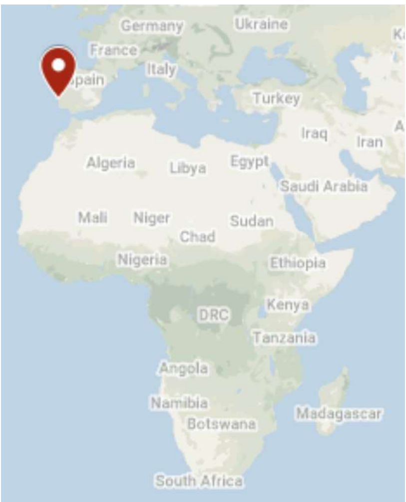
CASE STUDY 1-02: CML KINDERGARTEN | PORTUGAL



GEOGRAPHICAL AND CLIMATE INFORMATION	
Location	Rua Margarida de Abreu 4, 1900-314, Lisbon, Portugal
Latitude; Longitude	38.74359816203614, -9.131250349942396
Climate zone (Köppen–Geiger classification)	Csa: Warm temperate climate with dry and hot summer
BUILDING INFORMATION	
Building Type	Educational (Kindergarten)
Project Type	New construction
Completion Date	2013
Number of buildings	1
Number of storeys	2
Total Floor Area (m²)	680
Net Floor Area (m²)	582.3
Thermally conditioned space area (m²)	0
Spaces with Natural Ventilation (with or without Ceiling Fans) Only (m²)	The entire building is naturally ventilated
Total cost (€)	-
Cost /m² (€/m²)	-
Performance Standards or Certification	Portuguese National Code (RECS, 2013)
Awards	-
STAKEHOLDERS	
Building Owner/ Representative	Municipality of Lisbon (CML)
Architect / Designer	Appleton & Domingos, Arquitetos
Construction manager	Municipality of Lisbon (CML)
Environmental consultancy	NaturalWorks
Structural Engineer, Civil Engineer	A2P
Product Manufacturer	-

ABC21 is funded by the EU's H2020 programme

Certification company	NaturalWorks

PROJECT DESCRIPTION

Figure 18 : Elements of the natural ventilation system

The CML kindergarten, constructed in 2013, is a small two-story building with a total area of 680 m^2 distributed in two floors with 3 m floor to ceiling height.

This school is naturally ventilated and does not have a mechanical cooling or ventilation. A natural displacement ventilation system was developed to provide fresh air with adequate acoustic insulation.

The CML Kindergarten uses solar thermal energy to heat domestic hot water that fed the hydraulic radiators which were installed in each classroom.

The design also includes high exposed thermal mass, daylighting, and solar shading.

Figure 19: CML kindergarten building schematics.

SITE INTEGRATION

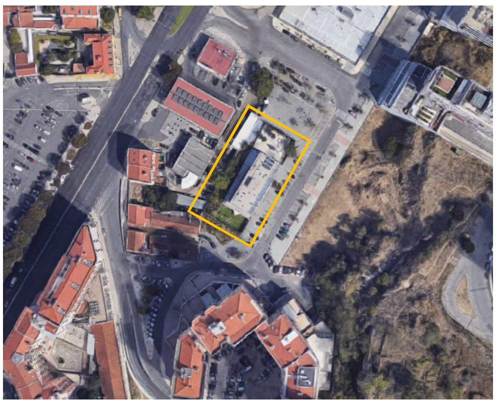


Figure 20: Aerial view of the building.

The building is located in the outskirts of an urban dense neighbourhood in Lisbon, and it is a grid connected building. The CML Kindergarten is immediately surrounded by a garden (Southwest and Northwest, as shown in the figure), a playground area (Northeast) and a parking lot (Southeast). Regarding other buildings, the CML Kindergarten is surrounded by low to mid-rise buildings from the South, West, and North directions and from East by a small cliff (equivalent to a low-rise building).

CLIMATE ANALYSIS

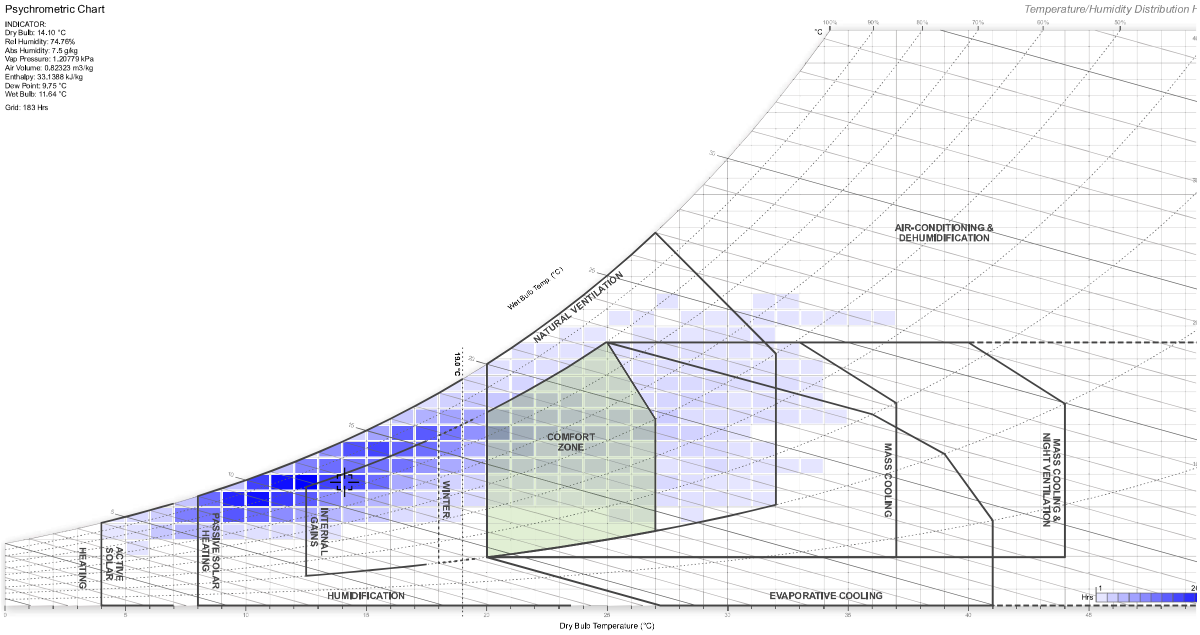


Figure 21 – Givoni Bioclimatic chart for the climate of Lisbon (Source: Andrew Marsh online tool).

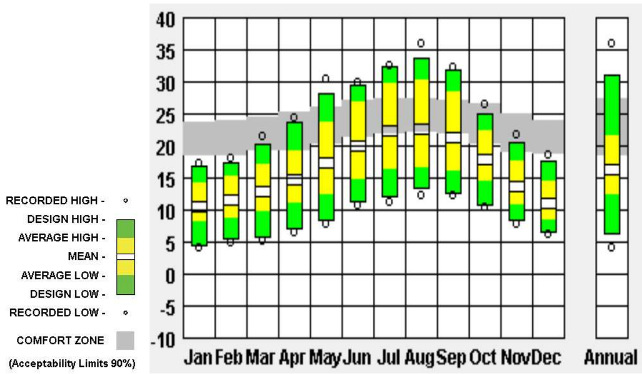


Figure 22 – Typical monthly air temperature range in Lisbon (Source: Climate consultant – Adaptative Comfort model).

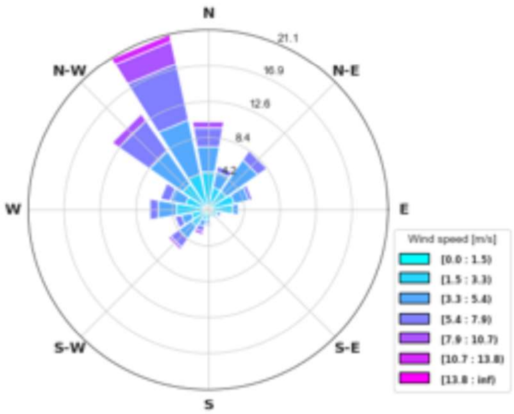


Figure 23 : Annual wind rose for Lisbon (Beaufort wind scale).

Global horizontal radiation (Avg daily total) Min (month) / Max (month)	Min: **1 946** Wh/m^2 (December) Max: **7 548** Wh/m^2 (July)
Annual Degree-Days for weather classification according to ASHRAE Standard 169-2020	HDD 18°C: **978** CDD 10°C: **2 549**
Annual Degree-Days for the Adaptive Comfort Base Temperature according to the ASHRAE 55-2017 for 80% of acceptability	HDD (Lower limit 80%): **1 295** CDD (Upper limit 80%): **18.5**
Annual Degree-Days for a static comfort temperature approach	HDD 18.6ºC: **1 063** CDD 26º: **17**

KEY BIOCLIMATIC DESIGN PRINCIPLES	
Passive cooling strategy	The natural ventilation strategy consists of air being introduced into the space through low level grilles (or openable windows) on the façade and being exhausted in the centre or back of the room, through one or two chimneys depending on the size of the room. With this strategy, both comfort ventilation and nocturnal convective ventilation are used in summertime (see figure below in summer operation mode).
Passive heating strategy	The winter operation mode allows for a semi-passive heating strategy with the heating being provided by passive convectors, feed by a heat pump.
Solar protection	Passive solar protection for the ground floor with horizontal overhangs, and active solar protection for the first floor with horizontal fins (see figure below).
Building orientation	The building has a rectangular shape with its main façades facing Northwest and Southeast.
Insulation	Insulation applied in the outer layers of the façades and roof.
Vegetation	-
Natural daylighting	The lighting project included natural and artificial lighting. There are several skylights throughout the building. Due to limited financial resources for initial and running costs, the systems are manually operated.
Use of local and embedded materials	-
Water saving and heat recovery on hot water drain	-
Waste management	-
Others features	-

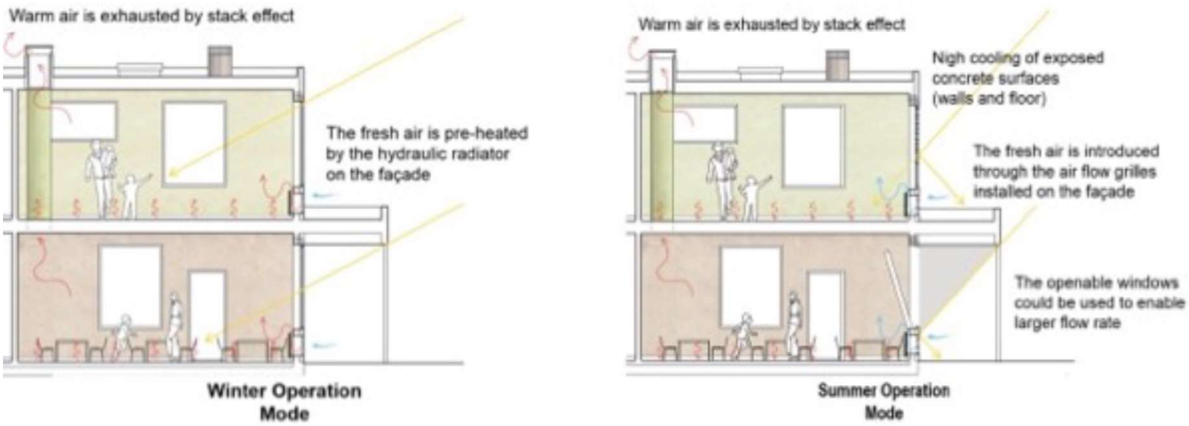


Figure 24: Winter and Summer operation modes.

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): No
Protected bike parking and showers	No Ratio with number of users:
Ceiling fans	In every room, even those conditioned: No

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Lighting system fractioned to allow using light only in zones occupied and where daylighting insufficient	In every room, even those conditioned: No
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.: Yes
BUILDING FABRIC AND MATERIALS	
Roof	The roof is structured as (from outside to inside): 1. Aluminium (thickness 0.01 m, thermal conductivity 15.1 W/m·ºC, thermal resistance 0 m^2·ºC/W and density 8055 kg/m^3) 2. Rockwool (thickness 0.1 m, thermal conductivity 0.04 W/m·ºC, thermal resistance 2.5 m^2·ºC/W and density 150 kg/m^3) 3. Air space (thickness 0.05 m, thermal conductivity 0.03 W/m·ºC, thermal resistance 1.67 m^2·ºC/W and density 1.16 kg/m^3) 4. Rockwool-gypsum board (thickness 0.065 m, thermal conductivity 0.04 W/m·ºC, thermal resistance 1.63 m^2·ºC/W and density 40 kg/m^3)
	Overall R-value: 6.01 [m^2·K/W] **U-value:** 0.38 [W/m^2·K]
Ceiling	The ceiling is structured as: 1. Rockwool- gypsum board (thickness 0.065 m, thermal conductivity 0.04 W/m·ºC, thermal resistance 1.63 m^2·ºC/W and density 40 kg/m^3) 2. Air space (thickness 0.05 m, thermal conductivity 0.03 W/m·ºC, thermal resistance 1.67 m^2·ºC/W and density 1.16 kg/m^3) 3. Heavyweight concrete (thickness 0.2 m, thermal conductivity 2.3 W/m·ºC, thermal resistance 0.09 m^2·ºC/W and density 1375 kg/m^3)
	Overall R-value: 3.59 [m^2·K/W] **U-value:** 0.28 [W/m^2·K]
Exterior Wall	The exterior wall is structured as (from outside to inside): 1. Plaster (thickness 0.01 m, thermal conductivity 1.3 W/m·ºC, thermal resistance 0.01 m^2·ºC/W and density 2000 kg/m^3) 2. Polyethylene (thickness 0.08 m, thermal conductivity 0.04 W/m·ºC, thermal resistance 2 m^2·ºC/W and density 40 kg/m^3) 3. Heavyweight Concrete (thickness 0.13 m, thermal conductivity 2.3 W/m·ºC, thermal resistance 0.27 m^2·ºC/W and density 2300 kg/m^3)
	Overall R-value: 2.45 [m^2·K/W] **U-value:** 0.41 [W/m^2·K]

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Interior Wall	The interior wall is structured as: 1. Gypsum board (thickness 0.025 m, thermal conductivity 0.25 W/m·°C, thermal resistance 0.56 m^2·°C/W and density 500 kg/m^3) 2. Air space (thickness 0.05 m, thermal conductivity 0.03 W/m·°C, thermal resistance 1.67 m^2·°C/W and density 750 kg/m^3) 3. Rockwool (thickness 0.07 m, thermal conductivity W/m·°C, thermal resistance 0.18 m^2·°C/W and density kg/m^3) 4. Gypsum board (thickness 0.025 m, thermal conductivity 0.04 W/m·°C, thermal resistance 0.63 m^2·°C/W and density 35 kg/m^3)
	Overall R-value: 3.3 [m^2·K/W] **U-value:** 0.30 [W/m^2·K]
Floor	The floor is structured as (from outside to inside): 1. Soil (thickness 1.7 m, thermal conductivity 1.14 W/m·°C, thermal resistance 1.49 m^2·°C/W and density 1000 kg/m^3) 2. Riprap (thickness 0.25 m, thermal conductivity 1.2 W/m·°C, thermal resistance 0.21 m^2·°C/W and density 1000 kg/m^3) 3. Heavyweight concrete (thickness 0.2 m, thermal conductivity 2.3 W/m·°C, thermal resistance 0.18 m^2·°C/W and density 2240 kg/m^3)
	Overall R-value: 1.88 [m^2·K/W] **U-value:** 0.41 [W/m^2·K]
Windows	Low-emissivity double glazed windows (λ=0.9 W/m·K; τ=0.75)
	Window-to-wall ratio (WWR) 18%
	U-value: 3.5 [W/m^2·K] Visual transmittance 0.75

ENERGY EFFICIENT BUILDING SYSTEMS	
Low-energy cooling systems	None
Low-energy heating systems	The winter operation mode allows for a low-energy heating strategy with the fresh outdoor air being pre-heated by passive convectors fed by a heat pump which has a maximum heating power output of 38.6kW and a COP of 3.5 (see Figure 24 above, in winter operation mode).
Ceiling fans	None
Mechanical ventilation / air renewal	The air renewal strategies are: • Natural ventilation: 1. Displacement ventilation; 2. Single sided ventilation. The ventilation solution consists in a high-level openable window plus low-level grilles installed on the façade of each classroom that control the inflow air. The air will be exhausted in the back of the room, through one or two thermal chimneys. Due to limited financial resources for initial and running costs, the implemented natural ventilation strategies are manually operated, and their usage relies on the occupant perception of the internal environment
Domestic Hot Water	Solar thermal system The building is served by:

	• The heat pump over-mentioned for heating system; • Solar thermal system. The solar thermal system is composed by 6 solar panels and a 500 litres water deposit. The heat pump is used as an auxiliary system whenever the solar thermal panels cannot supply the necessary amount of energy.
Artificial lighting	The whole building is equipped with high-efficiency LED lighting.
Control and energy management	None
RENEWABLE ENERGY	
PV	None
Solar thermal	The solar thermal system consists of seven flat collectors installed on the roof with a total area of 10m^2.
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, II category EN16798-1, cooling season): **39.7%**
2. Percentage of time outside an operative temperature range (Fanger, II category EN16798-1, heating season): **1.07%**
3. Degree-hours (Adaptive, II category EN16798-1, cooling season): **505**
4. Degree-hours (Fanger, II category EN16798-1, heating season): **93**
5. Percentage of time inside the Givoni comfort zone of 1m/s:
   Whole year: **80% /** Cooling season: **83%** (see Figure 25)
6. Percentage of time inside the Givoni comfort zone of 0m/s:
   Whole year: **69% /** Cooling season: **63%** (see Figure 25)
7. Number of hours within a certain temperature range

Heating Season (1st-10 to 31th-03)		
Range	Nº of Hours	Frequency
T≤20	**253**	17.1%
19≤T≤24	**1223**	82.9%
T≥24	**0**	0.0%

Cooling Season (1st-04 to 30th-09)		
Range	Nº of Hours	Frequency
T≤23	**0**	0.00%
23≤T≤26	**1050**	90.21%
T≥26	**114**	9.79%

Energy performance indicators

1. Energy needs for heating: **0.7** [kWh/m^2/year]
2. Energy needs for cooling: **13.0** [kWh/m^2/year]
3. Energy use for lighting: **22.7** [kWh/m^2/year]
4. Energy needs for Sanitary Hot water: **9.5** [kWh/m^2/year]
5. Total Primary energy use: **193.4** [kWh/m^2/year]
6. Renewable Primary energy generated on-site: **8.1** [kWh/m^2/year]
7. Renewable Primary energy generated on-site and self-consumed: **7.6** [kWh/m^2/year]
8. Renewable Primary energy exported to the grid: **0.5** [kWh/m^2/year]

	9. Ratio of renewable primary energy over the total primary energy use (with and without compensation): **4.2** (%)
	10. Delivered energy: **34.5** [kWh/m²/year] (from electricity bills)
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): **500** [lux]
	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	-

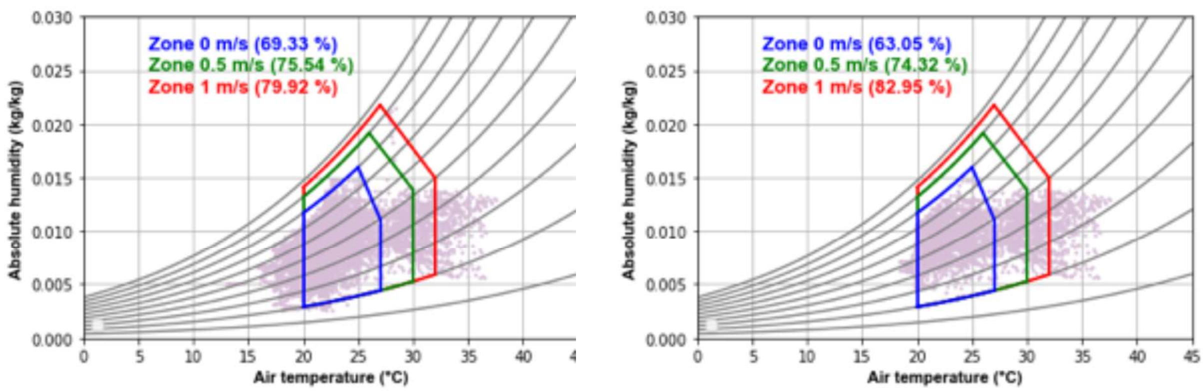
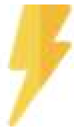


Figure 25 : Givoni bioclimatic chart – distribution of hourly mean air temperature: (a) for the whole year and (b) for the summer period.

LESSONS LEARNED AND RECOMMENDATIONS	
Lessons learned	The stack driven natural ventilation (NV) system is very effective and self-regulating. This system can meet the airflow rate goals during the spring and winter periods. If possible, this sort of NV system should have easily accessible manual control.
Recommendations	User training is essential and may need to be periodic (every 3 to 4years). In this school, the current users were convinced that the chimneys were poorly designed skylights.

BUILDING STRENGTHS AND WEAKNESSES

Strengths

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

Weaknesses

The main problem of this NV system occurs during the hottest days of summer, when it is necessary to promote the interior air renewal (to maintain acceptable CO_2 concentration, below the limit of 1625ppm for hybrid/passive buildings) but the outdoor air is much warmer than indoor air, which makes the use of natural ventilation prohibitive. In these cases, the users will determine what comfort parameter is more relevant to his comfort and to define if the openings should be maintained closed or be opened.

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