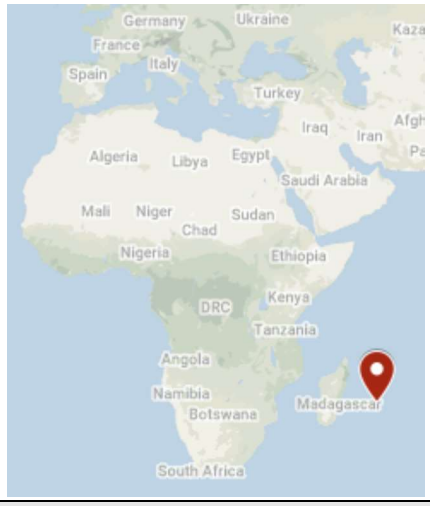
CASE STUDY 2-03: AIME CESAIRE SCHOOL | LA REUNION



GEOGRAPHICAL AND CLIMATE INFORMATION	
Location	24 rue des Oliviers Bois d'Olives, 97432 Saint-Pierre, La Réunion
Latitude; Longitude	-21.295968339045405, 55.46041647459686
Climate zone (Köppen–Geiger classification)	Aw: Equatorial savannah with dry winter
BUILDING INFORMATION [1][2]	
Building Type	Educational (Kindergarten and primary school)
Project Type	New construction
Completion Date	2017
Number of buildings	1
Number of storeys	3
Total Floor Area (m²)	-
Net Floor Area (m²)	1 684
Thermally conditioned space area (m²)	44,5 (technical and IT rooms)
Spaces with Natural Ventilation (with or without Ceiling Fans) Only (m²)	1 330
Total cost (€)	4 886 463
Cost /m² (€/m²)	2901.7
Performance Standards or Certification	PERENE tool (acronym for Energy performance of buildings)
Awards	International winner of the Green Solutions Awards 2017 – Energy & Hot Climate category – Construction21
STAKEHOLDERS [2][3]	
Building Owner/ Representative	City council of Saint-Pierre (La Réunion)
Architect / Designer	APA - Antoine Perrau Architectures
Environmental consultancy	LEU Réunion
Structural Engineer, Civil Engineer	GECP

MEP consultancy	ATELIER D'INGENIERIE REUNIONNAIS
Landscape design	Michel Reynaud
Others	CREATEUR, DOREMI CONSEIL, CPS

PROJECT DESCRIPTION [2][3]

Figure 35 : Exterior view of the North-West façade of the building. (© Hervé DOURIS)

Figure 36 : Exterior view of the South-East façade of the building. (© Hervé DOURIS)

The Aimé Césaire school is composed of 12 classrooms (5 nursery classes, 7 elementary classes) and the associated external spaces, representing 1.676 m² of built surfaces, 345 m² of sheltered surfaces (courtyards and shelters) and 1.680 m² of exterior surfaces. The project is based on a sustainable development approach specific to tropical and subtropical climates, supported by the PERENE calculation tool. The building proposes a bioclimatic architecture which structures the organization of the volumes and the technical choices of the project.

This school was designed following two differentiated inscriptions. The first one protects the spaces to the point of covering them with a unifying shading structure. This is the space of the youngest. The other one opens its courtyards and its playgrounds around and under the buildings, and is protected by their vegetation forming a boundary with respect to the trade winds of the eastern sector. This is the space of the elementary school.

The school is the first place of experience with the educational environment. The main objective was to design an architecture that would allow children to form their spatial, visual and sensory references. Bioclimatic design is therefore a tool for raising awareness among the youngest and can be used by teachers for educational purposes.

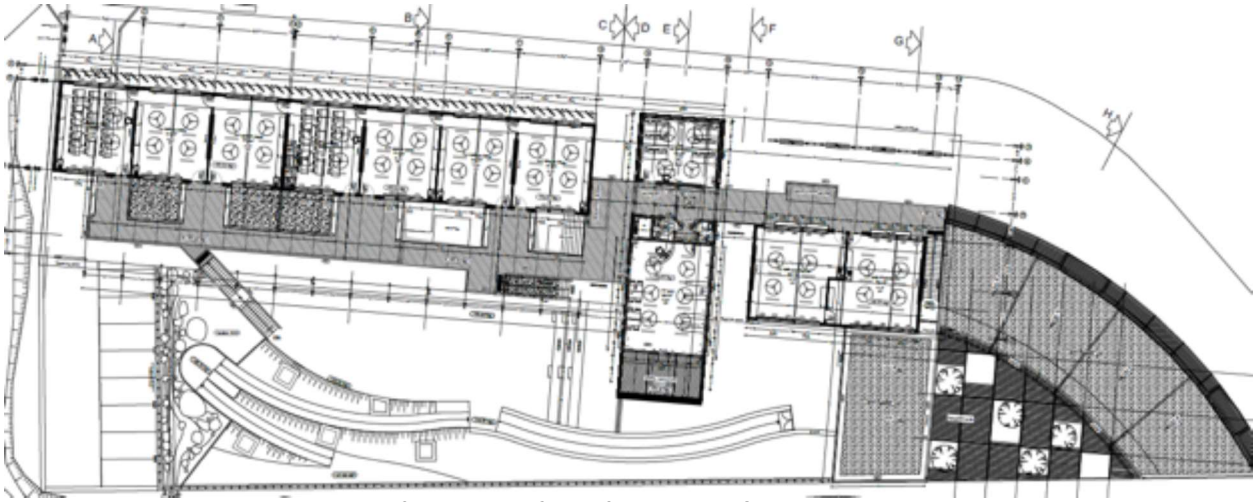


Figure 37: Floor plan of the second floor of the school. © Antoine Perrau Architecture.

SITE INTEGRATION [3]

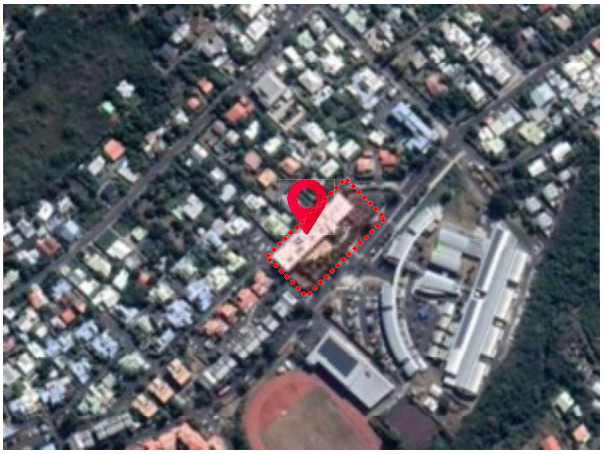


Figure 38 : Aerial view of the building in its surrounding environment. (Source: Google Map)

The 12-classroom school is located in the neighbourhood of "Bois d'Olive" at Saint-Pierre, La Reunion. The Bois d'Olives neighborhood is a spontaneous and continuous urbanization of agricultural land under land pressure. It is in this context, mixed with vernacular housing, collective housing and facilities, that the Aimé Césaire school is located. The building faces the entrance of the high school located on the other side of the Laurent Vergés Avenue, which is itself well served by public transportation. A minimal disruption of the site is operated which allows to limit the impact of the project on the territory. The project proposes a very sober volumetric impact deployed by making the best use of the effects of site and natural slopes, slightly embedded upstream and on piles downstream.

CLIMATE ANALYSIS

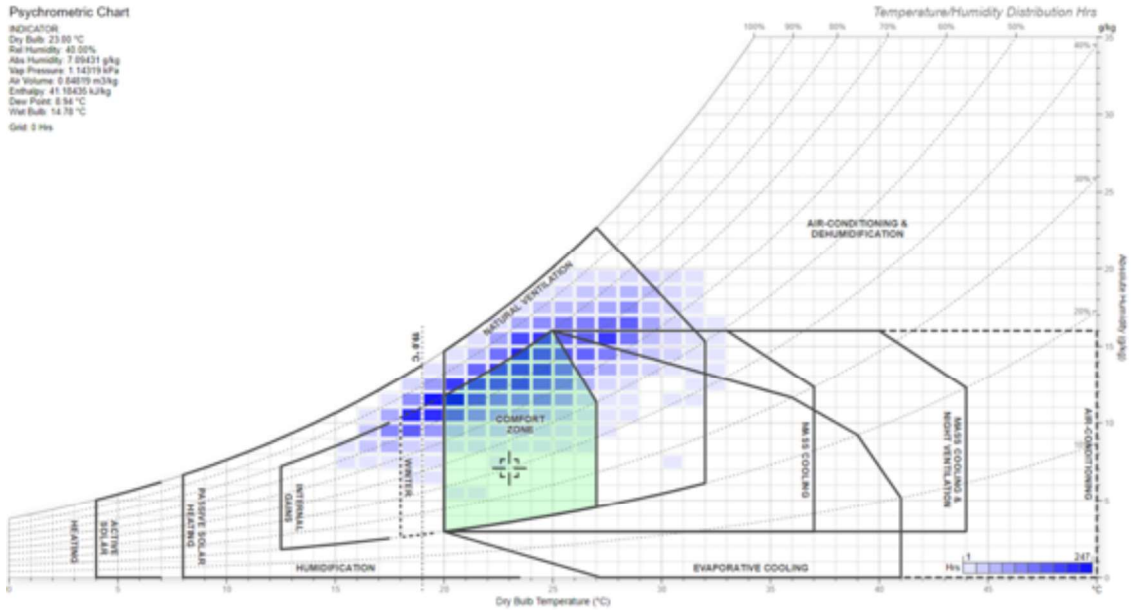


Figure 39: Givoni Bioclimatic chart for the climate of Saint-Pierre, La Reunion using Andrew Marsh online tool [2].

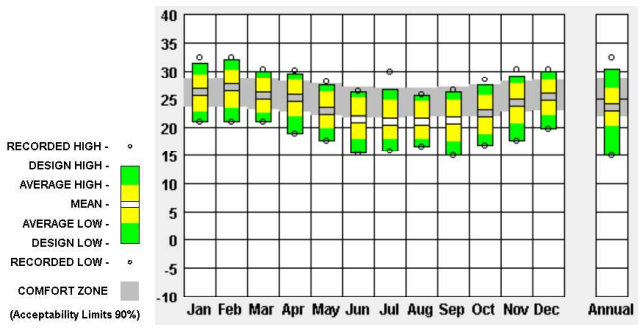


Figure 40: Temperature range by month for Saint-Pierre, La Reunion (Source: Climate consultant – Adaptative Comfort model).

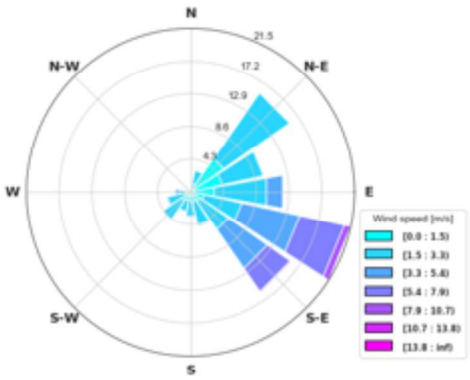


Figure 41: Wind rose for Saint-Pierre, La Reunion (Beaufort wind scale).

Global horizontal radiation (Avg daily total) Min (month) / Max (month)	Min: **3 933** Wh/m² (Jun) Max: **7 580** Wh/m² (Dec) Mean: **5 750,25** Wh/m²
Annual Degree-Days for weather classification according to ASHRAE Standard 169-2020	HDD 18°C: **9** CDD 10°C: **4977**
Annual Degree-Days for the Adaptive Comfort Base Temperature according to the ASHRAE 55-2017	HDD: **158** CDD: **8**
Annual Degree-Days for a static comfort temperature approach	HDD 18.6ºC: **20** CDD 26º: **171**

KEY BIOCLIMATIC DESIGN PRINCIPLES [2][3]	
Passive cooling strategy	**Comfort ventilation** (natural cross ventilation) All the classrooms and offices are naturally ventilated. This was made possible thanks to the design of a simple, elongated and thin building form, the optimal orientation of the building, the general interior organization of the classrooms as well as the use of full-height glass louvers located on opposite facades, with a high porosity.
Passive heating strategy	None
Solar protection	Solar and climatic protection of indoor and outdoor spaces are provided by the large roof that acts as a canopy and covers the various built volumes and unbuilt spaces, as well as different solar protection strategies for each orientation. Bioclimatic pergolas placed in the courtyards also create shaded spaces that serve both as a friendly playground area and as a climate refuge.
Building orientation	The main facades of the building are oriented NW/SE. Urban issues and the need to fit into the site were of course predominant in the building's layout. However, they were able to combine with a satisfactory solar exposure (even if not completely optimal) and with an orientation very favourable to thermal breezes.
Insulation	Thermal and acoustic insulation of the roof are ensured by a double-skinned reflective metal cover and two green roofs.

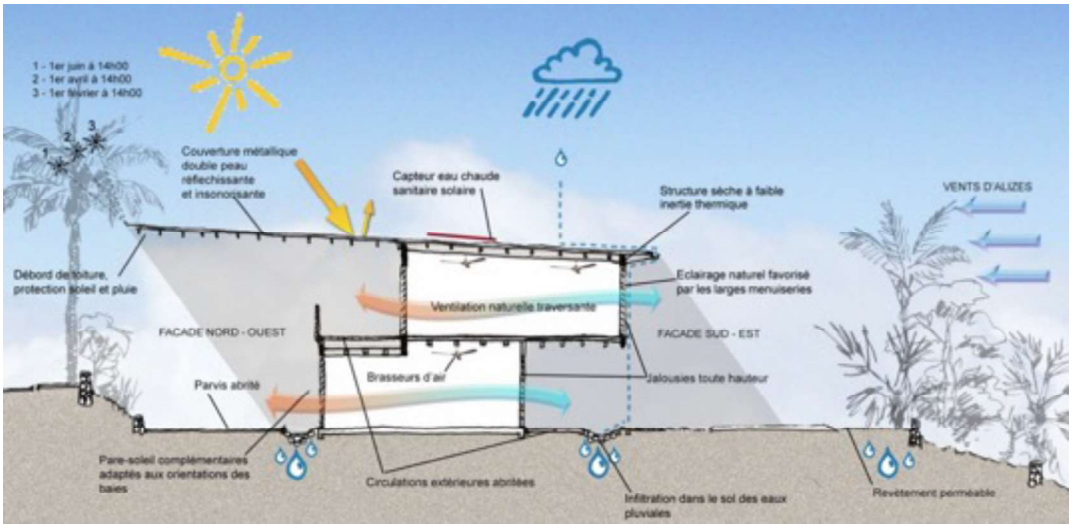


Figure 42: Cross section of the passive solutions set up for the school. © Antoine Perrau Architectures

Vegetation	The vegetation is used as a design element aiming, through omnipresent gardens designed on the forest model, at hygrothermal comfort, visual comfort and air quality by dust filtration. The gardens also contribute to the pleasantness of the place. The vegetation at the interface of Vergés Avenue provides protection from the prevailing east/southeast winds. Endemic species were chosen for their ability to adapt to the local climate and thus limit the need for watering and maintenance.
Natural daylighting	Daylighting autonomy during school hours is maximize thanks to thin buildings, reflective ceilings and full-height louvers on both facades.
Use of local and embedded materials	None. The choice of a "dry" wood-frame architecture has been considered as a relevant response to the issues of hygrothermal comfort. The use of concrete was restricted to the infrastructure and the dining room for structural and maintenance reasons.
Water saving and flood management	Management of rainwater by infiltration and temporization on the plot thanks to drainage ditches and embankments.
Waste management	Specific bins for recyclable waste (paper, cardboard, plastic and metal)
Others features	The choice of materials was determined by their durability, low maintenance and sanitary quality. The exterior materials are used raw and/or without paint: Class IV pine frame, Douka (exotic wood) cladding and decking, thermo-lacquered composite panel cladding, natural aluminum finish roofing and rubble stone cladding. For the interior materials, the choice of healthy products was privileged: Acrylic-based interior paints without VOCs (organo-volatile compounds), rubber floors recognized for their low VOC emissions, plasterboard partitions (hygrometry regulation quality).

(a) (b) (c)

Figure 43: Different solar protection strategies have been set up according to the orientation of the facades: (a) The umbrella roof is the key feature of the project, (b) Vertical textile sunshades on metal frame in front of the primary classrooms and composite cladding in front of the dining room, and (c) Double skin with horizontal wood strips on the facade of the kindergarten classes (N-W) on pedestrian pathway. © Hervé DOURIS

Figure 44 : Wooden pergola and trees in the kindergarten playground.

Figure 45: View on the second-floor exterior corridors.

INFRASTRUCTURES and REGULATIONS to enable SUFFICIENCY ACTION	
Dressing code	Informal dressing, adapted to the season, is welcome and promoted (e.g. short trousers and short leaves in hot periods): **Yes**
Protected bike parking and showers	**Yes: 5 bike racks** If yes, Ratio with number of users: **-**
Ceiling fans	In every room, even those conditioned: **Yes**
Lighting system fractioned to allow using light only in zones occupied and where daylighting insufficient	In every room, even those conditioned: **Yes**
Space and facilities for line drying clothes (especially important in residences, hotels, sport facilities…)	In every room, even those conditioned: **No**
Book of instruction for correct use of the passive features (windows, solar protections, water savings) and active (lighting…) in order to promote sufficiency and efficiency actions	Available through leaflets and posters at relevant places, online, etc.: **No**
BUILDING FABRIC AND MATERIALS	
Roof	The **umbrella roof** is composed of (from outside to inside): ▪ Steel roofing sheet [0.04m] (COVERIB, Ondulit) ▪ Air gap [0.06m] ▪ Double-sided pre-painted galvanized steel ribbed sheet [0.04m]
Windows	Type of materials: Clear glass louvers – different height [1.9m, 2.40m or 2.90m]
	Window-to-wall ratio (WWR): **-** (% of glazed area)
Walls	The majority of the **Exterior walls** are composed of (from outside to inside): ▪ Composite cement siding (HardiePlank type) [0.022m] ▪ Counter batten section 25/40 mm (treated pine) ▪ Rainscreen film ▪ Timber frame 58/168 mm (treated pine) with 0.1-68 m of rock wool ▪ FERMACELL panel [0.0125m]
	The **Interior Walls** are structured as: ▪ FERMACELL panel [2 × 0.0125m] ▪ Timber frame 46/120 mm (in treated pine) with 0.12m of rock wool ▪ FERMACELL panel [2 × 0.0125m]

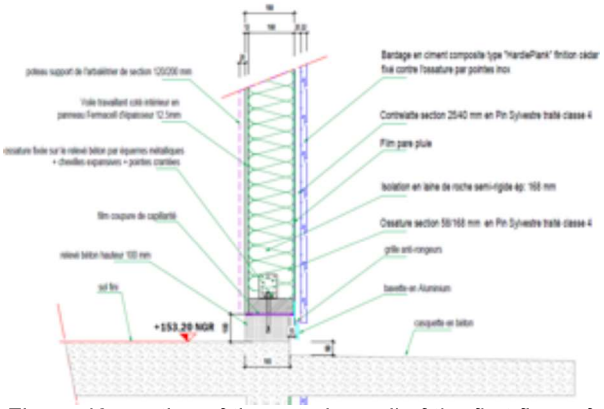


Figure 46: section of the exterior wall of the first floor of the primary school. © Antoine Perrau Architecture.

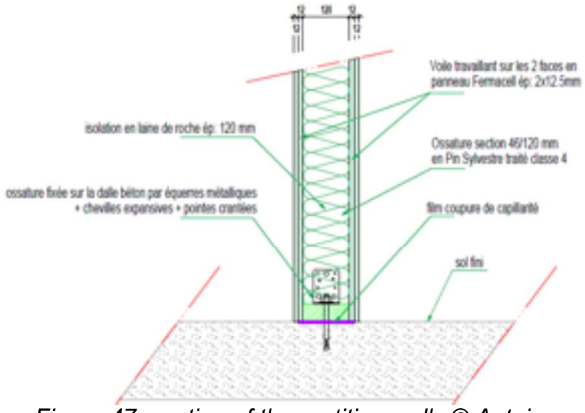


Figure 47: section of the partition walls.© Antoine Perrau Architecture.

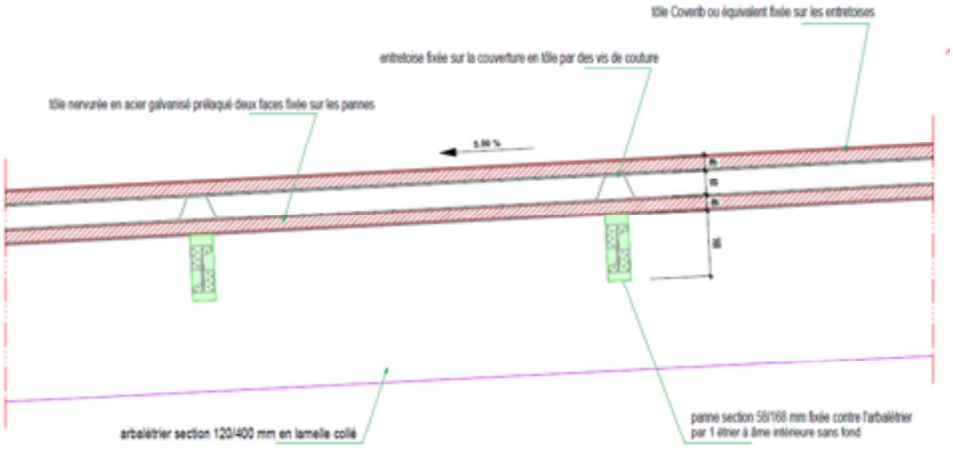


Figure 48: section of the umbrella roof. © Antoine Perrau Architecture.

ENERGY EFFICIENT BUILDING SYSTEMS	
Low-energy cooling systems	Only the IT and technical room are air-conditioned thanks to energy efficient split systems (European energy efficiency category: A+ / EER (Energy Efficiency Ratio) measured by Eurovent superior to 3.4)
Low-energy heating systems	None
Ceiling fans	**Brand / Model: Hunter Carera -** Model 24241 A total of **88 ceiling fans** with a **132 cm blade diameter** are installed in the offices, the classrooms and the canteen. The use of ceiling fans guarantees additional air speed during windless days. They are used in conjunction with the natural ventilation strategy to create air movement on the skin of the occupants, increasing their comfort. The **maximum power** used for one ceiling fan is **67 W**, with a ratio of **one ceiling fan per 10-15 m².** Ceiling fans have **three speed levels** and a **maximum speed of 190 Rpm.**
Mechanical ventilation / air renewal	The principle of ventilation/ air renewal retained is as follows: ▪ natural ventilation of the premises (preferred solution) through the openings,

	▪ specific ventilation of the pantry and the laundry by mechanical extraction through a hood, ▪ ventilation by single flow mechanical extraction of the checkrooms and the kitchen storerooms.
Domestic Hot Water	The hot water needs are covered by: ▪ A solar hot water production system for the kitchen and the restaurant; ▪ Instantaneous electric water heaters for the other needs, such as the cleanliness room or the locker rooms.
Artificial lighting	Fluorescent and LED lights have been installed depending on the type of rooms and usage. The installed electric density for artificial lighting ranges from 8 to 11 W/m^2. The exterior lighting is provided by luminaires controlled automatically by a twilight switch and programmable timer with the possibility of manual control from the administration building.
Control and energy management	None

Figure 49: All classrooms are naturally ventilated and equipped with efficient ceiling fans. © Hervé DOURIS

Figure 50 : Interior view of the school canteen. © Hervé DOURIS

Figure 51 : View of the full-height glass louvers from the exterior corridor

Figure 52 :View of the green roof

RENEWABLE ENERGY	
PV	None
Solar thermal	Solar thermal panels, totalling 30 m², ensure the supply of hot water in the kitchen and the restaurant.
Wind	None
Geothermal	None
Biomass	None

BUILDING ANALYSIS AND KEY PERFORMANCE INDICATORS

Thermal comfort indicators

1. Percentage of time outside an operative temperature range (Adaptive)
2. Percentage of time outside an operative temperature range (Fanger)
3. Degree-hours (Adaptive)
4. Degree-hours (Fanger)
5. Percentage of time inside the Givoni comfort zone of 1m/s: **Ground Floor: 90-95 %** **First floor: 24-70%**
6. Percentage of time inside the Givoni comfort zone of 0m/s: **Ground Floor: 0 %** **First floor: 0%**
7. Number of hours within a certain temperature range: **Hot period (26th Feb. to 12th March 2022) / Occupation time: 8:00am to 4:00pm**

	GROUND LEVEL							
	E1		E2		E4		E5	
Range	Nb of Hours	Fq	Nb of Hours	Fq	Nb of Hours	Fq	Nb of Hours	Fq
T<22°C	0	0%	0	0%	0	0%	0	0%
22°C≤T<24°C	0	0%	0	0%	0	0%	0	0%
24°C≤T<26°C	1	1%	1	1%	0	0%	2	1%
26°C≤T<28°C	45	33%	55	41%	43	32%	102	76%
28°C≤T<30°C	85	63%	78	58%	86	64%	31	23%
30°C≤T<32°C	4	3%	1	1%	6	4%	0	0%
32°C≤T<34°C	0	0%	0	0%	0	0%	0	0%
34°C≤T<36°C	0	0%	0	0%	0	0%	0	0%
T≥36°C	0	0%	0	0%	0	0%	0	0%

	FIRST LEVEL							
	P1		P3		P4		P5	
Range	Nb of Hours	Fq	Nb of Hours	Fq	Nb of Hours	Fq	Nb of Hours	Fq
T<22°C	0	0%	0	0%	0	0%	0	0%
22°C≤T<24°C	0	0%	0	0%	0	0%	0	0%
24°C≤T<26°C	0	0%	1	1%	0	0%	0	0%
26°C≤T<28°C	3	2%	15	11%	23	17%	5	4%
28°C≤T<30°C	32	24%	**94**	70%	**82**	61%	42	31%
30°C≤T<32°C	**72**	53%	**24**	18%	27	20%	**85**	63%
32°C≤T<34°C	**28**	21%	1	1%	3	2%	**3**	2%
34°C≤T<36°C	0	0%	0	0%	0	0%	0	0%
T≥36°C	0	0%	0	0%	0	0%	0	0%

Energy performance indicators	1. Energy needs for heating (kWh/y/m2)
	2. Energy needs for cooling (kWh/y/m2)
	3. Energy use for lighting (kWh/y/m2)
	4. Energy needs for Sanitary Hot water (kWh/y/m2)
	5. Total Primary energy use: **89 [kWh/m^2/year] (total Primary Energy Factor (PEF) equal to 3.3 for electrical energy from the grid)**
	6. Renewable Primary energy generated on-site (kWh/y/m2)
	7. Renewable Primary energy generated on-site and self-consumed (kWh/y/m2)
	8. Renewable Primary energy exported to the grid: **0 [kWh/m^2/year]**
	9. Ratio of renewable primary energy over the total primary energy use (with and without compensation) (%)
	10. Delivered energy (from electricity bills): **27 [kWh/m^2/year]**
Acoustic comfort indicators	1. Airborne sound insulation
	2. Equivalent continuous sound Level
	3. HVAC noise level
	4. Reverberation time
	5. Masking/barriers
Visual comfort indicators	1. Light level (illuminance)
	2. Useful Daylight Illuminance (UDI)
	3. Glare control
	4. Quality view
	5. Zoning control
Indoor Air Quality indicators	1. Organic compound
	2. VOCs
	3. Inorganic gases
	4. Particulates (filtration)
	5. Minimum outdoor air provision
	6. Moisture (humidity, leaks)
	7. Hazard material
Users' feedback	No POE has been conducted for this school but we had some negative feedback from the teachers, specifically for the classrooms at the first floor. Two classrooms present uncomfortable indoor conditions due to the lack of solar shadings of the South-East facades coupled with a bad insulation of the roof. Users complain about the hot conditions of work in summer. They complain as well about the too important air movements in the classrooms.

LESSONS LEARNED AND RECOMMENDATIONS	
Lessons learned	Overall, the classrooms at the ground level are comfortable with comfort conditions that are reached 90% of the time during the hot season. Despite the bioclimatic and passive design of the school, the measurement campaign has pointed out a bad thermal behaviour for all the classrooms at the first level that lead to higher air temperatures and dissatisfaction. Comfort conditions in those classrooms are reached only 25%-40% of the time only.
Recommendations	It is recommended:

- to improve the insulation of the roof;
- to install horizontal solar shadings for the classrooms located at the first-floor level that are exposed to solar radiation.

BUILDING STRENGTHS AND WEAKNESSES

Strengths



Passive Design	**Energy Efficiency**	**Renewable Energy**

Weaknesses

Lack of efficient solar shading systems for 2 classrooms facing SE, at the second floor and low insulation of the roof.

REFERENCES

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2. https://www.construction21.org/france/case-studies/h/groupe-scolaire-de-bois-d-olives.html
3. https://www.envirobat-reunion.com/SPASSDATA/ALGEDIM/QOKQWR/D717/D71755.pdf