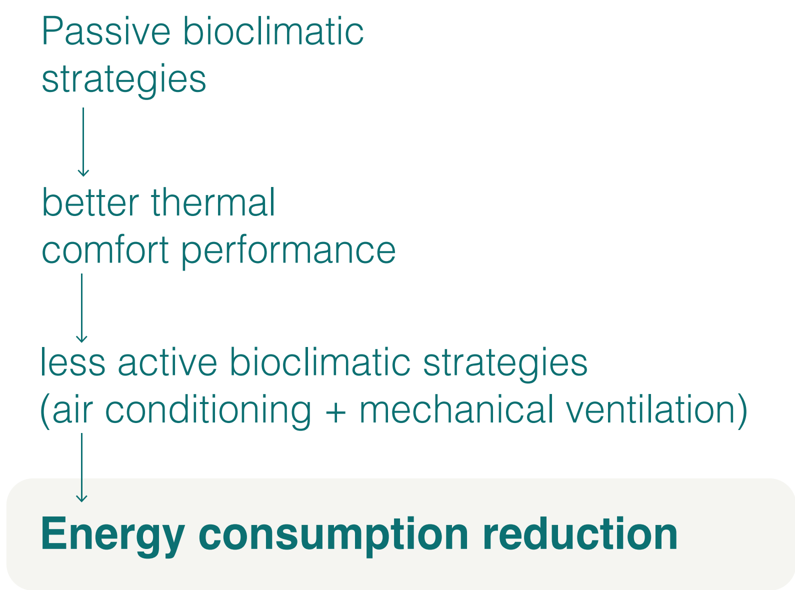


Figure 53. Energy reduction strategies. Source: Self-created, 2023.

That is why studies show that the use of both types of strategies can guarantee climatic comfort without compromising the dependence on active strategies, avoiding the high energy consumption of these strategies.

In the case of specific types of buildings, such as schools, the adaptive model of comfort presents an additional set of problems. Previous studies have found that students tend not to modify their thermal environment due to strict discipline codes, lack of agency, or different thermal preferences between teachers and students. Furthermore, researchers have criticized the use of mainstream comfort standards in schools, as they were developed based on adult subjects whose perceptions and preferences of comfort may differ from those of children in various stages of development (Rodríguez et al., 2021, p. 1).

Several studies show that children are more sensitive to high temperatures than adults, and therefore prefer lower temperatures in classrooms. Understanding thermal comfort in school environments is very important given that children spend a significant portion of their time within classrooms. Rodriguez et al. (2021) highlights the importance of understanding that classrooms with high occupancy rates may result in elevated concentrations of CO_2 that exceed healthy limits. The consequences of inadequate thermal conditions extend beyond immediate discomfort, impacting the health and cognitive functions of students (Rodríguez et al., 2021, p. 2).

This relation between thermal comfort, health, and energy efficiency underscores the need for a holistic approach to architecture design, ensuring not only physical comfort but also fostering an environment conducive to well-being.

BIPV Systems

BIPV systems are a strategy for integrating photovoltaic systems into architecture to take advantage of the built structures as space to produce energy. The integration of these systems into building architecture is crucial due to their significant impact on energy consumption in the building industry and building energy use.

In this way, these systems can provide a percentage or all of the energy that will be consumed in the building itself. Individual systems have the advantage of providing energy production at the same scale as their consumption. The development of solar panel technology makes it possible for most of the uses of a building to achieve a zero balance between production and consumption by counting on the surface area on the roof for the installation of solar panels.

It is worth noting that certain systems are designed in conjunction with the building envelope, including roofs, facades, and windows that incorporate transparent photovoltaic panels, as well as other innovative forms of integration. **This shows the importance of taking energy consumption into account as one of the primary variables in the architectural design of a building (Stähr, 2012).**

The design of these systems requires considering the relationship of the building to the climate and the context in which it is located. These variables determine the production capacity of each strategy used in the building envelope. The most common integration is the use of solar panels on building roofs to take advantage of the high exposure to solar radiation. Integration into facades depends on the technology used in opaque or transparent facades and the sun exposure of each facade.
The technological development of photovoltaic panels has allowed the production of these with different characteristics of shapes, materials, colors, and textures that enable creative integration into the design of buildings.

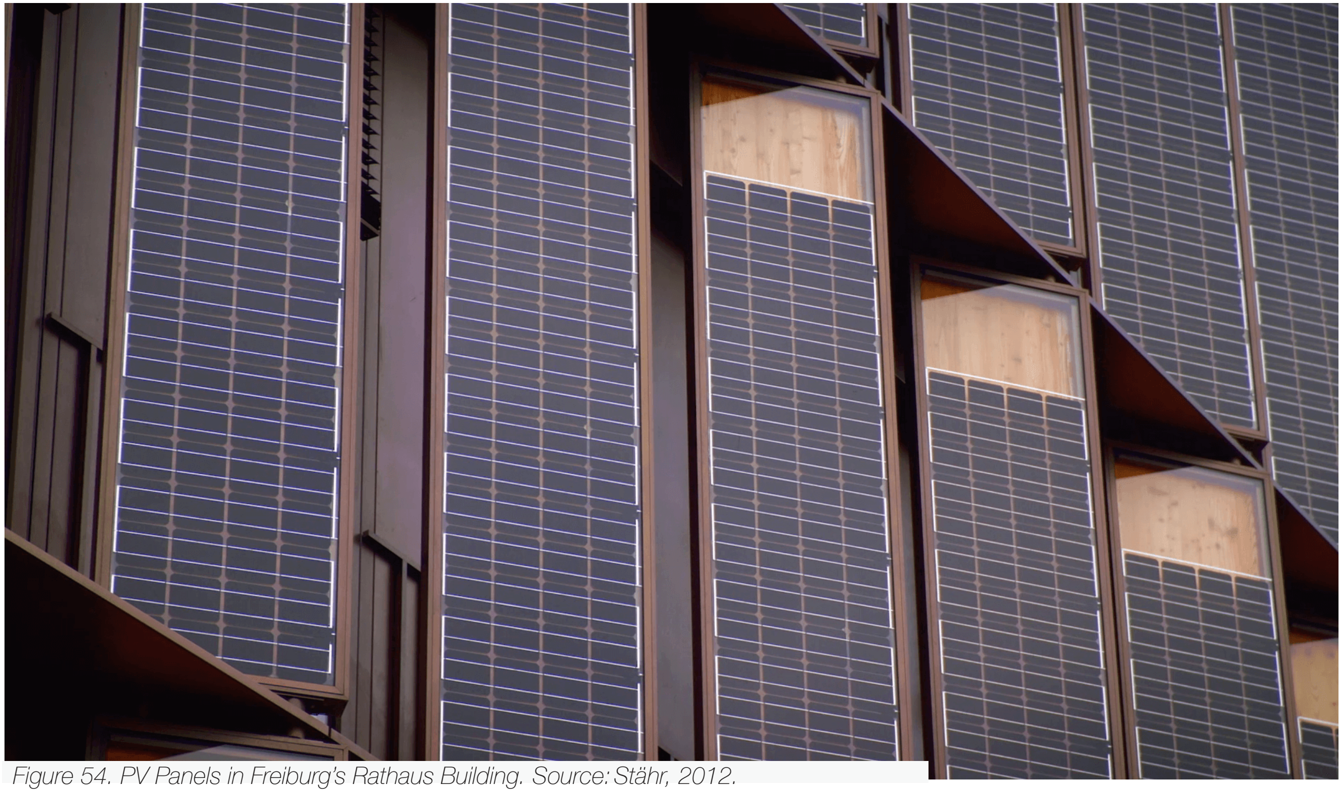


Figure 54. PV Panels in Freiburg's Rathaus Building. Source: Stähr, 2012.

Environmental benefits	Social benefits
Reduction in the burning of fossil fuels used for power generation, thus reducing emissions of NO_2, SO_2, CO, and CO_2.	Generating better living conditions and revitalizing the local and/or regional economy.
Public health benefits from reduced air pollutants.	Improvement in the quality of education by enabling the use of new technologies such as electronic audiovisual media, the Internet, and the use of computers.
Promoting the use of renewable natural resources, their rational and efficient use, energy saving, and energy efficiency.	Strengthening the social infrastructure of communities in the sectors of health, public services, and telecommunications, among others.
Decreased pressure on forest resources, used as energy by communities, and dependence on external fossil fuel supplies.	Development of productive processes that improve the living conditions of communities.
Elimination of hazardous wastes generated by the operation of diesel engines that contaminate soil and water bodies such as oils, greases, refrigerants, and sludges, among others.	Possibility of obtaining water by pumping for consumption and irrigation in crops.
Elimination of risks and impacts arising from fuels during their extraction, processing, transport, and combustion, benefiting the atmosphere, soil, water, fauna, and vegetation.	Promotion of organizational forms in communities, given the need to conform themselves as users of the energy service.

Figure 55. Environmental and social benefits of photovoltaic energy. Source: Self-created, 2023.

Figure 56. PV Panels installation Source: Colciencias, 2015.

Figure 57. PV Panels installation Source: Colciencias, 2015.

Figure 58. PV Panels installation Source: Colciencias, 2015.

7. Case studies

Figure 59. Minga House South Facade. Source: Self-created, 2019.

7.1 Colombian pacific architecture references

Minga House SDLAC 2019

The Solar Decathlon is an international competition that seeks the participation of different universities to achieve sustainable housing proposals, evaluated in ten competitions that assess the integrity of the projects. The competencies that made up this latest version were: Architecture, Engineering and Construction, Energy Efficiency, Energy Balance, Comfort, Operation, Communication and Marketing, Urban Design and Feasibility, Innovation and Sustainability.

The Pontifical Javeriana University Cali, the Federal University of Santa Catarina and the Federal Institute of Santa Catarina joined for the nomination as participants of the Solar Decathlon Latin America & Caribbean 2019 contest. In the union of these three universities, the Minga Team was created, consisting of 40 students from eight academic programs and a multidisciplinary team of professors. The team's result, the Minga House, won prizes in nine of the ten competitions and was declared the overall winner of the competition by winning first place in the competition. Minga was born from the reflection of the housing in the tropics in a future that threatens new conditions due to the effects of climate change. The team sought to create a sustainable housing prototype with low environmental impact and solutions for the current effects of the climate crisis. Its design principle is based on the adaptability of the prototype to the cultural, natural and user context.

Figure 59. Minga House Facade. Source: Self-created, 2019.

Based on the constructive traditions of stilts for flood-prone areas, our proposal of buildings is set up on the edges to contain the horizontal expansion over the sea, to achieve greater urban density and to maintain a direct relationship with the sea. A proposal was planned for a seafront pier, intermodal boat transport stations, the creation of floodable public spaces and the housing cluster model adaptable to rising sea levels.

The configuration of the spaces of the Minga house is based on the co-housing strategy. Reflecting on the formation of families in Buenaventura, we consider that the most common and commercial types of housing are not appropriate for the region. In the coastal areas of the tropic, the increase in temperature can be harmful to human health, which is why the architectural design of the Minga House is also based on comfort strategies.

The house consists of four closed volumes for private use and free spaces between these for shared use, on a platform attached to the main structure that is a large common roof that covers all these spaces. The closed and private volumes are two divisible bedrooms and two bathrooms, while the free platform spaces are kitchen, dressing area, living room, dining room and terraces.

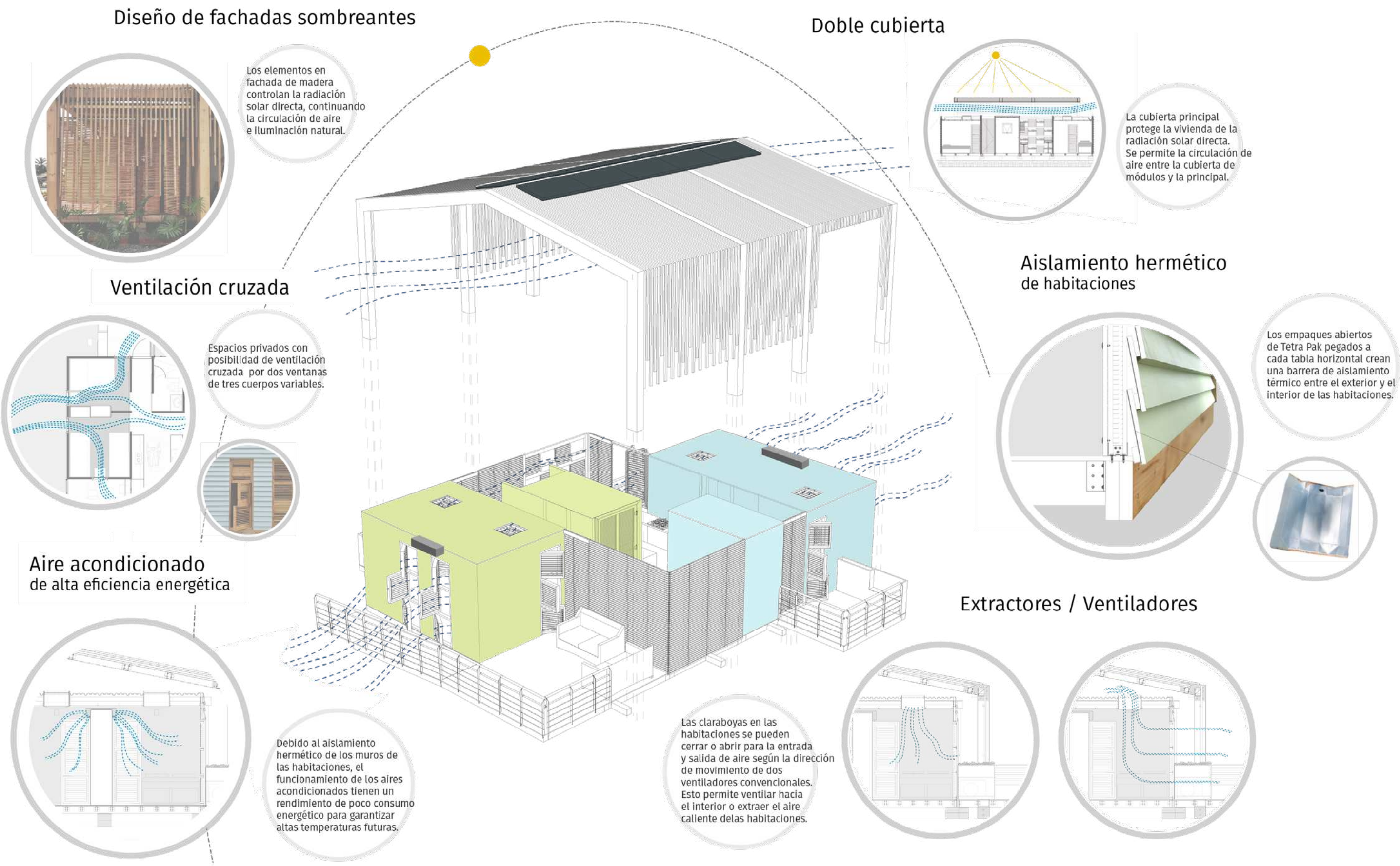


Figure 60. Minga House' bioclimatic strategies. Source: Self-created, 2020.

In addition to the passive strategies of the vernacular architecture of the Pacific applied to the prototype, the use of active cooling strategies of the closed modules of rooms is proposed. Due to the high temperatures in the region that are projected in a future scenario of global warming, the use of air conditioners and fans is proposed.

The use of air conditioners is carried out under controlled conditions for only a few hours a day when the temperature is higher, ensuring efficiency by closing windows and doors. After a temperature check in the room, the air conditioning can be turned off and the temperature in the room will remain constant for a few more hours as long as windows and doors are kept insulated.

The use of fans is a strategy to improve natural cross-ventilation. The fans allow to increase the wind speed, and therefore, cool the spaces and improve the air quality inside.

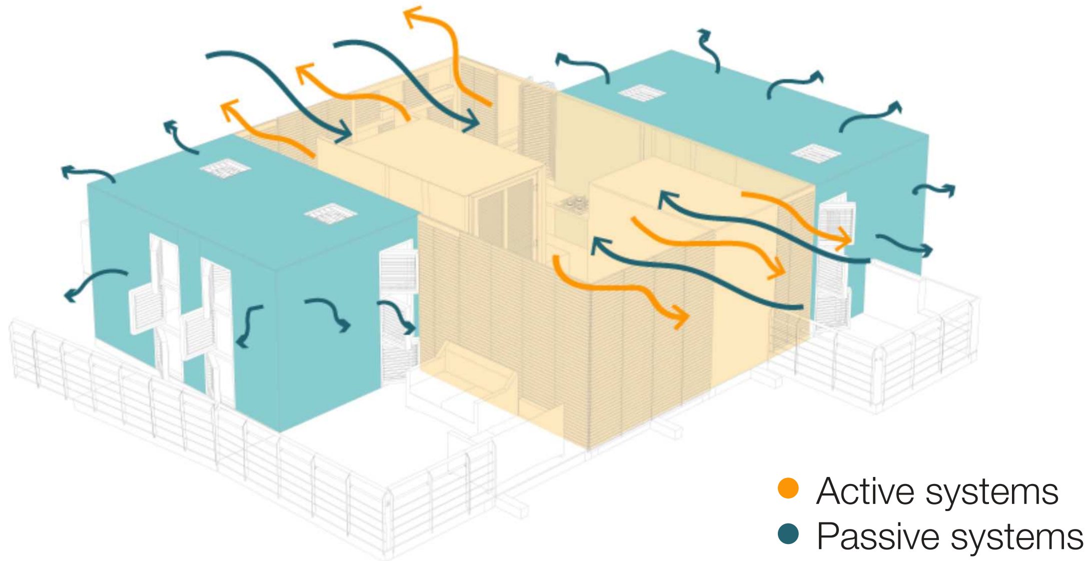


Figure 61. Active and passive areas in Minga House. Source: Self-created, 2020.

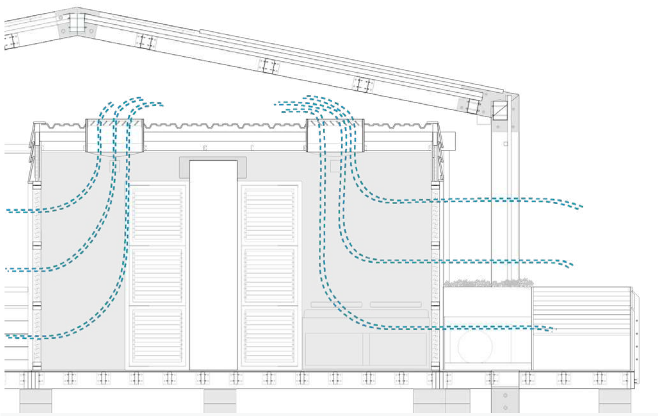


Figure 62. Natural ventilation strategy. Source: Self-created, 2020.

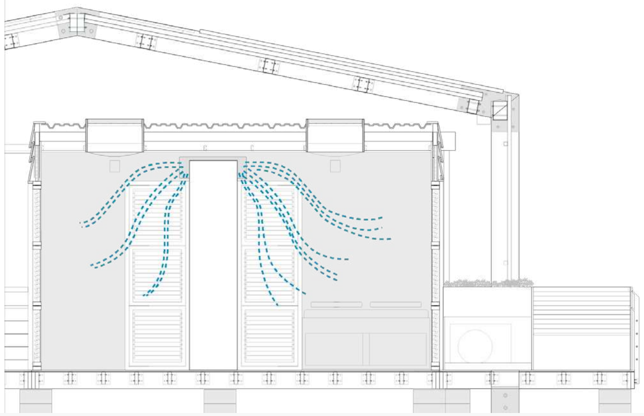


Figure 63. Air conditioning strategy. Source: Self-created, 2020.

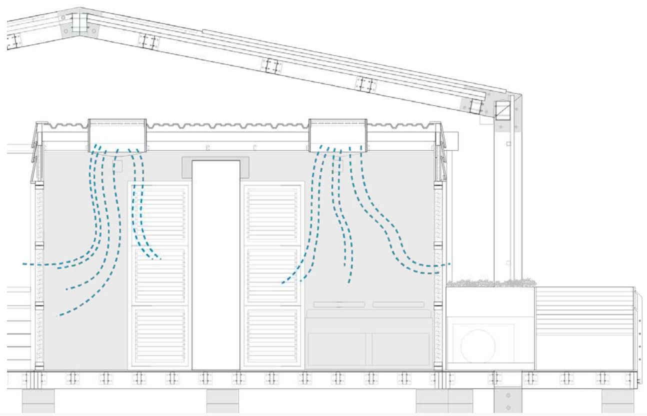


Figure 64. Mechanical ventilation. Source: Self-created, 2020.

Figure 65. Minga House plan. Source: Self-created, 2020.

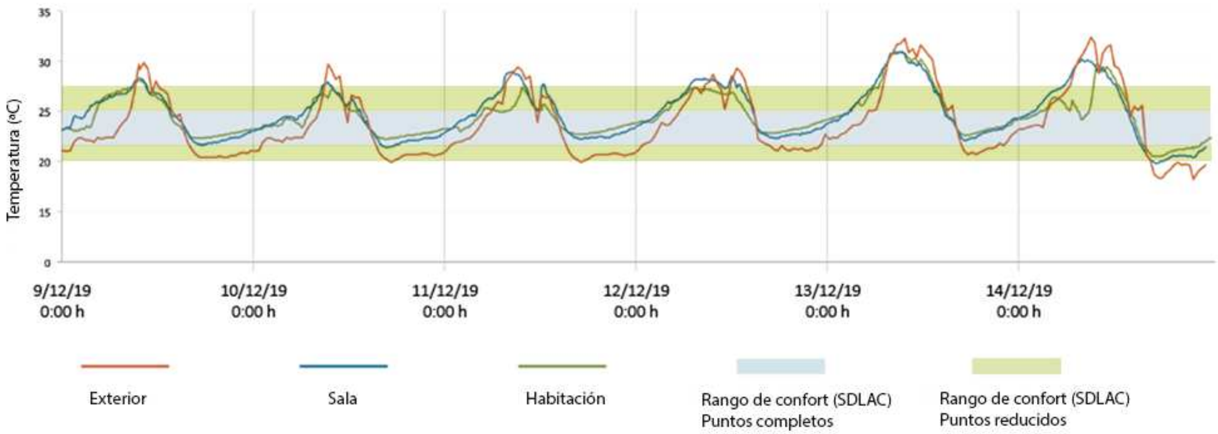


Figure 66. Minga House temperature analysis Source: Self-created, 2020.

The energy comfort results showed the difference between passive and active house strategies, showing that climate comfort is not achievable even when applying all passive strategies. During peak heat hours the correct and efficient use of air conditioning in the rooms reduces the temperature to the required comfort standards and can provide heat shelter in extreme climates in the future.

However, the bioclimatic strategies that can be seen applied had a very good functioning as you can buy with the outside temperature. This proves the effectiveness of the bioclimatic strategies that were applied in the prototype.

It can be highlighted that the combination of active and passive strategies is a solution to address future climate change scenarios and at the same time mitigate consumption by misuse of active systems.

One of the 10 contests of the competition was Energy Balance, which main objective was to the self-sufficiency of the home's electrical energy by means of the balance between electricity generation and consumption. In the competition was sought that the prototypes will reach a balance between 0 kWh and -20 kWh in the generation-consumption ratio and avoid the peak power of the electric charge.

The energy efficiency competition evaluated the temporal correlation between photovoltaic solar power generation and electricity demand during the competition week. In this competition, the energy demand for residential consumption was assessed by setting a limit of 70 kWh in total during the competition week.

One of the key goals for achieving sustainability of the project was to achieve zero-consumption housing. For this, the design of the enclosure, the strategies implemented in the architectural design and the exclusive use of renewable energy, which includes solar thermal energy for water heating and photovoltaic energy for the supply of the house were fundamental.

It is important to emphasize that the balance between these four competencies was fundamental to achieve good results because of the direct relationship between their parameters.

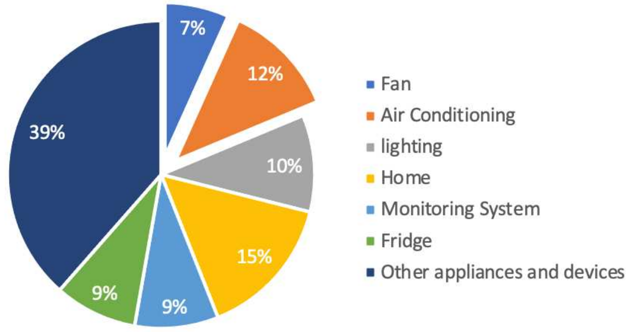


Figure 66. Consumption characterization. Source: Minga Team, 2019.

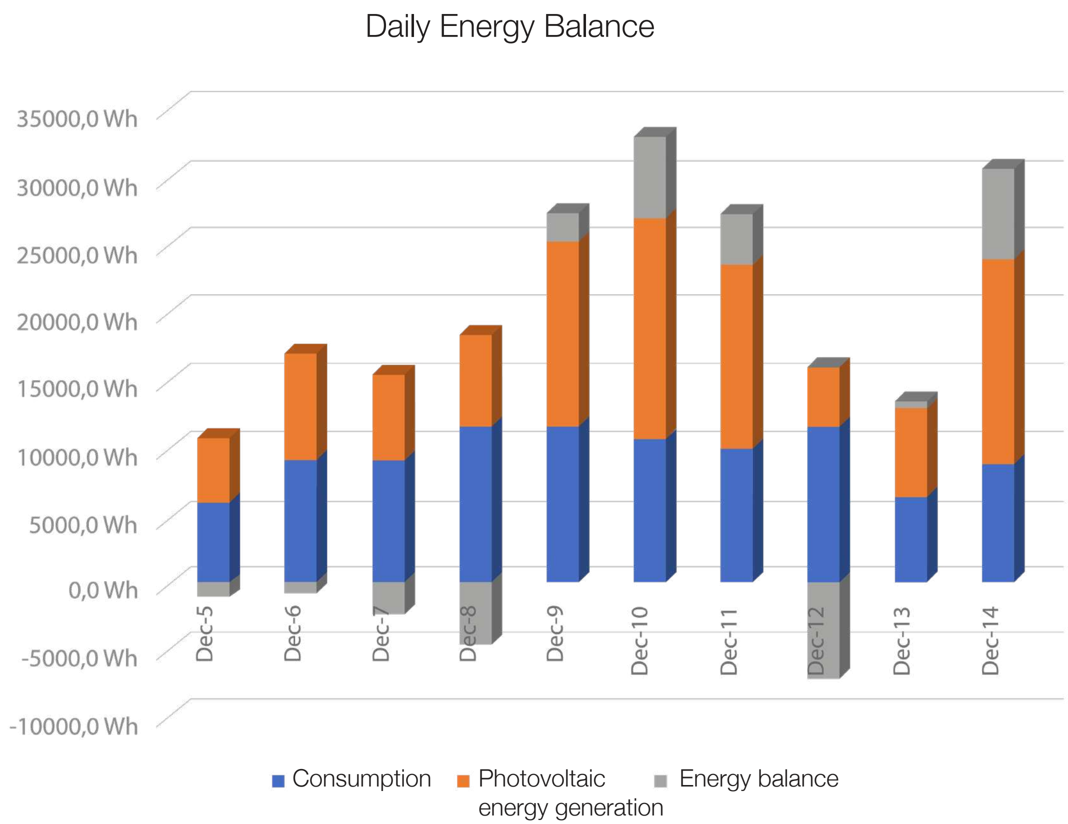


Figure 67. Daily energy balance. Source: Minga Team, 2019.

7.2 EnergyPlus Buildings Reference

Hallenbad Zuffenhausen

Figure 68. Hallenbad Zuffenhausen Visualization. Source: Behnisch Architekten, 2021.

The design for the new indoor swimming hall in Stuttgart-Zuffenhausen is characterized by large, overlapping roofs slabs, seemingly floating above the swimming hall which connects fluidly with the surrounding park. The building utilizes a timber structure, and together with recycled concrete, implements various sustainable energy concepts as the new building is committed to the climate policy goals of the state capitol.

- Description from Behnisch Architekten. https://behnisch.com/work/projects/1787

The Hallenbad Zuffenhausen designed by Behnsich Architekten starts with the competition for the renovation of a public swimming pool in the north of the city of Stuttgart, Germany.
The public project is proposed as the first swimming pool in Germany with the capacity to produce more energy than it consumes. The ambition of this proposal promotes the search for energy efficiency alternatives, promoting low energy consumption for water heating and high production of photovoltaic energy in the facades of the building.

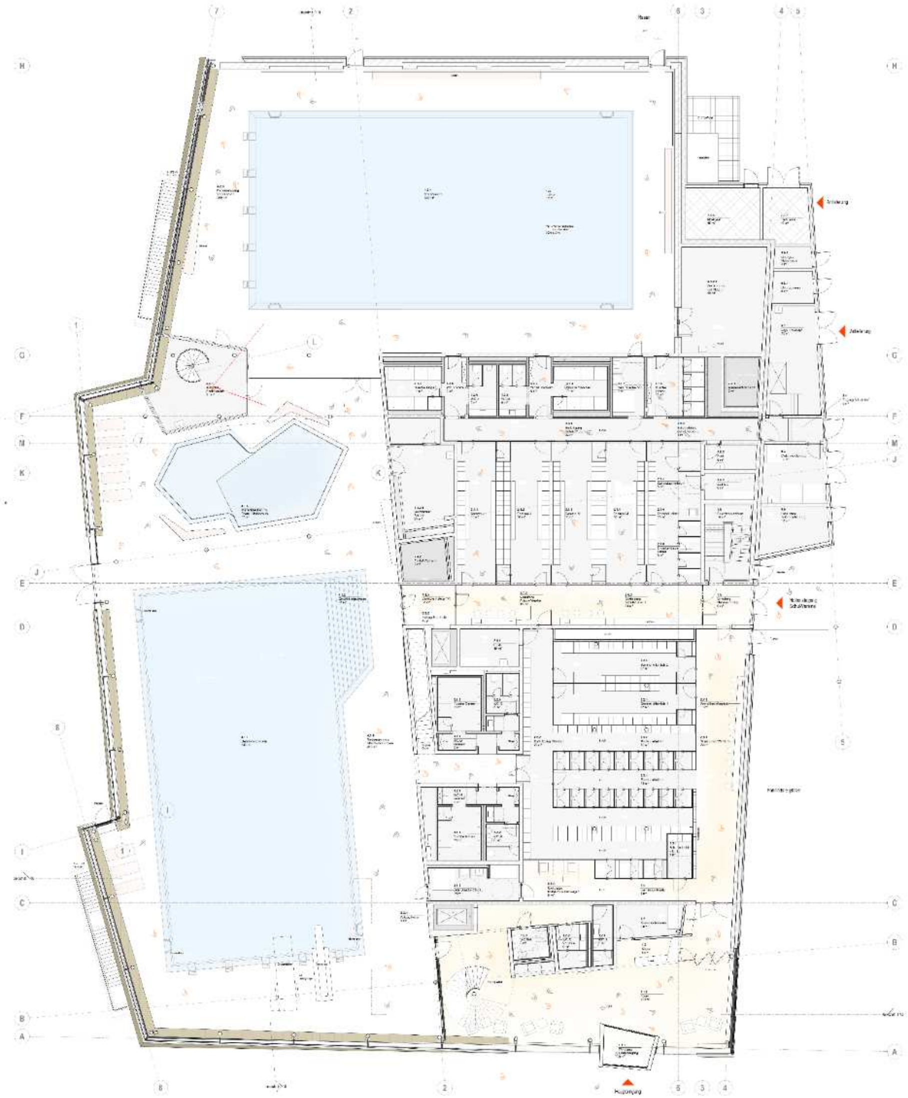


Figure 69. Hallenbad Zuffenhausen Ground floor. Source: Behnisch Architekten, 2023.

Figure 70. Hallenbad Zuffenhausen roof plan. Source: Behnisch Architekten, 2023.

Architectural changes for better energy efficiency performance

Figure 71. Hallenbad Zuffenhausen facades for competition phase.
Source: Behnisch Architekten, 2021.

Figure 72. Hallenbad Zuffenhausen facades for design phase III.
Source: Behnisch Architekten, 2023.

Despite the strategies in technology and high-efficiency electrical systems to reduce the energy consumption of the building, these have not been sufficient. Architectural design plays a fundamental role in reducing energy consumption and providing more photovoltaic generation surfaces. That is why the architectural changes of the building have allowed to achieve a balance of 110% energy autonomy.

	Surface Area	%
Transparent façade	1080 m²	79 %
Opaque façade	289 m²	21 %
Total	**1.369 m²**	**100 %**

	Surface Area	%		
Transparent façade	920 m²	62 %	**-17 %**	**-252 m²**
Opaque façade	565 m²	38 %	**+17 %**	**+252 m²**
Total	**1485 m²**	**100 %**		

Figure 73. Envelope surfaces comparison between competition phase design and design phase III.
Source: Behnisch Architekten, 2023.

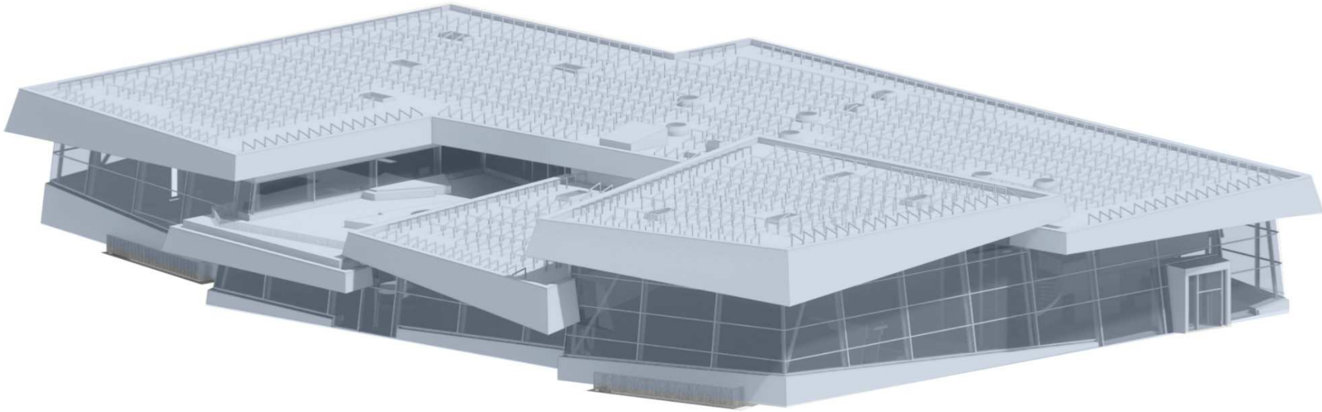


Figure 74. Envelope visualization design phase III.
Source: Behnisch Architekten, 2023.

The opaque surfaces of the façade are made up of different layers of insulation and the elements exposed to the outside are solar panels of different colours. In this way, materials such as wood and concrete are simulated, replacing them with solar panels that contribute to photovoltaic production by taking advantage of the diffuse solar radiation they capture.

Figure 75. Energy balance comparison.
Source: Behnisch Architekten, 2023.

The results of the architectural design are projected to reach 115% of production based on the consumption of the building. Studies show that modernising an existing building consumes more energy than constructing a new building with better energy efficiency strategies.

Annual electricity production	202.833 kWh/a
Electricity demand for heat generation	169.790 kWh/a
Eligible production	86.283 kWh/a
Compliance with the use of renewable heat energy	115,7 %

8. Prototype proposal

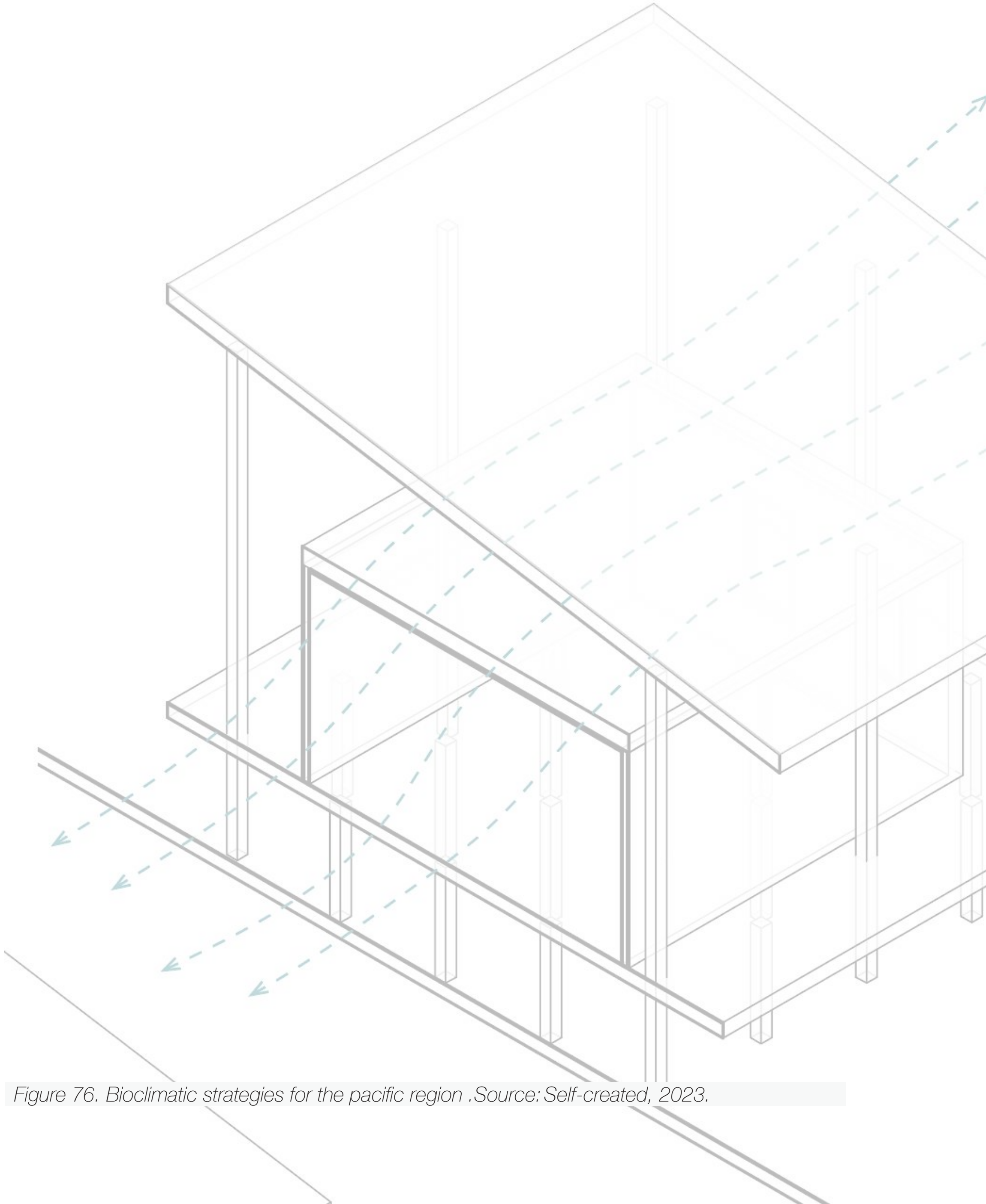


Figure 76. Bioclimatic strategies for the pacific region .Source: Self-created, 2023.

8.1 Site Analysis

Bajo Baudó, Chocó.

Among different non-interconnected areas of the Colombian Pacific, the municipality of Bajo Baudo, Chocó, has been chosen for this proposal.

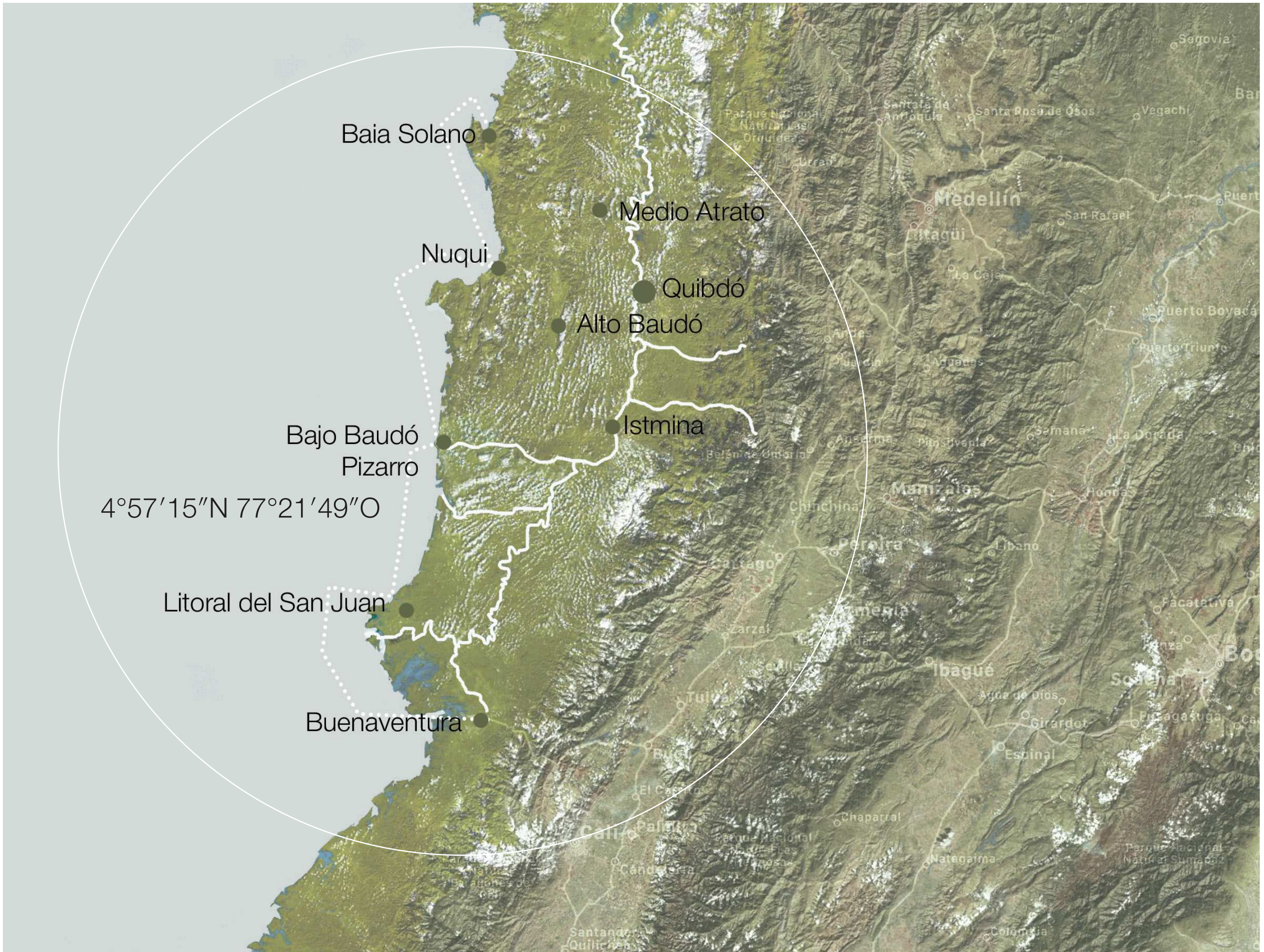


Figure 77. Bajo Baudó Regional analysis .Source: Self-created, 2023.

Telemetry report: Pizarro July 2023

The telemetry system shows the daily operation of a system of 3 diesel generators, Caterpillar brand, with a total capacity of 1,817 kW. Despite this availability, the generators have faults and the hours of power per day record the faults.

Connection system

The supply system at Pizarro is powered by three Caterpillar fuel-based generators, two of them of 591 kW and one of 635 kW, with a 1000 kVA transformer. This system does not have energy storage.

Service provision energy per week / day

The system delivers between 40,000 and 30,000 kWh. On average, the system delivers between 250 kWh and 450 kWh per hour. These variations are reflected in the service provision hours during which citizens are available for use.

Localidad:	**PIZARRO**
Municipio:	BAJO BAUDÓ
Departamento:	CHOCÓ
Región:	
Coordenadas:	
Latitud:	4.953442
Longitud:	-77.366002
Usuarios:	1,530
Operador de red:	EMPRESA DE SERVICIOS PÚBLICOS DE ENERGÍA ELÉCTRICA DE BAJO BAUDÓ PIZARRO S.A. E.S.P. - ELECTROBAUDO S.A. - E.S.P.
Código localidad:	27077000
Código SUI, operador:	1811

Ilustración 84: Esquema de conexión de la localidad

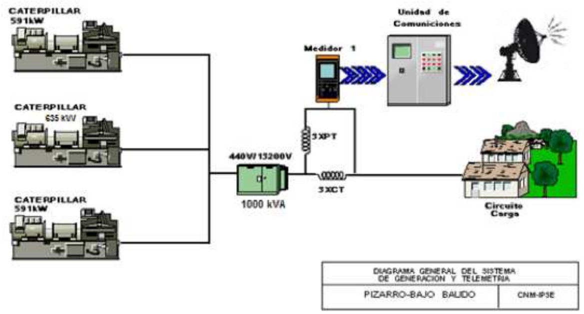


Tabla 89: Infraestructura de la localidad.

GRUPO ELECTRÓGENO			
ITEM	MARCA	CAPACIDAD	ESTADO
1	CATERPILLAR	591 kW	EN OPERACIÓN
2	CATERPILLAR	591 kW	EN MANTENIMIENTO
3	CATERPILLAR	635 Kw (prime) 800 kW(Stand-by)	EN OPERACIÓN
TRANSFORMADORES			
ITEM	CAPACIDAD	ESTADO	
1	1000 kVA	EN OPERACIÓN	

Ilustración 85: Energía entregada por día de la semana.

Ilustración 86: Curva de Carga Promedio Diaria Mensual.

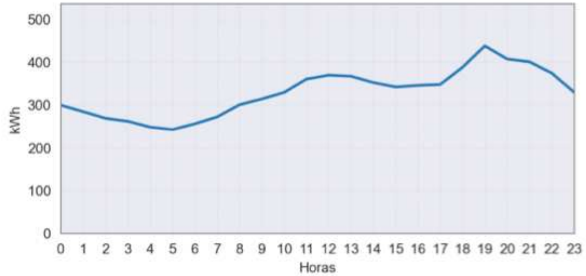


Figure 78. Bajo Baudó Telemetry Report July 2023 .Source: Self-created, 2023.

Service provision hours

The telemetry system records daily operating hours as an indicator of system performance, in addition to active, reactive, apparent energy and power factor.

Active Energy (kWh): It is the actual energy consumed by an electrical device to perform work.

Reactive Energy (kVARh): It is the energy exchanged between electrical equipment and the grid without performing useful work. It is necessary to maintain voltage at a usable level but does not perform direct work.

Apparent Energy (kVAh): It is the total magnitude of power in an alternating current system. It is measured in kilovolt-amperes-hours (kVAh). Apparent energy is the combination of active and reactive energy and represents the total power flowing in a circuit.

Power Factor: It is the ratio of active power to apparent power in an electrical system. It is expressed as a number between -1 and 1 or as a percentage between 0% and 100%. A power factor close to 1 indicates high efficiency, while a low power factor (close to 0) indicates low efficiency and inefficient use of energy.

Tabla 88: Energía Activa, Reactiva, Aparente y Factor de Potencia.

PIZARRO (BAJO BAUDÓ - CHOCÓ)					Julio
Fecha	Energía Activa (kWh)	Energía Reactiva (kVARh)	Energía Aparente (kVAh)	Factor de Potencia (p.u)	Horas de servicio promedio en el día [hh:mm]
Julio 01, Sábado	8,159	3,536	8,892.52	0.92	24 Horas
Julio 02, Domingo	8,029	3,475	8,748.75	0.92	24 Horas
Julio 03, Lunes	7,401	3,187	8,058.06	0.92	22 Horas 45 Minutos
Julio 04, Martes	8,159	3,458	8,861.36	0.92	24 Horas
Julio 05, Miércoles	8,062	3,432	8,762.53	0.92	24 Horas
Julio 06, Jueves	6,621	2,769	7,176.52	0.92	18 Horas 30 Minutos
Julio 07, Viernes	8,123	3,509	8,848.31	0.92	24 Horas
Julio 08, Sábado	7,836	3,360	8,526.37	0.92	23 Horas 15 Minutos
Julio 09, Domingo	7,880	3,347	8,561.67	0.92	23 Horas 15 Minutos
Julio 10, Lunes	8,476	3,632	9,220.97	0.92	24 Horas
Julio 11, Martes	8,198	3,431	8,887.17	0.92	23 Horas 15 Minutos
Julio 12, Miércoles	8,782	3,705	9,531.84	0.92	24 Horas
Julio 13, Jueves	8,171	3,399	8,849.71	0.92	23 Horas 30 Minutos
Julio 14, Viernes	8,088	3,213	8,702.74	0.93	23 Horas
Julio 15, Sábado	8,757	3,656	9,489.95	0.92	24 Horas
Julio 16, Domingo	8,600	3,515	9,290.96	0.93	23 Horas 45 Minutos
Julio 17, Lunes	4,415	1,766	4,754.92	0.93	12 Horas 45 Minutos
Julio 18, Martes	2,499	867	2,645.64	0.94	5 Horas 30 Minutos
Julio 19, Miércoles	6,027	2,175	6,407.88	0.94	13 Horas 30 Minutos
Julio 20, Jueves	8,834	3,321	9,437.29	0.94	22 Horas 30 Minutos
Julio 21, Viernes	8,920	3,297	9,509.34	0.94	24 Horas
Julio 22, Sábado	8,675	3,282	9,275.14	0.94	24 Horas
Julio 23, Domingo	8,594	3,287	9,200.61	0.93	24 Horas
Julio 24, Lunes	8,693	3,361	9,319.71	0.93	24 Horas
Julio 25, Martes	8,664	3,341	9,285.66	0.93	24 Horas
Julio 26, Miércoles	8,744	3,425	9,390.90	0.93	24 Horas
Julio 27, Jueves	8,774	3,365	9,397.01	0.93	24 Horas
Julio 28, Viernes	8,567	3,271	9,170.59	0.93	24 Horas
Julio 29, Sábado	7,792	2,964	8,336.68	0.93	21 Horas 15 Minutos
Julio 30, Domingo	8,356	3,203	8,948.82	0.93	24 Horas
Julio 31, Lunes	8,403	3,230	9,002.50	0.93	24 Horas
Total	**245,300**	**98,778**	**264,441.44**	**0.93**	

Figure 79. Bajo Baudó Telemetry Report July 2023 .Source: Self-created, 2023.

Municipal capital Pizarro.

This population is located at the mouth of the Baudó River, bordering the coast of the Pacific Ocean. On the other hand, it is surrounded by mangrove forests, which concentrates the urban population in the municipal capital of Pizarro. This municipality has an urban population of 3,180 inhabitants (DANE, 2015).

It is located 198 km from the capital of the department of Quibdó. Its Extent is 4,840 square kilometers, and 12 meters above sea level, and has an average temperature of 28 degrees centigrade. The territory of the Bajo Baudó is mostly flat topography with small undulations formed by the foothills of the Serranía del Baudó, with strong slopes in its northern part, borders with the Alto Baudó (Romero, 2009, p. 14).

The vast majority of the soils of the municipality are covered with natural forest, the farms are located on the natural dams of the rivers and ravines along the banks of the beaches. About 12.5% of the area of the municipality is devoted to crops and the area under pasture is not significant due to the scarce livestock population (Romero, 2009, p. 14).

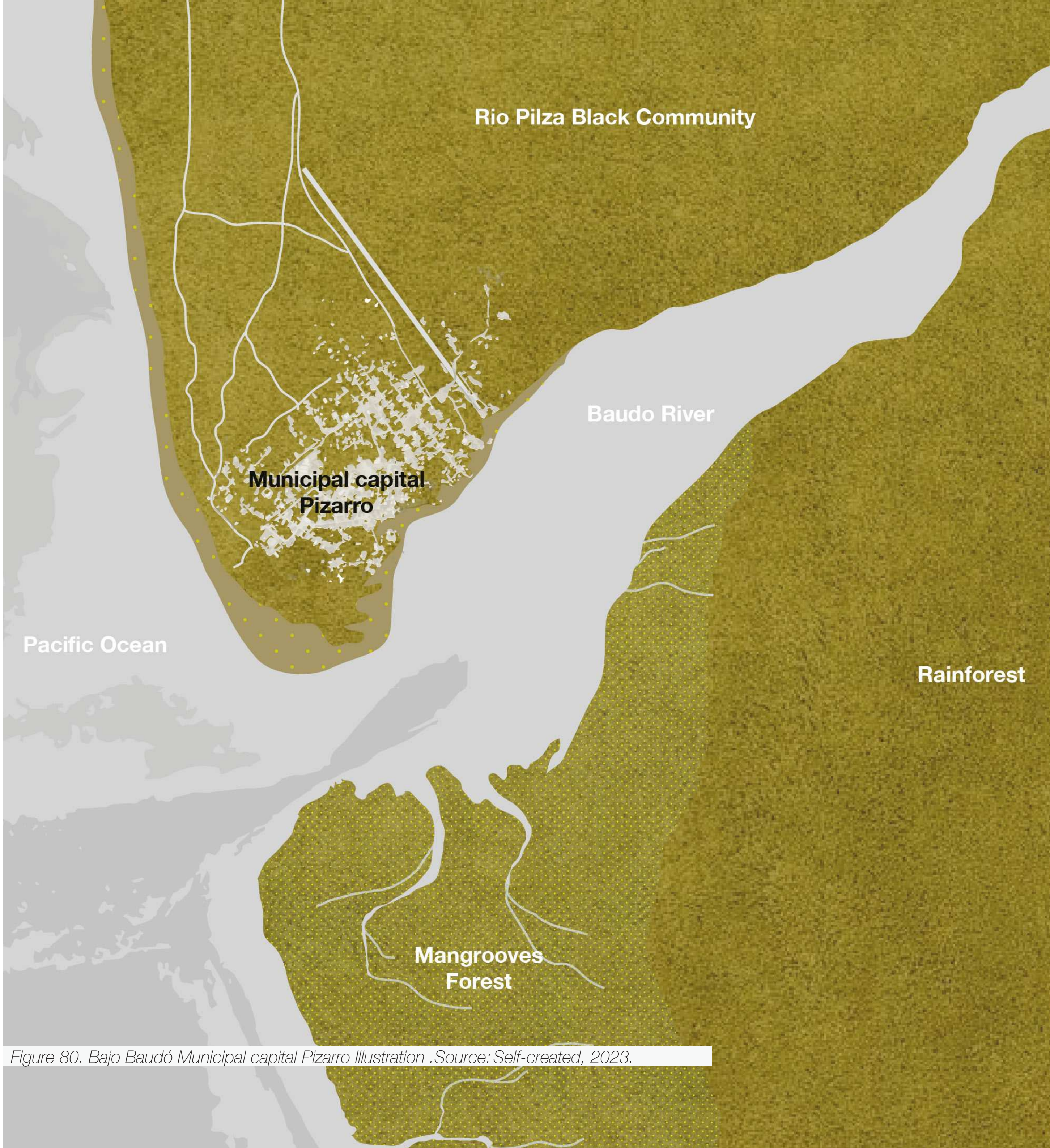


Figure 80. Bajo Baudó Municipal capital Pizarro Illustration .Source: Self-created, 2023.

Sun path

The geographical location close to the equatorial line shows minimal a low variability in the solar path during the year. The local noon angles during the year are as in the following table:

	Azimuth	Altitude
Sommer solstice:	3,76°	71,48°
Winter solstice:	179,49°	61,62°
Spring equinox:	150,30°	84,35°
Autumm equinox:	-167,93°	85,84°

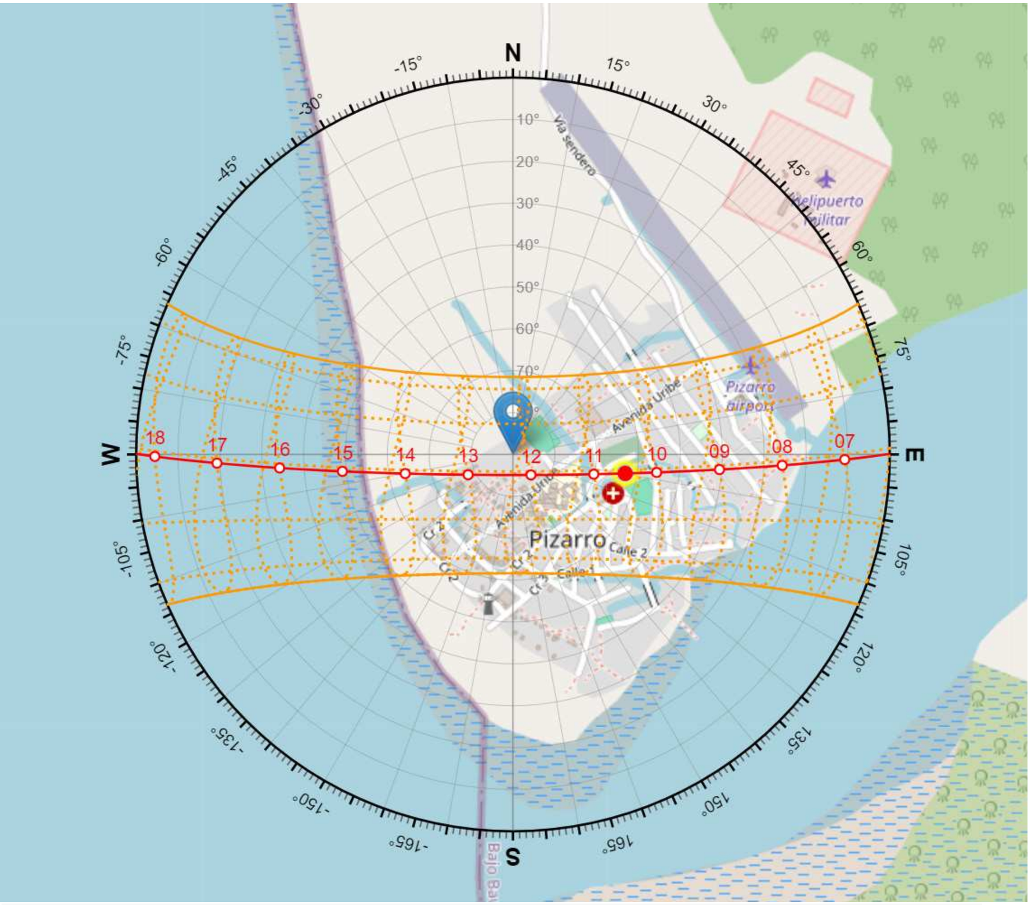


Figure 81. Solar Chart over Pizarro .Source: Self-created, 2023.

Prevailing wing direction

The geographical location between river and sea generates a high wind speed in the area. During the night the winds change in the opposite direction, from the sea to the mainland and during the day there are some changes in angle. However, the prevailing wind direction is from east to west.

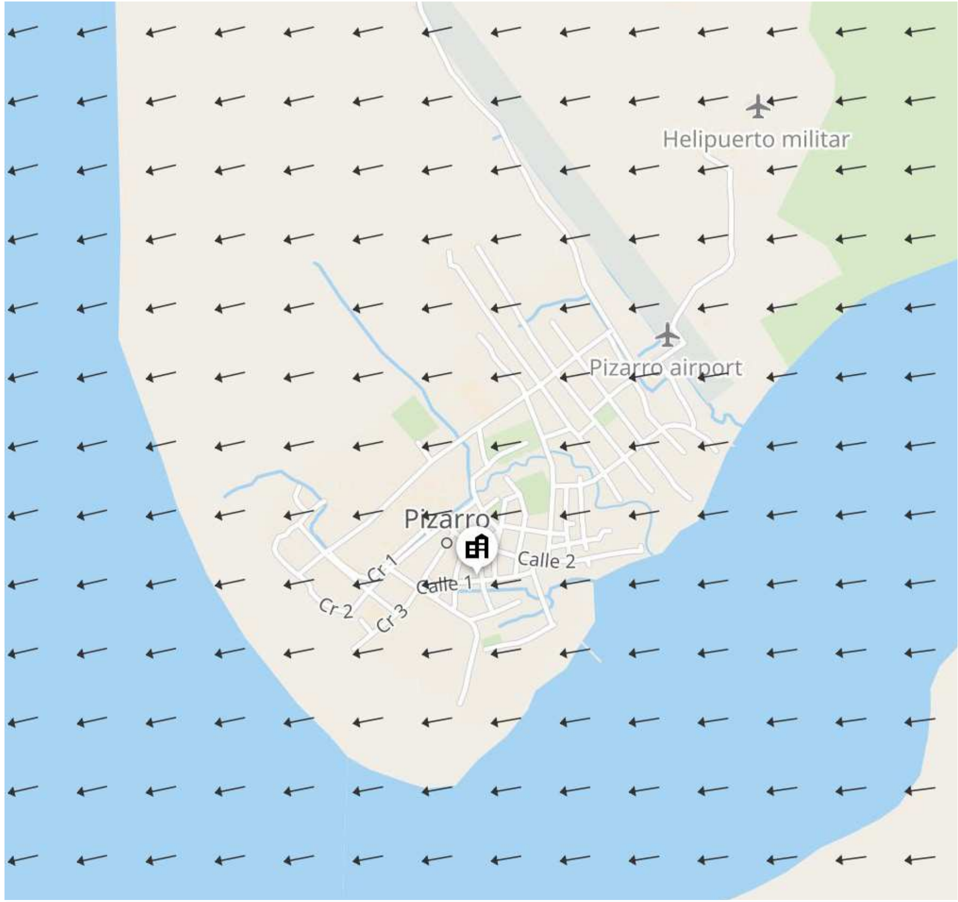


Figure 82. Predominant wind direction .Source: Self-created, 2023.

Figure 83. Pizarro urban analysis.Source: Self-created, 2023.

As shown by the demographic analysis of the region and the social development guidelines of the road map, higher secondary and technical education institutions are the most precarious in the area. This proposal proposes a prototype module that can be repeated to form a technical education institution.

Figure 84. Pizarro river. Source: Google Maps, 2023.

Figure 85. Pizarro turistic port
. Source: Alcaldía de Pizarro, 2022.

Figure 86. Pizarro main plaza. Source: Google Maps, 2023.

Figure 87. Pizarro's view. Source: Google Maps, 2023.

Schools typologies around the region of Pizarro, Bajo Baudó

Figure 88. Schools typologies in the region on aereal views. Source: Google Maps, 2023.

Around the Bajo Baudó area, satellite images of schools or educational centres in municipal capitals and in rural areas were found. They have the following common features:

1. Long-narrow typologies: Most schools consist of rectangular blocks with their shorter sides facing west-east facades.

2. Central layout towards the main courtyard or sports field: Rest areas are fundamental for educational establishments and these are the focal point of spatial organisation.

3. Inclined roofs: Most of them are two-slope roofs. This characteristic is important and also corresponds to the conditions of rainfall and sun exposure in the region.

4. Architectural composition consistent with the urban framework: In the case of schools in urban centres, the morphology of the city continues in the design of the schools.

5. Repetition of modules or configurations: The same modules are distinguished that make up projects with large green spaces instead of compact, single-volume projects.

Educational center in Bajo Baudo and computers room

Figure 89. Computer services. Source: Alcaldia de Pizarro, 2021.

Digital points are a strategy of public facilities to provide computer services for student learning. Schools often do not have the resources to provide computer rooms, so system service points are opportunities for educational development in rural communities.

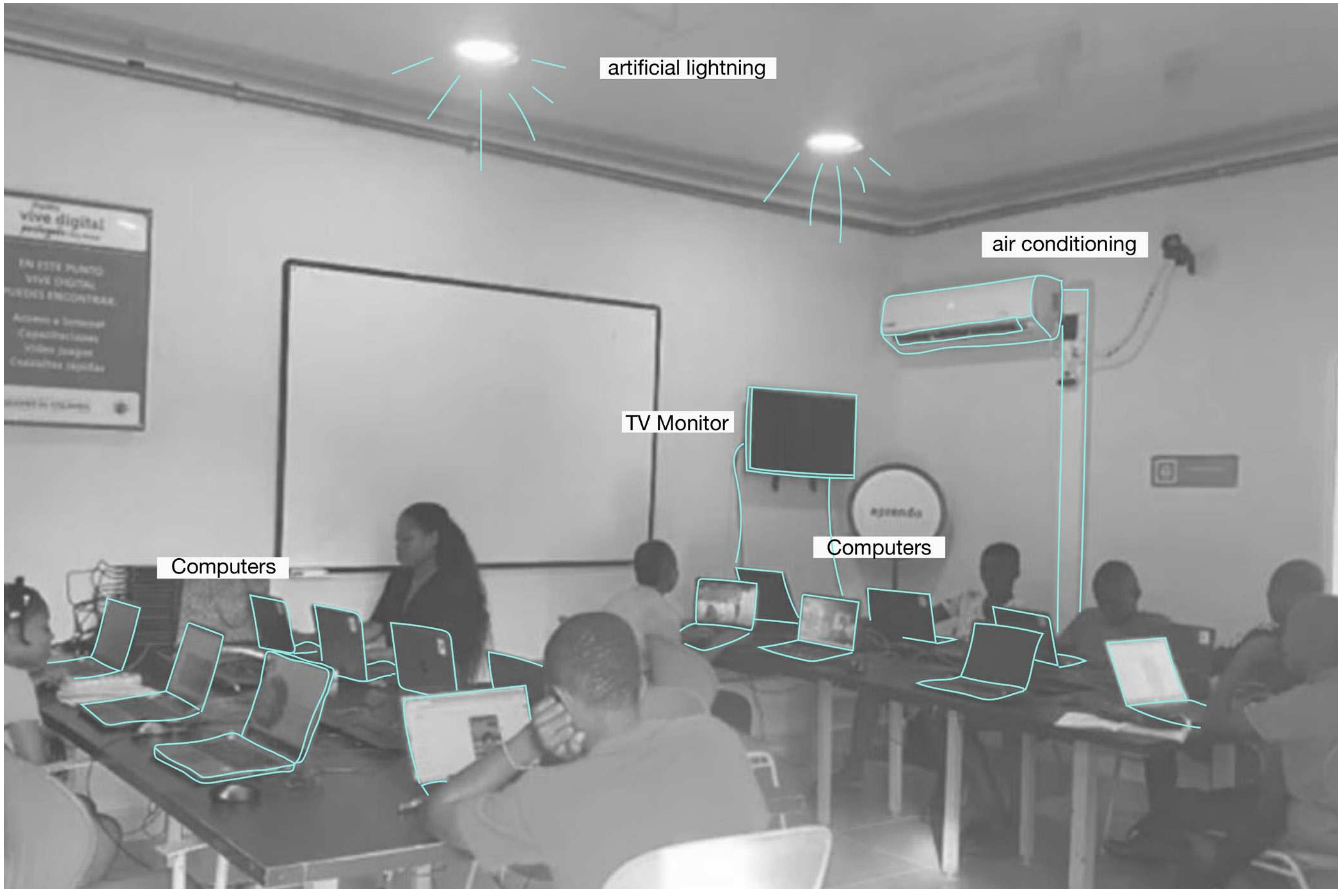


Figure 90. Computer services devices analysis. Source:Self-created, 2023.

8.2 Climate comfort design

Thermal confort analysis

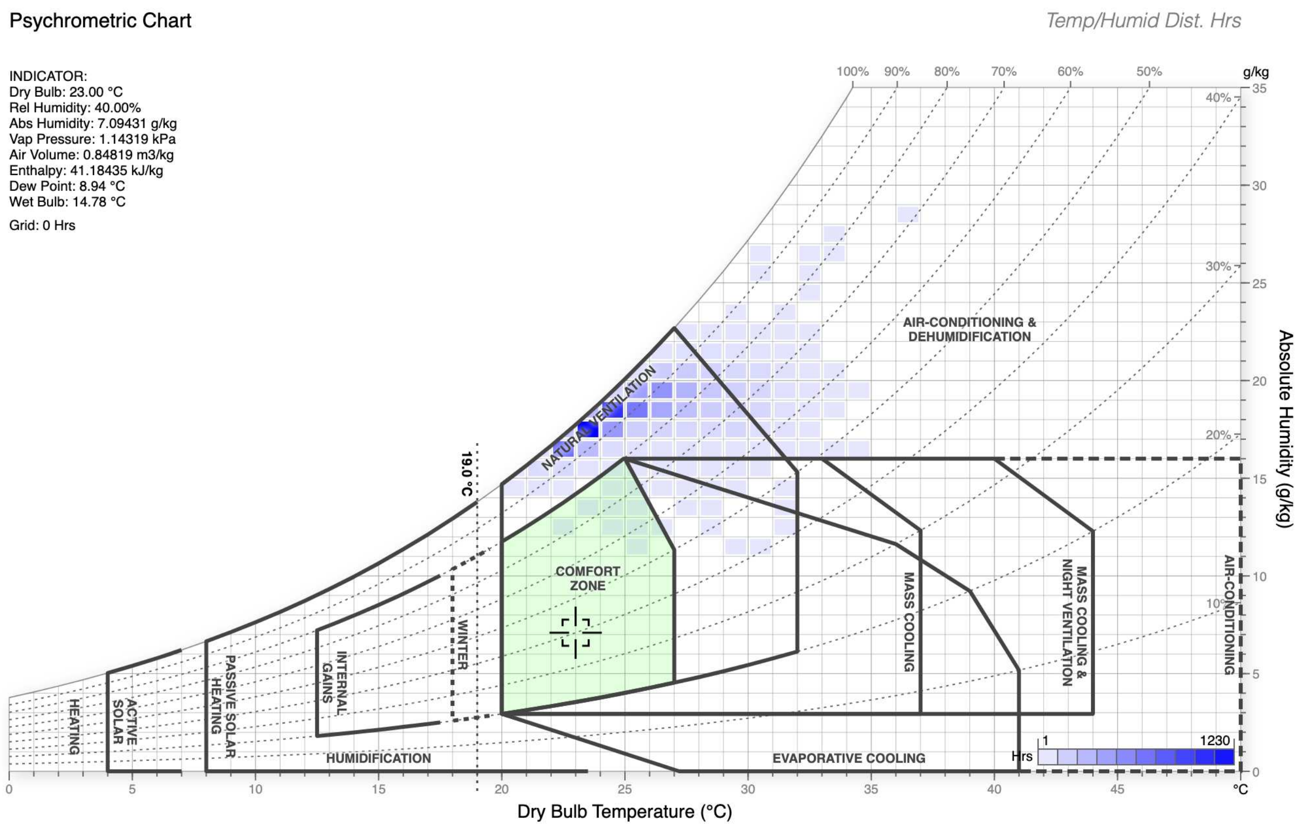


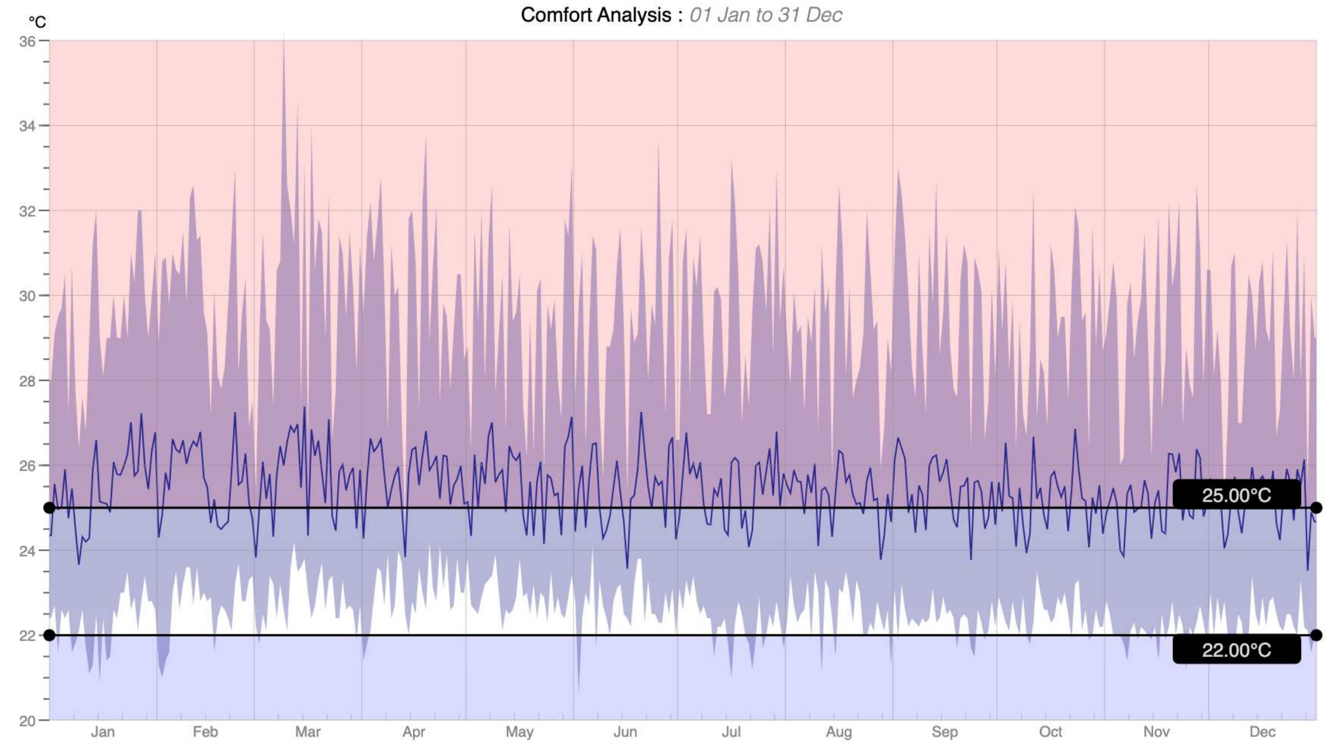
Figure 91. Psycometric chart of Quibdo Weather Data and confort strategies. Source:Andrewmarsch Climate Analysis, 2023.

To start an analysis of bioclimatic strategies it is necessary to recognize the comfort needs of the place to work. The psychometric chart is a diagram based on the climate station file closest to the project. In this case, the climatic station of the city of Quibdó, capital of the department of Chocó, was used. The Giovanni Bioclimatic chart is overlaid to identify the strategies needed in this area.

Throughout the year for 24 hours a day, 100% equals hours of comfort using the following selected strategies:

- 17.9% Sun shading of windows
- 62.2% Adaptative comfort ventilation
- 61.2% Dehumidification
- 15.6% Cooling systems

The results of the graph are described under the parameters of the adaptive conformance model ASHRAE Standard 55-2010. “In naturally ventilated spaces where occupants can open and close windows, their thermal response will depend in part on the outdoor climate, and may have a wider comfort range than in buildings with centralized HVAC systems. This model assumes occupants adapt their clothing to thermal conditions, and are sedentary (1.0 to 1.3 met). There must be no mechanical Cooling System, but this method does not apply if a Mechanical Heating System is in operation.” (Climate consultant comfort model description)



BELOW COMFORT			WITHIN COMFORT		ABOVE COMFORT		
Hrs	Deg.Hrs	Percent	Hrs	Percent	Hrs	Deg.Hrs	Percent
14	3.9	0.5%	664	22.7%	2242	6858.7	76.8%

Figure 92.Confort analysis in operation hours of schools. Source:Andrewmarsch Climate Analysis, 2023.

The comfort analysis shows that the temperature has an average variation of 7ºC per day, causing states outside the climatic comfort zone because it is lower at night and higher during the day. In analysis it shows that the hours above climatic comfort are 76.8% while below it is only 0.5%.

This variability shows the importance of looking for strategies that favor reducing the temperature to achieve climatic comfort between 22oC and 25oC. According to previous climate change studies, the hours when the temperature may be above the climatic comfort band are much longer.

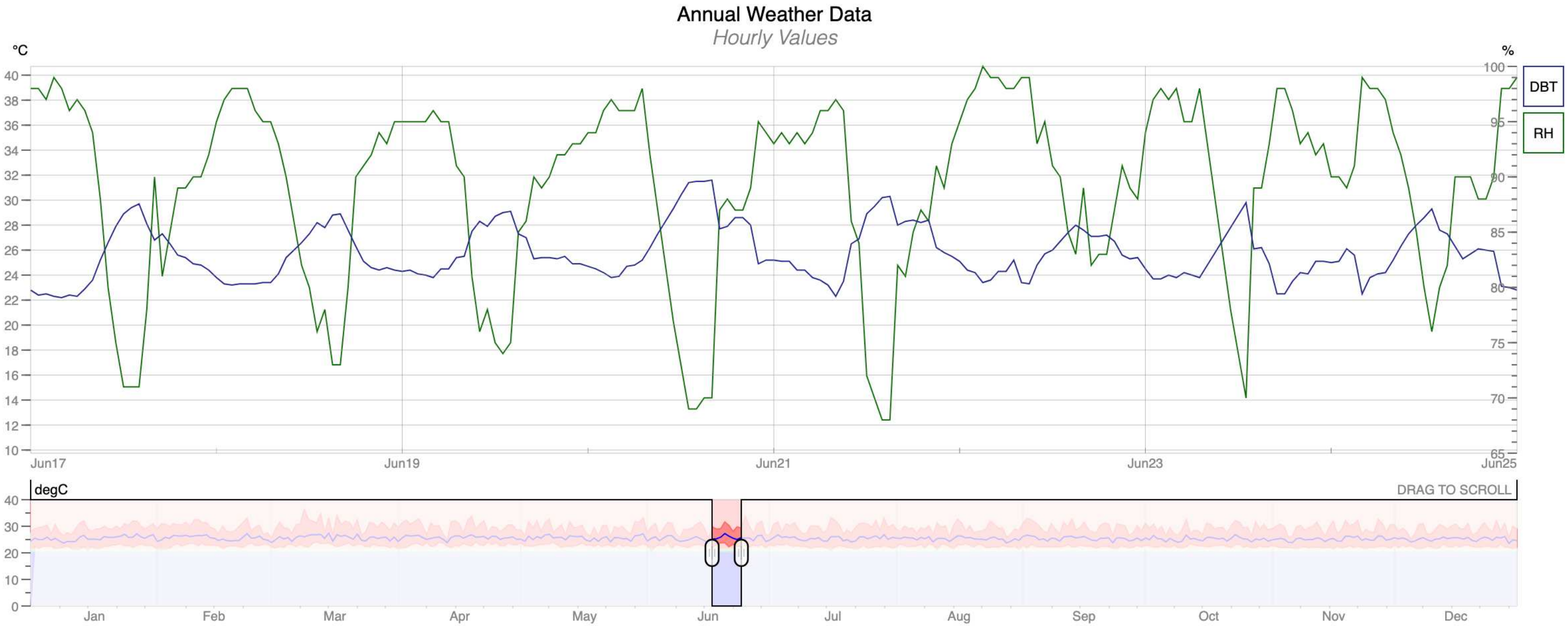


Figure 93. Humidity and temperature corelation analysis. Source:Andrewmarsch Climate Analysis, 2023.

In this analysis, temperature and humidity data are related to understand the dynamics between them. The average results of a week during the summer solstice were taken to more easily evaluate the relationship between temperature and humidity. As can be seen with the green line (RH=Relative Humidity) the variability is up to 30% during a day. Meanwhile the temperature (DBT = Dry Bulb Temperature) shows a variability between 22ºC and 32ºC. The graph shows that the higher the temperature, the lower the relative humidity and also the lower the temperature, the relative humidity increases. These changes occur during the night and day, with the highest and lowest peaks between 1 and 2 hours before sunrise and sunset.

Passive bioclimatic strategies

Long-narrow volumetries, with short sides facing east and west orientation

The east and west facades are more exposed to the hottest hours of the day due to the effects of direct solar radiation. If the shorter sides of the volume are in these directions, the heat absorption is much lower.

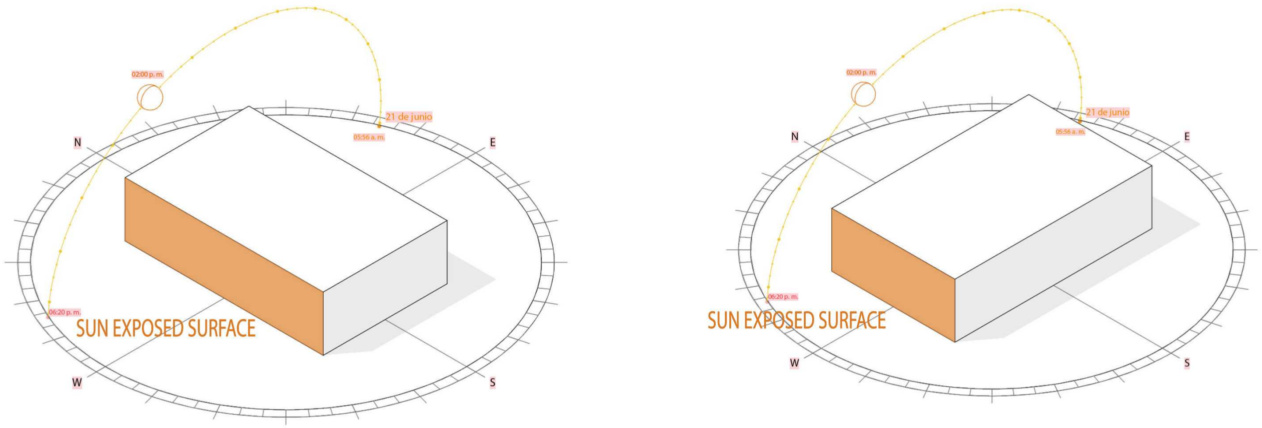


Figure 94. Sun exposed surfaces. Source: Self-created, 2023

High ceilings / Vertical amplitude

By exchanging heat and differential air pressure, high ceilings allow an indoor air circulation causing the hot air to rise and renew.

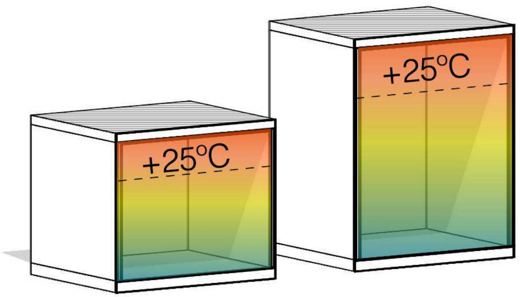


Figure 95. Air temperature in relation to volume composition. Source: Self-created, 2023

Divided / separated volumes

Small volumes separated from each other, rather than large, compact volumes, allow for greater ventilation between them and better control of the interior temperature.

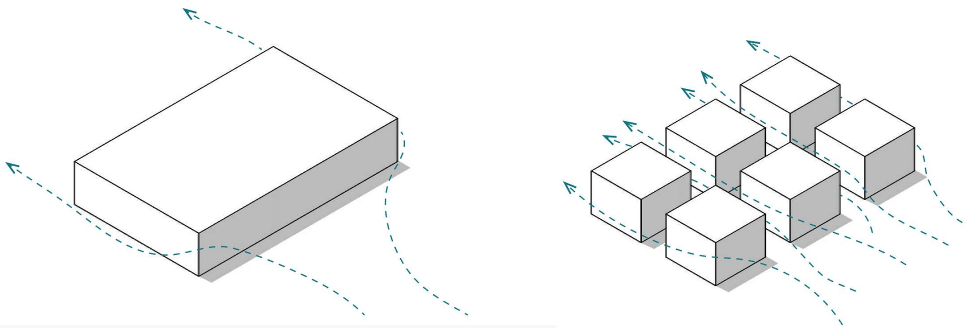


Figure 96. Volumes air flow. Source: Self-created, 2023

Capture wind direction with external elements

The elements outside the volume may change the direction of the wind to favour the circulation inside the volume. Architectural elements or vegetation can be used.

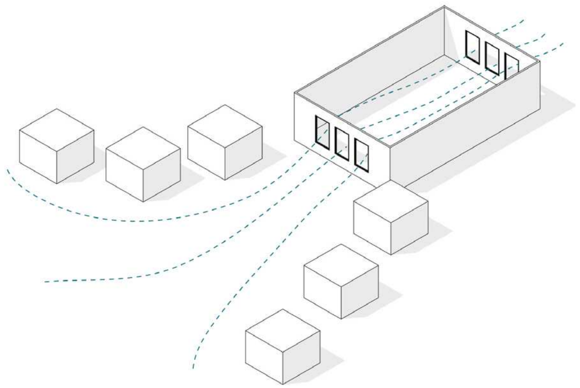


Figure 97. Volumes air flow direction. Source: Self-created, 2023

Building high above ground

In humid soils it is advisable to raise the building to avoid moisture by capillarity and allow air circulation that cools the floor.

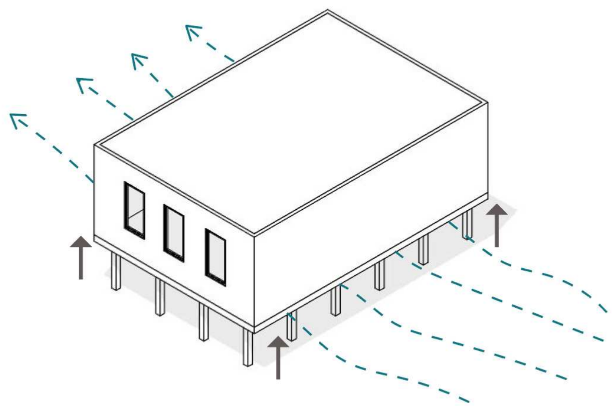


Figure 99. High above the ground strategy. Source: Self-created, 2023

Volume openings on opposite sides

Volume openings for windows or doors on opposite sides allow cross ventilation into the interior of the spaces, as the wind speed increases.

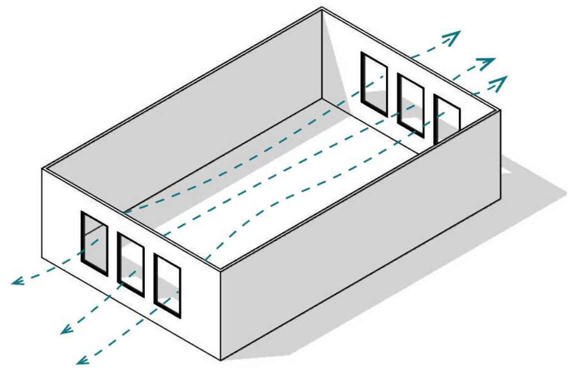


Figure 98. Openings strategy. Source: Self-created, 2023

Pitched roofs to shed rain

In areas with high rainfall, sloping roofs help drain water faster and prevent stagnation that causes moisture indoors.

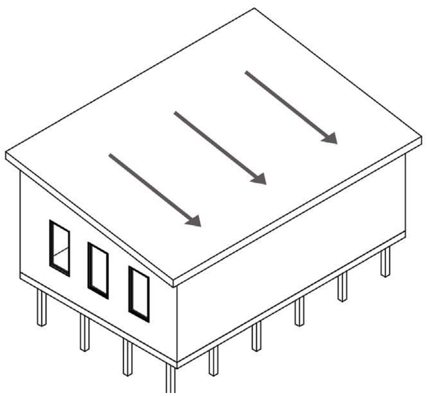


Figure 100. Pitched roof strategy. Source: Self-created, 2023

Shaded exterior areas

The outer platforms under the roof serve as a transitional space between the interior and exterior of the project. This is another way to insulate the heat and protect the internal volumes from solar radiation.

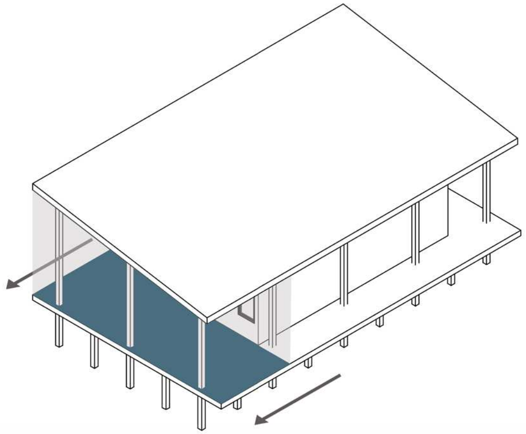


Figure 101. Shaded exterior areas strategy. Source: Self-created, 2023

Overhangs and façade shading elements

Additional elements to the façade allow its position to be adjusted according to changes in direct sunlight during the year. The angle of these can be designed according to the solar study of the hottest hours per day.

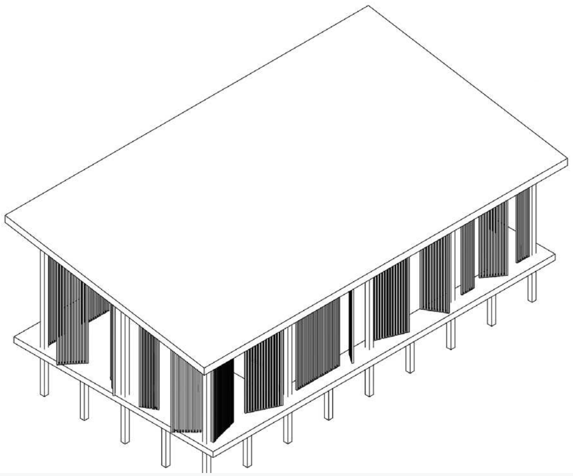


Figure 102. Shading elements strategy. Source: Self-created, 2023

Double roof: general roof and roof for volumes

The double roof allows to generate a layer of ventilation between two roofs, insulating much more the heat received by the overall roof from direct solar radiation.

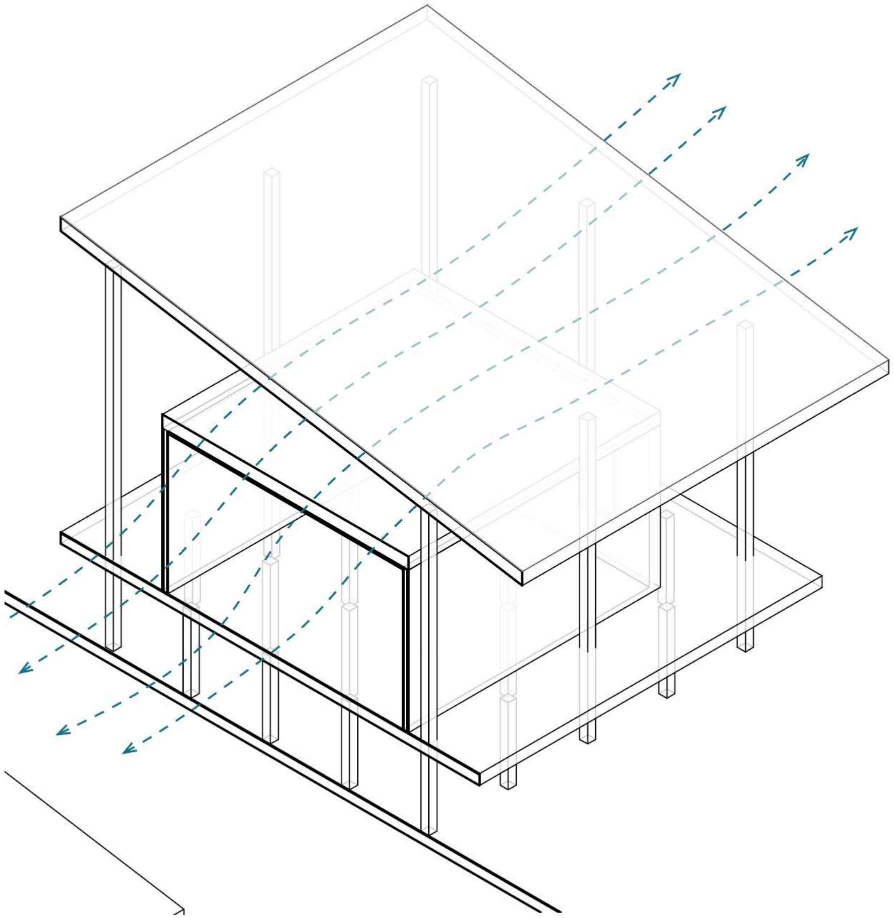


Figure 103. Double roof strategy Source: Self-created, 2023

Functional spaces charaterization

Classrooms (24 students)

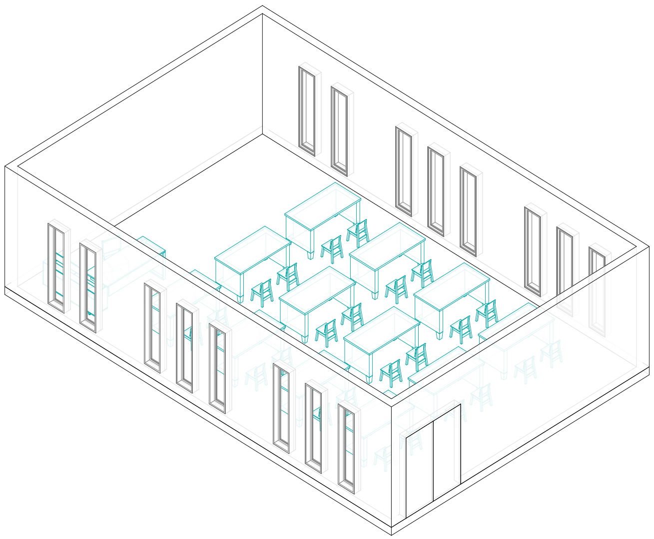


Figure 104.Classrooms view. Source: Self-created, 2023

Functions:
Lessons, computer labs, sciences labs

Architectural features:
Closed and isolated, possibility of air conditioning, double roofing, windows to the east, north, and west.

Climatic conditions:

Temperature:	22º-26ºC
Humidity:	50% - 70%
Natural lighting:	>4%

Study rooms and offices

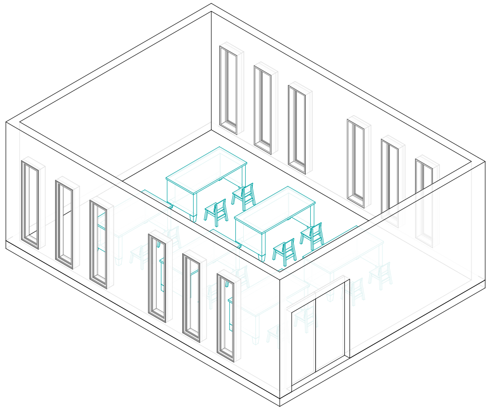


Figure 105.Study rooms view. Source: Self-created, 2023

Functions:
Study rooms on the weekeng, computer labs

Architectural features:
Closed and isolated, possibility of air conditioning, double roofing, windows to the east, north, and west.

Climatic conditions:

Temperature:	22º-26ºC
Humidity:	50% - 70%
Natural lighting:	>4%

Open spaces

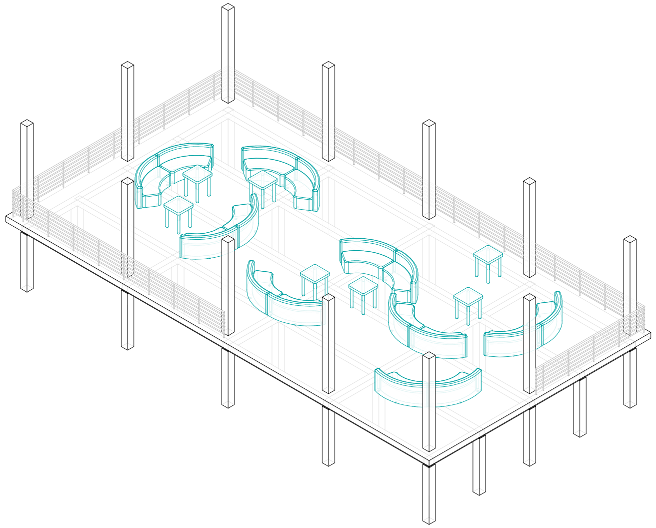


Figure 106. Open spaces view.. Source: Self-created, 2023

Functions:
Rest areas, meeting places,

Architectural features:
Open spaces without walls, natural ventilation, under roofs, views to the landscape, centrally located among classrooms.

Climatic conditions:

Temperature:	22º-28ºC
Humidity:	50% - 90%
Natural lighting:	>10%

8.3 Architectural design

Functional programm

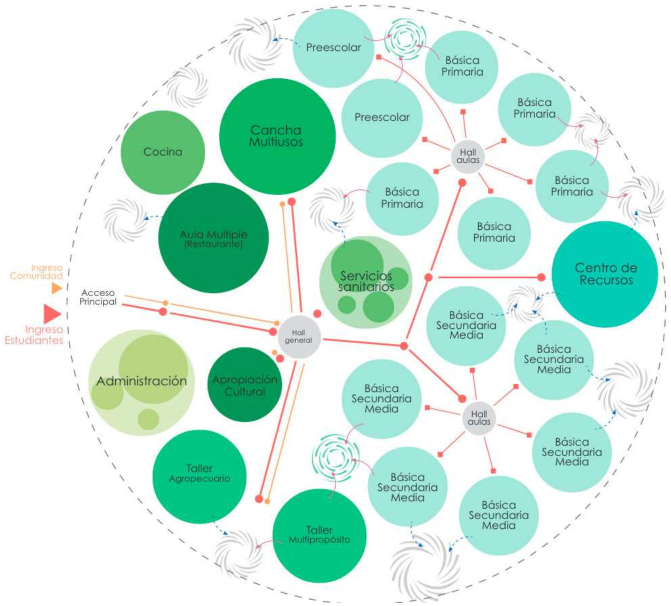


Figure 108. Functional program for rural schools. Ministerio de Educación de Colombia, 2023.

An architectural programme was based on the Guidelines for Rural Education Infrastructure of the Ministry of National Education. This includes the categories of rural schools and their needs.

The document highlights the importance of creating rural schools with the versatility to function as social facilities, not just for students. Rural schools can offer community services such as library, auditorium, study rooms, computing rooms, multi-sports court. This is why it is important that educational institutions are planned according to two types of users: students and the community.

The manual also emphasizes that the zoning of educational centres can be organized in stages of construction to give priority to community services because of the versatility of these spaces.

Thus, an A6-category school is proposed (category for kindergarden, primary, and secondary schools). This type of school has at least 2 groups of rooms in addition to the basic services of hall, bathrooms, administration, auditorium, cafeteria and library.

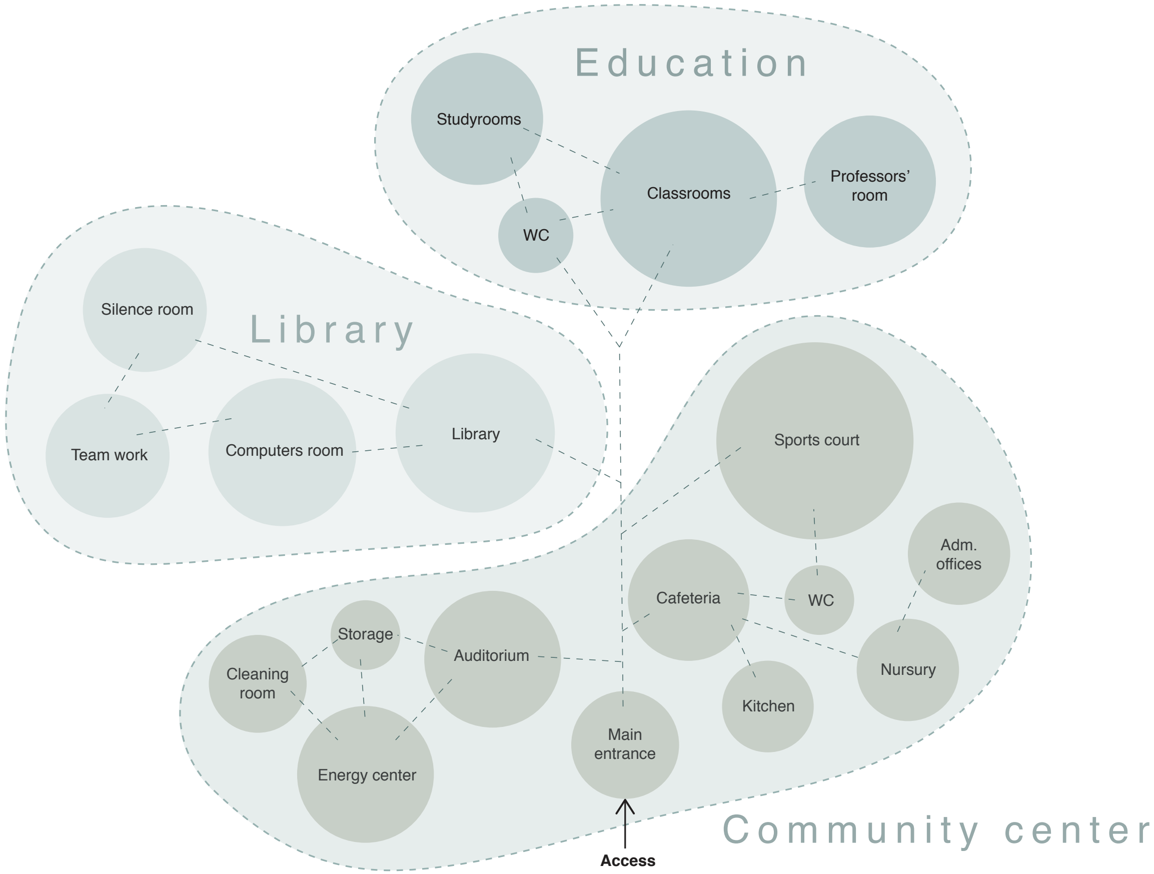


Figure 109. Functional program. Source: Self-created, 2023.

Functional programm

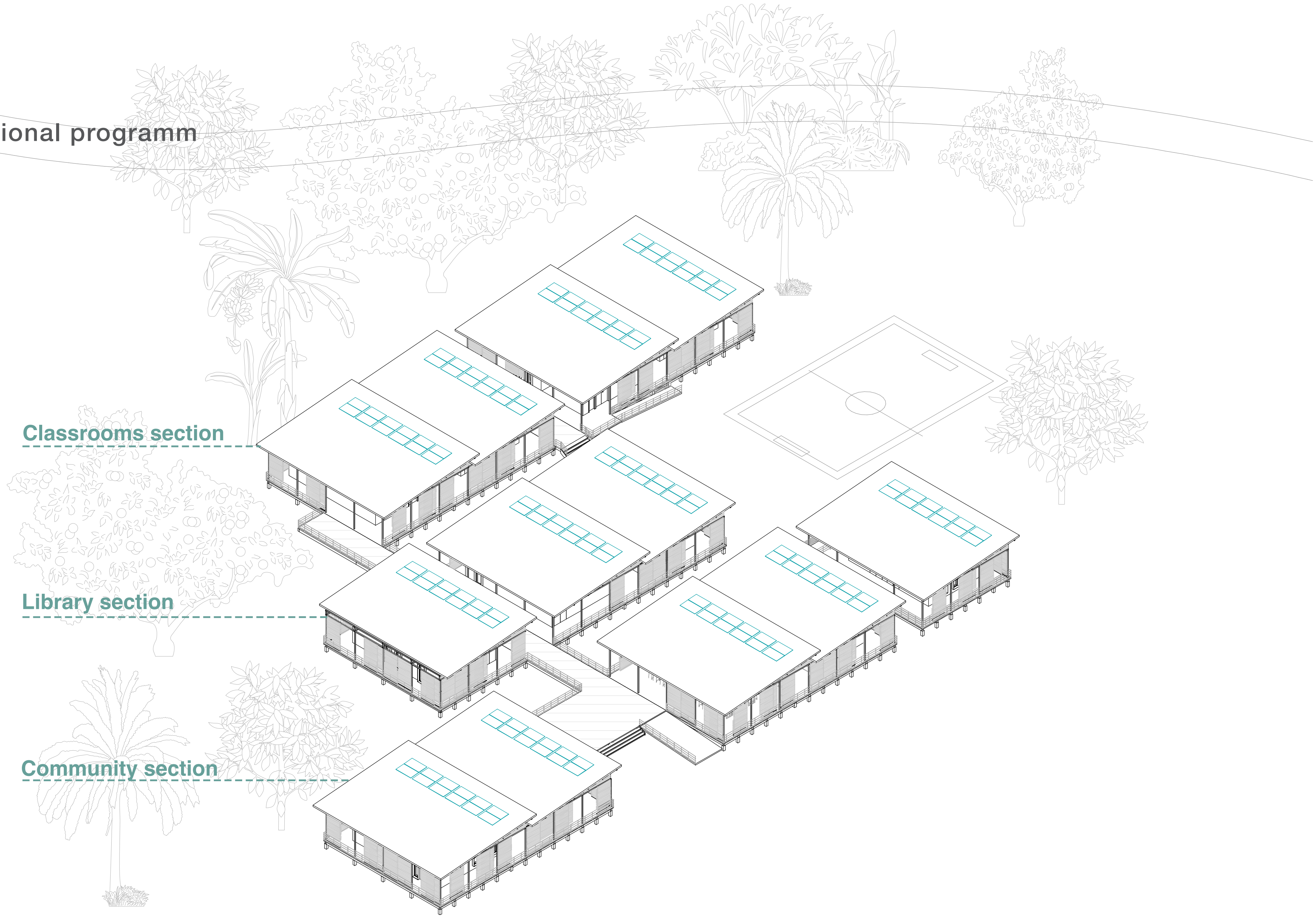


Figure 110. Isometric view. Source: Self-created, 2023.

Functional program

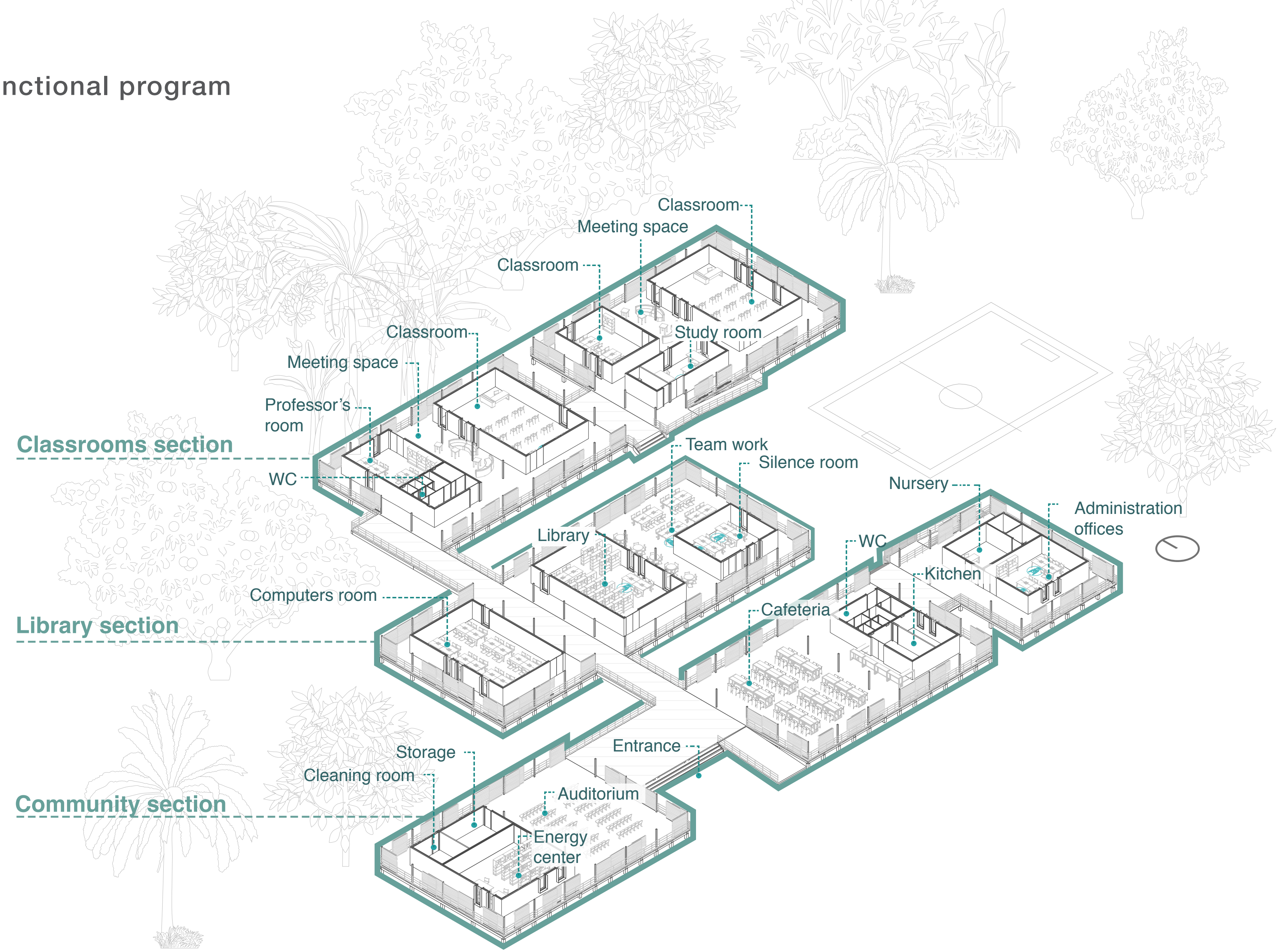


Figure 111. Isometric view of functional program. Source: Self-created, 2023.

Site plan

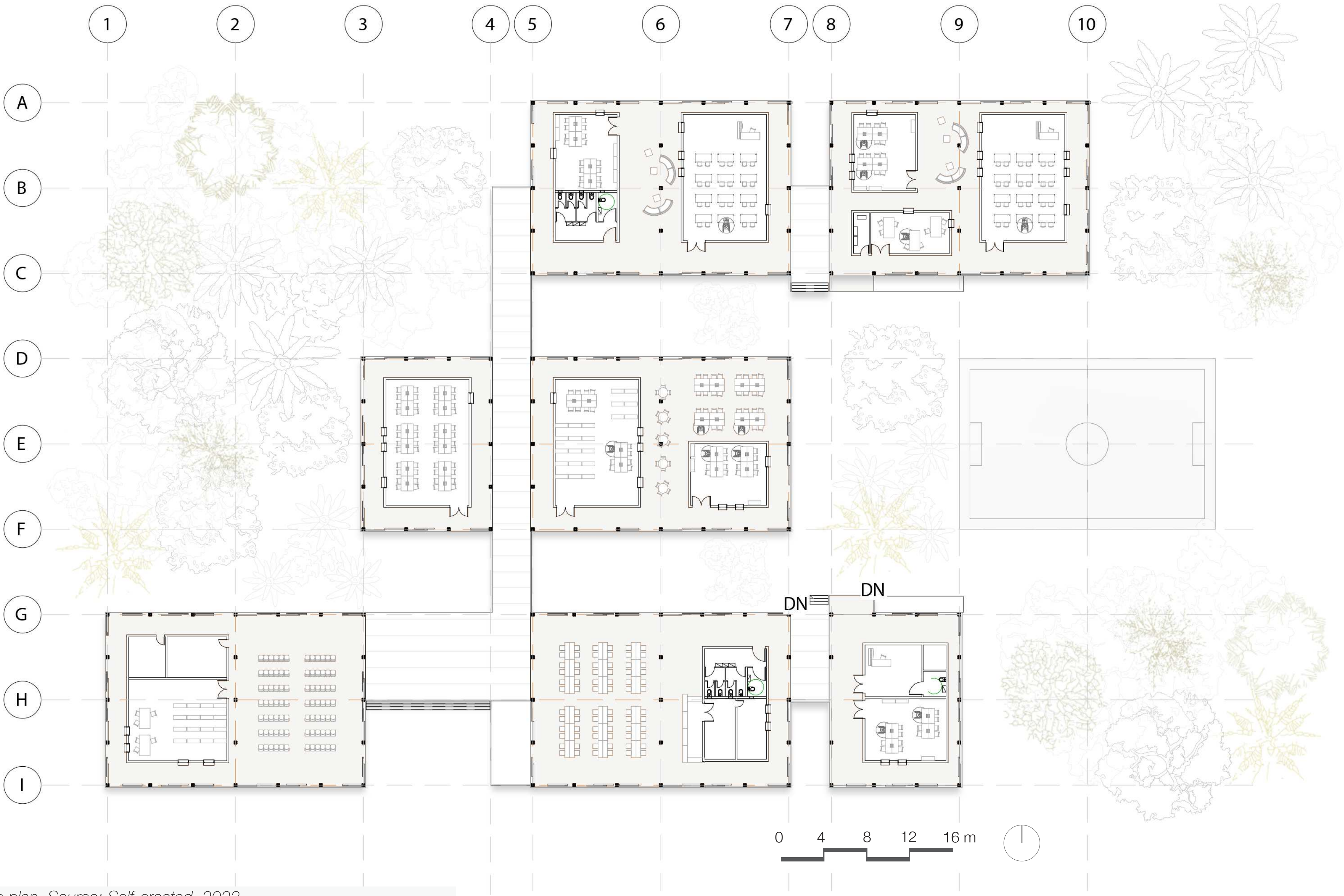


Figure 112. Site plan. Source: Self-created, 2023.

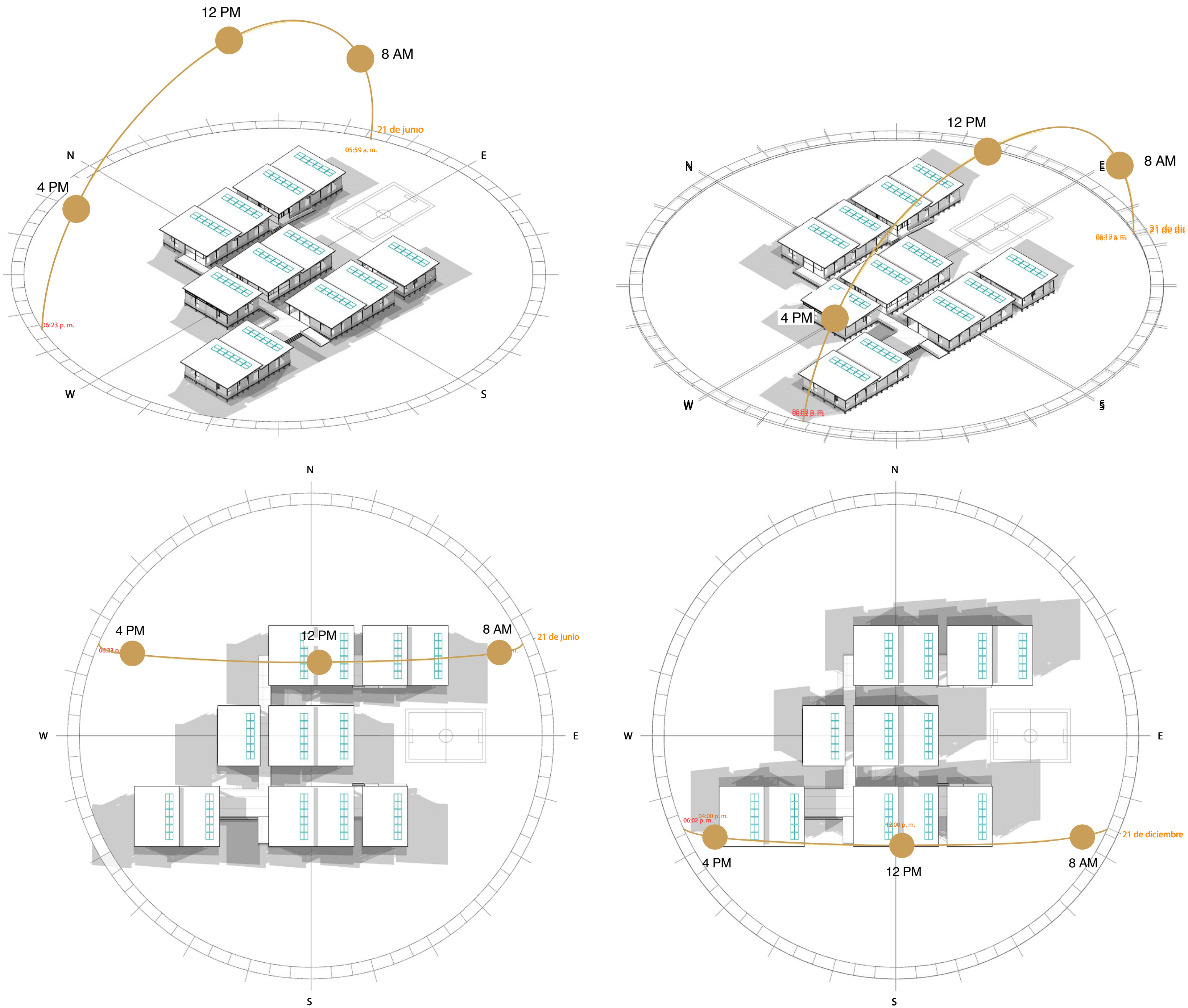


Figure 113. Solar radiaton analysis. Source: Self-created, 2023.

Solar radiation on platforms

Figure 112. Summer solstice radiation. Source: Self-created, 2023.

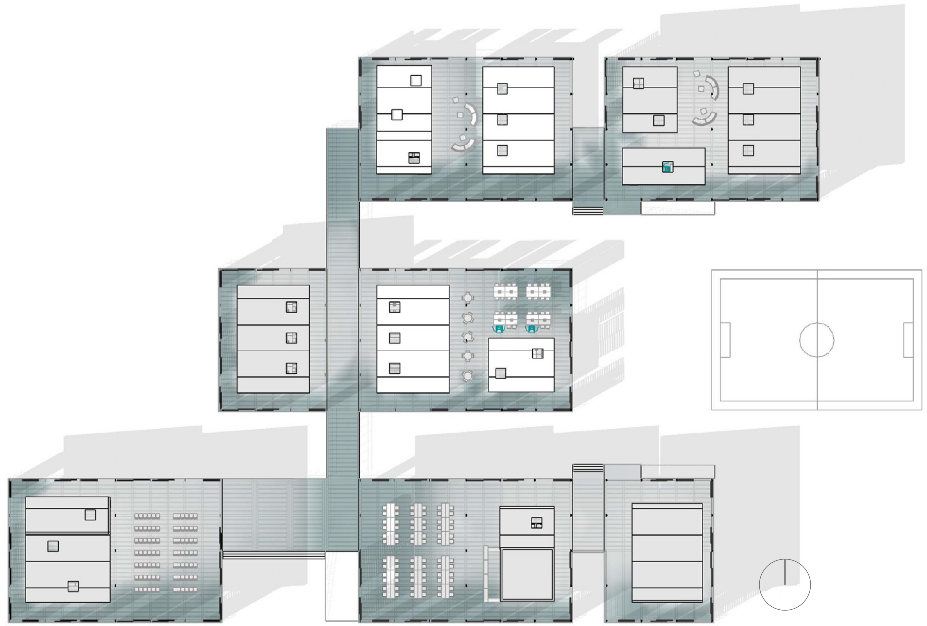


Figure 113. Winter solstice radiation. Source: Self-created, 2023.

The solar radiation over the platforms was analyzed to position the enclosed modules, avoiding direct contact with sunlight. This prevents them from heating up significantly thanks to the covers. However, solar protection on facades is necessary in some areas, which is why an adjustable option for each space is needed.

Solar radiation on roof angles

PV Panels tillt optimization

Azimuth	Tillt Angle	kWh/m2 per day
North 0°	0°	4,305
	5°	4,288
	10°	4,245
	15°	4,177
	20°	4,084
	25°	3,967
	30°	3,828
	35°	3,667
	40°	3,486
	45°	3,287
East 90°	0°	4,305
	5°	4,264
	10°	4,198
	15°	4,111
	20°	4,005
	25°	3,883
	30°	3,746
	35°	3,596
	40°	3,436
	45°	3,267
South 180°	0°	4,305
	5°	4,311
	10°	4,291
	15°	4,245
	20°	4,173
	25°	4,078
	30°	3,958
	35°	3,816
	40°	3,653
	45°	3,470
West 270°	0°	4,305
	5°	4,336
	10°	4,341
	15°	4,321
	20°	4,280
	25°	4,216
	30°	4,131
	35°	4,028
	40°	3,906
	45°	3,768

Figure 114. Tilt optimization comparison. Source: Self-created, 2023.

Last hours of radiation per day during a year

According to climate analyses, direct and diffuse solar radiation are very similar (2.92 kWh/m2-day and 2.87 kWh/m2-day). Solar panel technology currently allows for a higher efficiency of energy production with diffuse solar radiation, which facilitates the installation angle of the panels. However, the efficiency of the panels is much higher with direct solar radiation.

Climate analyses of solar radiation show more hours of direct sunlight in the afternoon, between 2pm and 6pm. This is due to the lowest humidity point in the air during an average day. This is why the panels have a higher performance oriented to the west with an inclination between 5º-10o. Climatic studies were carried out and proposal 1 have greater sun exposure during the hours of direct radiation.

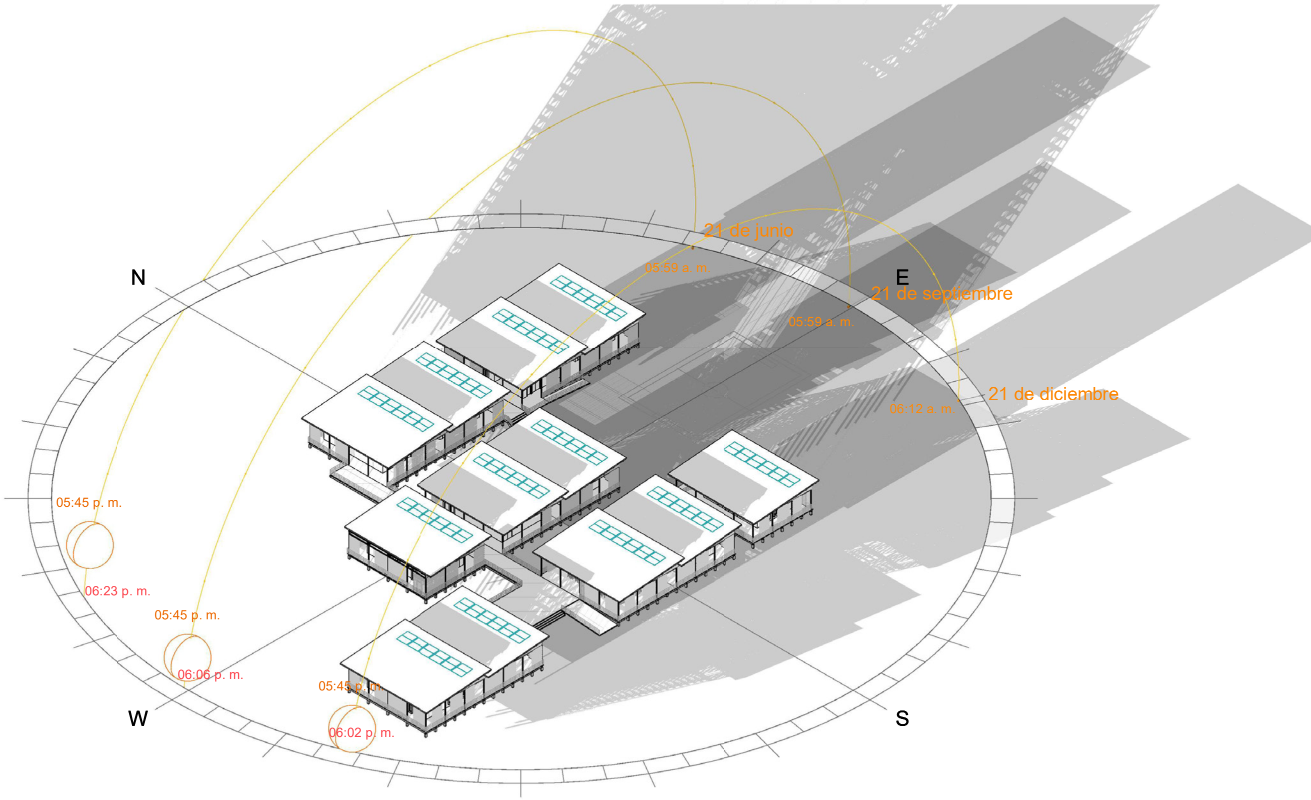


Figure 115. Last radiation hours analysis. Source: Self-created, 2023.

Roof options solar analysis

Winter solstice

Summer solstice

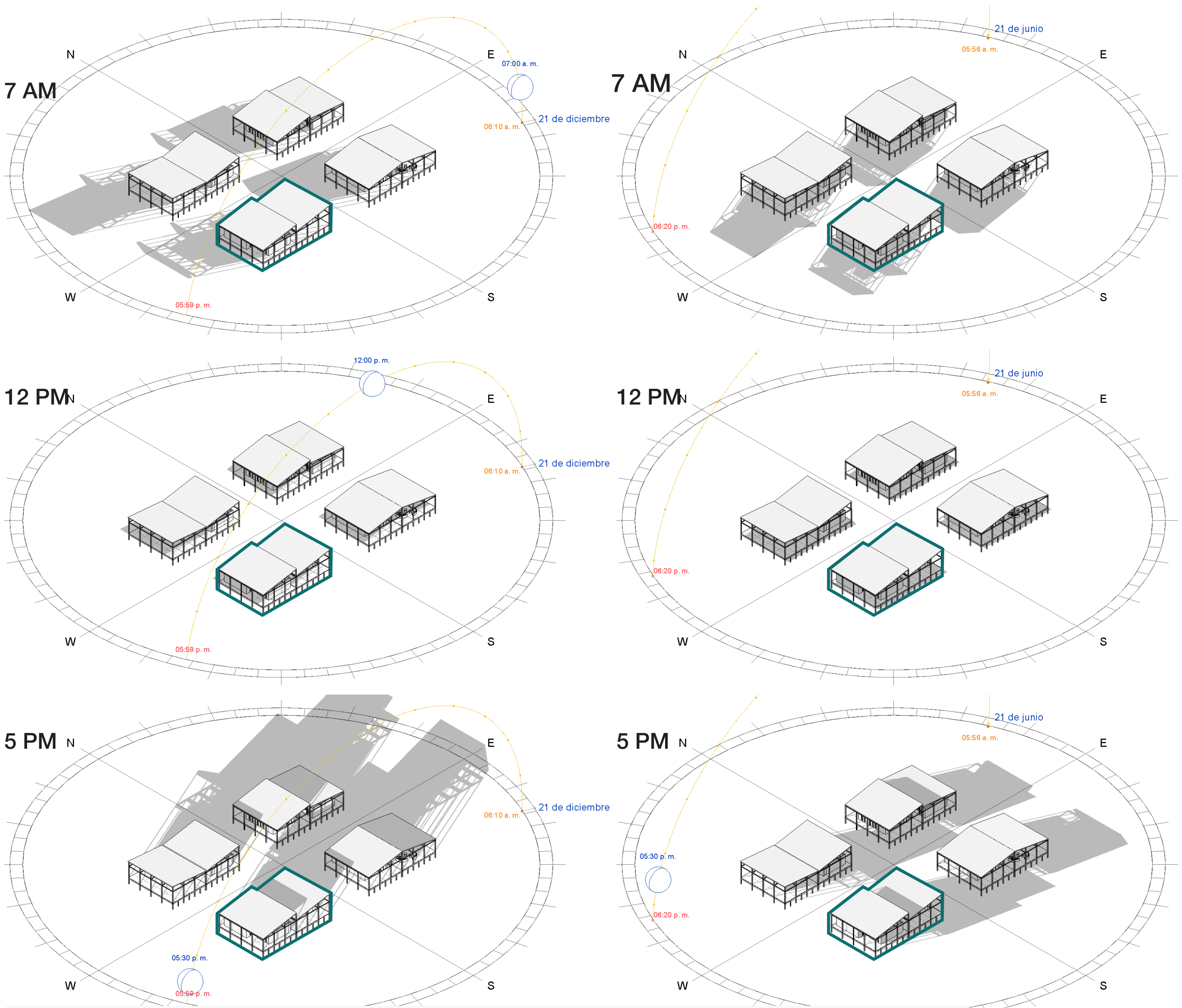


Figure 116. Roof options solar radiation alaysis, winter solstice and summer solstice. Source: Self-created, 2023.

The analysis seeks to find a variant for the roofs in which the solar panels are not shaded between them to take full advantage of the solar radiation. At the same time these have to be the main element to protect indoor spaces from solar radiation, especially in the afternoon, when the temperature is higher.

Classrooms section

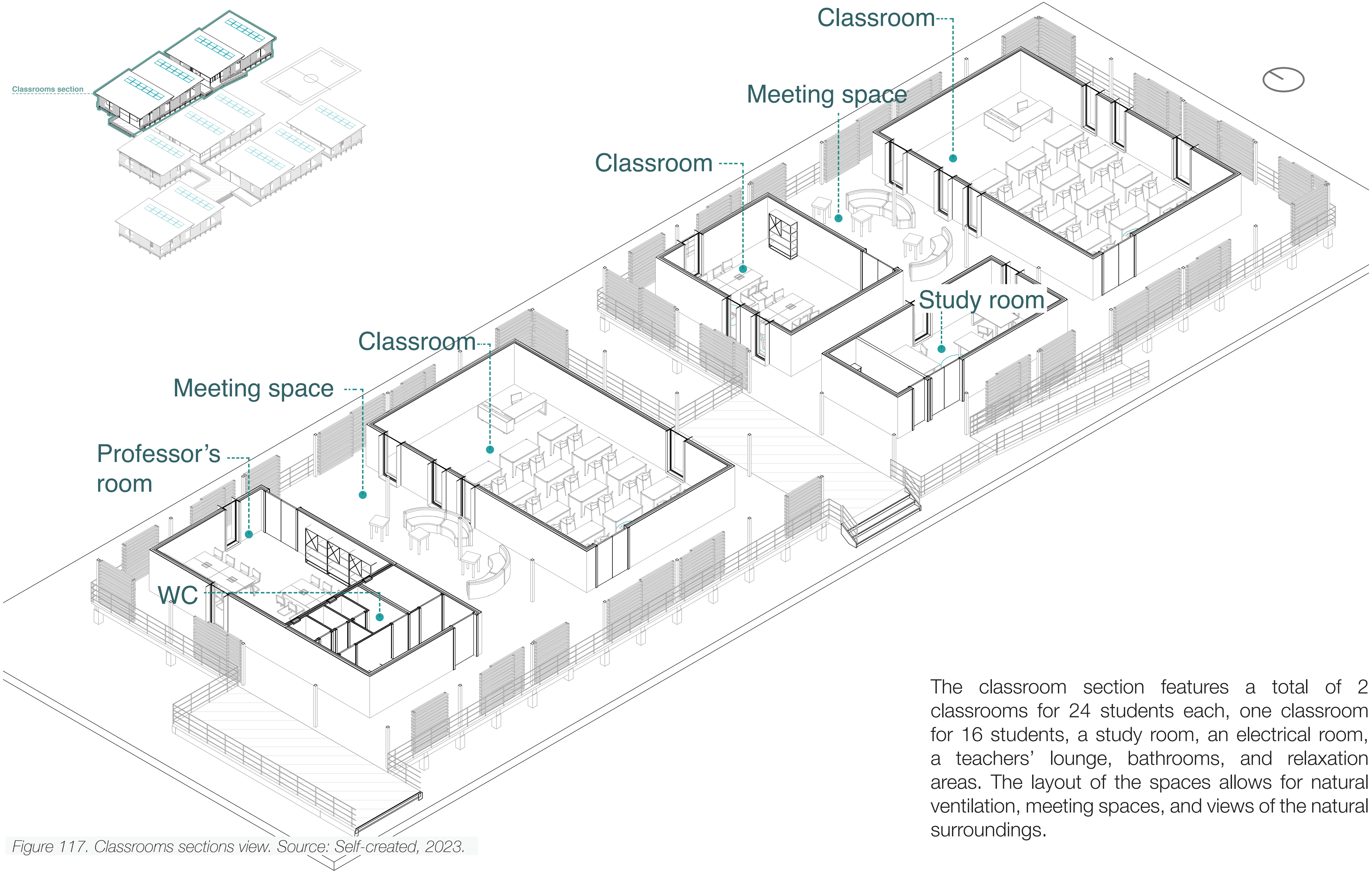
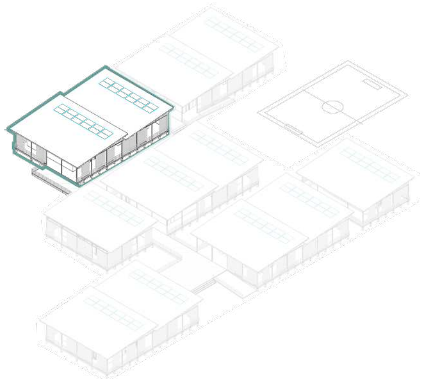


Figure 117. Classrooms sections view. Source: Self-created, 2023.

The classroom section features a total of 2 classrooms for 24 students each, one classroom for 16 students, a study room, an electrical room, a teachers' lounge, bathrooms, and relaxation areas. The layout of the spaces allows for natural ventilation, meeting spaces, and views of the natural surroundings.

Classrooms module view



Emphasis is placed on the combination of two modules to demonstrate how they are configured to join together and obtain a double module, which share the same platform and structure for two roofs.

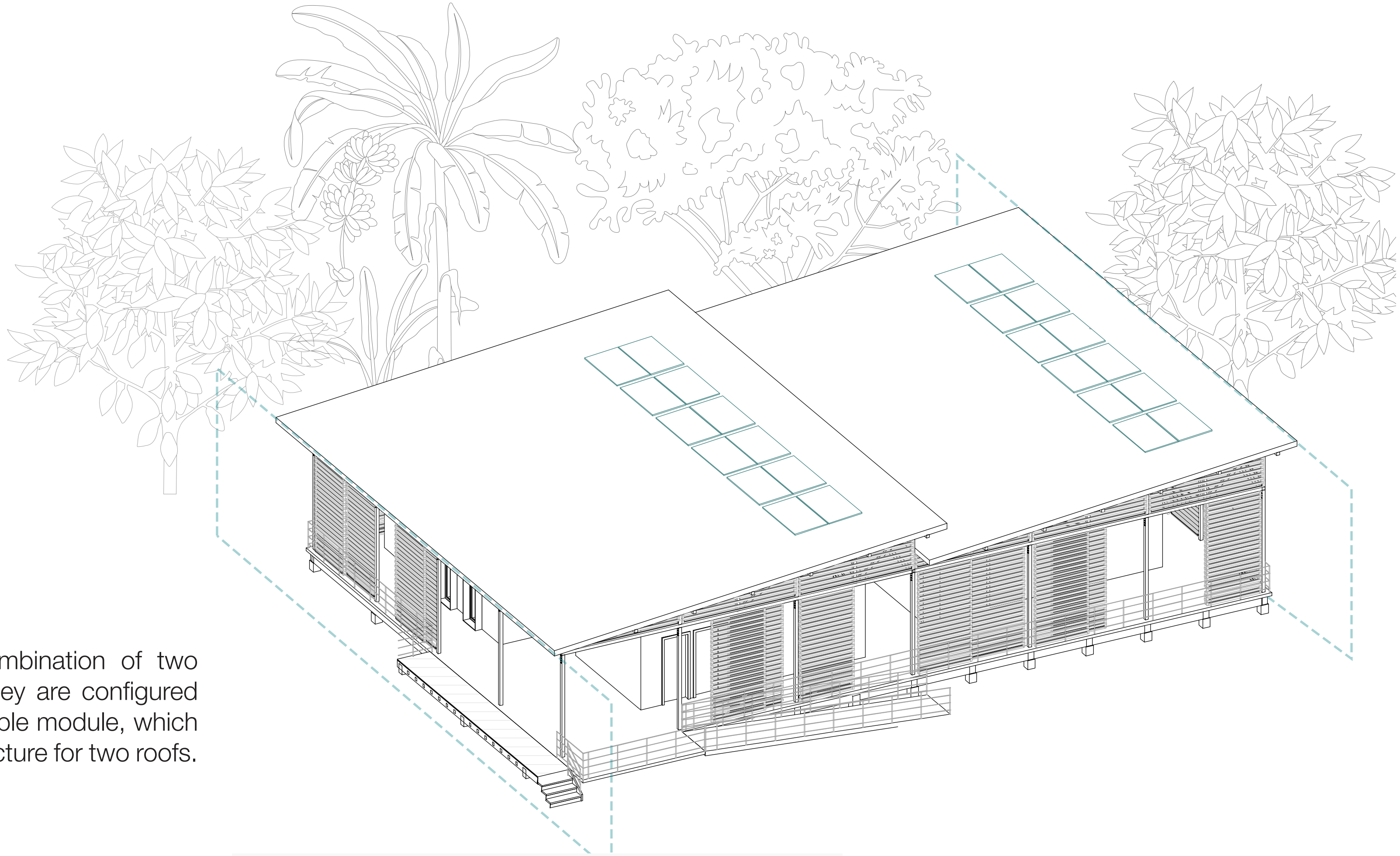
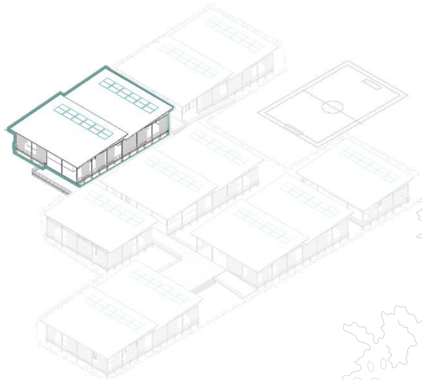


Figure 118. Classrooms module view. Source: Self-created, 2023.

Classrooms module plan



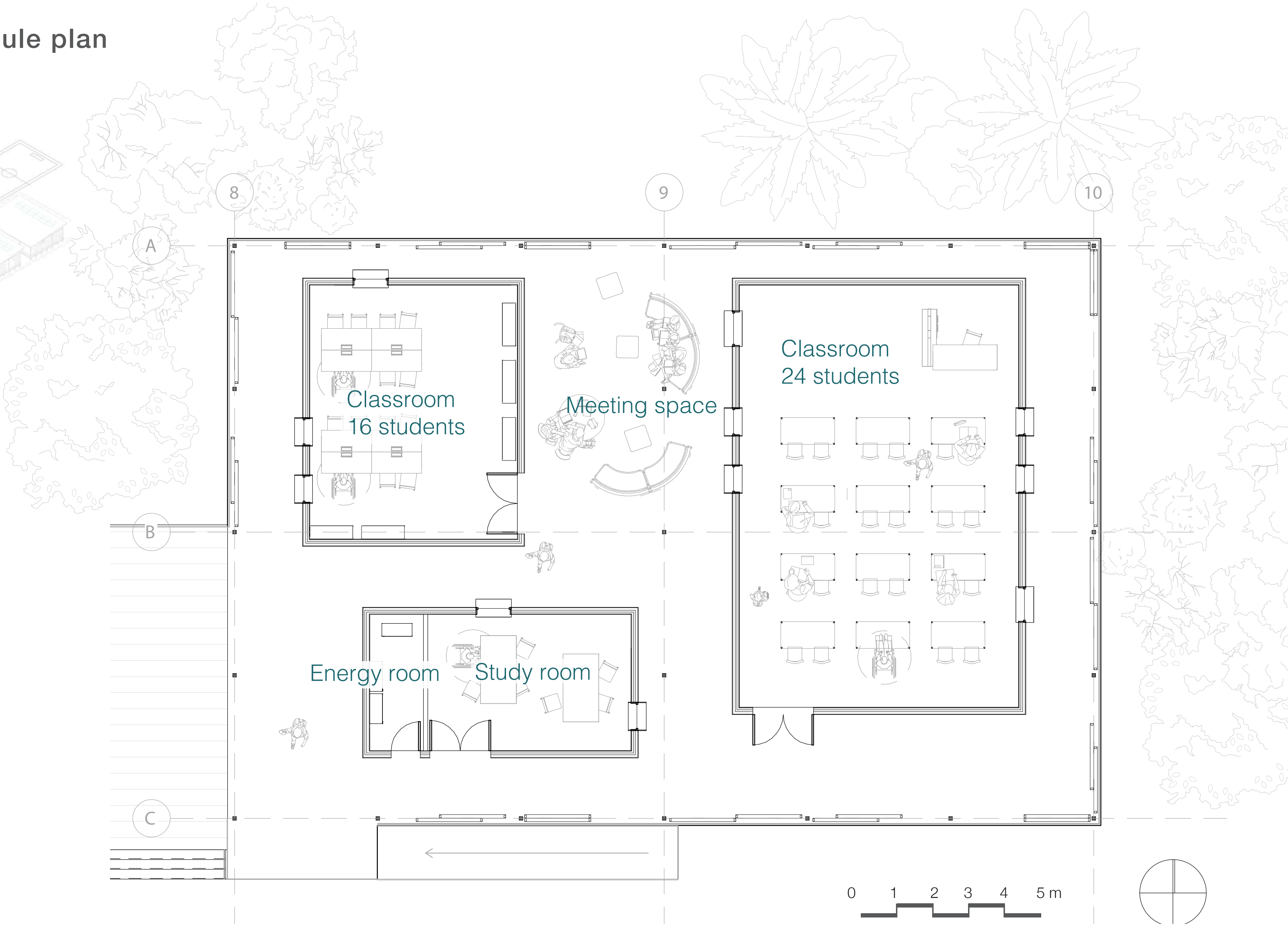
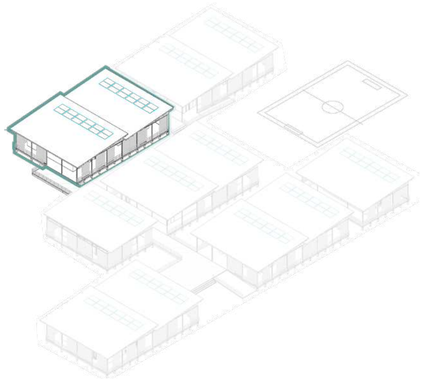


Figure 119. Classrooms module plan Source: Self-created, 2023.

Classrooms module elevations



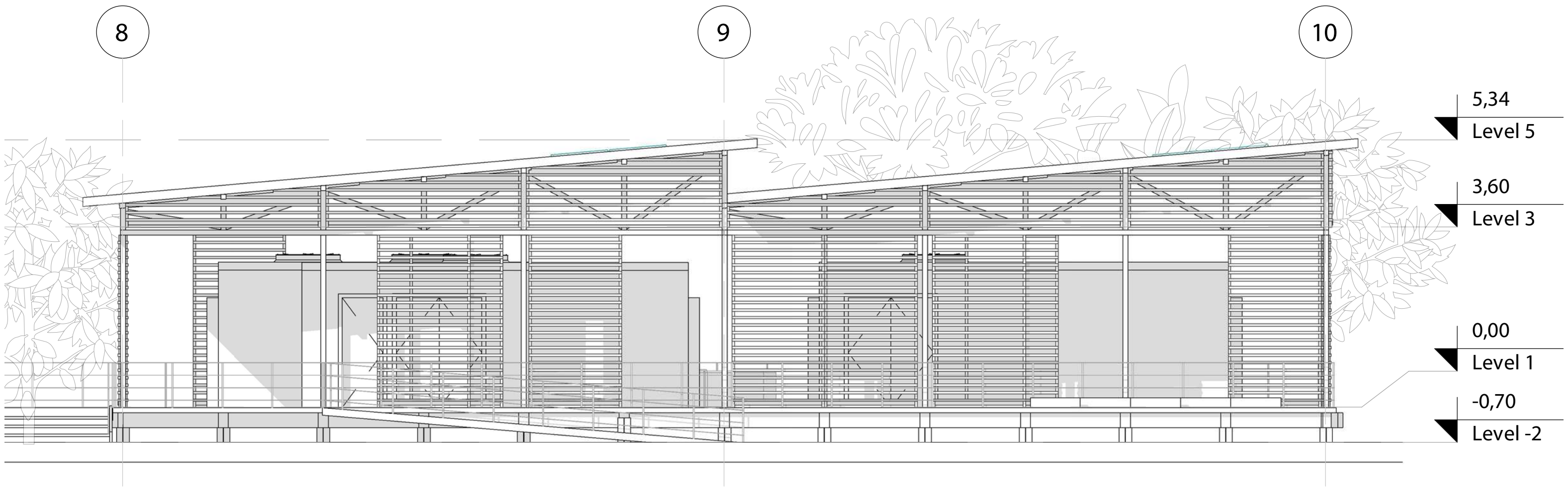


Figure 119. South elevation. Source: Self-created, 2023.

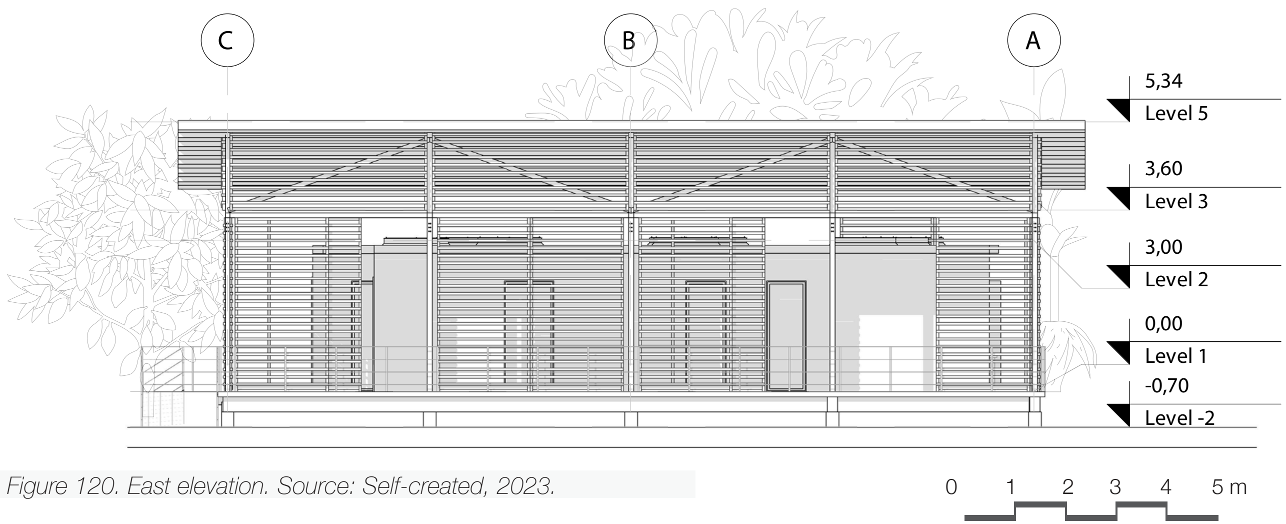
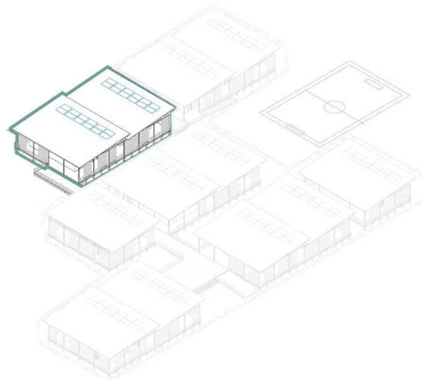


Figure 120. East elevation. Source: Self-created, 2023.

Classrooms module sections



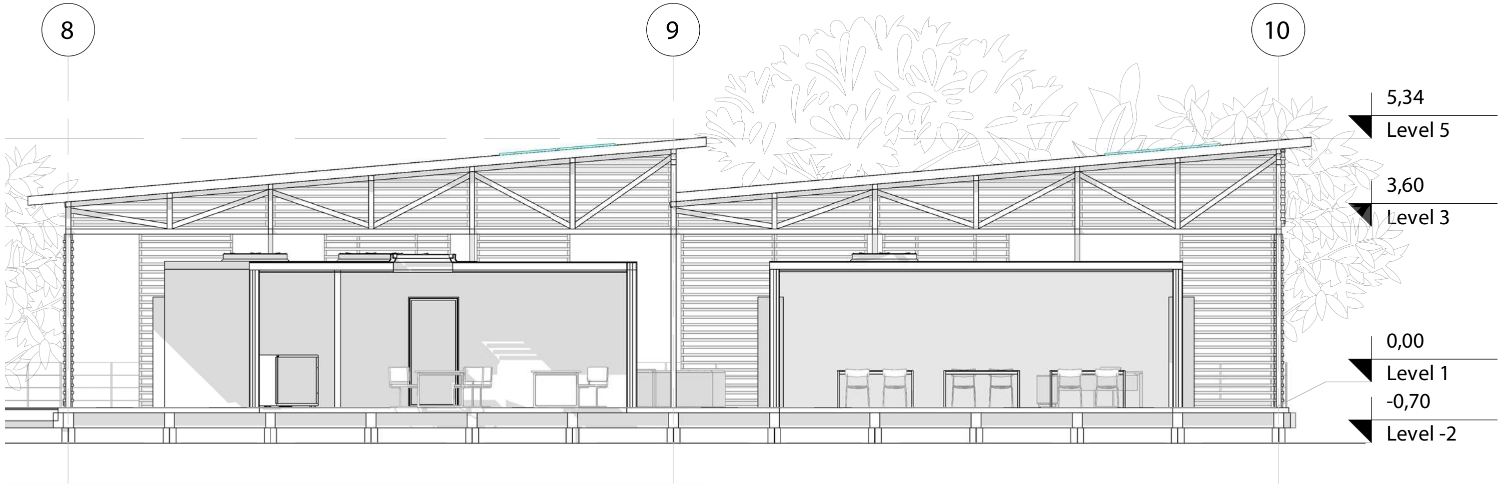


Figure 121. Section 1. Source: Self-created, 2023.

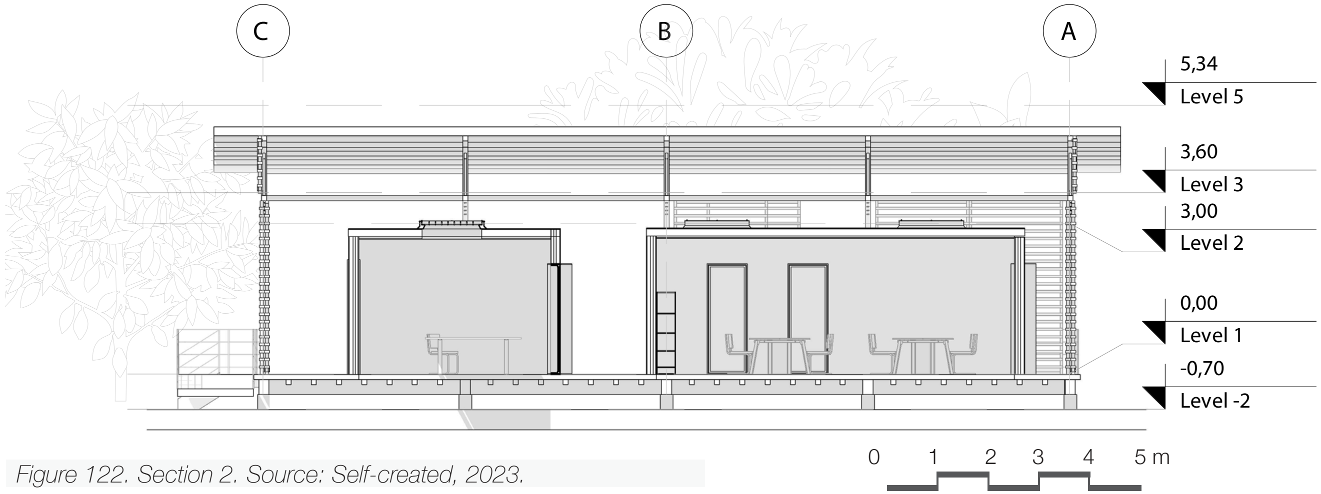


Figure 122. Section 2. Source: Self-created, 2023.

Classrooms module solar analysis

The accommodation of the closed modules allows the shade cover for most of the day and that they are also protected by the facade systems during the hours of greatest solar inclination.

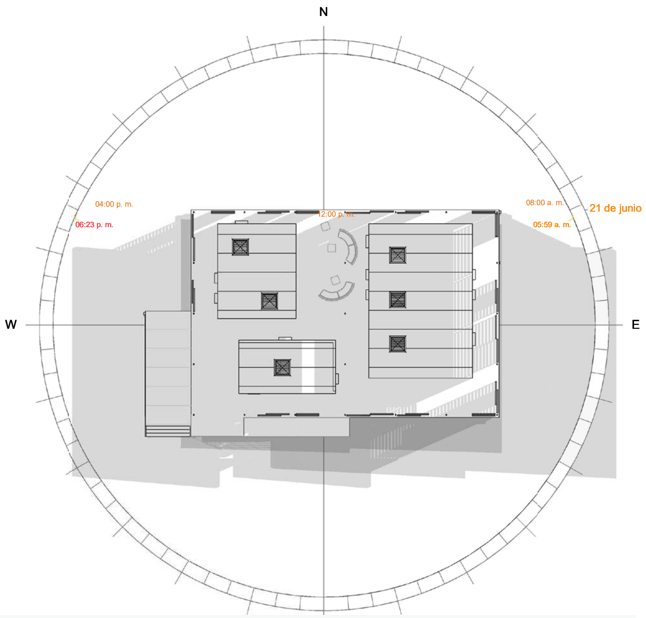


Figure 123. Sommer solstice solar analysis.
Source: Self-created, 2023.

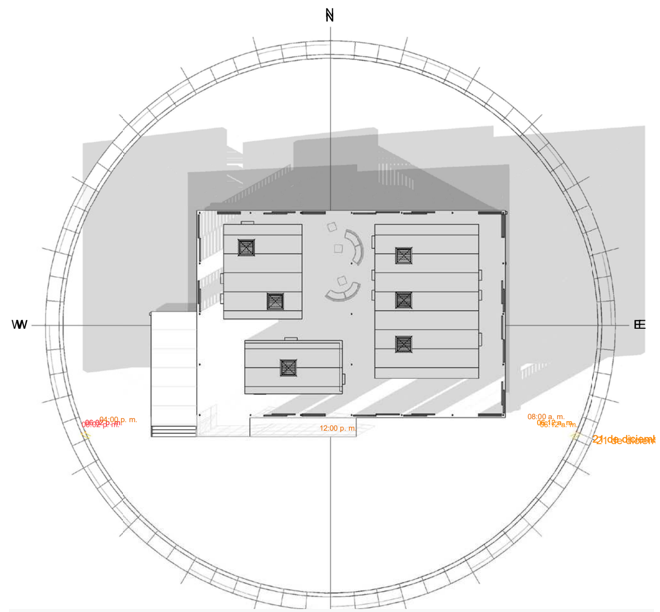


Figure 124. Winter solstice solar analysis.
Source: Self-created, 2023.

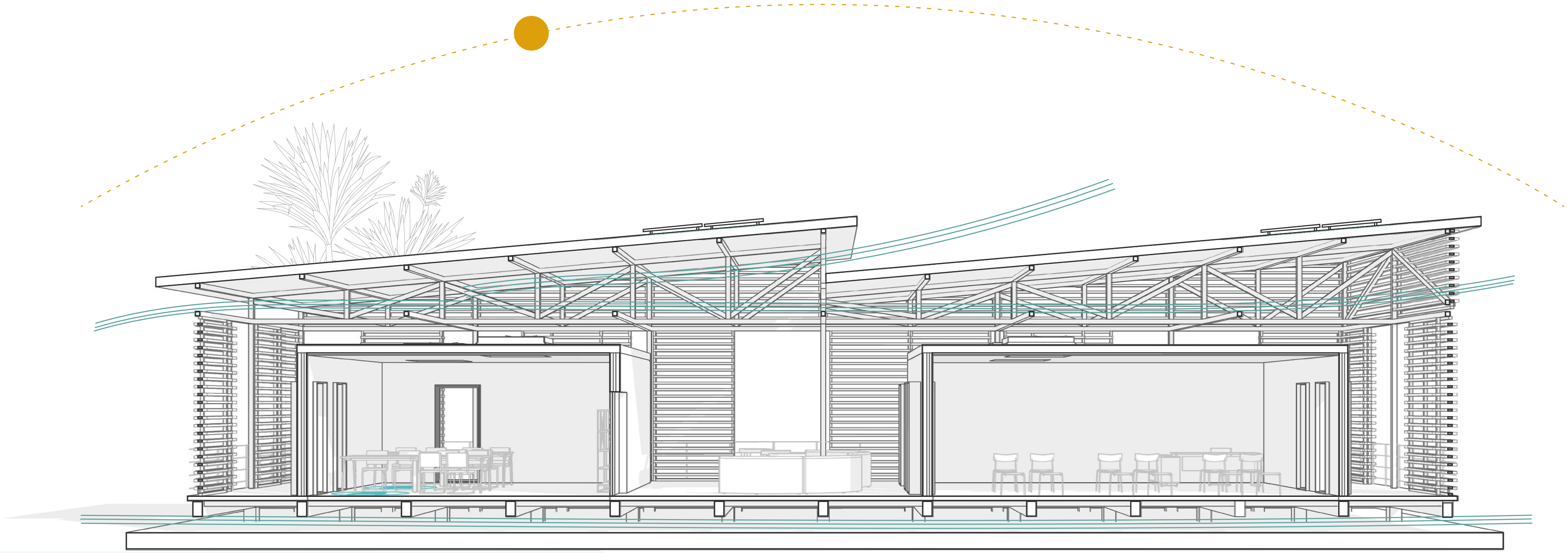
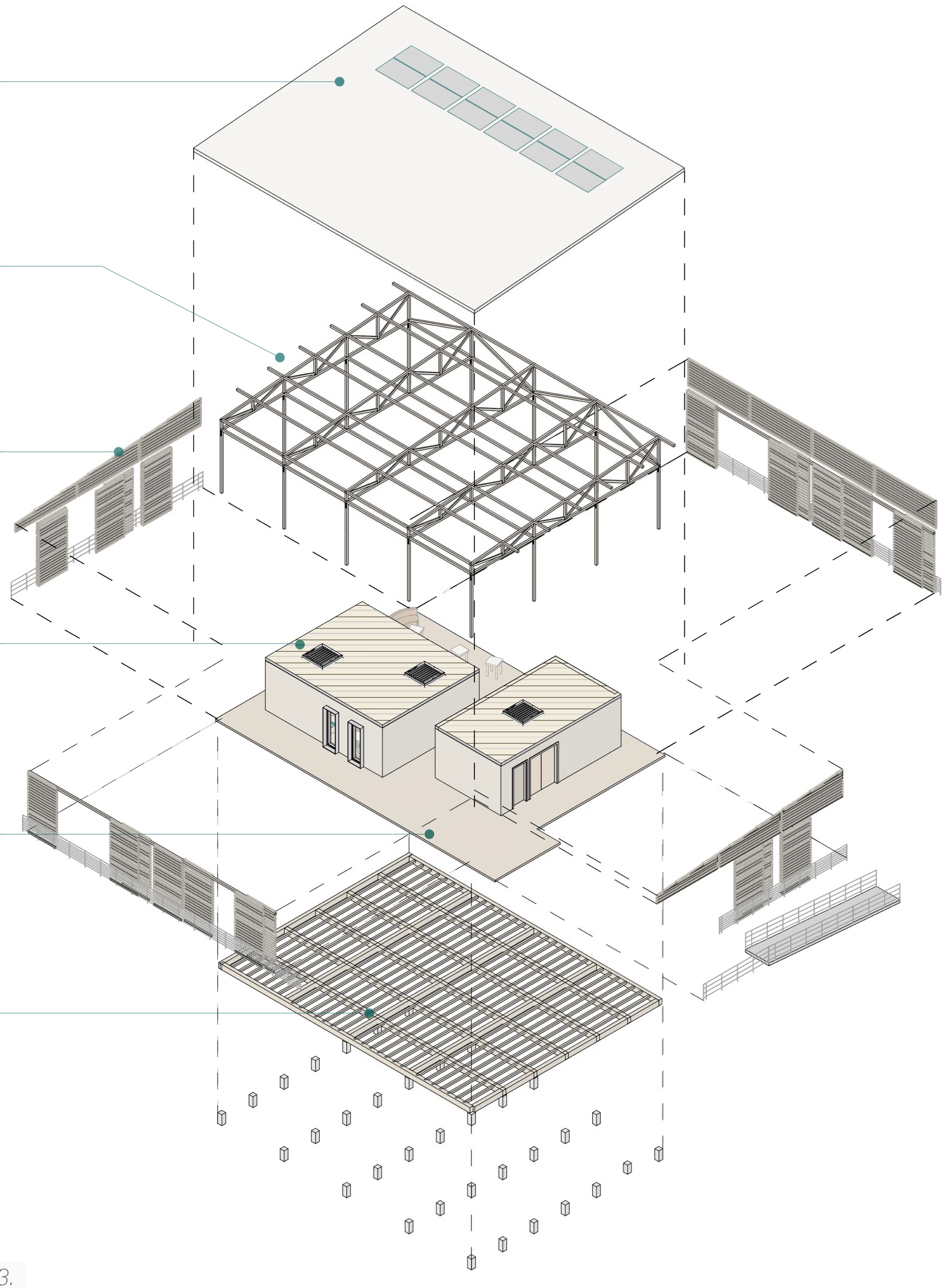


Figure 125. Perspective section. Source: Self-created, 2023.

Module construction components



Roof
· 12 Photovoltaic Modules 400W
· self-supporting sandwich panels of a steel sheet on the outer face, a sheet of polyester on the inner face

Roof structure
· wooden truss with triangular bracing and metal connections: horizontal top and bottom chords joined by diagonal members with metal gusset plates for stability.

Shading system façades
· Shading system with horizontal elements that allow visual connection with the exterior, as well as wind circulation. They provide shade to indoor spaces for most of the year.

Closed classroom modules
· Closed modules with double wooden walls and thermal insulation. Closed volumes allow better control of internal temperature and facilitate natural ventilation in open and indoor spaces.

Platforms
· Wooden platforms supporting the roof structure and modules, providing open circulation spaces and railings for visual connections to the exterior, resembling balconies.

Floor structure and foundations
· A structure that lifts the entire building off the ground level, enabling airflow underneath to enhance cooling. It also acts as a barrier against animals, insects, and direct ground moisture.

Figure 126. Module construction components. Source: Self-created, 2023.

Envelope analysis

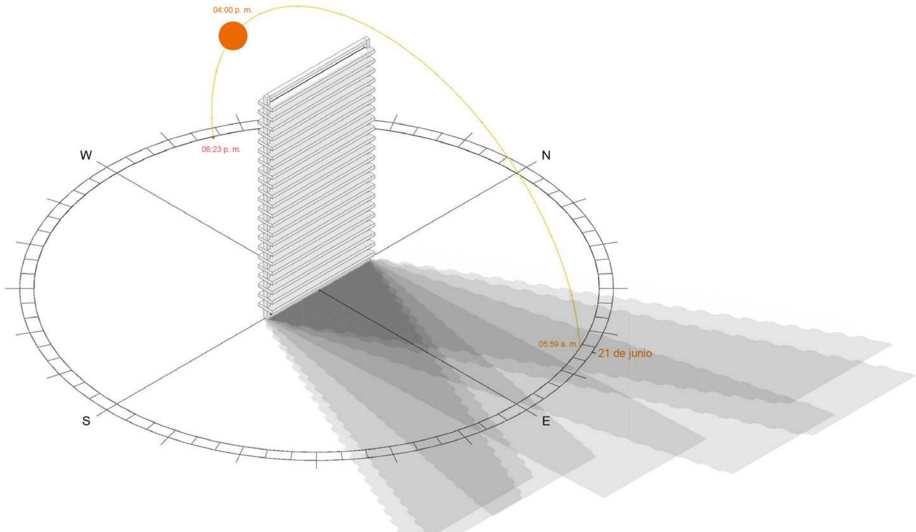


Figure 127. Horizontal elements shading analysis for west façades.
Source: Self-created, 2023.

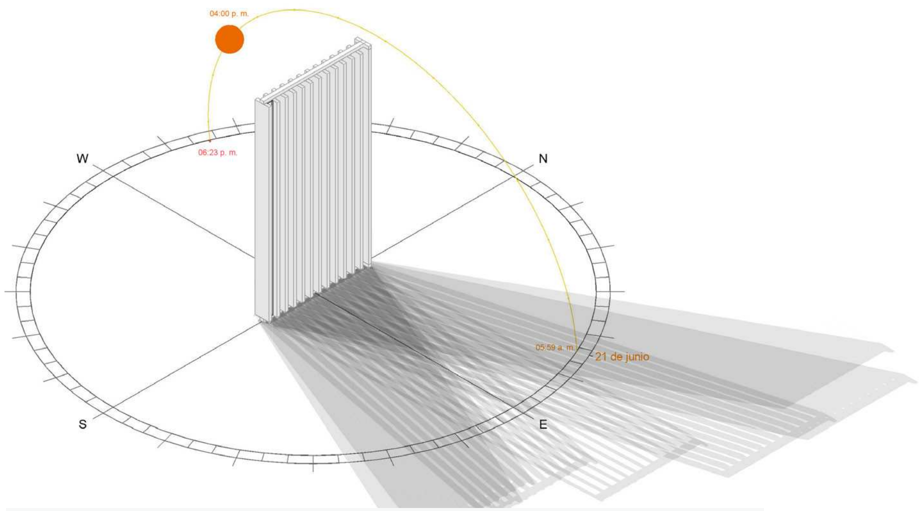


Figure 128. Vertical elements shading analysis for west façades.
Source: Self-created, 2023.

The walls of the enclosed rooms were chosen with these layers of materials for demonstrating very good thermal insulation parameters. The walls consist of two wooden slats towards the exterior and interior, and inside these two layers of thermal insulation plus an air chamber of 5 cm. The results of the hydrothermal factors demonstrate the resistance to external temperature and humidity to convert the modules into more controlled volumes.

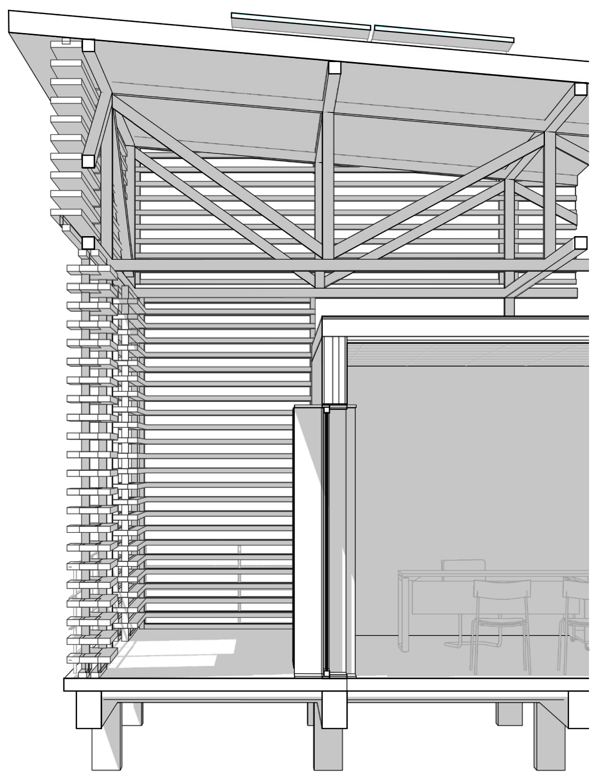


Figure 129. Detail section. Source: Self-created, 2023.

8.4 Energy balance design

Isolated photovoltaic production system

Isolated or independent photovoltaic power generation systems are those that use batteries to store the energy produced by the photovoltaic generator. They are isolated from the public centralized network to supply areas without network coverage.

These systems work differently from grid-connected systems because they have to be designed according to the relationship between generating capacity and electricity storage capacity.

According to the consumption profiles of users, the relationship between production and storage can be improved. This requires consumption habits consistent with the system and with the production of photovoltaic energy during the sunny hours of the day.

Taking into account that the consumption profiles do not always coincide with the hours of solar radiation, the battery system must be designed according to the production-consumption ratio.

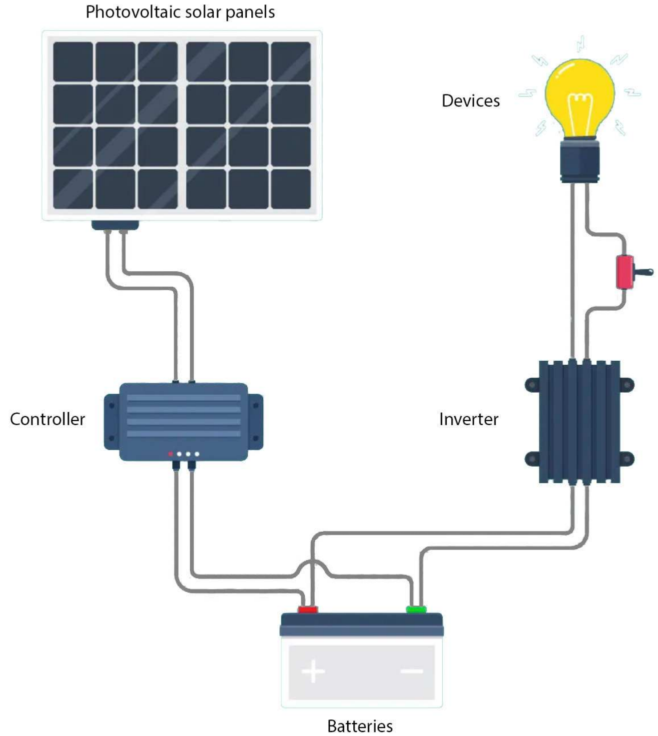


Figure 130. Isolated energy production system diagram. Source: Self-created, 2023.

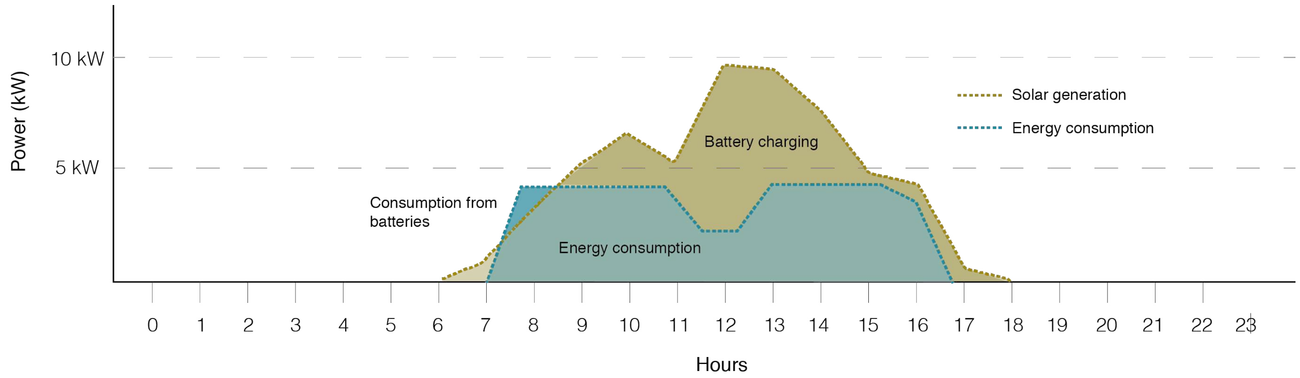
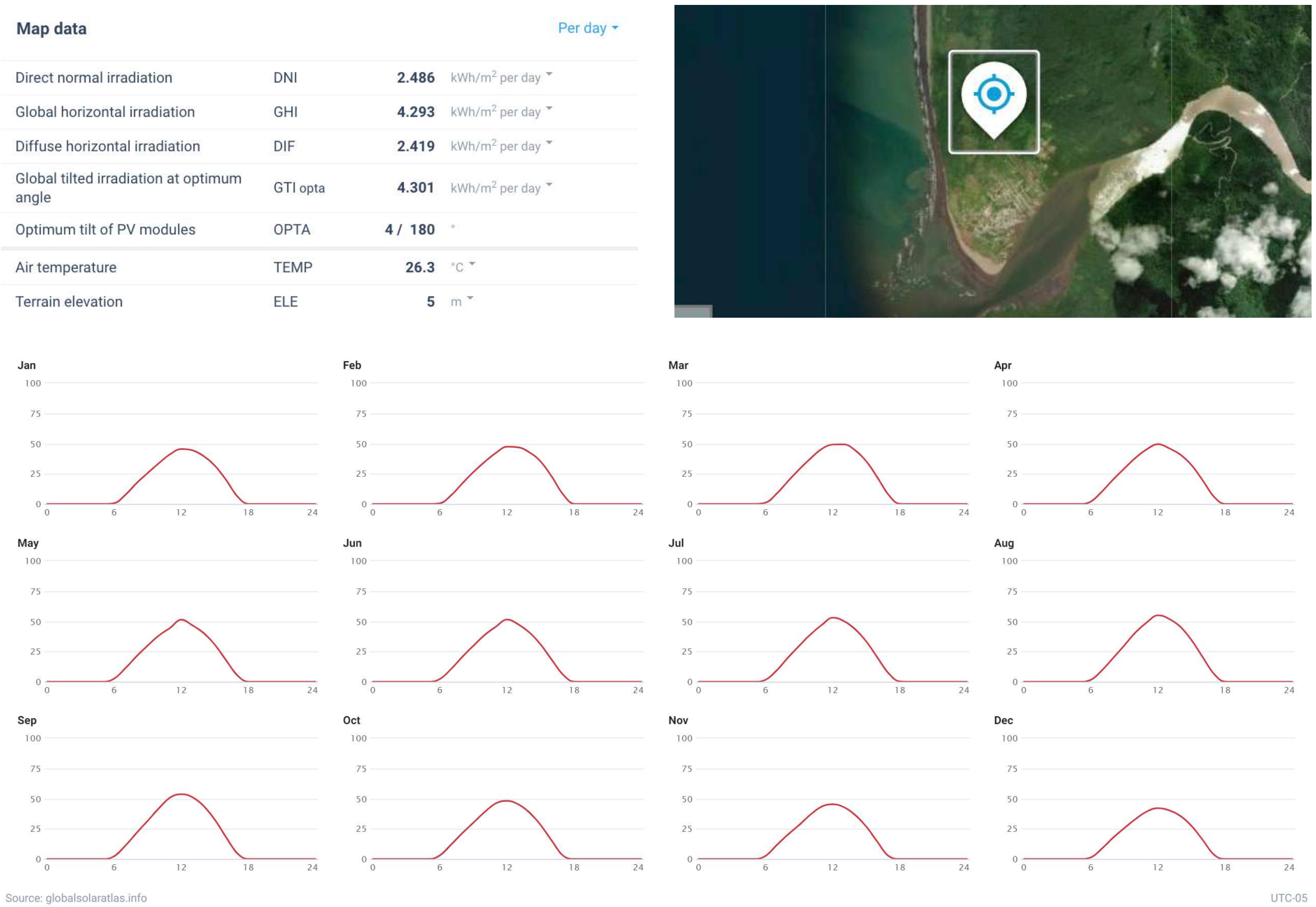


Figure 131. Energy production, storage and consumption diagram. Source: Self-created, 2023.

8.4.1 Manual calculation of the photovoltaic system

Solar radiation conditions in Pizarro



Map data Per day

Direct normal irradiation	DNI	2.486	kWh/m² per day
Global horizontal irradiation	GHI	4.293	kWh/m² per day
Diffuse horizontal irradiation	DIF	2.419	kWh/m² per day
Global tilted irradiation at optimum angle	GTI opta	4.301	kWh/m² per day
Optimum tilt of PV modules	OPTA	4 / 180	°
Air temperature	TEMP	26.3	°C
Terrain elevation	ELE	5	m

Figure 132. Solar radiation conditions in Pizarro, Choco, Colombia. Source: Global radiation atlas, 2018.

The first method used to size the PV system appropriate for the project proposal was the manual calculation of the system. For this purpose, a study of the solar radiation conditions in the area was first made in the Global Solar Atlas Software. This is important because the characteristics of solar panels may vary depending on direct, diffuse and global irradiation.

In the case of Pizarro, in Bajo Baudo (04.963831°, -077.366295°), peak solar hours (PSH) are 4.301 kWh/m2 per day. This means that out of the 24 hours of a day, 4.3 solar radiation reaches its peak, providing the production of kilowatts per hour in one square meter of solar surface.

The diffuse and direct solar radiation are very similar, 2,486 and 2,419 respectively. This means that the solar panels to be installed must have the same ability to capture diffuse and direct solar radiation. The software calculated that among the variants of direct and diffuse radiation, the highest yield angle is 4o at 180o Azimuth (meaning towards the south). It is also important to take into account the average ambient temperature of 26.3°C, as the efficiency of the panels decreases with higher temperatures.

Average hourly profiles

Total photovoltaic power output [kWh]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0 - 1												
1 - 2												
2 - 3												
3 - 4												
4 - 5												
5 - 6												
6 - 7	1	1	1	2	3	2	2	2	2	3	3	1
7 - 8	8	7	9	10	11	11	10	10	11	12	12	9
8 - 9	17	17	19	20	21	21	20	20	22	22	20	18
9 - 10	26	26	29	29	30	30	30	30	32	30	28	26
10 - 11	34	35	37	38	38	39	39	41	42	39	37	33
11 - 12	41	42	45	45	45	45	47	49	51	46	43	39
12 - 13	45	47	49	49	51	51	53	55	53	48	45	42
13 - 14	44	47	49	46	47	47	50	52	51	45	43	40
14 - 15	39	43	44	41	40	41	43	45	44	38	36	35
15 - 16	32	35	35	32	31	31	33	34	32	28	27	27
16 - 17	20	23	22	19	18	18	20	20	18	15	14	16
17 - 18	6	8	7	6	5	6	7	7	5	3	2	4
18 - 19	0	0	0	0	0	0	0	0	0			
19 - 20												
20 - 21												
21 - 22												
22 - 23												
23 - 24												
Sum	313	330	347	339	340	342	353	365	363	329	310	290

Figure 133. Total photovoltaic powe output in Pizarro, Choco, Colombia. Source: Global radiation atlas, 2018.

The average hourly profiles shows the total photovoltaic power output by month every hour of a day. This shows a variation between months, where the months of July, August and September have the highest power output according to the global solar radiation.

On the other hand, the timetable plots show the global horizontal radiation (Wh/sq.m.) with different percentages during an average year. The yellow lines show the sunrise and sunset, so it is shown a major radiation during the afternoon hours.

In the second timetable plot, it is shown the sky cover percentage and it's visible the lowest percentages of sky cover during the afternoon hours. This means, that the solar panels will receive more diffuse radiation during the morning and more direct radiation during the afternoon. This graph shows the energy production capacity (Wh/sq.m) in the solar path of an average year. The graph shows with the color legend that the radiation during the winter solstice at noon and 3 pm is much higher than in the rest of the year. This is important to consider in the orientation of the panels that receive more direct solar radiation and also to protect the building from sunlight during these hours of the year.

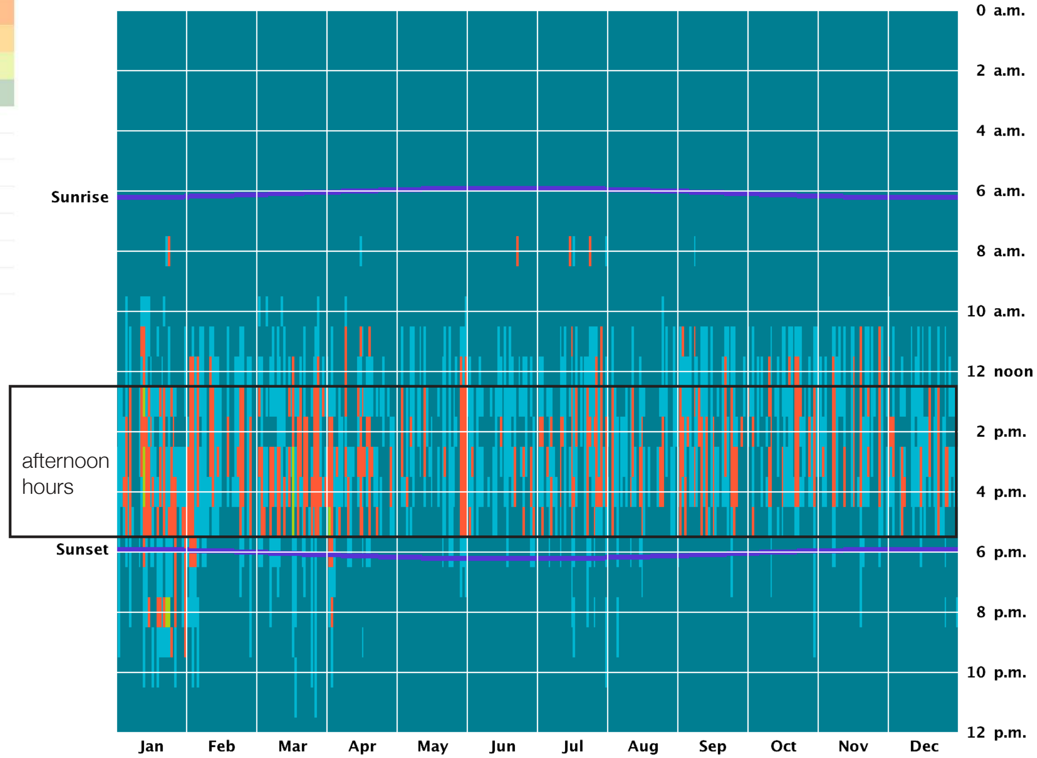


Figure 134. Solar radiation chart in average day in Pizarro, Choco, Colombia. Source: Processed by Climate Consultant, 2015.

Consumption profile characterization

Annual consumption profile

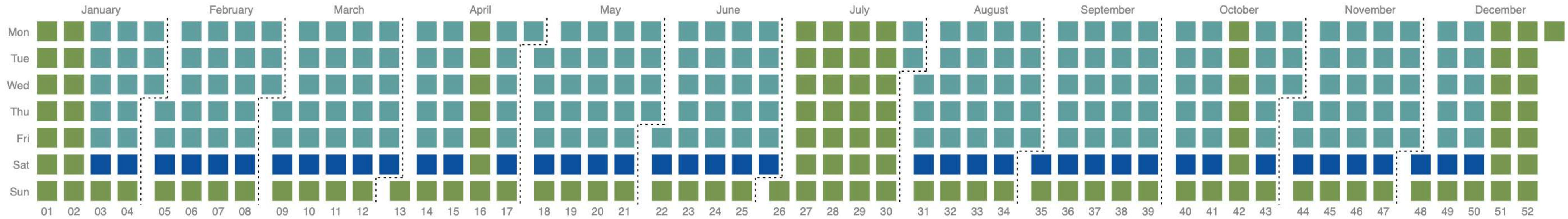


Figure 135. Annual consumption profiles. Source: Self-created, 2023.

Weekly consumption profile

Day	Classrooms	Administration offices	Professors room	WCs	Lightining corridors	Library	Cafeteria	Nursury	Study rooms	Resting rooms	Multi-sport court	Electric room	Storage	Cleaning room	Auditorium	External lightning
	Mon - Fri			Mon - Sat											Fri - Sat	Mon - Sun
Monday	6	8	8	8	8	8	4	4	4	4	4	2	2	2	0	12
Tuesday	6	8	8	8	8	8	4	4	4	4	4	2	2	2	0	12
Wednesday	6	8	8	8	8	8	4	4	4	4	4	2	2	2	0	12
Thursday	6	8	8	8	8	8	4	4	4	4	4	2	2	2	0	12
Friday	6	8	8	8	8	8	4	4	4	4	4	2	2	2	2	12
Saturday	0	0	0	4	8	6	4	4	4	4	4	2	2	2	3	12
Sunday	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12
Total	**30**	**40**	**40**	**44**	**48**	**46**	**24**	**24**	**24**	**24**	**24**	**12**	**12**	**12**	**5**	**84**
Daily average	**4.29**	**5.71**	**5.71**	**6.29**	**6.86**	**6.57**	**3.43**	**3.43**	**3.43**	**3.43**	**3.43**	**1.71**	**1.71**	**1.71**	**0.71**	**12.00**

Figure 136. Weekly consumption profile. Source: Self-created, 2023.

The Weekly schedule is the organization of operating hours for each space of the proposed project. Each space has different consumption times and is therefore specified individually. Similarly, the spaces are grouped into the bands: Monday-Friday, Monday-Saturday, Friday-Saturday and Monday-Sunday.

On each day, the number of hours they are in operation is marked to calculate a total of weekly hours and an average of hours per day for a year.

The energy consumption habits are also represented in a daily profile where the amount of Watts consumed during a day is shown and an annual plan is built according to these.

Daily consumption profiles

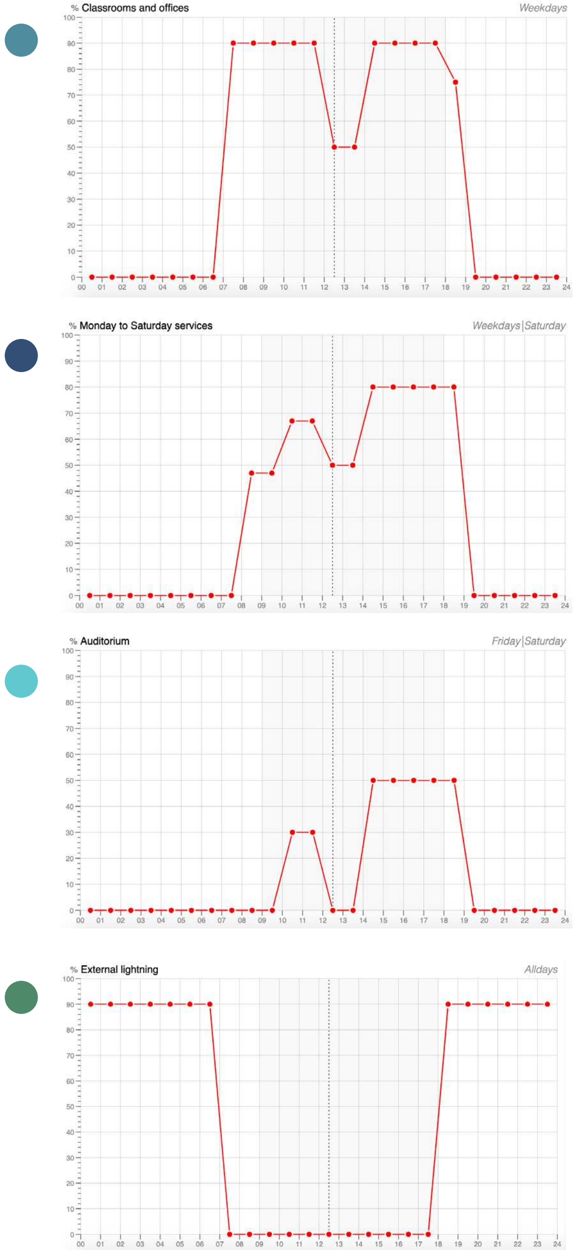


Figure 137. Daily consumption profiles. Source: Self-created, 2023.

Each space has different consumption characteristics. The graphs show the types of consumption and how they vary throughout the day. It is important to determine the type of consumption during a day, a week, and a year for an accurate calculation of the school's required production and to know the additional production capacity beyond this consumption.

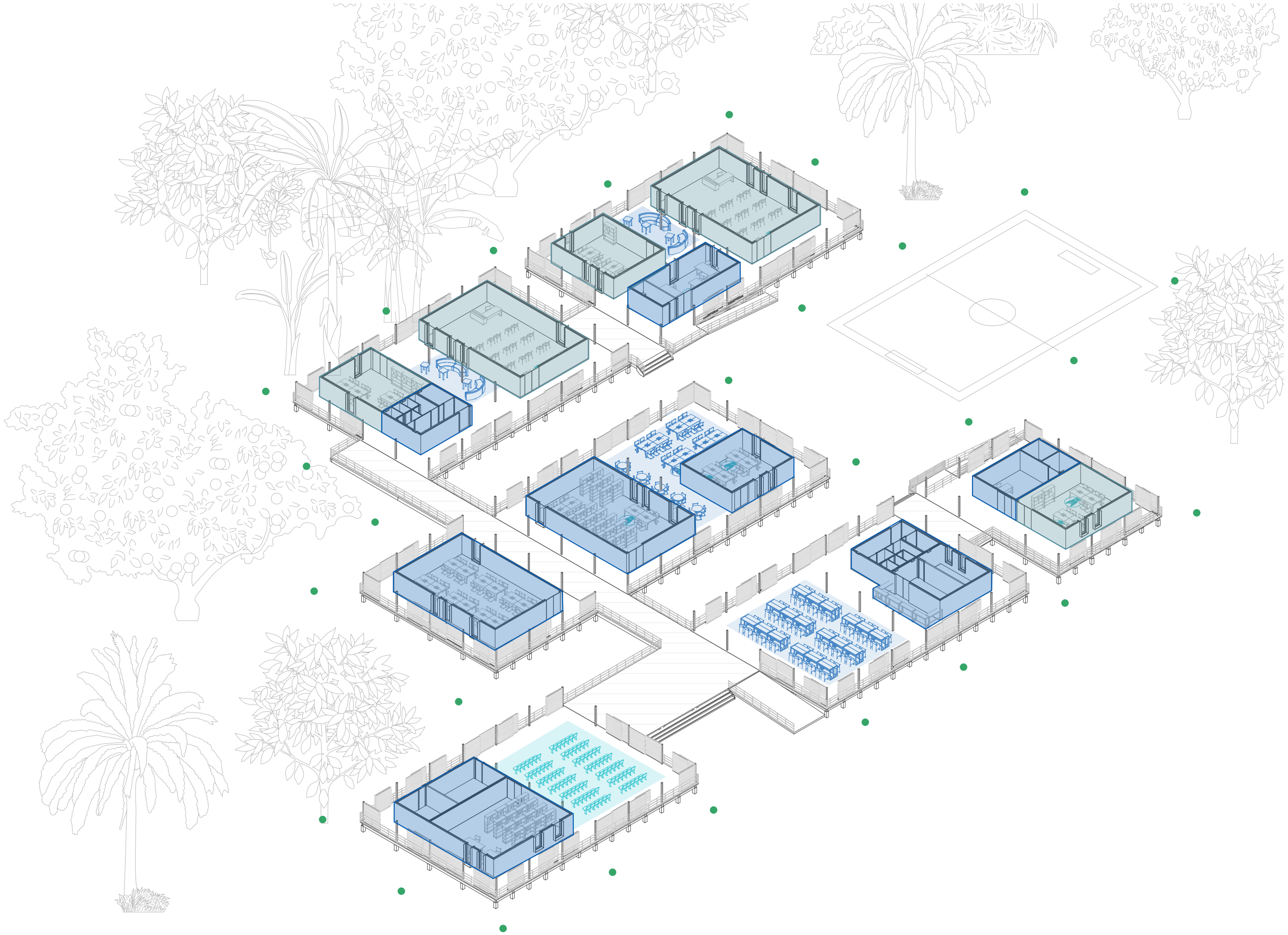


Figure 138. Consumption profiles view. Source: Self-created, 2023.

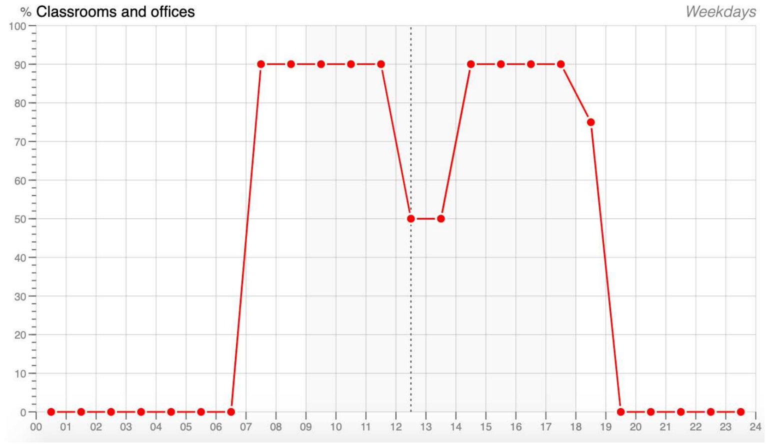
Consumption calculations

The table shows the consumption of each space according to the devices that are needed for the specific operation of each. An estimated consumption was calculated for each space per hour and then multiplied by the number of spaces by each section of the project.

Educational section: Estimated daily consumption (kWh) **23.42**

Room	Power (W)	Quantity per room (units)	Consumption time (hours)	Total per space (kWh)	Total all spaces (kWh)
Classroom				**1.95**	**9.76**
Projector	350	1	4.3	1505.00	18.06
Phone charges	10	1	4.3	43.00	0.52
Computer	30	1	4.3	129.00	1.55
LED lights	8	8	4.3	275.20	3.30
Study rooms				**3.35**	**6.69**
Computer	30	4	3.5	420.00	1.68
Tablets	25	2	3.5	175.00	0.70
Phone charges	10	1	3.5	35.00	0.14
Air conditioning	720	1	3.5	2520.00	10.08
LED lights	8	7	3.5	196.00	0.78
Proffesors room				**4.55**	**4.55**
Computer	30	8	4.3	1032	1.032
Phone charges	10	1	4.3	43	0.043
Air conditioning	720	1	4.3	3096	3.096
LED lights	9	8	4.3	309.6	0.3096
Coffee maschine	15	1.00	4.3	64.5	0.0645
Electric room				**1.11**	**1.11**
WIFI Modem	8	1	1.7	13.6	0.0136
Inversor	15	1	1.7	25.5	0.0255
LED lights	9	3	1.7	45.9	0.0459
Air conditioning	600.00	1.00	1.7	1020	1.02
Resting spaces				**0.18**	**0.35**
Phone charges	10	1	4.3	21.50	0.06
LED lights	9	4	4.3	154.80	0.46
WCs				**0.19**	**0.19**
LED lights	9	5	4.3	193.50	0.19
Corridors lightning				**0.77**	**0.77**
LED lights	9.00	20	4.30	774.00	0.77

Daily consumption: 23.42 kWh
Monthly consuption: 702.70 kWh
Annual consumption: 8549.47 kWh



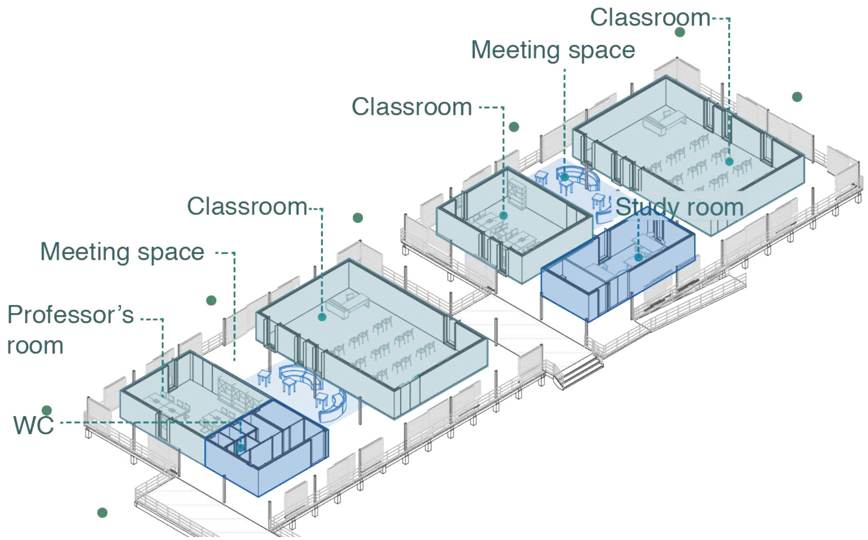
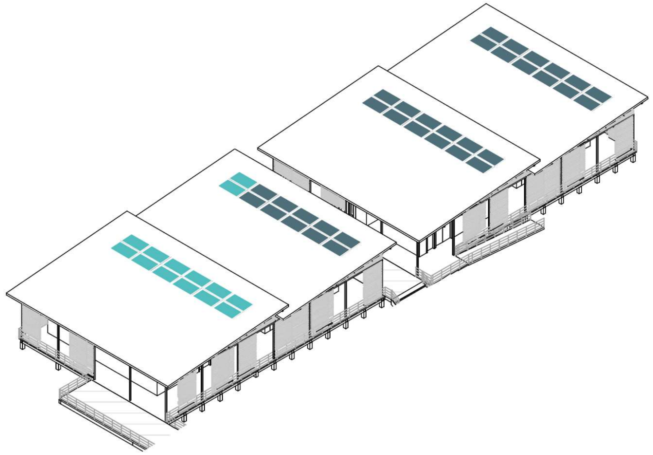


Figure 139. Classrooms consumption calculation Source: Self-created, 2023.

$$\textbf{Required Power Generation} = \frac{\text{Estimated Energy Consumption}}{\text{Daily energy yield (kWh/m2-day)} \ast \text{Days a month (30 days)} \ast \text{Performance factor (Oversizing capacity)}}$$

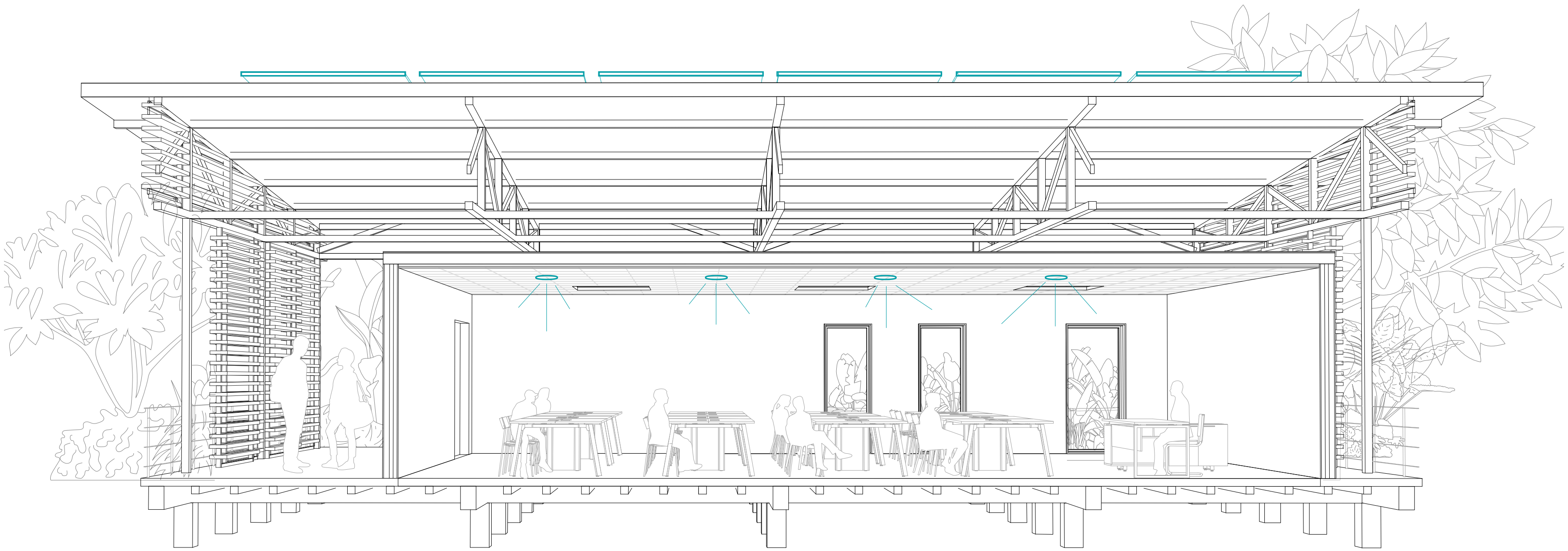
$$\textbf{Quantity of solar panels} = \frac{\text{Required Power Generation}}{\text{Solar Panel Power}}$$



Educational section

$$\textbf{Required Power Generation} = \frac{702.70}{4.341\ \text{(kWh/m2-day)} \quad 30\ \text{(a month)} \quad 1\ \text{ersizing capacity)}} = \textbf{5.40}\ \text{kW (PV Generator System)}$$

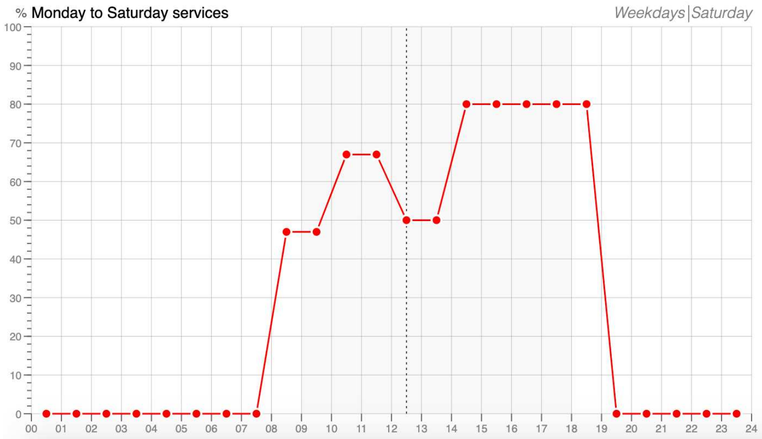
$$\textbf{Quantity of solar panels} = \frac{5395.81}{400} = \textbf{13.5}\ \text{solar panels units}$$



Library section: Estimated daily consumption (kWh) **36.84**

Room	Power (W)	Quantity per room (units)	Consumption time (hours)	Total per space (kWh)	Total all spaces (kWh)
Library				**12.03**	**24.05**
Computer	30	20	6.50	3900.00	7.80
Tablets	25	10	6.50	1625.00	3.25
Phone charges	10	10	6.50	650.00	1.30
LED lights	9	20	6.50	1170.00	2.34
Air conditioning	720	1	6.50	4680.00	9.36
Computer rooms				**10.91**	**10.91**
Computer	30	20	6.50	3900.00	3.90
Tablets	20	10	6.50	1300.00	1.30
Phone charges	10	5	6.50	325.00	0.33
Air conditioning	720	1	6.50	4680.00	4.68
LED lights	9	12	6.50	702.00	0.70
Corridors lightning				**0.77**	**0.77**
LED lights	9.00	20	4.30	774.00	0.77
Electric room				**1.11**	**1.11**
WIFI Modem	8	1	1.7	13.6	0.0136
Inversor	15	1	1.7	25.5	0.0255
LED lights	9	3	1.7	45.9	0.0459
Air conditioning	600.00	1.00	1.7	1020	1.02

Daily consumption: 36.84 kWh
Monthly consuption: 1105.08 kWh
Annual consumption: 13445.14 kWh



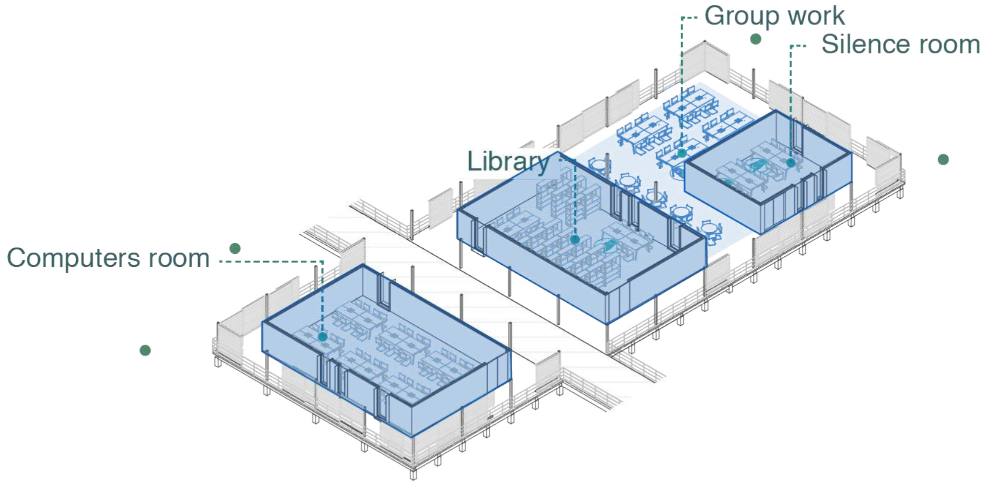
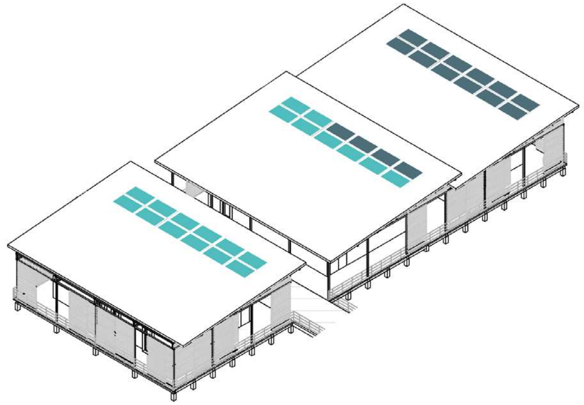


Figure 140. Library consumption calculation Source: Self-created, 2023.

Required Power Generation = $\dfrac{\textit{Estimated Energy Consumption}}{\textit{Daily energy yield (kWh/m2-day)} \; * \; \textit{Days a month (30 days)} \; * \; \textit{Performance factor (Oversizing capacity)}}$

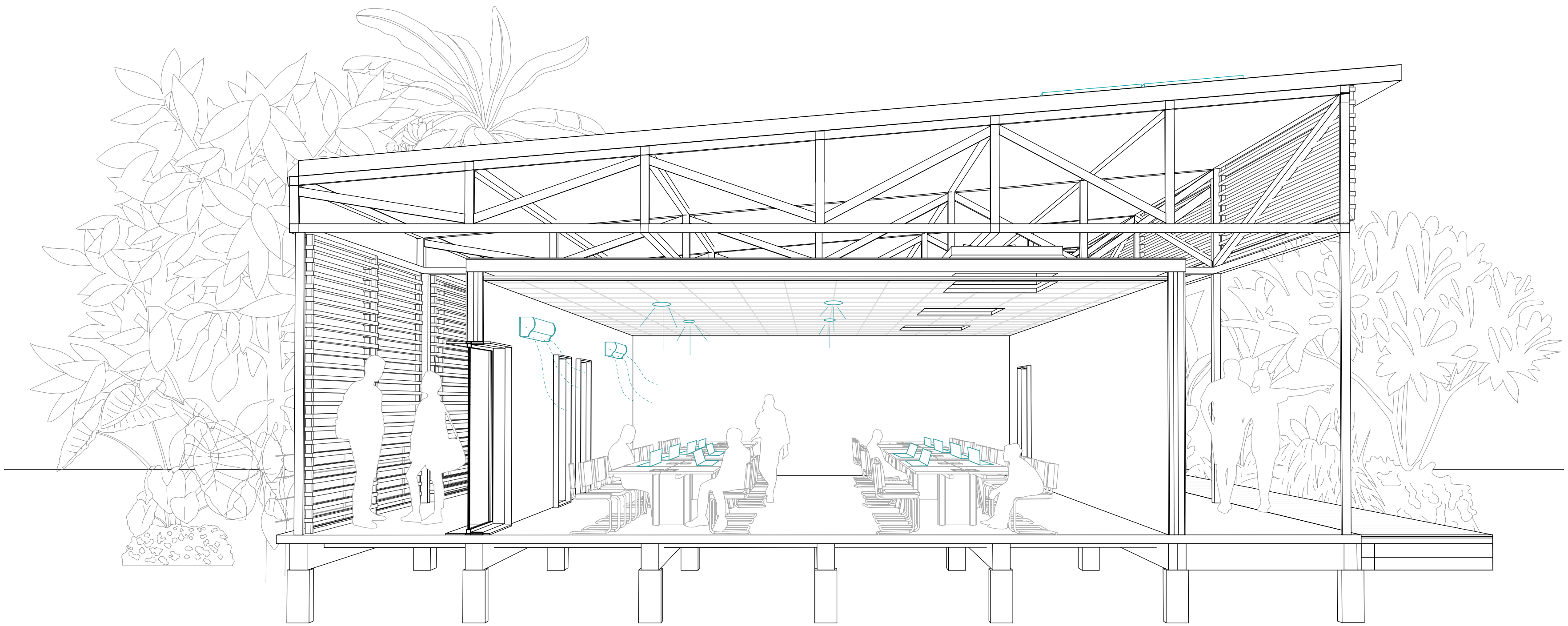
Quantity of solar panels = $\dfrac{\textit{Required Power Generation}}{\textit{Solar Panel Power}}$



Library

Required Power Generation = $\dfrac{1,105.08}{4.341 \text{ (kWh/m2-day)} \quad 30 \text{ (a month)} \quad 1 \text{ (ersizing capacity)}}$ = **8.49** kW (PV Generator System)

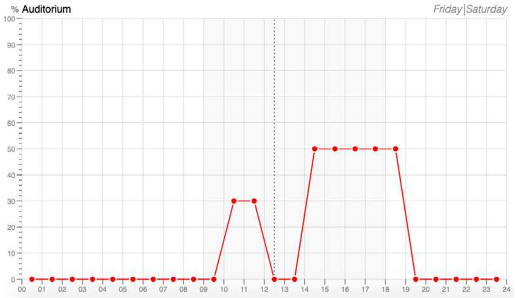
Quantity of solar panels = $\dfrac{8485.60}{500}$ = **17.0** solar panels units

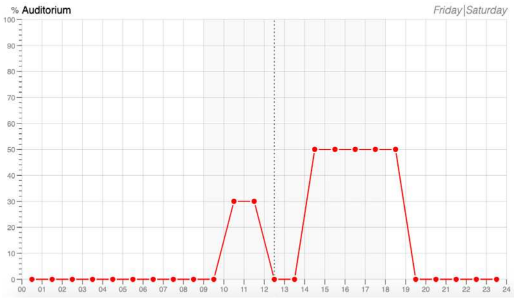


Cultural section: Estimated daily consumption (kWh) **27.31**

Room	Power (W)	Quantity per room (units)	Consumption time (hours)	Total per space (kWh)	Total all spaces (kWh)
Administration				**1.58**	**1.58**
Computer	30.00	8.00	5.70	1.37	1.37
Phone charges	10.00	1.00	5.70	0.06	0.06
LED lights	9.00	3.00	5.70	0.15	0.15
Auditorium				**0.97**	**0.97**
Computer	30	1	1.20	0.04	0.04
Music box	25	1	1.20	0.03	0.03
Music speakers	50	4	1.20	0.24	0.24
Proyector	350	1	1.20	0.42	0.42
Phone charges	10	2	1.20	0.02	0.02
LED lights	9	20	1.20	0.22	0.22
Cafeteria				**16.39**	**16.39**
Fridges	20	2	3.40	0.14	0.14
Stove	1800	1	3.40	6.12	6.12
Oven	2450	1	3.40	8.33	8.33
Mixer	350	1	3.40	1.19	1.19
LED lights	9	20	3.40	0.61	0.61
Nursury				**2.74**	**2.74**
Computer	30.00	1.00	3.40	0.10	0.10
Fridge	20.00	1.00	3.40	0.07	0.07
Air conditioning	720.00	1.00	3.40	2.45	2.45
LED lights	9.00	4.00	3.40	0.12	0.12
Energy center				**3.46**	**3.46**
Computer	30.00	4.00	3.40	0.41	0.41
LED lights	9	6	3.40	0.18	0.18
Air conditioning	720.00	1.00	3.40	2.45	2.45
Proyector	350	1	1.20	0.42	0.42
Phone charges	10	2	1.20	0.02	0.02
Storage				**0.06**	**0.06**
LED lights	9.00	2.00	3.40	61.20	0.06
Cleaning room				**0.06**	**0.06**
LED lights	9.00	2.00	3.40	61.20	0.06

Daily consumption: 27.31 kWh
Monthly consuption: 819.22 kWh
Annual consumption: 9967.16 kWh





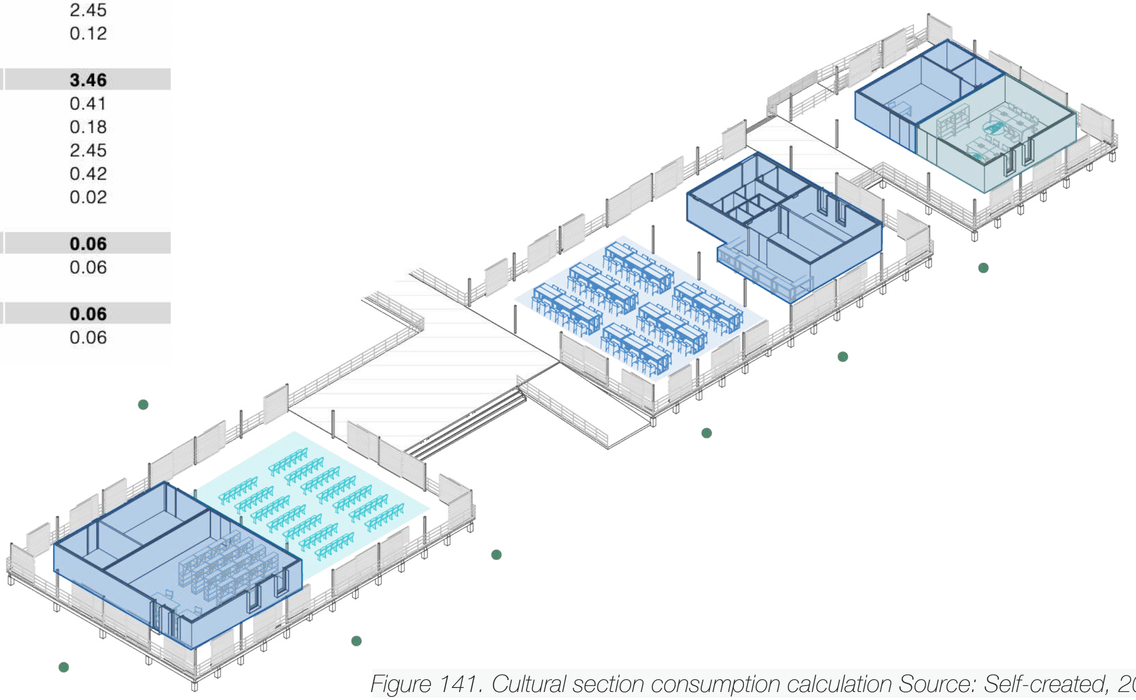
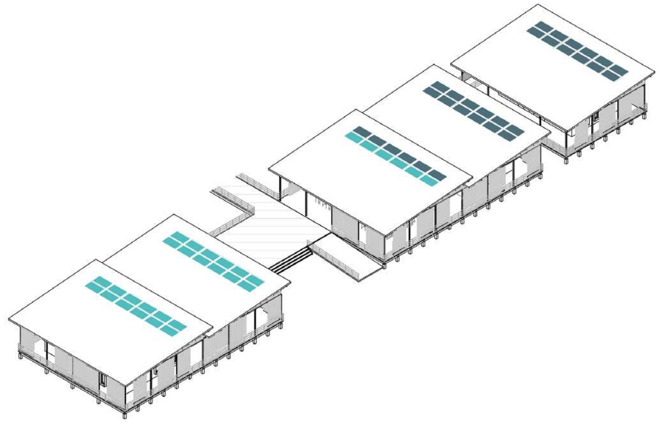


Figure 141. Cultural section consumption calculation Source: Self-created, 2023.

Required Power Generation = *Estimated Energy Consumption* / *Daily energy yield (kWh/m2-day) * Days a month (30 days) * Performance factor (Oversizing capacity)*

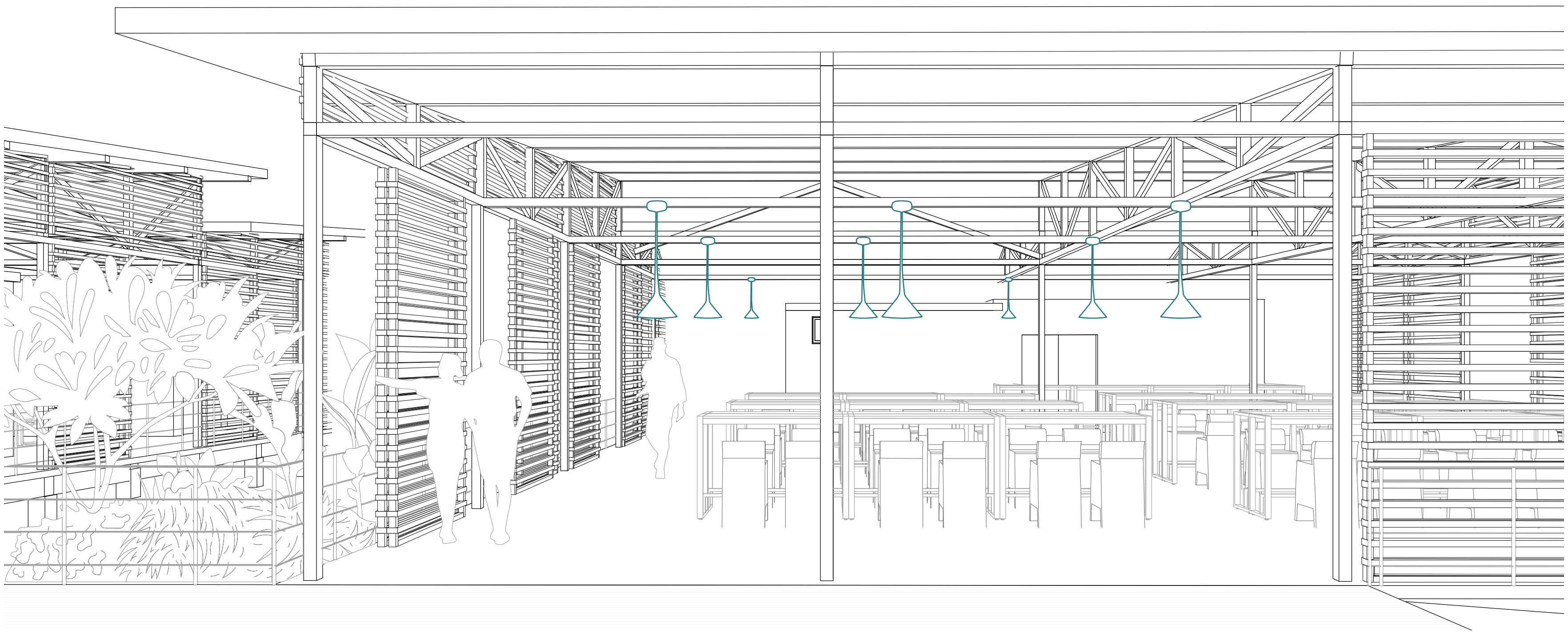
Quantity of solar panels = *Required Power Generation* / *Solar Panel Power*



Cultural section

Required Power Generation = 819.22 / 4.341 (kWh/m2-day) 30 (a month) 0.5 versizing capacity) = **12.58** kW (PV Generator System)

Quantity of solar panels = 12581.11 / 400 = **31.5** solar panels units



Total consumption calculations

After describing the consumption of each space, it is multiplied by the number of hours per day to obtain the result with daily, weekly, monthly and annual consumption. The sum of these consumptions of each space allows to know the capacity of the photovoltaic generator system.

Section	Daily consumption (kWh)	Monthly consumption (kWh)	Annual consumption (kWh)
Education	23.42	702.696	8549.468
Library	36.84	1105.08	13445.14
Cultural	27.31	819.219	9967.1645
Total	87.57	2627.00	31961.77

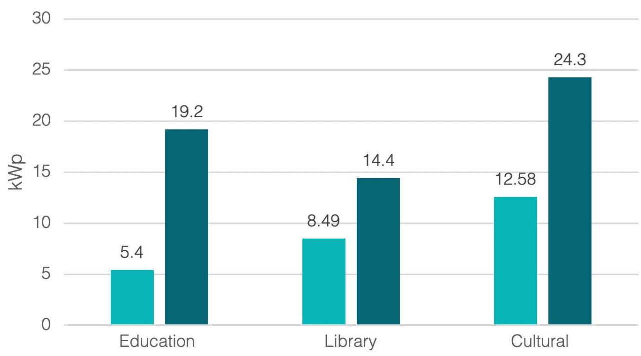


Figure 142. Required and potencial capacity comparison. Source: Self-created, 2023.

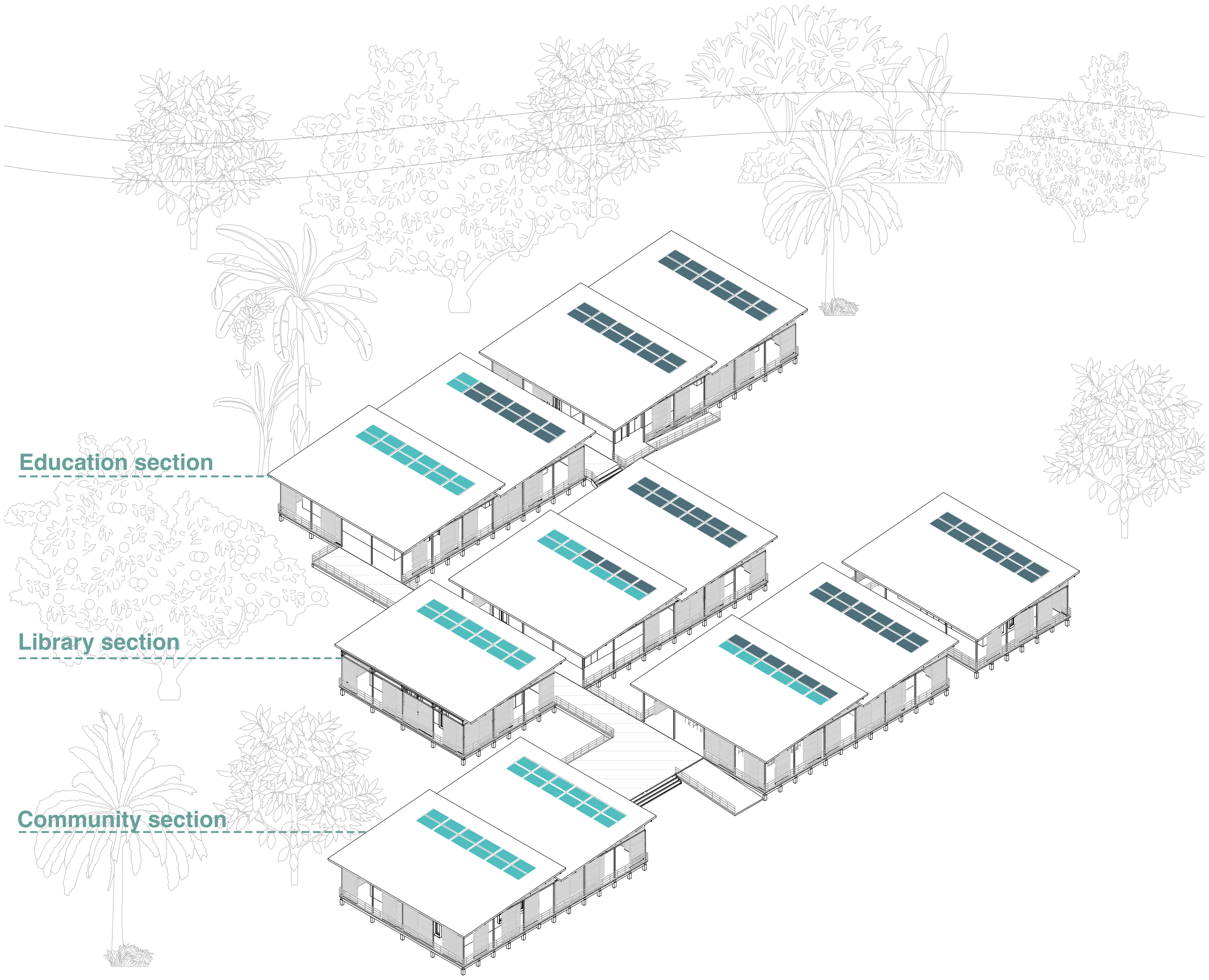
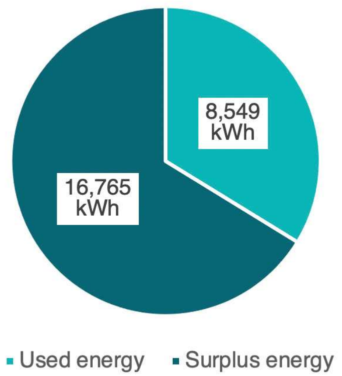


Figure 143. Required and potencial capacity comparison view. Source: Self-created, 2023.

Energy autonomy results

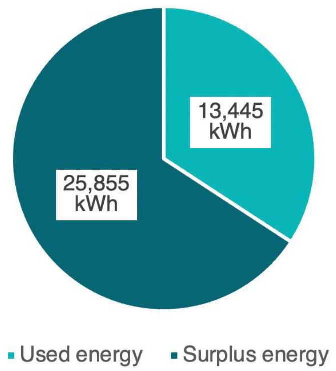
Classrooms



Required Power generation (kWp)	5.4
Potential Power generation (kWp)	19.2
Energy storage (kWh)	411.6
Annual available energy (kWh)	26409
Used energy (kWh)	8,549
Surplus energy (kWh)	16,765

Surplus energy:
67.62 %

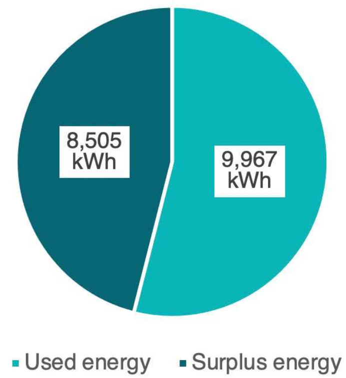
Library



Required Power generation (kWp)	8.49
Potential Power generation (kWp)	21.2
Energy storage (kWh)	14.4
Annual available energy (kWh)	39300
Used energy (kWh)	13445
Surplus energy (kWh)	25855

Surplus energy:
65.77 %

Cultural



Required Power generation (kWp)	12.58
Potential Power generation (kWp)	31.5
Energy storage (kWh)	24.3
Annual available energy (kWh)	19650
Used energy (kWh)	9967
Surplus energy (kWh)	8505

Surplus energy:
50.68 %

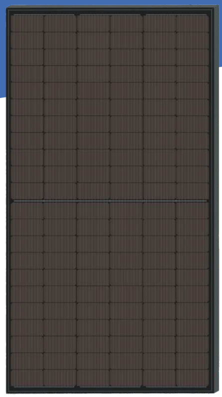
System devices specifications: Photovoltaic panels

THERMO WIRE
TRANSFORMA TU ENERGIA

THPS 500W

M10 / Celda de182 mm - 132 Medias Celdas

MODELO EGE-500W-132M(M10)

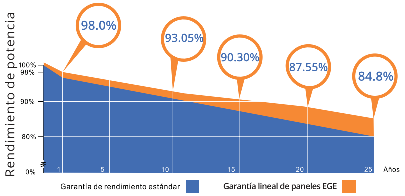


CARACTERÍSTICAS CLAVE

- Tecnología dopada con galio
- Menor LCOE y BOS
- Menor riesgo de puntos calientes por efectos de sombreado
- Protección Anti PID / Bajo nivel de LID
- Bajo coeficiente de temperatura

GARANTÍA DE RENDIMIENTO LINEAL

12 años de garantía producto • 25 años de garantía potencia lineal



132 Medias Celdas
Módulo Monocristalino (10BB)

21.27%
Eficiencia Máxima

0~+5W
Tolerancia de Potencia Positiva

GRADO A
Células Garantizadas

CERTIFICADOS INTEGRALES

BUCARAMANGA
Cra. 22 No. 100 - 77
Barrio Provenza

BOGOTÁ
Calle 114A No. 15b-10
Oficina 403

SOGAMOSO
PLANTA DE PRODUCCIÓN
Carrera 30 No. 11-49

Cel: 310 625 5635
thermowire@gmail.com
www.thermowire.com.co

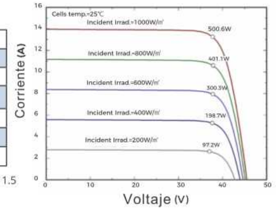
EGE-500W-132M(M10)

INFORMACIÓN ELÉCTRICA EN STC*

Potencia máxima (Pmax)	500 W
Tolerancia de potencia	0~+5 W
Eficiencia del módulo	21.27 %
Máxima capacidad de voltaje (Vmp)	37.43 V
Máxima capacidad de corriente (Imp)	13.36 A
Voltaje de circuito abierto (Voc)	45.49 V
Corriente de cortocircuito (Isc)	13.96 A

*Condiciones Estándar de Medida (STC) : Radiación : 1,000 W/m² ·Temperatura de las celdas : 25°C · AM : 1.5

EGE-500W-132M(M10) Curva I-V de Irradiancia

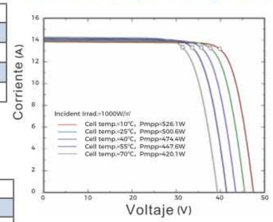


INFORMACIÓN ELÉCTRICA EN NOCT**

Potencia máxima (Pmax)	372.81 W
Máxima capacidad de voltaje (Vmp)	35.09 V
Máxima capacidad de corriente (Imp)	10.61 A
Voltaje de circuito abierto (Voc)	42.19 V
Corriente de cortocircuito (Isc)	11.53 A

**Temperatura Nominal de Operación de la Celda (NOCT) : Irradiación:800W/m² · Temperatura ambiente : 20°C · AM : 1.5 · Velocidad del viento : 1m/s

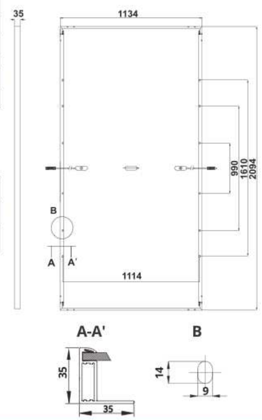
EGE-500W-132M(M10) Curva de temperatura I-V



CARACTERÍSTICAS MECÁNICAS

Tipo de celdas	Monocristalino (182x91 mm)
Número de celdas	132
Dimensiones	2094x1134x35mm
Peso	26.3 kg
Vidrio	3.2 mm Vidrio Templado
Marco	Aleación de aluminio anodizado
Caja de conexiones	Clasificación IP68
Cable	1.4m
Conector	Compatible con MC4 o MC4
Máxima carga frontal (ejem. nieve)	5,400 Pa
Máxima carga posterior (ejem. viento)	2,400 Pa

Dimensión del módulo fotovoltaico (mm)



CARACTERÍSTICAS DE TEMPERATURA RANGO MÁXIMO

NOCT	45 °C ±2 °C
Coeficiente de temperatura de Pmax	-0.35%/°C
Coeficiente de temperatura de Voc	-0.28%/°C
Coeficiente de temperatura de Isc	+0.048%/°C

Rango de temperatura de operación	-40 °C ~+85 °C
Máximo voltaje del sistema	1,500 DC (IEC)
Rango máximo de capacidad del fusible	25 A

EMBALAJE (2094x1134x35mm)

Tipo	Cantidad	Peso
Paleta	31 pzas	850 kg
Contenedor 40HQ	682 pzas	18.70 t

THERMO WIRE
TRANSFORMA TU ENERGIA

Las especificaciones incluidas en esta hoja de datos están sujetas a cambios sin previo aviso. Consulte nuestro sitio web para obtener más información o póngase en contacto con uno de nuestro personal de ventas.

System devices specifications: Inversor and Batteries

Technical data	Sunny Island 4.4M	Sunny Island 6.0H	Sunny Island 8.0H
AC-2 (External source: utility grid or generator)			
Rated grid voltage / AC voltage range	230 V / 172.5 V to 264.5 V		
Rated grid frequency / permitted frequency range	50 Hz / 40 Hz to 70 Hz		
Maximum AC current for increased self-consumption (grid operation)	14.5 A	20 A	26.1 A[6]
Maximum apparent AC power for increased self-consumption (grid operation)	3.3 kVA	4.6 kVA	6 kVA[6]
Maximum AC input current	50 A	50 A	50 A
Maximum AC input power	11500 W	11500 W	11500 W
Power factor range	0.8 overexcited to 0.8 underexcited		
AC-1 (Stand-alone mode, battery-backup, load)			
Rated grid voltage / AC voltage range	230 V / 202 V to 253 V		
Rated frequency / frequency range (adjustable)	50 Hz / 45 Hz to 65 Hz		
Rated power (at Unom, fnom / 25°C / cos φ = 1)	3300 W	4600 W	6000 W
AC power at 25 °C for 30 min / 5 min / 3 sec	4400 W / 4600 W / 5500 W	6000 W / 6800 W / 11000 W	8000 W / 9100 W / 11000 W
AC power at 45°C continuously	3000 W	3700 W	5430 W
Rated current / maximum output current (for 60 ms)	14.5 A / 60 A	20 A / 120 A	26.1 A / 120 A
Total harmonic distortion output voltage	< 5%	< 1.5%	< 1.5%
Power factor range	0.0 overexcited to 0.0 underexcited		
Battery DC input			
Rated input voltage / DC voltage range	48 V / 41 V to 63 V	48 V / 41 V to 63 V	48 V / 41 V to 63 V
Maximum battery charging current / rated DC charging current / DC discharging current	75 A / 63 A /75 A	110 A / 90 A / 103 A	140 A / 115 A /136 A
Battery type / battery capacity (range)	Li-Ion[1], FLA, VRLA / 100 Ah to 10000 Ah (lead-acid) 50 Ah to 10000 Ah (li-Ion)		
Charge control	IUoU charge procedure with automatic full charge and equalization charge		
Efficiency / self-consumption of the device			
Maximum efficiency	95.5 %	95.8 %	95.8 %
No-load consumption / standby	18 W / 6.8 W	25.8 W / 6.5 W	25.8 W / 6.5 W
Protective devices (equipment)			
AC short-circuit / AC overload	● / ●		
DC reverse polarity protection / DC fuse	– / –		
Overtemperature / battery deep discharge	● / ●		
Overvoltage category as per IEC 60664-1	III		
General Data			
Dimensions (W / H /D)	467 mm / 612 mm / 242 mm (18.4 inches / 21.1 inches / 9.5 inches)		
Weight	44 kg (97 lbs)	63 kg (138.9 lbs)	63 kg (138.9 lbs)
Operating temperature range	−25°C to +60°C (−13°F to +14°F)		
Protection class as per IEC 62103	I		
Climatic category as per IEC 60721	3K6		
Degree of protection according to IEC 60529	IP54		
RoHS-III compliant	●		

8.4.2 Cerchocó Comparison Analysis

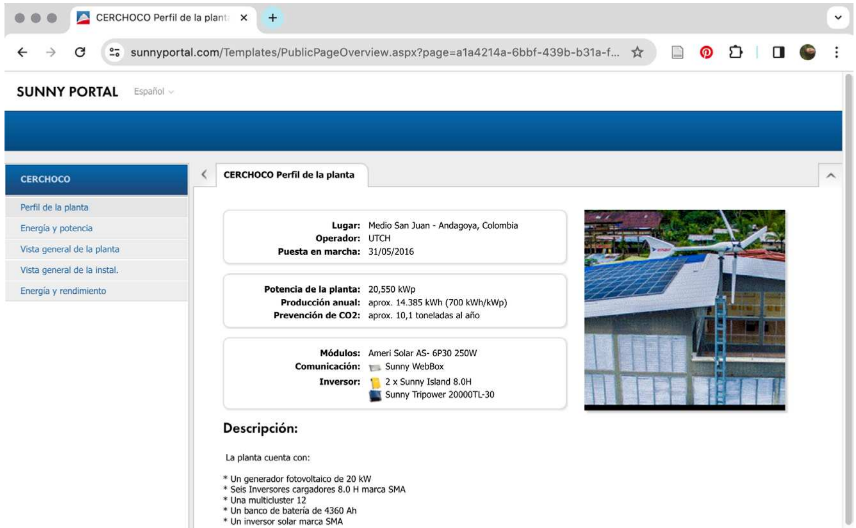


Figure 144. Cerchocó Online Overview. Source: sunnyportal.com, 2023.

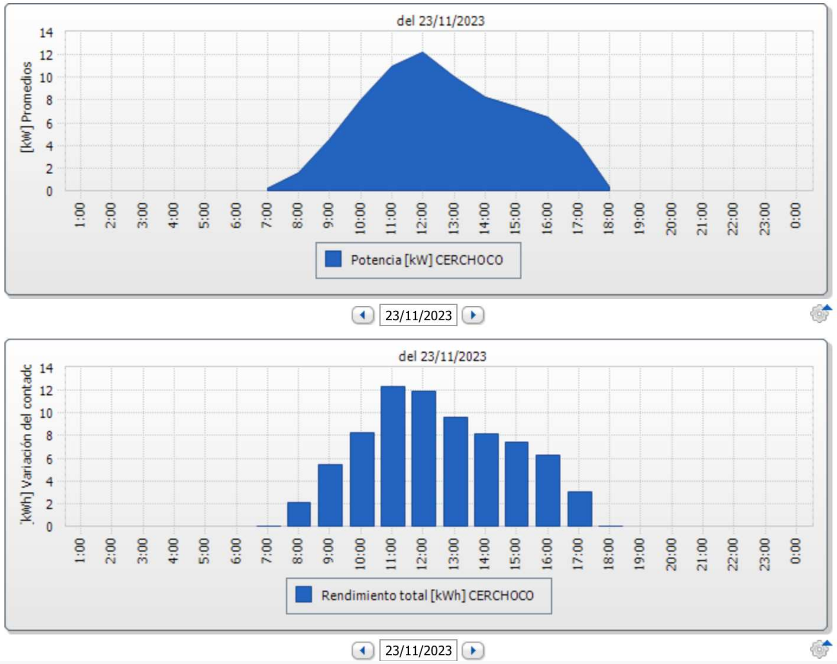


Figure 145. Cerchocó Online Overview results. Source: sunnyportal.com, 2023.

This analysis consists of comparing and staggering the Cerchocó solar plant, located in the municipality of Andagoya, 90 km away from Pizarro. This solar plant was inaugurated in 2016 with the intention of testing the energy performance of a 20 kW photovoltaic system in the Pacific region. The plant publishes the results online on the Sunnyportal.com website to share the results with the academic community. In this way, it is proposed to study this plant and make a staggering with the demand of consumption that was made in the manual calculation of pre-dimensioning.

Solar panels		
Amerisolar ASP-6P30		
Polycristalline silicon modules	80	units
Power (W)	250	W
Array power	20	kW
Batteries		
Sunlight (OPZS 2765)	48	units
Battery bank	132.7	kAh
Inverters		
SMS Sunny Island AC/DC	6	units
Power	20	kW
Vcc	220	Vac
Herz	60	Hz
Vmmp		
Range	320-800	V
Parallel branches	4	
Series per branch	20	

Figure 146. Battery system in Cerchocó Source: Aristizabal, 2023.

Figure 147. Photovoltaic modules in roof of Cerchocó. Source: Aristizabal, 2023.

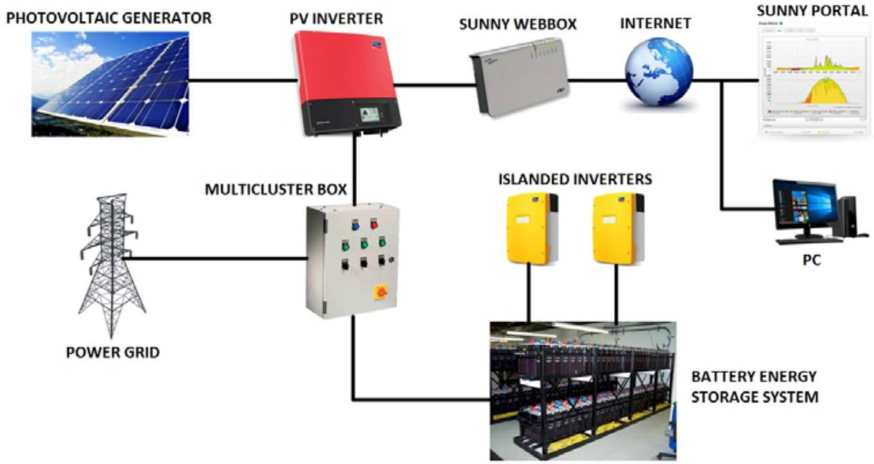


Fig. 3. Block diagram of the microgrid, including the devices of the monitoring system.

Figure 148. Block diagram of Cerchocó microgrid. Source: Aristizabal, 2023.

The system consists of 80 solar panels, each of 250 W, connected in 4 branches in parallel with 20 modules in series per branch. In addition to being connected to the centralized power grid, they also have a battery bank to simulate energy storage and analyze its efficiency.

After a year of operation, the professors in charge of the project conclude that the production of photovoltaic solar energy exceeded the forecast with 217 kWh/year in 2016. The solar radiation in the area averages 2.83 kWh/m2-day, allowing an increase in the AC-Power generation. The energy quality parameters were all within the limits recomended by IEEE-929-2000. (Aristizabal, 2017)

Cerchocó Comparison Analysis in 2022

Month	Total performance (kWh)	Forecast (kWh)
Jan	1,335.12	828.58
Feb	1,382.60	975.30
Mar	1,733.18	1,350.75
Apr	1,527.58	1,514.74
May	1,303.10	1,439.93
Jun	1,805.61	1,083.19
Jul	1,676.65	1,176.69
Aug	1,676.58	917.76
Sep	1,966.11	1,448.87
Oct	1,809.26	1,291.17
Nov	1,421.17	1,191.08
Dec	1,397.67	1,166.62
Annual	**19,034.63**	**14,384.68**
Monthly average	**1,586.22**	**1,198.72**

Year	Total performance (kWh)	Forecast (kWh)
2016	7,350	14,000
2017	8,920	14,000
2018	14,390	14,000
2019	11,030	14,000
2020	15,110	14,000
2021	15,590	14,000
2022	19,020	14,000
2023	15,320	14,000
	13,341 kWh	**14,000** kWh

Figure 149. Cerchocó comparison analysis Source: Aristizabal, 2023.

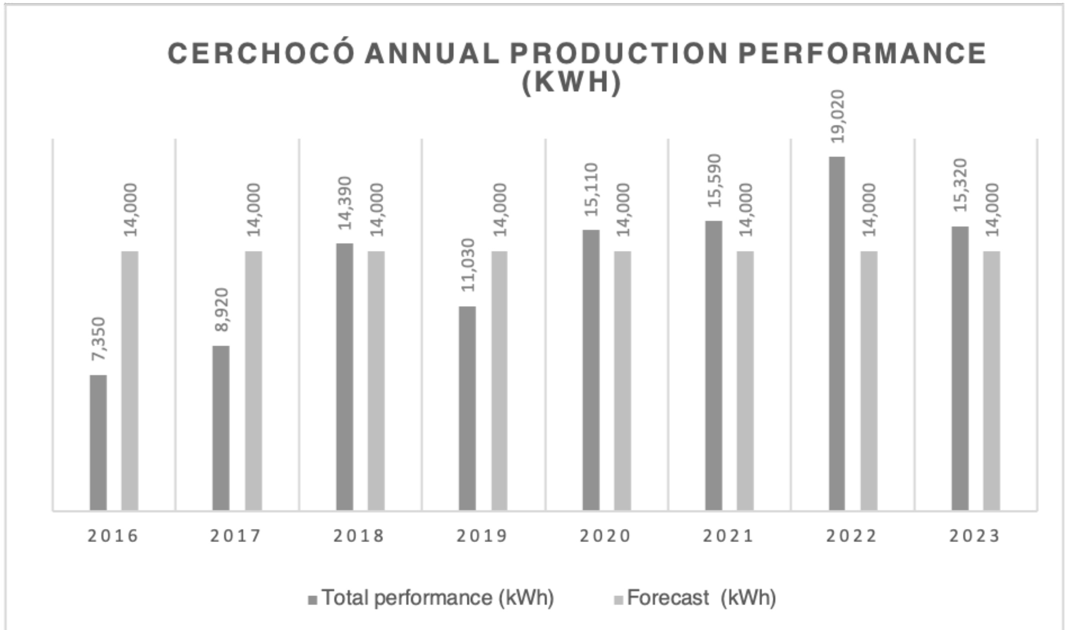


Figure 149. Cerchocó comparison analysis Source: Self-created, 2023.

This comparative analysis shows the number of panels that the proposal would need to supply its consumer needs. Making this dimensioning, the architectural proposal must use 256 panels in the case of consumption with passive systems and 321 panels in the case of the active system. It is important to note that this presizing requires more solar panels because they are 250W modules each.

8.4.3 PV Syst Software Simulation

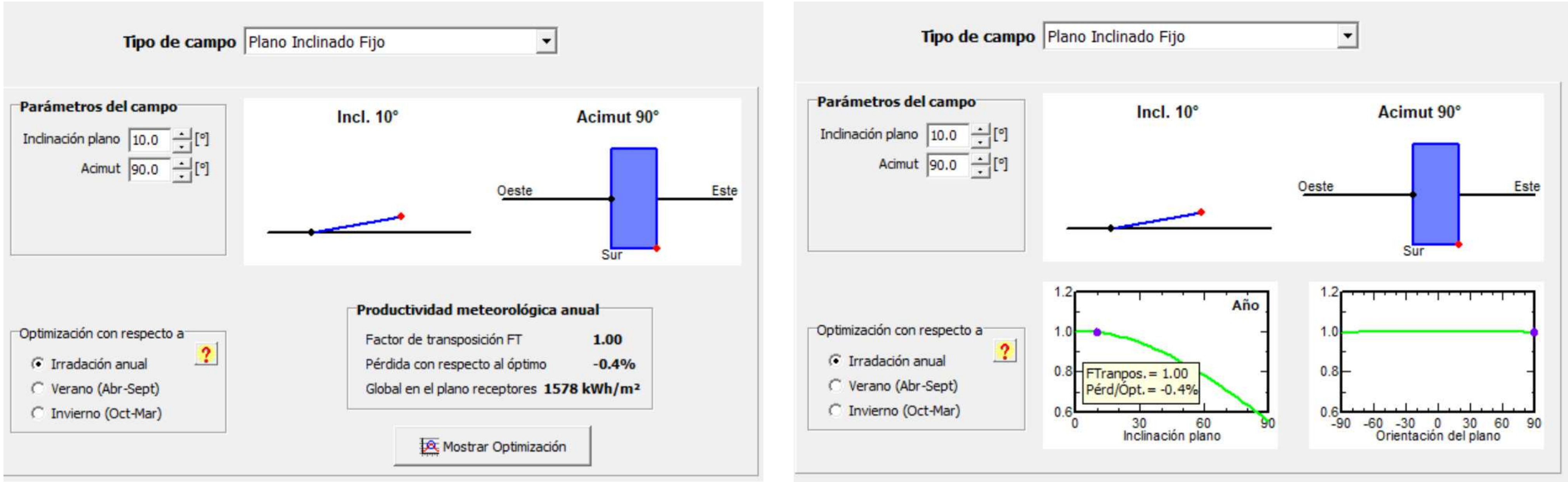


Figure 150. PV Syst Tilt configuration. Source: PV Syst, 2023. .

PV Syst is a software that allows you to simulate and dimension a photovoltaic system with accuracy. Preliminary to the calculation, the working area is defined in the software and the epw. data of the nearest weather station is loaded. The global solar radiation is the same as used in the previous calculations (4.3 kWh/m2-day).

After this is given the angle of inclination and orientation of the solar panels. In this section we also get a short analysis of the angle of inclination optimization. In this case it was provided from 10° to the west.

Because the program cannot do the calculation with different inclinations of the solar panels, this calculation was done with only one of the modules and not with the whole school. The results will therefore be individual per module. This type of calculation allows to modulate the proposal of the photovoltaic system and make a staggering according to the overall project.

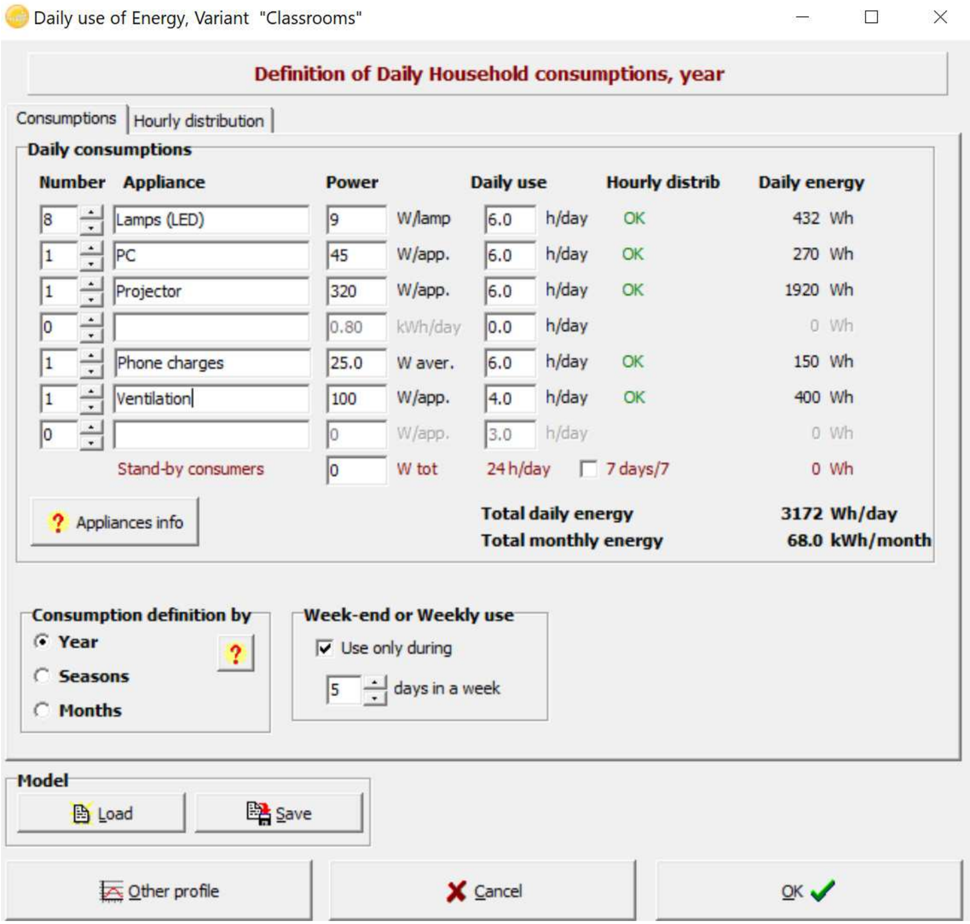


Figure 151. PV Syst Consumption profile configuration. Source: PV Syst, 2023. .

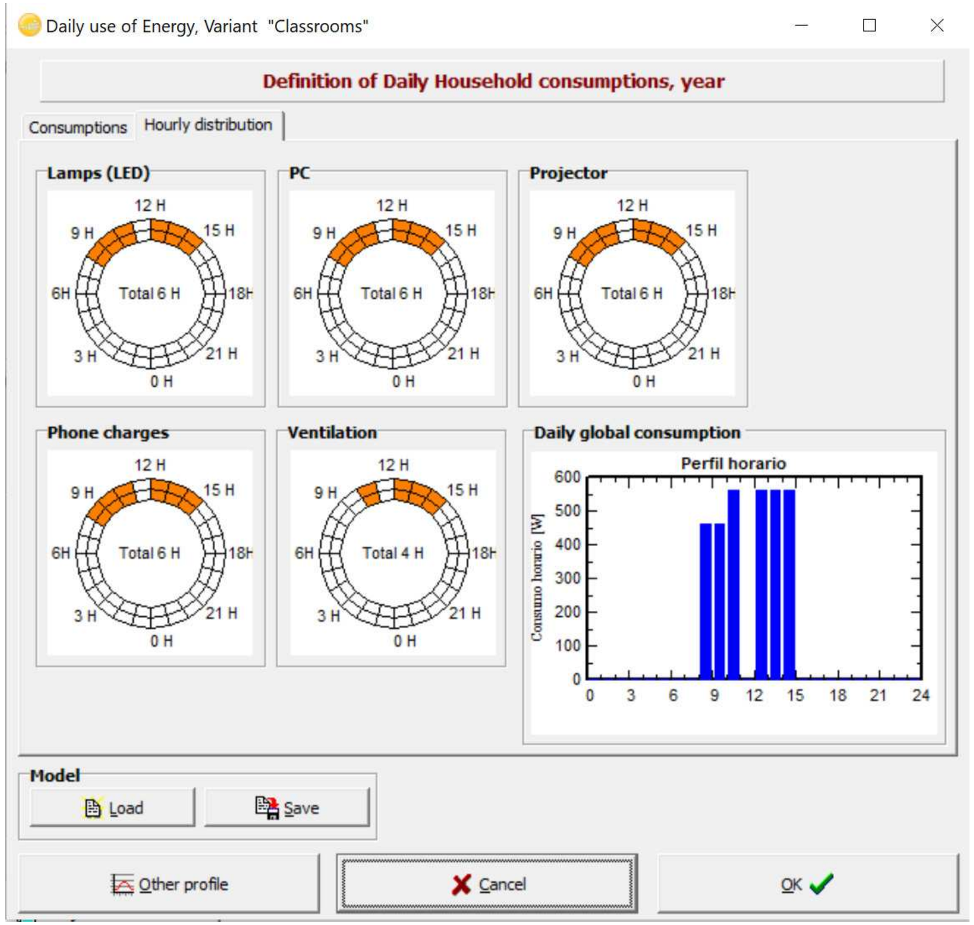


Figure 152. PV Syst Consumption profile configuration. Source: PV Syst, 2023. .

To define the consumption of the module, the software makes an annual calculation with the appliances that are used. The calculation is done in the same way as the manual calculation, multiplying the power by the number of appliances by the hours of daily use. This creates a consumption profile specifying the times of use and an average daily consumption profile is made. It is also possible to enter how many days a week have this consumption profile, to exclude weekends in the case of a school.

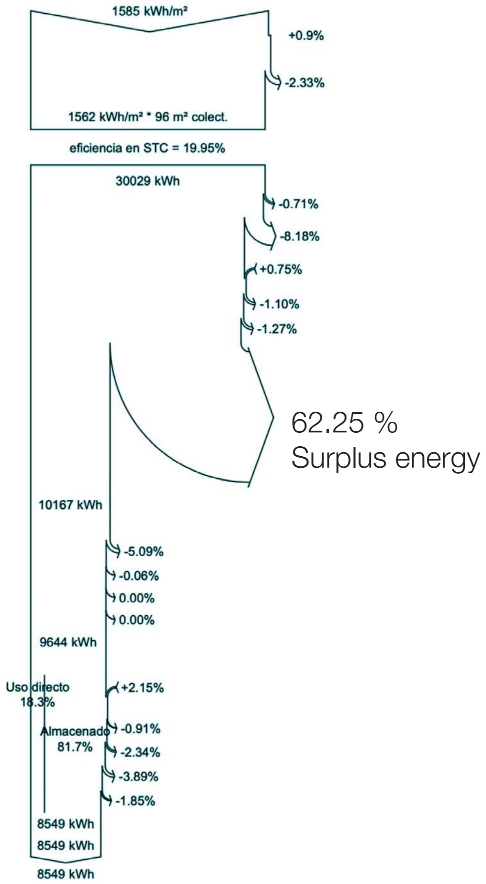
Then the operating system and its constituent parts are defined. This system definition is divided into: storage, photovoltaic generator, auxiliary system and a simplified calculation scheme advised.

You can also define the available area for solar panels and the program makes a system suggestion according to the need of consumption and available area.

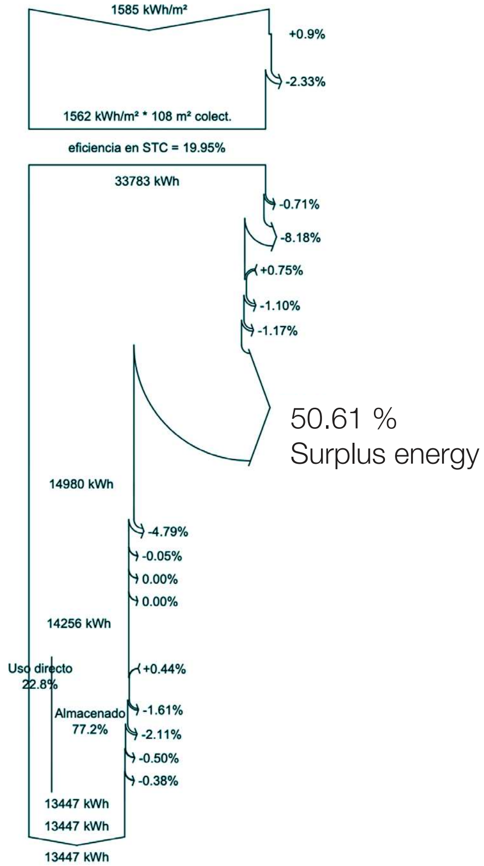
In this case, 400 W solar panels were chosen because they are the highest ever recorded in the program. The inverter is 36-48 V and 45 A, which means that you need more 1 inverter per classroom module. Solar panel set design is connected in 3 branches in parallel with 12 modules in series per branch.

The results of the calculations with the software were very similar to the manual calculations. This demonstrates the effectiveness of the pre-sizing method and the accuracy in the potential operation of the proposed photovoltaic system.

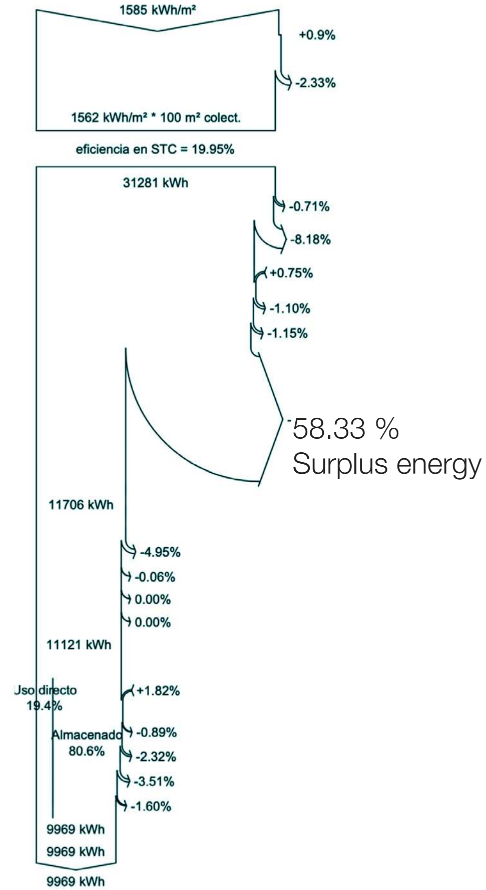
Classrooms



Library

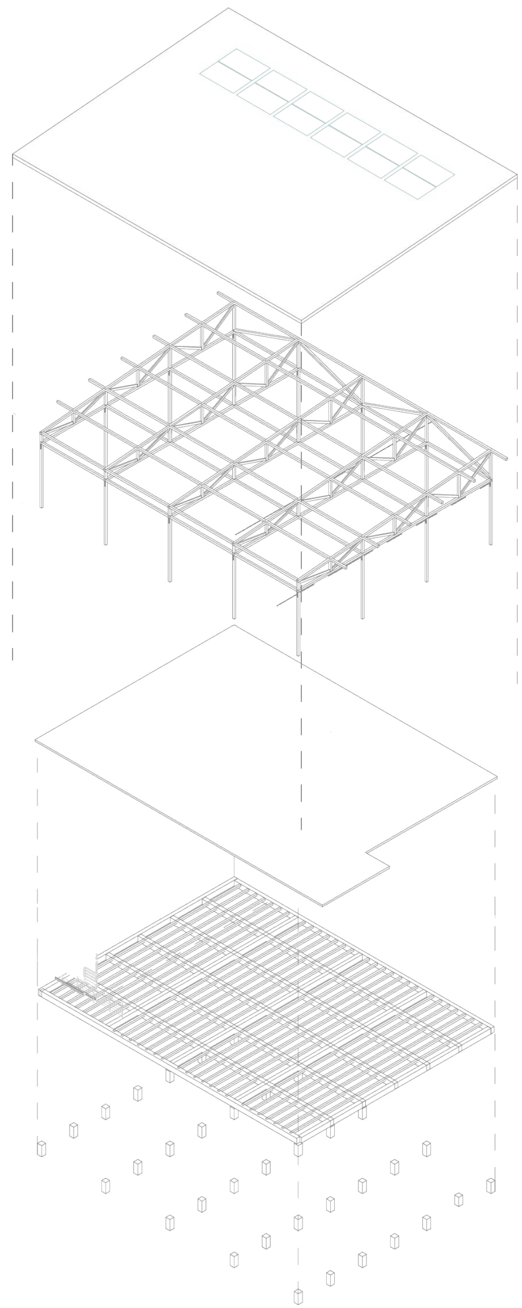


Cultural



9. Conclusions

9.1 Architecture
9.2 Energy autonomy



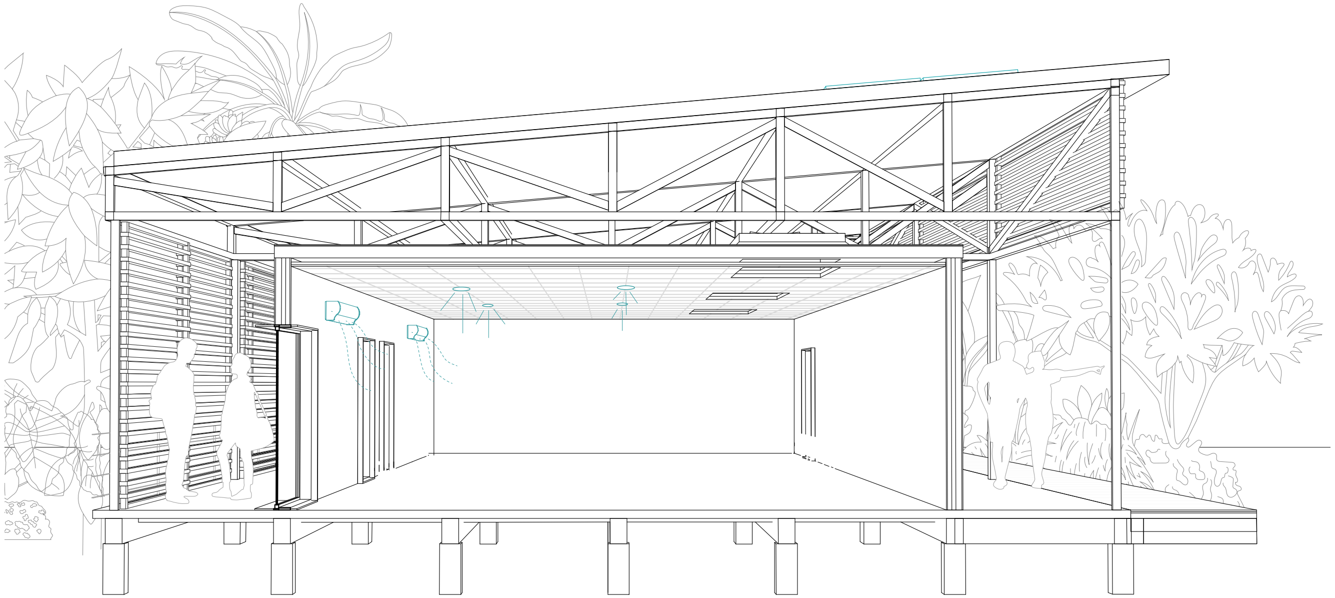
9.1 Architecture

The traditional architecture of the Pacific is distinguished by its bioclimatic passive strategies, preserving a cultural identity and coherence with the territory, while meeting standards of climatic comfort. This vernacular architecture not only embodies strategies that are easily translatable into contemporary architecture, but also offers modular solutions ideal for social investment projects.

The modularity inherent in this architecture allows flexible adaptation to different needs and contexts. In addition, it is shown that it is feasible to combine elements of tradition and culture with advances in photovoltaic technology in contemporary architecture.

This integrative approach not only preserves cultural richness and traditional practices, but also harnesses the opportunities that modern technology, especially photovoltaics, can offer to enhance sustainability and energy efficiency in the region.

For future projects, the integration of photovoltaic energy into traditional Pacific architecture can occur on smaller scales to facilitate prototype construction. It is important to maintain the functions offered by vernacular architecture while also innovating with construction systems that enhance energy efficiency and project feasibility.



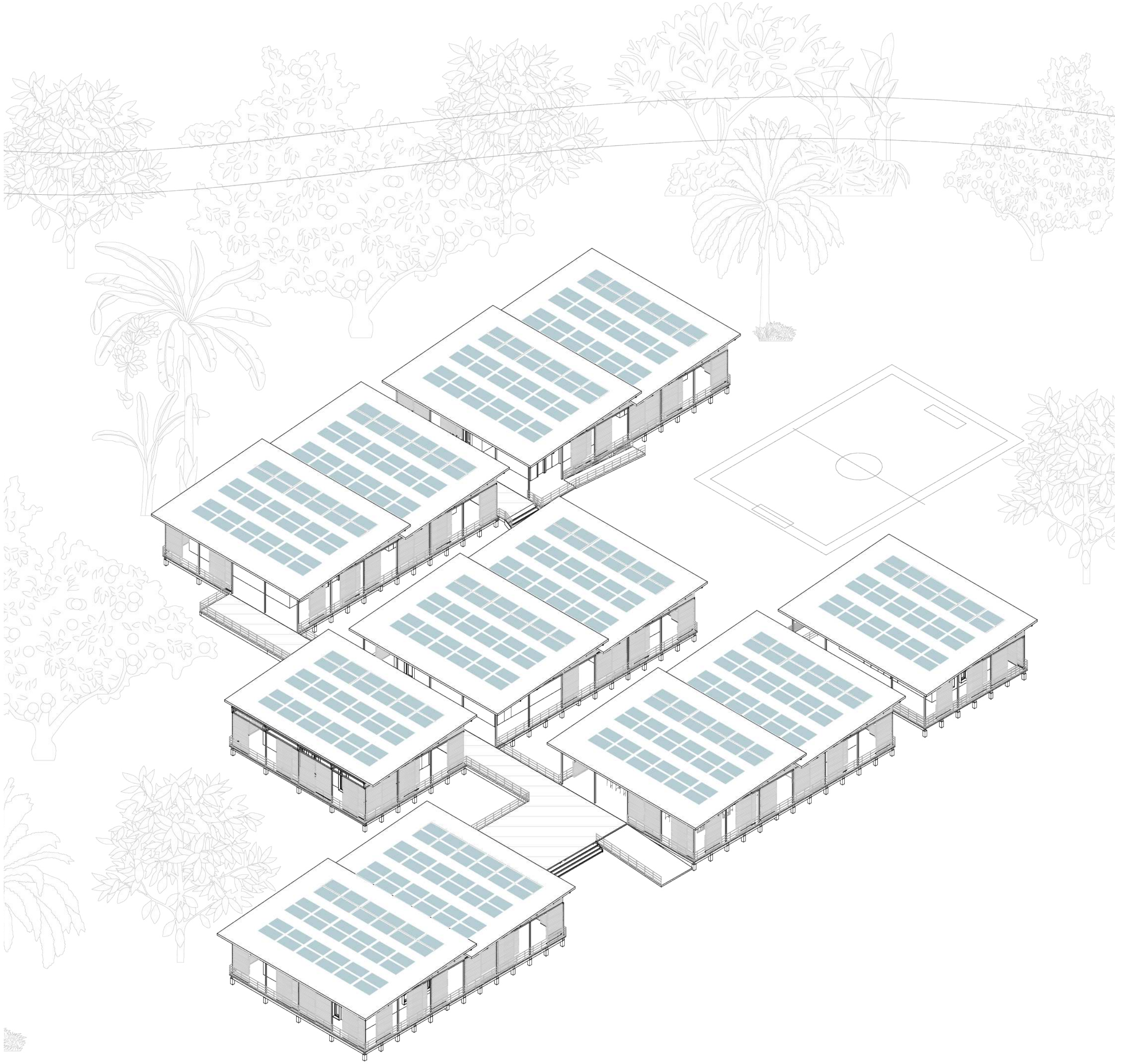
9.2 Energy autonomy

Energy efficiency design should be conceived as a comprehensive proposal from the early stages of architectural design, rather than being a later adaptation. Through a deep understanding of both needs, they can be met more effectively.

The non-interconnected areas of Colombia's Pacific have significant potential to lead the country's energy transition, replacing fuel-based generators with photovoltaic systems. Public facilities, such as schools, play a crucial role in this transition due to their community use. The community services of a school may also be reflected in the energy production it provides to the community.

Despite the economic and social resources available, energy self-sufficiency in the Colombian Pacific is not yet fully feasible. This is due to the yearly variations inherent in dependence on climatic events, and the constancy of these conditions cannot always be predicted. Dependence on batteries entails high costs, which makes completely autonomous proposals economically unfeasible. An energy transition, where energy sources and storage are diversified, is presented as a more affordable alternative to diesel generators.

Colombia is shown to have a significant photovoltaic power generation capacity. Although the Pacific region has lower capacity, production results are sufficient to supply local communities. These results can serve as an example for other areas of the country, connected to the national electricity grid, promoting photovoltaic production projects in public schools as sources of energy for their communities.



10. Bibliography

Acevedo Agudelo, H., Vásquez, A., & Ramírez Cardona, D. A. (2012). Sostenibilidad: Actualidad y necesidad en el sector de la construcción en Colombia. Gestión y Ambiente, 15(1), 105–117.

Acuna, M., Silva, C., Tocaruncho, A., Vargas, D., Patiño, D., Barrera, D., & Peña, J. (2021). Operational Planning of Energy for Non-Interconnected Zones: A Simulation-Optimization Approach and a Case Study to Tackle Energy Poverty in Colombia. Energies, 14(10), 2789. https://doi.org/10.3390/en14102789

Agencia de Renovación del territorio. (2021). Documento Hoja de Ruta. Región Chocó. https://www.renovacionterritorio.gov.co/especiales/hoja-ruta-pdet/choco.html

Akbari, H., Browne, M. C., Ortega, A., Huang, M. J., Hewitt, N. J., Norton, B., & McCormack, S. J. (2019). Efficient energy storage technologies for photovoltaic systems. Solar Energy, 192, 144–168. https://doi.org/10.1016/j.solener.2018.03.052

Andresen, I., Healey Trulsrud, T., Finocchiaro, L., Nocente, A., Tamm, M., Ortiz, J., Salom, J., Magyari, A., Hoes-van Oeffelen, L., Borsboom, W., Kornaat, W., & Gaitani, N. (2022). Design and performance predictions of plus energy neighbourhoods – Case studies of demonstration projects in four different European climates. Energy and Buildings, 274, 112447. https://doi.org/10.1016/j.enbuild.2022.112447

Ankara Yıldırım Beyazıt University, Faculty of Architecture and Fine Art, Ankara, Turkey, & Emekci, Ş. (2021). Sustainability in Architecture: Low-tech or High-tech? Proceedings Article, 107–111. https://doi.org/10.38027/ICCAUA2021216n14

Anzellini, M. (2016). Técnicas vernáculas. Programa Paisajes de Conservación. https://rds.org.co/apc-aa-files/ba03645a7c069b5ed406f13122a61c07/tecnicas_vernaculas.pdf

Arias-Gaviria, J., Valencia, V., Olaya, Y., & Arango-Aramburo, S. (2021). Simulating the effect of sustainable buildings and energy efficiency standards on electricity consumption in four cities in Colombia: A system dynamics approach. Journal of Cleaner Production, 314, 128041. https://doi.org/10.1016/j.jclepro.2021.128041

Aristizábal, C. E., & González, J. L. (2022). Energía solar fotovoltaica en instituciones educativas: Caso de estudio ITM campus Robledo. Semestre Económico, 24(57), 30–57. https://doi.org/10.22395/seec.v24n57a2

Banguero, E., Aristizábal, A. J., Habib, A., & Ospina, D. (2019). Experimental investigation and optimal power flow modelling of the first renewable microgrid in Chocó, Colombia. Energy Procedia, 157, 953–965. https://doi.org/10.1016/j.egypro.2018.11.262

Banguero, E., Aristizábal, A. J., & Murillo, W. (2017). A Verification Study for Grid-Connected 20 kW Solar PV System Operating in Chocó, Colombia. Energy Procedia, 141, 96–101. https://doi.org/10.1016/j.egypro.2017.11.019

Baptiste, B., & Franco, L. (n.d.). Revisión de las bases conceptuales de la Política Nacional de Biodiversidad. Anexo 1. Informe final: Fundamentos Técnicos y Conceptuales propuestos para la revisión de la Política Nacional en Biodiversidad.

Bonet-Morón, J. A., & Meisel-Roca, A. (2006). El legado colonial como determinante del ingreso per cápita departamental en Colombia. Banco de la República. https://doi.org/10.32468/dtseru.75

BP Statistical Review of World Energy BP p.l.c. (2022). BP Statistical Review of World Energy 2017 (p. 50). https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2022-full-report.pdf

Chandel, S. S., Sharma, V., & Marwah, B. M. (2016). Review of energy efficient features in vernacular architecture for improving indoor thermal comfort conditions. Renewable and Sustainable Energy Reviews, 65, 459–477. https://doi.org/10.1016/j.rser.2016.07.038

Colciencias. (2015). Ideas para el cambio. Pacífico Pura Energía. Catalogo de proyectos. Buenos y creativos S.A.S. https://drive.google.com/file/d/0B2kV7NZoxM-FSU5FREZSVjR4TTg/view?resourcekey=0-AuhA9eY5sVKoTiAwc-aV5g

Corredor, G. (2018). Colombia y la transición energética. Ciencia Política, 13(25), 107–125. https://doi.org/10.15446/cp.v12n25.70257

Di Terlizzi Escallón, S., Gama Rodríguez, I. D., & Jaramillo Quintero, T. (2021). Transición energética en colombia: No necesariamente una realidad que se sustenta en el cambio climático. Verba Iuris, 46(2), 105–128. https://doi.org/10.18041/0121-3474/verbaiuris.2.8493

Dias Pereira, L., Raimondo, D., Corgnati, S. P., & Gameiro Da Silva, M. (2014). Energy consumption in schools – A review paper. Renewable and Sustainable Energy Reviews, 40, 911–922. https://doi.org/10.1016/j.rser.2014.08.010

Documento de Manejo Ambiental Proyectos con sistemas fotovoltaicos. (p. 31). (2019). Instituto de Planificación y Promoción de Soluciones Energéticas para las ZNI. https://ipse.gov.co/requisites_formatos_y_guias/documentos/guia_manejo_ambiental/9%20A%20Gu%C3%ADa%20manejo%20ambiental%20tipo%20solares.pdf

Documento Hoja de Ruta. Región Pacífico y Fronter Nariñense. (2021). https://www.renovacionterritorio.gov.co/especiales/hoja-ruta-pdet/pacifico-frontera-narinense.html

Energy Profil. Colombia. (2023). International Renewable Energy Agency. https://www.irena.org/-/media/Files/IRENA/Agency/Statistics/Statistical_Profiles/South-America/Colombia_South-America_RE_SP.pdf?rev=d711a92ed4b2461582a959d55d4dd609

Escobar, A. (2018). Designs for the Pluriverse. Radical Interdependence, Autonomy and the Making of Worlds. Duke University Press.

Esteve, D. L. (n.d.). Análisis de la adaptabilidad de los criterios de diseño para una arquitectura resiliente y sostenible. 47.

García-Reyes Röthlisberger, M. I., & Fajardo, S. A. (2019). Saberes compartidos del hábitat: Una arquitectura para el paisaje rural. Dearq, 24, 34–47. https://doi.org/10.18389/dearq24.2019.03

Global Solar Atlas 2.0. (2019). Photovoltaic Power Potential. Colombia. (p. 1). World Bank Group. https://globalsolaratlas.info/download/colombia

Instituto de Planificación y Promoción de Soluciones Energéticas para las Zonas No Interconectadas - IPSE. (2022). ABC Estructuración de proyectos. https://ipse.gov.co/documentos_guia_estructuracion_proyectos/documentos/ABC%20Estructuraci%C3%B3n%20de%20Proyectos.pdf

International Energy Agency. (2023). Colombia 2023—Energy Policy Review. https://www.iea.org/reports/colombia-2023

IPSE & Centro Nacional del Monitoreo. (2023a). Informe mensual de telemetría Enero de 2023 (IPSE-GI-F06; p. 183). IPSE. https://ipse.gov.co/documentos_cmn/documentos/informes_mensuales_de_telemetria/2023/enero/INFORME_MENSUAL_DE%20TELEMETRIA_ENERO_DE_2023.pdf

IPSE, & Centro Nacional del Monitoreo. (2023b). Informe mensual de telemetría Julio 1-31 de 2023 (IPSE-GI-F06; p. 93). IPSE. https://ipse.gov.co/documentos_cmn/documentos/informes_mensuales_de_telemetria/2023/julio/INFORME_MENSUAL_TELEMETRIA_JULIO_DE_2023.pdf

Iván Higuera-Mendieta. (2017). Capítulo 8. Persistencias históricas y discontinuidades espaciales: El caso de los territorios comunitarios. In Estudios sociales del Pacífico colombiano (Luis Armando Galvis-Aponte, p. Pág.:291-322). Banco de la República de Colombia. https://repositorio.banrep.gov.co/handle/20.500.12134/7172

Ladino Peralta, R. E., & Vargas Navarro, F. (2020). La energía solar fotovoltaica como factor de desarrollo en zonas rurales de Colombia. Caso vereda Carupana, municipio de Tauramena, departamento de Casanare [Pontificia Universidad Javeriana]. https://doi.org/10.11144/Javeriana.10554.1085

Loyo, J. C., & Márquez, S. (2014, September). Dignificación y mejoramiento de técnicas vernáculas para el empoderamiento constructivo y el acceso a la habitabilidad básica: El caso de la familia Sánchez y el programa VACA del Tecnológico de Monterrey en Puebla. Sinapsis Social: Revista Cientifica de Sostenibilidad, 1(1), 43–66.

Ministerio de Minas y Energía. (2023). Diagnóstico—Base para la transición energética justa. (p. 393). Ministerio de Minas y Energia. https://www.minenergia.gov.co/documents/10439/2._Diagn%C3%B3stico_base_para_la_TEJ.pdf

Mora-Guarda, N. (2020, March 2). Zonas no interconectadas (ZNI) en Colombia: Un paraíso natural oculto donde las energias renovables se enfrentan a los combustibles fósiles, el aislamiento y la corrupción. Empowering People Network. https://empowering-people-network.siemens-stiftung.org/zonas-no-interconectadas-zni-en-colombia-un-paraiso-natural-oculto-donde-las-energias-renovables-se-enfrentan-a-los-combustibles-fosiles-el-aislamiento-y-la-corrupcion/

Nuñez de Castro, I., Barrera de Aragón, M., Sopo, A. M., Bedate, C. A., Mendoza, R., Salas Cardona, J. C., & Rueda, E. A. (1998). Ecología-humana: Una propuesta bioética (G. Cely Galindo S.J., Ed.; Colección Bioética). Centro Editorial Javeriano.
Osorio, C. E. (2016). Vivienda palafitica del pacífico. Expresión y persistencia de una forma de ver el mundo. Banco de la República. https://babel.banrepcultural.org/digital/collection/p17054coll18/id/331/

Ovalle, J. A., Rodriguez, N. M., & Escobar, A. (2020). ESTADO DE LA COBERTURA ELÉCTRICA Y LAS ZONAS NO INTERCONECTADAS EN LA REGIÓN CENTRAL. Región Administrativa y de Planeación Especial RAP-E - Universidad Distrital Francisco José de Caldas. https://regioncentralrape.gov.co/wp-content/uploads/2020/04/ESTADO-DE-LA-COBERTURA-ELECTRICA-Y-LAS-ZONAS-NO-INTERCONECTADAS-EN-LA-REGIÓN-CENTRAL-3-1.pdf

Peña Salamanca, E. J., & Palacios Peñaranda, M. L. (2015). LA BIODIVERSIDAD COMO ESTRATEGIA PARA EL DESARROLLO SUSTENTABLE EN EL PACÍFICO COLOMBIANO: ALGUNOS ENFOQUES PARA SU GESTIÓN. Ambiente y Sostenibilidad, 3(1), 37. https://doi.org/10.25100/ays.v3i1.4322

Poveda-M, I. C., Rojas-P, C. A., Rudas-Ll, A., & Rangel-Ch, J. O. (n.d.). EL CHOCÓ BIOGEOGRÁFICO: AMBIENTE FÍSICO. 22.

Quijano, A. (2000). Coloniality of Power and Eurocentrism in Latin America. International Sociology, 15(2), 215–232. https://doi.org/10.1177/0268580900015002005

Rodriguez Zambran, F. E., & Rodelo, L. M. (2020). Formulación de lineamientos básicos para el planeamiento de los asentamientos palafíticos en las zonas de baja mar de Tumaco—Nariño [Pontificia Universidad Javeriana]. https://doi.org/10.11144/Javeriana.10554.15558

Romero, J. (2009). Geografía económica del pacífico colombiano. Documentos de trabajo sobre economía regional. Banco de la República. https://repositorio.banrep.gov.co/handle/20.500.12134/3065

Unidad para las víctimas. (n.d.). Informe semestral de desplazamiento forzado 2022-1 (2022–1).
Uribe, D. (n.d.). Día de la Afrocolombianidad. https://open.spotify.com/episode/23ZgLFxrrRbWsmDxDblxvo?si=9eaa62cda7a746ad

Uribe, J. D. (n.d.). PRÓLOGO LOS RETOS DEL PACÍFICO COLOMBIANO: A MANERA DE INTRODUCCIÓN.
Viloria de la Hoz, J. (2008). Economías del Pacífico colombiano (1. ed). Banco de la República.

Vivas, J. (n.d.). El mapa de 1.710 poblados que aún se alumbran con velas en Colombia. El pacífico nariñense y chocoano, zonas del país con más rezago en el servicio de energía eléctrica. https://www.eltiempo.com/colombia/otras-ciudades/los-lugares-que-aun-viven-sin-energia-electrica-en-colombia-325892

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Acknowledgments

A este trabajo,

por ser puente a nuevas etapas,
dejarme con más ganas de crear y creer,
mostrarme el apoyo incondicional y sin límites de mi familia,
vivir el proceso con las personas que se conviertieron en mi familia,
dejarme recibir fortaleza de las personas a mi alrededor,
ayudarme a encontrar aprendizajes y oportunidades en los tropiezos,
conectarme con mi país y permitirme conocerlo más,
dejarme imaginar escenarios futuros en los que antes no creía,
guiarme a estar en constante aprendizaje y mantener viva la curiosidad,
enseñarme sobre mis debilidades y virtudes,
mostrarme todo lo que aún quiero aprender y hacer,

por ser puente para que mucho más continue,

Gracias.