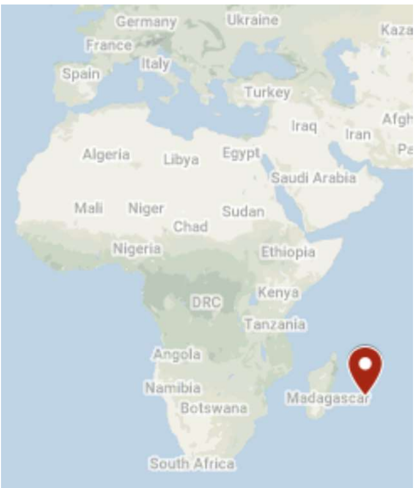
CASE STUDY 2-04: ESIROI BUILDING | LA REUNION



GEOGRAPHICAL AND CLIMATE INFORMATION	
Location	40 avenue de Soweto, Saint-Pierre, La Réunion, France
Latitude; Longitude	-21.340362377393678, 55.49108279968073
Climate zone (Köppen–Geiger classification)	Aw: Equatorial savannah with dry winter
BUILDING INFORMATION [1][2]	
Building Type	Educational - University
Project Type	New construction
Completion Date	2020
Number of buildings	1
Number of storeys	5
Total Floor Area (m²)	-
Net Floor Area (m²)	3 531
Thermally conditioned space area (m²)	1 461 m² (only air conditioning: 651 m² / air conditioning and ceiling fans: 810m²)
Spaces with Natural Ventilation (with or without Ceiling Fans) Only (m²)	2 070
Total cost (€)	10 171 145 €
Cost /m² (€/m²)	2 618.1
Performance Standards or Certification	PREBAT-REUNION approach - A quality approach which rewards buildings with low environmental impact, supported by ADEME Réunion.
Awards	None
STAKEHOLDERS [2][3]	
Building Owner/ Representative	University of La Reunion
Architect / Designer	LAB Réunion
Assistance to the contracting authority	SODIAC
Thermal consultancy	LEU Réunion

Environmental consultancy	LEU Réunion
Structural Engineer, Civil Engineer	A3 Structures
MEP consultancy	INSET SUD
Others	CREATEUR (roads and services infrastructure), Delhom Acoustique (Consulting firm in acoustics)

PROJECT DESCRIPTION

Figure 53 : Exterior view of the eastern façade.

Figure 54 : Exterior view of the western façade.

The new building of the ESIROI (Ecole Supérieure d'Ingénieurs Réunion Océan Indien) houses all the courses offered by the engineering school, i.e., the Integrated Preparatory Cycle (CPI) and its three engineering cycle specialties (Agri-food, Computer Science and Telecommunications, Building and Energy). One wing of the building also accommodates an extension of the IUT (University and Technological Institute) located on the same campus.

The building offers innovative architectural solutions to cope with the vagaries of a humid tropical climate, while being as environmentally friendly as possible and ensuring a comfortable working environment at the forefront of innovation for the users. The bioclimatic approach is directly inspired by traditional Creole architecture: Protection from the sun, comfort ventilation and vegetation. The airflow design has been validated thanks to a model in a wind tunnel test facility. The choice of a mixed metal / light wall structure alternative to the "all-concrete" one, and the importance of vegetation within the project are examples of the key bioclimatic solutions implemented.

Like the future engineers who will be trained there, the ESIROI building demonstrates local know-how in bioclimatic design with low environmental impact.

SITE INTEGRATION

Figure 55 : Aerial view of the building in its surrounding environment.

The new building of the ESIROI is located on the Terre Sainte university campus, in Saint Pierre, La Reunion, which hosts different university buildings, such as ENERPOS and the modules of the IUT. The building is erected on rocky grounds with a steep slope towards the sea and the lateral ravines. The premises are surrounded by native plants and benefit from the vegetation of the nearby ravine.

The site is isolated from the "urban" fabric of the town of St Pierre but it is well served by public transportation and easily accessible by car.

CLIMATE ANALYSIS

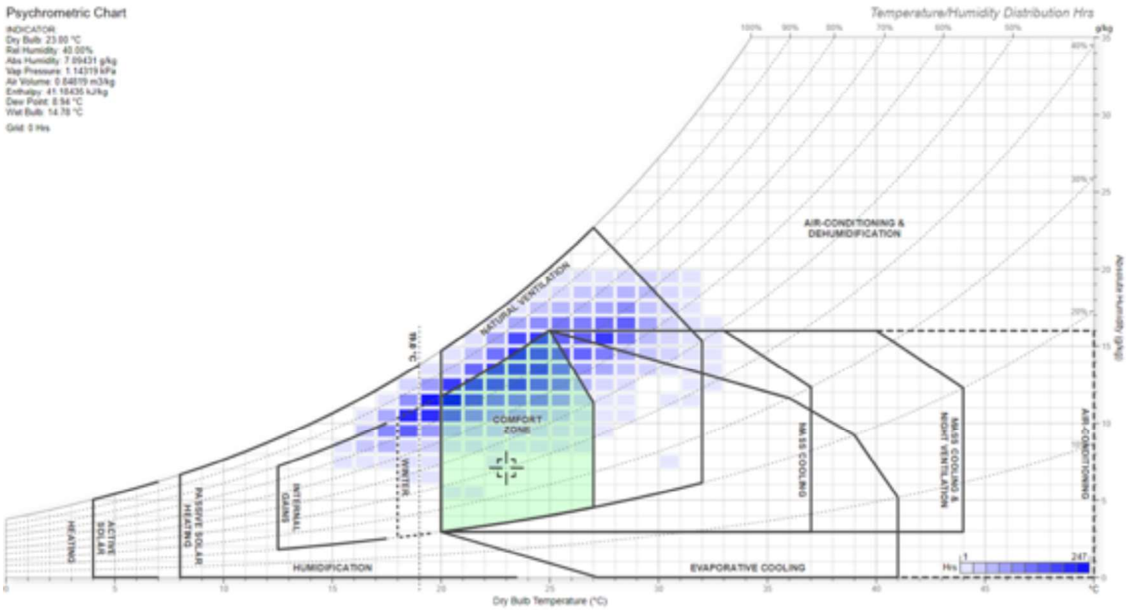


Figure 56: Givoni Bioclimatic chart for the climate of Saint-Pierre, La Reunion using Andrew Marsh online tool [2].

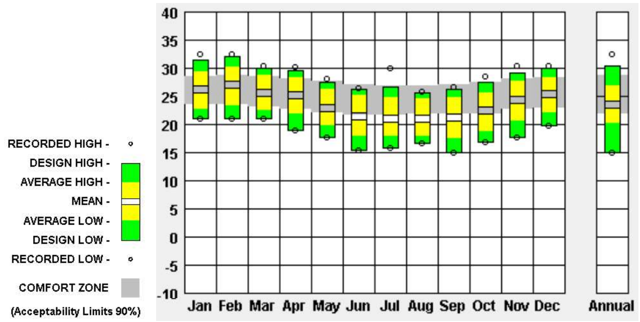


Figure 57: Temperature range by month for Saint-Pierre, La Reunion (Source: Climate consultant – Adaptative Comfort model).

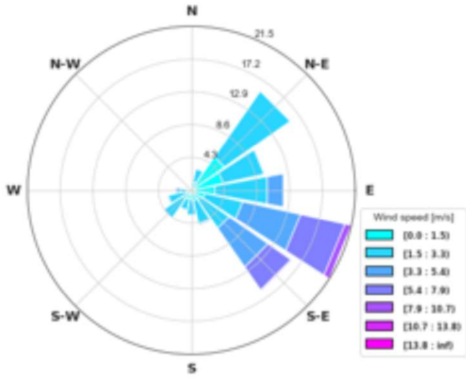


Figure 58: Wind rose for Saint-Pierre, La Reunion (Beaufort wind scale).

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]	
Passive cooling strategy	**Comfort ventilation** (natural cross ventilation and night ventilation) The shape of the building itself, in a "C" shape, optimises the phenomenon of pressure/depression, the driving force behind natural ventilation. The passive solutions for ventilation include large openings manually adjustable by users on opposite sides of the building to create cross-currents of air and vacuum well systems. Airflow engineering played a pivotal role in validating, optimising and dimensioning the natural ventilation principle of the premises. The airflow design has been validated by using a wind tunnel testing facility (Eiffel laboratory).
Passive heating strategy	None
Solar protection	Limitation of thermal overheating of the rooms thanks to different solar protection such as detached horizontal solar shading systems (1m from the facade) in aluminium, wooden strips and the large roof canopy. The external common areas are also protected from the sun by the use of these tensioned canvas. This system required the roof structure to be sized to withstand possible cyclonic seasons.
Building orientation	From the beginning of the project, important thought was given to the orientation of the building in order to take advantage of the intensity of the prevailing winds in the hot season, and to minimise it in the cool season. In addition, the work on the orientation makes it possible to create "blind" gables to the east and west, limiting solar gain on the façades.
Insulation	The roof is insulated thanks to 10cm insulating material. No insulation for the exterior walls.
Vegetation	Dense vegetation around and inside the building to take advantage of all the benefits of vegetation such as evapotranspiration, shading, dust absorption. Creation of a vegetated roof terrace above the IUT extension and all the advantages linked to such a choice (roof insulation, limitation of the project's impermeability, rainfall temporisation upstream of the outlets, etc.).

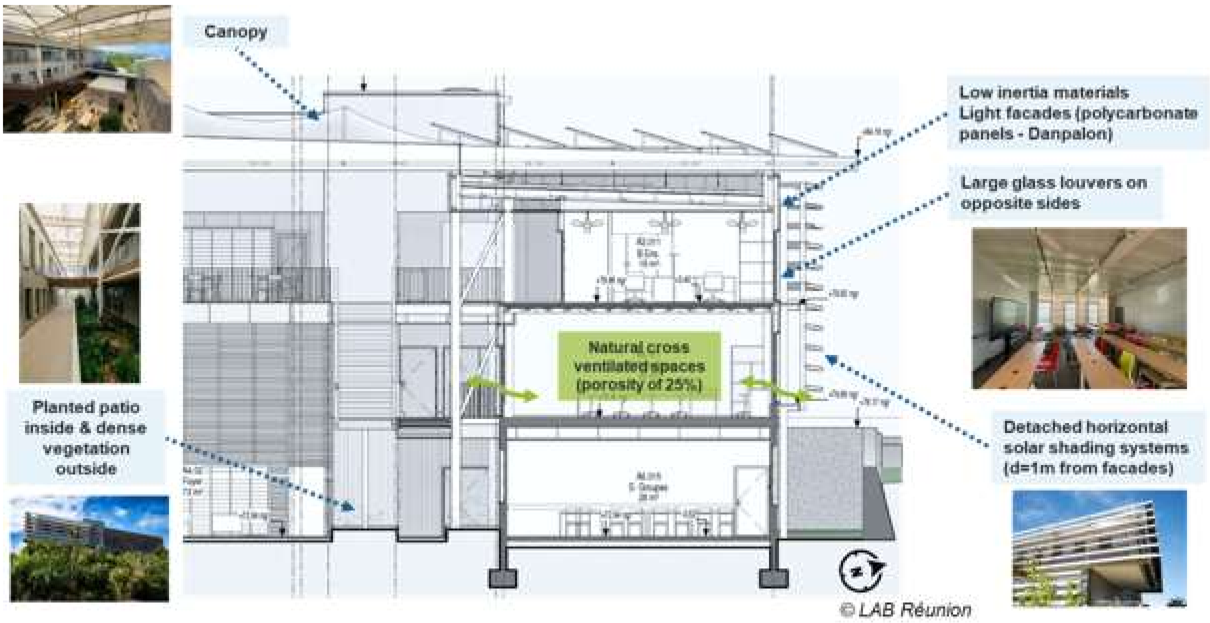


Figure 59: Cross section of the bioclimatic strategies implemented in the ESIROI building. The main strategies include natural cross ventilation, low inertia materials, efficient solar shading systems, dense vegetation and efficient ceiling fans in all rooms.

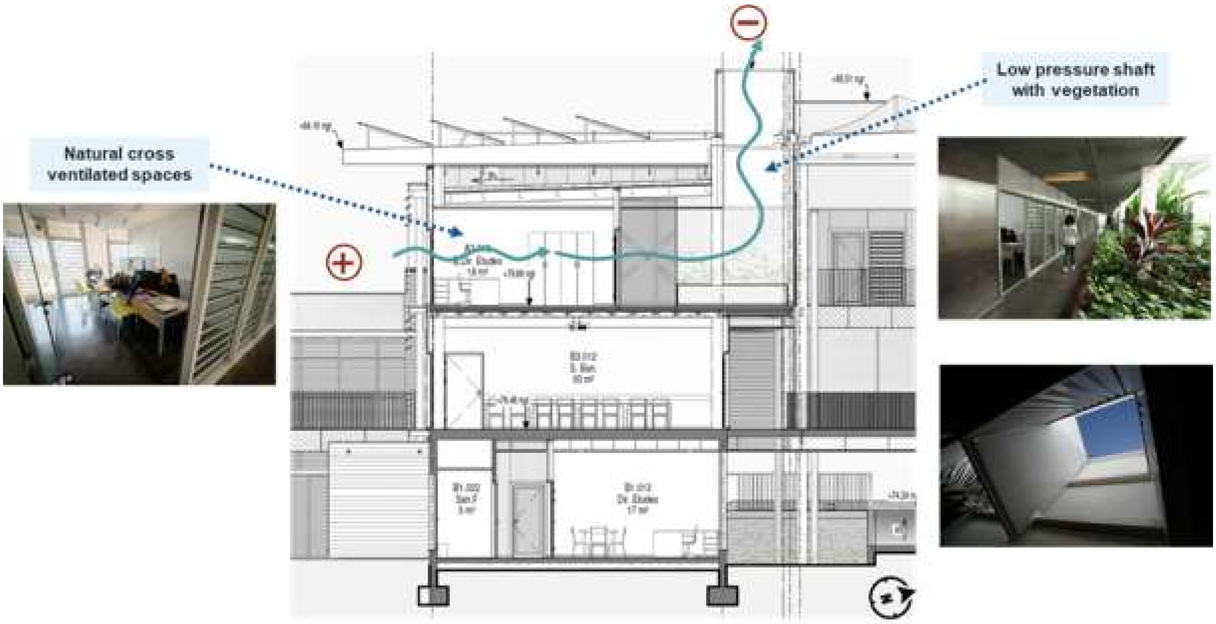


Figure 60 : Cross section of the low-pressure shaft principle, with the vegetated interior patio and the full height glass louvers.

Natural daylighting	An innovative translucent material was used in the façade to take advantage of natural light in addition to the large windows. Indeed, Danpalon® panel is developed from a high-quality synthetic material, polycarbonate, and its performance is certified by certification bodies. Its translucency allows excellent light transmission, which reduces the amount of artificial lighting required in the premises.
Use of local and embedded materials	None. Choice to use mixed materials as an alternative to the all-concrete project in order to reduce greenhouse gas emissions. The upper parts of the building are made of metal structures and light facades.
Water saving and flood management	Interior and exterior landscaping combining technical efficiency, environmental and aesthetic aspects, especially in terms of rainwater management. The outdoor gardens contribute to rainwater management. The idea is to limit as much as possible the creation of buried networks by keeping as much as possible on the surface the path of the drop of water which expresses itself and is thus understood through the landscape. Thus, obstacles to the planted areas calibrated to receive water will be avoided. The soils will be composed of mixtures of topsoil, earth and stone and cyclopean blocks in order to increase the temporization of the water while being favourable to the clinging of the plants.
Waste management	Specific bins for recyclable waste (paper, cardboard, plastic and metal)
Others features	▪ Work on thermal zoning: Grouping of rooms with the same cooling strategy. ▪ The possibility for users to access the building by soft modes of transport such as cycling or walking, thanks to the presence on site of changing rooms equipped with showers, individual secure lockers as well as adapted parking spaces for vehicles. ▪ Installation of efficient equipment to reduce internal thermal loads. ▪ Four EVBOX Type 2S charging stations for electric vehicles have been installed in the R-2 parking lot, with two outlets per station. The installed power is 61.4 kW.

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** If yes, Ratio with number of users: **0.04** *(11 outdoor bike racks for 300 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** However, all users are made aware of the environmental aspects of the project through technical visits of the site to each class of students and administrative staff members.

(a) (b)

Figure 61: Different solar protection strategies have been set up such as (a) detached horizontal solar shading systems in aluminum and (b) wooden strips

BUILDING FABRIC AND MATERIALS	
Roof	The **PV roof** is composed of (from outside to inside): ▪ PV over-roof ▪ Glass wool insulation [0.10m] ▪ Metal roof panels U-value= 0.37 [W / m²K] Overall R-value: 2.5 [m^{2}K/W]
	The **terrace roof** is composed of (from outside to inside): ▪ Waterproofing ▪ Glass wool insulation [0.10m] ▪ Concrete [0.23m] U-value= 0.35 [W / m²K]

	Overall R-value: 2.63 [m²K/W]
	The **sheet metal roof** is composed of (from outside to inside): ▪ ONDULIT Steel Roofing System ▪ Glass wool insulation [0.10m] U-value= 0.45 [W / m²K] Overall R-value: 2.0 [m²K/W]
Windows	Louvered windows of different dimensions Type of materials: clear glass Thickness: 0.006 m
	Window-to-wall ratio (WWR): Superior to **20%** for the naturally ventilated rooms.
Walls	The majority of the **exterior walls of the offices and classrooms** are composed of DANPALON® polycarbonate panels.
	Thickness= 0.016m U-value= 1.9 [W / m²K] Overall R-value: 0.53 [m²K/W]

(a) (b)

Figure 62 : (a) Aerial view of the canopy and (b) view of the canopy from the inside.

ENERGY EFFICIENT BUILDING SYSTEMS	
Low-energy cooling systems	The classrooms and offices on the upper floors are naturally ventilated, with the use of fans when necessary. The practical rooms and laboratories equipped with state-of-the-art professional equipment are air-conditioned and located on the lower levels of the building. Some rooms are in mixed-mode, i.e., air-conditioning and fans. The cold production is carried out by a LENNOX chiller (Model Ecomfort) with its hydraulic station (D+ Edrive), with a **maximum power** of **82.4** kW and an European seasonal energy efficiency ratio (**ESEER**)of **4.19.** Wall-mounted monosplit units are installed in the storage rooms. Three models from the Airwell brand are used for this emergency cold production, with different power (0.9kW, 1.15 kW and 1.75 kW). The units switch on automatically at night when the chiller is switched off and they switch on during the day when the temperature rises more than 2°C above the set point after 10 minutes. Finally, chilled water terminals have been installed in the air-conditioned classrooms. Ducted units and indoor units, both from the Sabiana Brand and with a maximum power of 139kW, are present in the various rooms.

ABC21 is funded by the EU's H2020 programme

Low-energy heating systems	None
Ceiling fans	All offices and classrooms are equipped with efficient ceiling fans. Two high performance air movers for large volumes have also been installed to improve comfort in external common areas. 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 mean surface covered by a ceiling fan is equal to 12.5m^2. With the exception of 8 premises, the ceiling fans are designed for surfaces between 9 and 15 m². The outcome of the French PREBAT program recommends 1 fan for 15 m^2.
 	**1. Brand / Model: Hunter / Industrie II** a. Where: offices and classrooms b. Number: 158 c. Diameter: 132 cm d. Maximum power : 66 W e. Others: 3 speed levels / maximum speed of 157 Rpm. **2. Brand / Model: Hunter Industrial ECO HVLS fan** a. Where: Exterior common areas b. Number: 2 c. Diameters: 305 cm (10ft) and 488cm (16ft)
Mechanical ventilation / air renewal	The air treatment is composed of : - an air treatment unit for the kitchen area and another one for the amphitheatre (SAIVER brand) ; - a ventilation system for the laboratories and practical rooms composed of 12 motorized fans for the extraction of the fume hoods, a compensation box and motorized dampers; - Two ventilation systems for fresh air and extracted air (VMC) of 0.2 kW.
Domestic Hot Water	In the building, there are three systems for the production of domestic hot water: solar hot water, centralised production by recovery from the chiller and electric backup and instantaneous water heaters. The domestic hot water produced for the needs of the kitchen comes from a centralized solar production, composed of 10 m² of solar collectors installed on the roof of the building, and a 600L Cordivari tank with a heat exchanger and an auxiliary heating element. The second system is a heat recovery system produced by the chiller. The heat output recovered from the chiller is 28.2 kW. The chiller is equipped with a desuperheater for each refrigeration circuit, to which a primary network equipped with heat recovery is connected and feeds the recovery tank located in the technical room. The instantaneous DHW tanks are small, placed close to the needs and operate with an electric resistance. They are placed under the sinks and benches of the cafeteria and the energy physics laboratory. These 4.5kW tanks are used for rooms far from the two other systems.

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Artificial lighting	The building has several types of lighting equipment, such as: • Suspended (for example Milena LED and SIGMA II LED from PXF LIGHTING and others); • Surface mounted such as the Bari ECO DLN IP65 LED model from PXF LIGHTING and others; • Ceiling recessed mounting (Start Flat Panel LED from SYLVANIA, GreenSpace Accent Gridlight model from PHILIPS and others) All the lights installed are LED. This type of lighting is the most energy efficient with low consumption and long life. The installed electric density for artificial lighting is equal to 6.0 W/m^2.
Control and energy management	The ESIROI buildings and the IUT extension are equipped with three monitoring systems: ▪ Two electricity consumption monitoring systems: The first one composed of 10 energy meters installed at the output of the divisional panels and the second one based on detailed energy sub-metering by usage (interior and exterior lighting, plug loads, fans, etc.). ▪ A system for monitoring the consumption of air conditioning and ventilation operations: Input and output module to centralise information on the operation of the HVAC equipment, the air temperatures and relative humidity of certain rooms as well as the delivered energy of each conditioned zone.

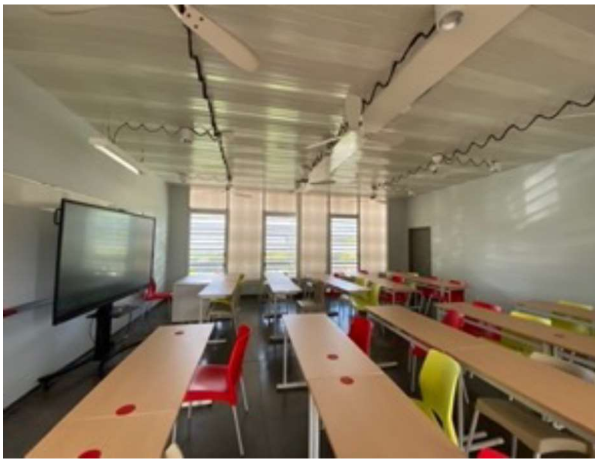

Figure 63: Interior view of a typical classroom.

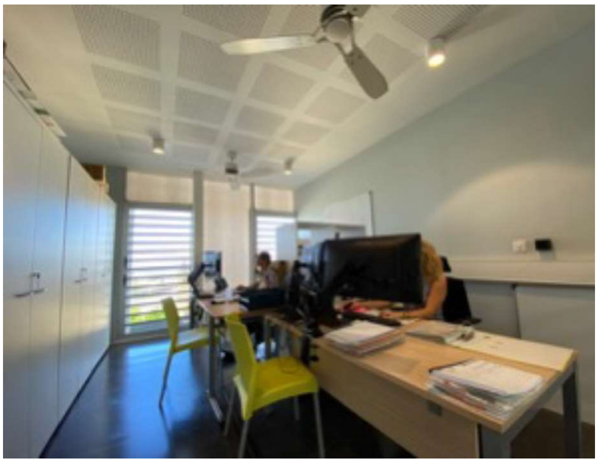

Figure 64 : Interior view of a typical office equipped with efficient ceiling fans and full-height glass louvers.

RENEWABLE ENERGY	
PV	**Brand:** TRINASOLAR VERTEX S 395Wp - 253 PV modules **Technology**: Monocrystalline silicon cells **Total area:** 486.36 m² **Nominal power:** 99.935 kWp The slope of the PV cells is 15° for 2 roofs and 9° for the last one.
Solar thermal	Thermal solar panels are installed on rooftop of the building for the production of hot water. Total area: 10 m² of flat collectors

Wind	None
Geothermal	None
Biomass	None

Figure 65: Solar thermal and PV panels have been installed on the rooftop of the building.

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: **≥ 95%**
	6. Percentage of time inside the Givoni comfort zone of 0m/s: **≥47%**
	7. Number of hours within a certain temperature range:

1st March 2022 to 1st March 2023 Occupation time: 8:00am to 5:00pm	GROUND LEVEL				FIRST FLOOR LEVEL					
	Classroom A204		Classroom A207		Office A301		Classroom A313		Office A320	
Range	Nb of Hours	Fq	Nb of Hours	Fq	Nb of Hours	Fq	Nb of Hours	Fq	Nb of Hours	Fq
T<20°C	2	0%	4	0%	1	0%	1	0%	22	1%
20°C≤T<22°C	116	4%	249	8%	246	8%	153	5%	332	11%
22°C≤T<24°C	527	17%	572	19%	547	18%	676	22%	669	22%
24°C≤T<26°C	876	29%	835	28%	775	26%	787	26%	750	25%
26°C≤T<28°C	901	30%	1001	33%	896	30%	893	30%	746	25%
28°C≤T<30°C	536	18%	330	11%	510	17%	450	15%	454	15%
30°C≤T<32°C	61	2%	29	1%	45	1%	60	2%	44	1%
32°C≤T<34°C	1	0%	0	0%	0	0%	0	0%	3	0%
34°C≤T<36°C	0	0%	0	0%	0	0%	0	0%	0	0%
T≥36°C	0	0%	0	0%	0	0%	0	0%	0	0%

Energy performanc e 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: **178** [kWh/m^2/year] for the ESIROI building only
244 [kWh/m^2/year] for the whole building (ESIROI, the IUT (University and Technological Institute) the laboratories and kitchen). The total Primary Energy Factor (PEF) equal to **3.3** for electrical energy from the grid.
6. Renewable Primary energy generated on-site : **52** [kWh/m^2/year] from PV
7. Renewable Primary energy generated on-site and self-consumed: **0** [kWh/m^2/year]
8. Renewable Primary energy exported to the grid: **52** [kWh/m^2/year]
9. Ratio of renewable primary energy over the total primary energy use (with and without compensation): **21%**
10. Delivered energy = **54** [kWh/m^2/year] for the ESIROI building only
74 [kWh/m^2/year] for the whole building (ESIROI, the IUT (University and Technological Institute) the laboratories and kitchen).

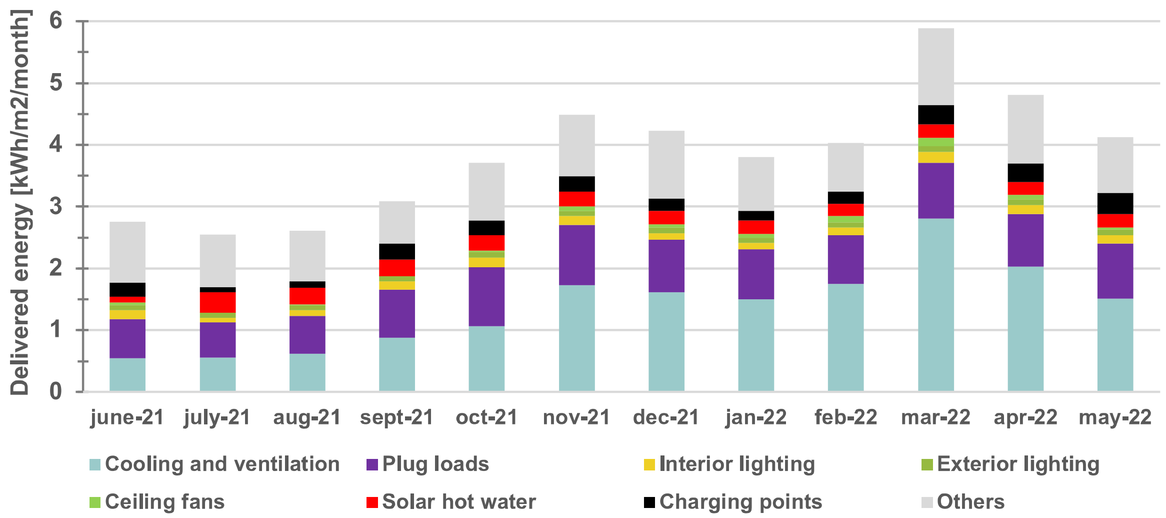

Figure 66: Monthly delivered energy by end-uses from June 2021 to May 2022 for the ESIROI building.

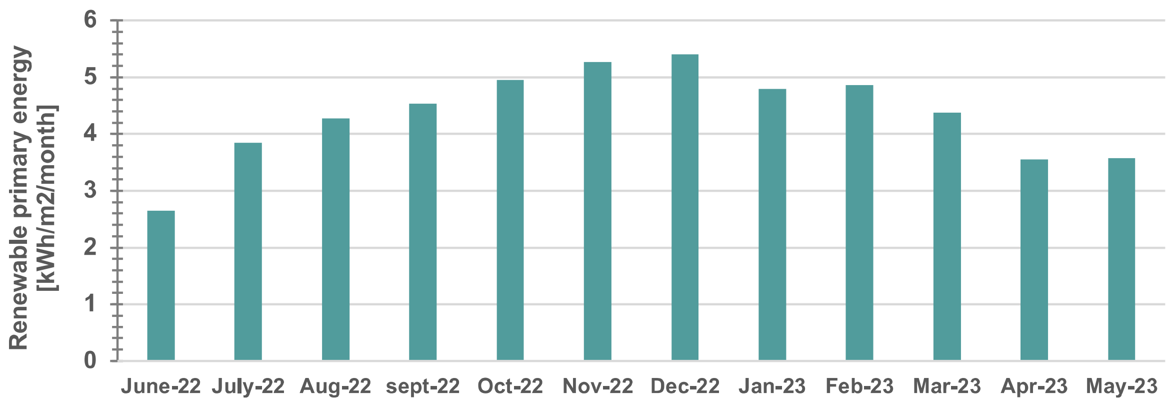

Figure 67 : Monthly primary energy generated on-site from PV for the years 2022-2023.

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	▪ Users are **overall satisfied** with the thermal comfort conditions in **summer** ▪ Users are **not satisfied** with the thermal comfort conditions in **winter,** which they consider **too windy and too cold.**

LESSONS LEARNED AND RECOMMENDATIONS

Lessons learned	▪ The management of natural ventilation is as essential in summer as in winter. ▪ Ceiling fans play a pivotal role in summer comfort, especially for days without wind.
Recommendations	▪ To consider and optimise natural ventilation both for summer and winter periods. ▪ To install efficient ceiling fans in all rooms and consider their maintenance. ▪ To draw inspiration from vernacular architecture.

BUILDING STRENGTHS AND WEAKNESSES

Strengths

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

Weaknesses

⊖ Wind management in winter (lot of draughts)

REFERENCES

1. https://labreunion.fr/projets/esiroi/
2. https://www.construction21.org/france/case-studies/h/new-esiroi-premises-en.html