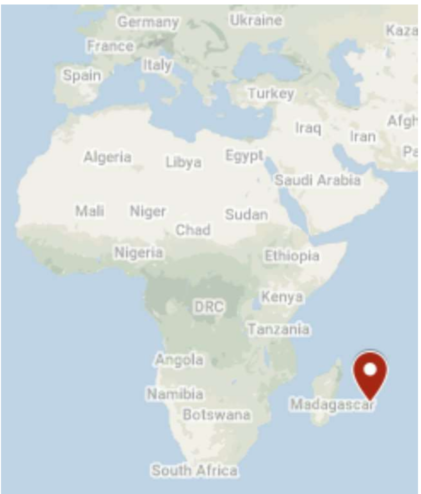
CASE STUDY 1-05: ENERPOS | LA REUNION



GEOGRAPHICAL AND CLIMATE INFORMATION	
Location	40 avenue de Soweto, Saint-Pierre, La Réunion, France
Latitude; Longitude	-21.34080841368781, 55.491067294562335
Climate zone (Köppen–Geiger classification)	Aw: Tropical savannah with dry winter

BUILDING INFORMATION [1]	
Building Type	Educational - University
Project Type	New building
Completion Date	2008
Number of buildings	2
Number of storeys	2
Total Floor Area (m²)	739
Net Floor Area (m²)	681
Thermally conditioned space area (m² area type)	286
Spaces with Natural Ventilation (with or without Ceiling Fans) Only (m²)	435
Total cost (€)	2 372 000
Cost /m² (€/m²)	3 209.74
Performance Standards or Certification	PERENE 2004 (Local standard for efficient buildings in La Reunion)
Awards	Winner of the PREBAT ADEME award (local award)

STAKEHOLDERS [1]	
Building Owner / Representative	University of La Reunion
Architect / Designer	Thierry Faessel-Bohe

ABC21 is funded by the EU's H2020 programme

Construction manager	Leon Grosse
Environmental consultancy	TRIBU Paris and IMAGEEN
Structural Engineer, Civil Engineer	RTI
Mechanical, Electrical Engineer	INSET

PROJECT DESCRIPTION [2]

Figure 70 : Southern façade with solar shadings (overhang and wooden strips) [2]

ENERPOS is a classroom and office building on the French island of La Reunion near Madagascar, which demonstrates that sustainable design saves significant energy while providing a comfortable environment. ENERPOS (French acronym for POSitive ENERgy) is the first net zero energy building (Net ZEB) on La Reunion and it is also one of only three NZEBs in a tropical climate. The two-story building splits into two parallel blocks separated by a green patio. The blocks are composed of an administration zone on the ground floor (seven offices and a meeting room), two computer rooms and five classrooms for a total net floor area of 681 m², as well as a car park under the building. The building has been designed with priority given to the passive design such as cross natural ventilation and solar shading [2].

Figure 71 : Eastern façade [2]

Figure 72 : Outdoor corridor and overhangs

SITE INTEGRATION

Figure 73 : Site integration of the building in the campus

The building is surrounded by native plants to prevent the air from heating up before entering the building. The car park is located under the building to avoid the excess heat that occurs from having pavement around the building, and to increase the soil permeability to prevent flooding after heavy tropical storms.

CLIMATE ANALYSIS

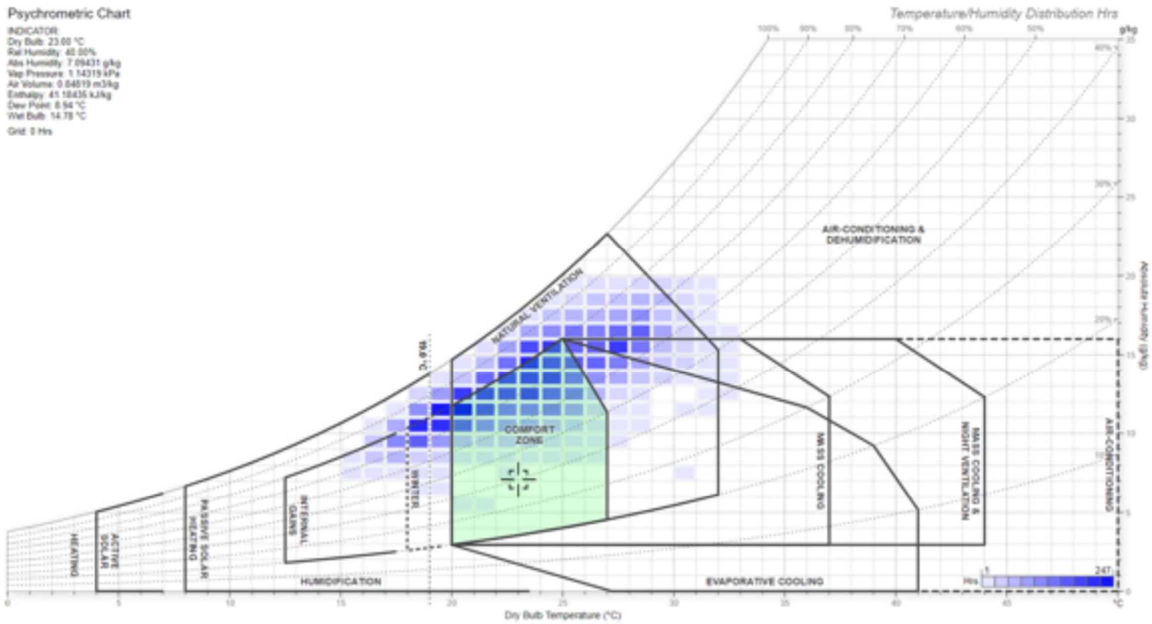


Figure 74: Givoni Bioclimatic chart for the climate of Saint-Pierre. [3]

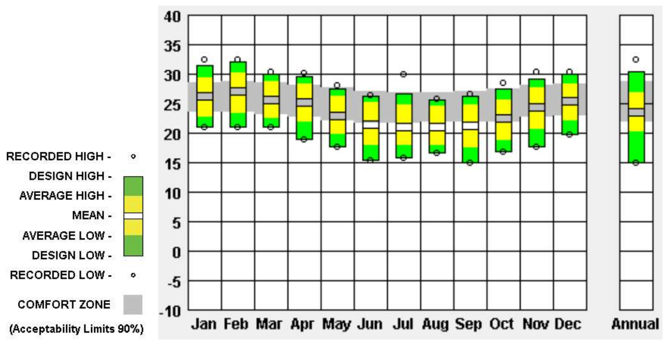


Figure 75: Temperature range by month for Saint-Pierre. Source: Climate consultant – Adaptative Comfort model [4]

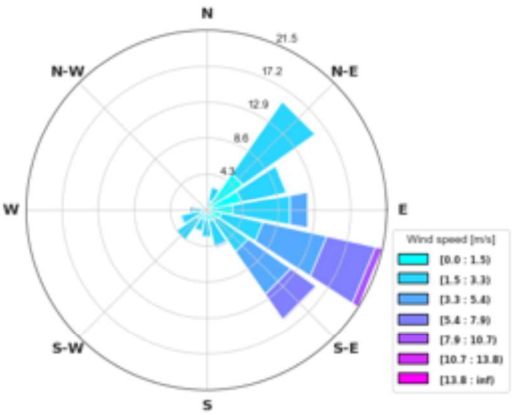


Figure 76 : Annual wind rose for Saint-Pierre (Beaufort wind scale) [4]

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: **4 977**
Annual Degree-Days for the Adaptive Comfort Base Temperature according to the ASHRAE 55-2017 for 80% of acceptability	HDD: **158** CDD: **8**
Annual Degree-Days for a static comfort temperature approach	HDD 18.6ºC: **20** CDD 26º: **171**

KEY BIOCLIMATIC DESIGN PRINCIPLES [5] [6] [7] [8]	
Passive cooling strategy	**Comfort ventilation / cross natural ventilation** The building is naturally cross ventilated by using glass louvers, which have the advantage of allowing regulation of the airflow while also providing protection against cyclones and break-ins. In the administration zone, the central corridor around which the offices are located was cutting off the ventilation. The installation of indoor louvers enhances interior airflow. providing a porosity of 30%.
Solar protection	North and South Façades are solar protected with horizontal wooden strips, that have been simulated and optimized with Sketchup. Besides electricity production, the PV panels provide a ventilated double roof, which creates solar shading of the terrace roof of the building.
Building orientation	The main façades are **north and south oriented** so as to use the thermal breezes during summer and to reduce the solar energy gained by the building on the western and eastern façades.
Insulation	The walls of the East and West facades are insulated thanks to 2 cm of polystyrene and wooden cladding. The roof is insulated with 8 cm polystyrene + solar protected by a BIPV roof. North and South facades are not insulated but solar protected.
Vegetation	The building is surrounded by a 3 m (9.8 ft) band of native plants to prevent the air from heating up before entering the building. Native plants have low water needs and are adapted to cyclones. The planted patio in ENERPOS creates a microclimate around the building by decreasing the air temperature. It also brings conviviality in a crossing point of the building.
Natural daylighting	The solar protections of the facades have been optimized for daylighting. Useful Daylight Index of 90% in most spaces. No artificial lighting in two classrooms on the first level facing the sea.
Use of local and low embedded energy materials	No local materials have been used but chairs were made from recycled plastic. The paint used for the coatings is completely organic.
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** (only 6). No showers.
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	Signs in classrooms explain how to properly use the building by opening the louvers or turning on ceiling fans, switching off unnecessary lights, and using the stairs, rather than the elevator. Signs also provide suggestions for reducing waste by printing on both sides of paper, using reusable cups and glasses, sorting the garbage for recycling, etc.

(lighting…) in order to promote sufficiency and efficiency actions	
Water saving	Low-flow toilets
Waste management	Not taken into consideration. Initial efforts focused on energy efficiency.

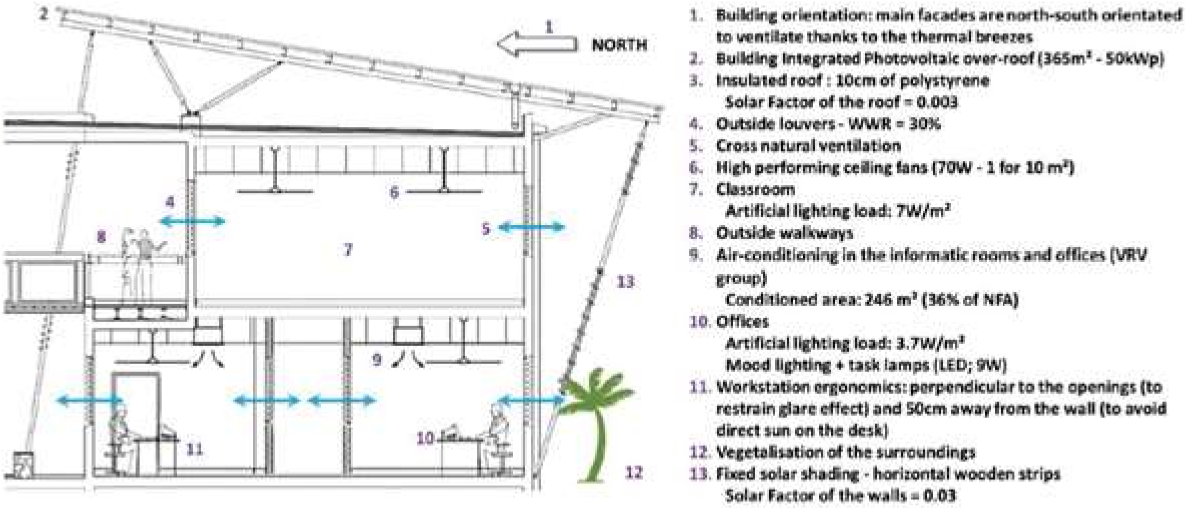


Figure 77 : cross section of the passive solutions [5]

BUILDING FABRIC AND MATERIALS [2]	
Roof	**Type:** BIPV over-roof + 10 cm (3.9 in.) of polystyrene + 20 cm (7.9 in.) concrete
	Overall R-value: 3.4
Windows	**Type: Glass** louvers
	Window-to-wall ratio: 30%
	U-value: 1.4
	Visual transmittance: 0.4
Walls	**Type:** East and West: 18 cm (7.1 in.) concrete + 8 cm (3.1 in.) mineral wool or 18 cm (7.1 in.) concrete + ventilated air gap + wooden siding North and South: 18 cm (7.1 in.) concrete + solar shading
	Overall R-value: East and West: 1.8 North and South: 0.1

ENERGY EFFICIENT BUILDING SYSTEMS [5] [6] [7] [8]	
Low-energy cooling systems	A variable refrigerant flow (VRF) air conditioning system is installed to cool the offices and the computer rooms. Its cooling capacity is 25.3 kW (89 tons) and the energy efficiency ratio is 4.8 (provided by the manufacturer).
Ceiling fans	Large ceiling fans are installed in all spaces, including those with air conditioning. The use of ceiling fans guarantees additional air speed during windless days and allows a transitional period before using active air-conditioning systems. Ceiling fans are used in conjunction with the natural ventilation strategy to create air movement on the skin of the occupants, increasing their comfort. A total of 55 ceiling fans with a 132 cm (4.3 ft) blade diameter are installed in the offices and classrooms. The maximum power used for one ceiling fan is 70 W (239 Btu/h), which represents 7 W/m² (255 Btu/ft²), with a ratio of one ceiling fan per 10 m² [108 ft²]). Ceiling fans are

	controlled individually (offices) or in groups of two or four (classrooms) from wall-mounted switches and have three speed levels.
Artificial lighting	Low energy T-5 tubular fluorescent luminaires provide indirect ambiance lighting, while 9W LED desk lamps in the offices provide additional lighting as needed. The installed electric density for artificial lighting is lower than in a standard building (7 W/m² [255 Btu/ft²] in the classrooms and 3.7 W/m² [134 Btu/ft²] in the offices). Timers in the classrooms turn the lights off automatically after two hours.
Control and energy management	Energy management strategies are used to decrease the total consumption of the active systems. A building management system controls the air-conditioning system (operating period, setpoint temperature); the schedules of exterior lighting; and energy consumption by type of end uses (lighting, ventilation, plug loads, air conditioning, elevator). The Building Management System includes 15 energy and power meters; 15 temperature and humidity sensors and presence detectors (in all classrooms and offices).

Figure 78 : a typical classroom with large louvers on both sides and efficient ceiling fans [2]

Figure 79 : Indoor louvers to facilitate indoor natural cross ventilation

Figure 80 :Efficient ceiling fans have been installed in the classrooms.

RENEWABLE ENERGY [5] [6] [7] [8]	
PV	**Type:** Building Iintegrated PV over-roof **Technology:** Polycrystalline cells (indicate efficiency or kWp /m2) **Surface:** 365 m² **Nominal power:** 50 kWp The slope of the PV cells is 9° for both roofs which is not the best choice in terms of photovoltaic efficiency as the optimum position for PV panels on La Reunion is a north orientation with a slope of 21°. The architect who designed the building wanted architectural homogeneity, with half the over-roof facing north and the other half facing south.

Figure 81 : The 50 kWp BIPV roofs [2]

Figure 82 : PV production on the panel [2]

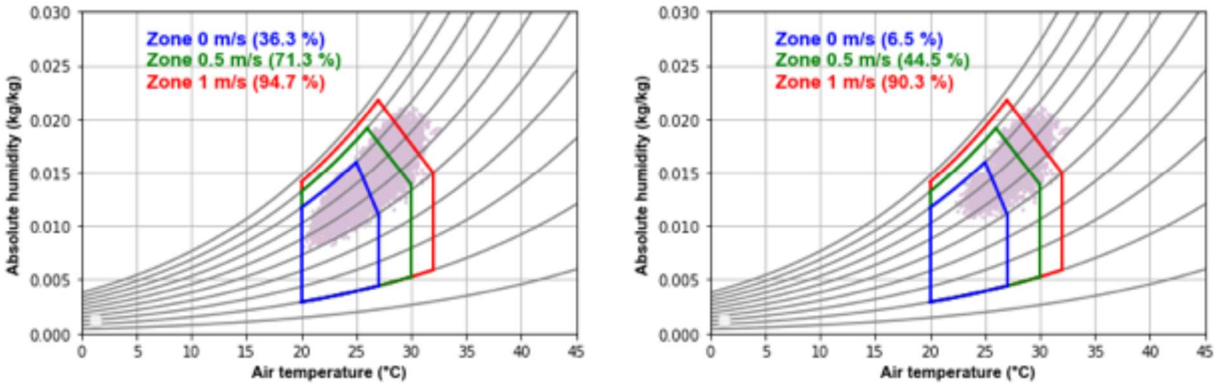
BUILDING ANALYSIS AND KEY PERFORMANCE INDICATORS [2] [5] [6] [7] [8]	
Thermal comfort indicators	1. Percentage of time outside an operative temperature range [Adaptive comfort method, Category II, EN16798-1, cooling season (1st-11 to 31th-03)]: **2.2%**
	2. Percentage of time outside an operative temperature range (Fanger): -
	3. Degree-hours [Adaptive comfort method, Category II, EN16798-1, cooling season (1st-11 to 31th-03)]: **13**
	4. Degree-hours (Fanger): -
	5. Percentage of time inside the Givoni comfort zone of 1m/s: **Summer period (**1st-11 to 31th-03**): 90 %** **Whole year: 95%**
	6. Percentage of time inside the Givoni comfort zone of 0m/s: **Summer period (**1st-11 to 31th-03**): 6.5 %** **Whole year: 36%**
	7. Number of hours within a certain temperature range: Monitored data of the year 2015 – Occupation time: 8:00am to 6:00pm

All year		
Range	Nb of Hours	Frequency
Ta≤26	1302	**39%**
26<Ta≤28	1093	**32%**
28<Ta≤30	931	**28%**
Ta>30	46	**1%**

Hot period (1st-11 to 31th-03)		
Range	Nb of Hours	Frequency
Ta≤26	98	**7%**
26<Ta≤28	504	**37%**
28<Ta≤30	732	**53%**
Ta>30	41	**3%**

Energy performance indicators	1. Energy needs for heating: **0** [kWh/m²/year]
	2. Energy needs for cooling: **4** [kWh/m²/year]
	3. Energy use for lighting: **3** [kWh/m²/year] **(indoor and outdoor)**
	4. Energy needs for Sanitary Hot water: **0** [kWh/m²/year]
	5. Total Primary energy use: **66** [kWh/m²/year] (total Primary Energy Factor (PEF) equal to 3.3 for electrical energy from the grid)
	6. Renewable Primary energy generated on-site: **105** [kWh/m²/year]
	7. Renewable Primary energy generated on-site and self-consumed: **0** [kWh/m²/year]
	8. Renewable Primary energy exported to the grid: **105** [kWh/m²/year]
	9. Ratio of renewable primary energy over the total primary energy use (with and without compensation): **0%** *(energy generated on site and self-consumed)* **159%** *(considering the energy from PV exported to the grid)*
	10. Delivered energy (from electricity bills) : **20** [kWh/m²/year]
Acoustic comfort indicators	1. Airborne sound insulation
	2. Equivalent continuous sound Level
	3. HVAC noise level
	4. Reverberation time
	5. Masking/barriers
	1. Light level (illuminance)

Visual comfort indicators	2. Useful Daylight Illuminance (UDI)
	3. Glare control
	4. Quality view
	5. Zoning control
Indoor Air Quality indicators	1. Organic compound : N/A
	2. VOCs : N/A
	3. Inorganic gases: N/A
	4. Particulates (filtration) : N/A
	5. Minimum outdoor air provision: N/A
	6. Moisture (humidity, leaks) : N/A
	7. Hazard material: N/A
Users' feedback	To assess the comfort level of ENERPOS, a post occupancy evaluation was conducted during three hot seasons (October to April). It involved surveying students and lecturers during the hours of occupancy. Students were asked to complete a questionnaire at the same time that the environment parameters were being recorded (air temperature, wet-bulb temperature, globe temperature, relative humidity and air velocity). More than 2,000 questionnaires were filled in by 600 students and their teachers. The main results are that the occupants usually don't complain about the heat and generally feel comfortable, even during the hottest period of the year [2].



(a) (b)

Figure 83: Givoni comfort zones on the psychometric chart obtained for all monitored rooms of the ENERPOS building during occupied hours: (a) for the whole year 2015 and (b) for the hot period (November 1st to March 31th). In summer, 90% of the points are located in the zone of 1m/s, which is very close to the one that was predicted during the design phase (86%).

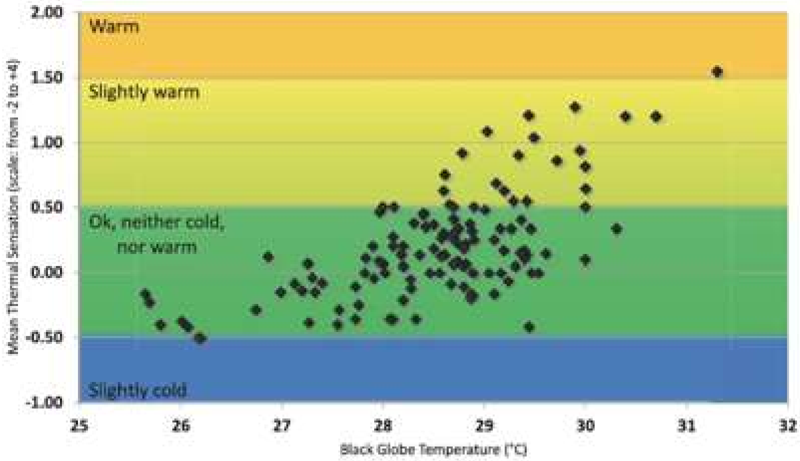


Figure 84 : Mean Thermal Sensation of the students inside the Enerpos building during 125 lectures over three summer seasons. Students were asked about their thermal sensation on a 7-point scale ranging from 'cold' (−2) to 'extremely warm' (+4). We can see that only 16% of the values are above 0.5 and that temperatures around 30◦C can be felt as "neutral" [5].

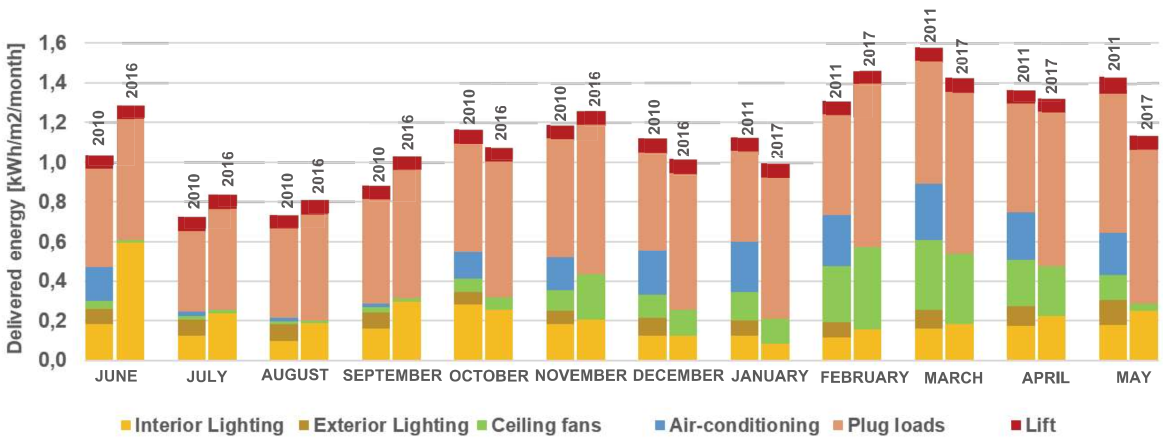


Figure 85: Monthly delivered energy for the years 2010-2011 and 2016-2017. In 2010-2011, the main source of consumption corresponds to the plug loads (46% of consumption over a year), followed by the air conditioning and ventilation (15%), interior lighting (14%), the ceiling fans (11%), the exterior lighting (7%) and the lift (7%). During the period 2016-2017, the delivered energy for the plug loads is higher (61% over a year), as well as for the interior lighting (20%) whereas the delivered energy for the ceiling fans and the lift are almost the same (respectively 12% and 6%). The air-conditioning and the exterior lighting were not used during this year.

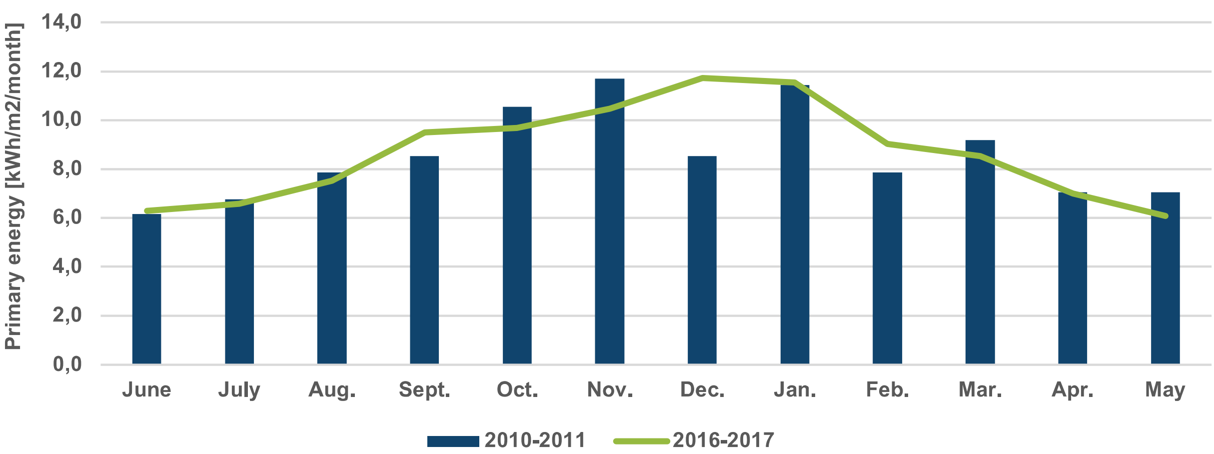
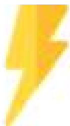


Figure 86: Monthly primary energy generated on-site from PV for the years 2010-2011 and 2016-2017.

ABC21 is funded by the
EU's H2020 programme

LESSONS LEARNED AND RECOMMENDATIONS	
Lessons learned	Designers reduced the predicted cooling period for the computing rooms to six weeks by using natural ventilation and ceiling fans. However, monitoring found that air conditioning has only been used about one week per year. ENERPOS shows that with current technologies and only 9% additional cost, it is possible to build a building that consumes 10 times less energy than a standard building and produces seven times more energy than it consumes at the daily scale. It also demonstrates that an academic building can significantly reduce its energy consumption by avoiding air conditioning while maintaining a good level of thermal comfort for its occupants by enabling them to use passive methods.
Recommendations	It is really important to get active people in a passive building, instead of passive people in an active building. To achieve this result, people need to be correctly informed on how to use the passive features of their building and to be conscious about their green behaviour impact. Communication and awareness-raising are essential.

BUILDING STRENGTHS AND WEAKNESSES		
Strengths		
		
Passive Design	**Energy Efficiency**	**Renewable Energy**
Weaknesses		
-		

REFERENCES

[1] Enerpos. construction21.org, https://www.construction21.org/france/case-studies/h/enerpos.html (accessed 12 May 2021).

[2] University of La Reunion's ENERPOS: Saint-Pierre, La Reunion, France. HPB Magazine, Summer 2012, https://www.hpbmagazine.org/university-of-la-reunions-enerpos-saint-pierre-la-reunion-france/ (2012, accessed 12 May 2021).

[3] PD: Psychrometric Chart n.d. https://drajmarsh.bitbucket.io/psychro-chart2d.html(accessed May 7, 2021).

[4] Milne (UCLA) M. Climate Consultant 6.0. n.d. http://www.energy-design-tools.aud.ucla.edu/climate-consultant/request-climate-consultant.php.

[5] Aurélie Lenoir, George Baird & François Garde (2012): Post-occupancy evaluation and experimental feedback of a net zero-energy building in a tropical climate, Architectural Science Review, DOI:10.1080/00038628.2012.702449

[6] IEA. 2008 "International Energy Agency SHC Task 40 / ECBCS Annex 52 – Towards Net Zero Energy Solar Buildings." www.iea-shc.org/task40/.

[7] Garde, F., A. Lenoir, and F. Thellier. 2011. "Towards net zero energy buildings in hot climates. Part I: new tools and methods." *ASHRAE Transactions* 117(1):458-65.

[8] Lenoir, A., F. Garde, and M. David. 2011. "Towards net zero energy buildings in hot climates. Part II: experimental feedback." *ASHRAE Transactions* 117(1):450-7

[9] Aurélie Lenoir. On Comfort in Tropical Climates. The Design and Operation of Net Zero Energy Buildings.. Physics. Université de La Réunion, 2013. English. <tel-01100526>.

ABC21 is funded by the EU's H2020 programme