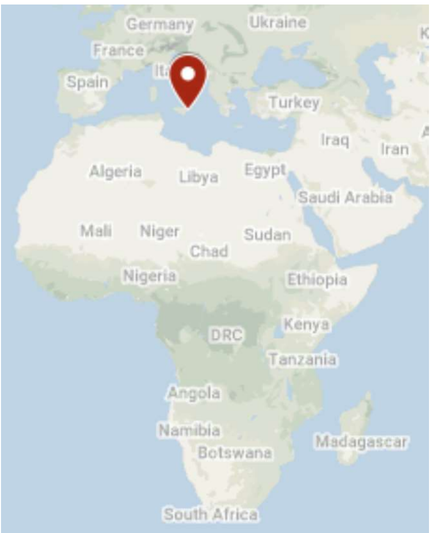
CASE STUDY 1-01: BOTTICELLI PROJECT | ITALY



GEOGRAPHICAL AND CLIMATE INFORMATION	
Location	Via Botticelli, Mascalucia (CT), Sicily, Italy
Latitude; Longitude	37.60422167605705, 15.045983886279847
Climate zone (Köppen–Geiger classification)	Csa: Warm temperate climate with dry and hot summer
BUILDING INFORMATION	
Building Type	Residential - Detached house
Project Type	New building
Completion Date	2012
Number of buildings	1
Number of storeys	1
Total Floor Area (m^2)	180 m^2
Net Floor Area (m^2)	150 m^2
Thermally conditioned space area (m^2)	144 m^2
Spaces with Natural Ventilation (with or without Ceiling Fans) Only (m^2)	the ventilation of the entire building can be natural or mechanical
Total cost (€)	400 000 [1]
Cost /m² (€/m²)	2 666.7 [1]
Performance Standards or Certification	Passivhaus e CasaClima Gold [2]
Awards	None
STAKEHOLDERS	
Building Owner/ Representative	Eng. Carmelo Sapienza
Architect / Designer	Eng. Carmelo Sapienza of Sapienza & Partners technical firm
Construction manager	Eng. Carmelo Sapienza
Environmental consultancy	Politecnico di Milano gruppo eERG
Structural Engineer, Civil Engineer	Eng Fabio Mondelli
Product Manufacturer	Rockwool Italia – Siemens building technologies
Certification company	Passivhaus standard [2]

ABC21 is funded by the EU's H2020 programme

PROJECT DESCRIPTION

Figure 1: Botticelli project external view [3]

Botticelli project is a single-story home, composed by a living room (including the kitchen), three bedrooms, a study room and two bathrooms (Figure 3). The layout has a U shape, with an internal patio communicating with the garden and allowing for crossflow ventilation and night-time ventilation strategies. The patio contributes also to daylighting. Botticelli project is among the first examples of Net Zero Energy Buildings located in the Mediterranean climate. The building, certified according to Passivhaus standard, is a single-family house monitored for research purposes and operated by a BACS, which is controlling the external solar blinds, the mixed-mode ventilation system, the PV and thermal solar panels and the Earth-to-Air Heat Exchanger (EAHE).

Figure 2: Botticelli project aerial view [3]

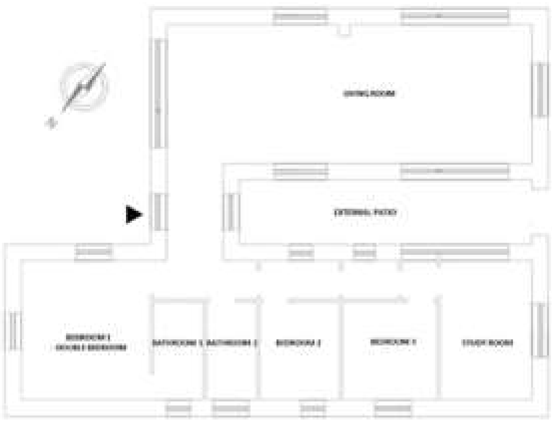


Figure 3: Botticelli project plan view [4]

SITE INTEGRATION

Botticelli project is an all-electric single-family detached house, located in the municipality of Mascalucia in Sicily, Italy. The U-shaped building is located in a residential urban context where surrounding constructions have a maximum height of two floors [5–7].

CLIMATE ANALYSIS

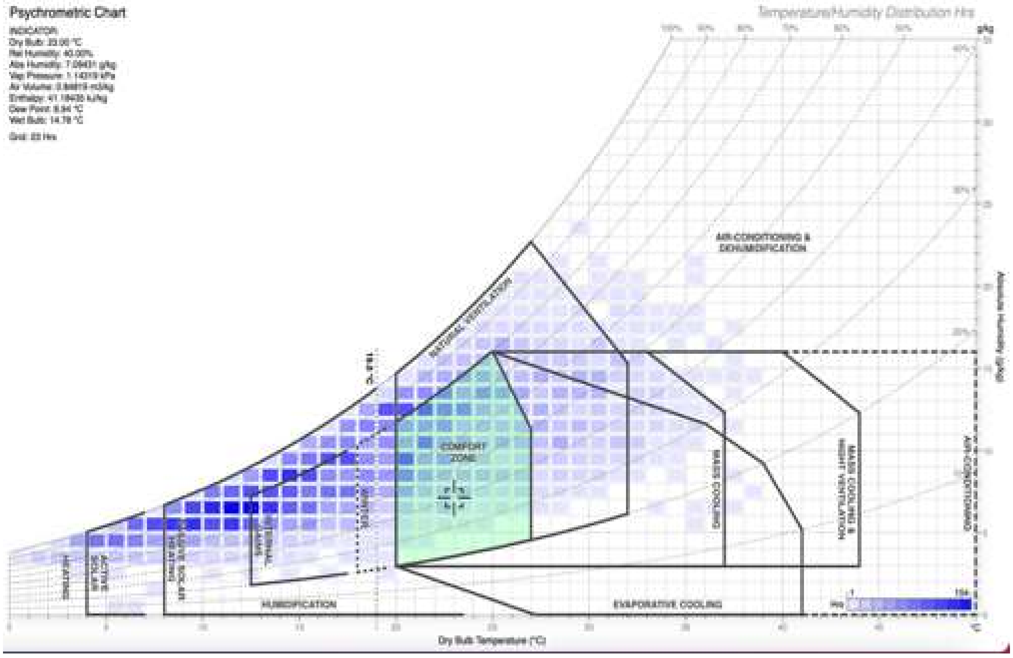


Figure 4: Givoni Bioclimatic chart for the climate of Mascalucia using Andrew Marsh online tool. Climate data are extracted from http://climate.onebuilding.org/WMO_Region_6_Europe/ITA_Italy/SC_Sicily/ITA_SC_Catania.Fontanarossa.AP.164600_TMYx.2004-2018.zip [8]

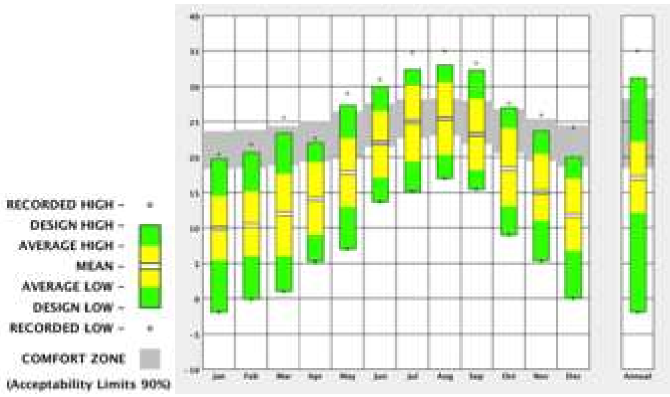


Figure 5: Temperature range by month for Mascalucia- Source: Climate consultant – Adaptative Comfort model [9]

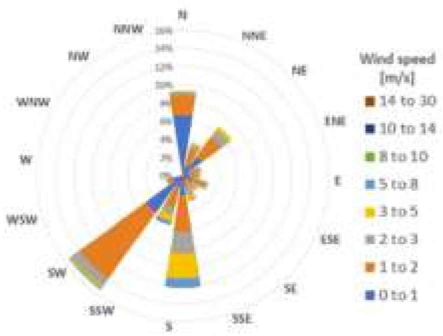


Figure 6: Annual wind rose for Mascalucia [4]

Global horizontal radiation (Avg daily total) Min (month) / Max (month)	Min: **2 248** Wh/m² (Dec) Max: **7 599** Wh/m² (Jul) Mean: **4 906,5** Wh/m²
Annual Degree-Days for weather classification according to ASHRAE Standard 169-2020	HDD 18°C: **1 129** CDD 10°C: **2 984**
Annual Degree-Days for the Adaptive Comfort Base Temperature according to the ASHRAE 55-2017 for 80% of acceptability	HDD (Lower limit 80%):**566** CDD (Upper limit 80%): **554** The Degree Days have been calculated considering the heating season from 15/11 to 31/03 and the cooling season from 01/04 to 14/11.

Annual Degree-Days for a static comfort temperature approach	HDD 18.6ºC: **1 000** CDD 26º: **169** The Degree Days have been calculated considering the heating season from 15/11 to 31/03 and the cooling season from 01/04 to 14/11.

KEY BIOCLIMATIC DESIGN PRINCIPLES	
Passive cooling strategy	**Comfort ventilation:** Natural ventilation strategy is activated through the manual opening of windows and is detected and registered by the KNX bus by means of an electrical sensor installed on each window. **Nocturnal convective ventilation** The natural ventilation (cross ventilation) is exploited during the night-time. **The Source as cooling source:** The Earth-to-Air Heat Exchangers (EAHE) serves the cooling/heating coil in order to pre-heat/cool the inlet air.
Passive heating strategy	The building exploits the thermal mass and its activation via ventilation. Technological application consists of a multilayer wall including a continuous mineral wool layer facing the outdoor environment and a core layer of massive elements such as masonry (for walls) and concrete (for slabs).
Solar protection	Shading systems is a motorized solar system which can be controlled manually or through an automatic system (lowering or raising the shadings and by setting the orientation of the louvres).
Building orientation	The structure of the detached-dwelling is defined approximately by a U-shape and is characterized by a slope roof equipped with photovoltaic system mainly on the south side. The entrance to the building is located on the east-south facade.
Insulation	Exterior insulation finishing system. The structure in reinforced concrete framed is designed without thermal bridges. Insulation mineral wool rock with all doors and windows characterized by mono-block with mosquito nets and shading system.
Vegetation	The permeable surfaces (vegetation and external pavement area) are more than the 40% of the land plot area. Soil permeability is maintained at 95% by infiltration with permeable floor and garden and rainwater collection. During the summer months, the irrigation of vegetation takes place by the re-use of grey water (recycled back into the water cycle) through a small phyto-treatment plant.

Natural daylighting	The lighting project is designed to optimize the interaction between natural light and artificial light, also in terms of energy efficiency.
Use of local and embedded materials	N/A
Water saving and heat recovery on hot water drain	The project Botticelli is equipped with a system of rainwater collection and water reuse. The rainwater collected and filtered is used to power the wastewater of the WC's toilet and the washing machine. The constructed Wetlands in the summer complements the reserve for the irrigation of the garden. The entire system is supported by the home automation system, which regulates its efficiency. The water system provides for the separation and collection of waste water of the building.
Waste management	N/A
Others features	The asset is equipped with bicycle racks to improve the use of alternative transport and a line drying spaces.

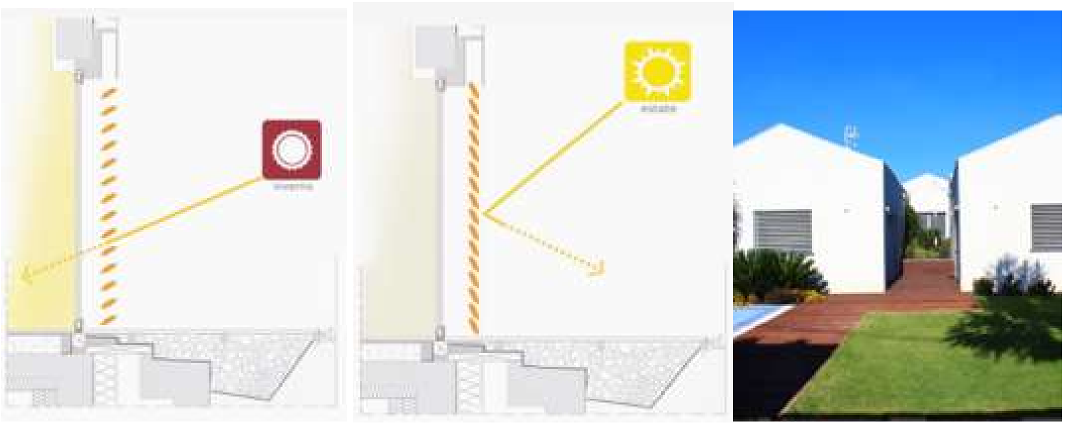


Figure 7: Project Botticelli shading systems [3]

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 *Ratio with number of users:* 2/4 showers/people
Ceiling fans	*In every room, even those conditioned:* No
Lighting system fractioned to allow using light only in zones occupied and where daylighting insufficient	*In every room, even those conditioned:* n/a
Space and facilities for line drying clothes (especially important in residences, hotels, sport facilities…)	*In every room, even those conditioned*: Yes

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.:* It is not necessary since the building is a detached residential house and the users are aware how to use the building correctly.

BUILDING FABRIC AND MATERIALS	
Roof	The roof is structured as Figure 8: 1. Impermeable breathable membrane (0.5 cm) 2. Rockwool insulation (28 cm) 3. Vapour barrier (-) 4. Reinforced concrete slab (20 cm) 5. Internal plaster (3 cm)
	U-value: 0.130 [W/m^{2}K] Overall R-value: 7.69 [m^{2}K/W]
Basement floor	The basement floor is structured as Figure 8: 1. Parquet (2 cm) 2. Acoustic insulation (0.5 cm) 3. Expanded clay (20 cm) 4. Rockwool insulation (1 cm)
	U-value: 0.231 [W/m^{2}K] Overall R-value: 4.33 [m^{2}K/W]
Windows	Type: Triple + double glazing 3G-Internorm IBE-LIGHT ESG4b/18g/ESG4/18b/b4ESG + 2G-Internorm IBE-LIGHT 6ESG/12g/b6ESG Kr (U g-value = 0.7 W/m^{2}K, g-value = 54 %)
	Window-to-wall ratio (WWR): n/a
	Windows thermal transmittance: 0.90 – 1.10 [W/m2K]
	Visual transmittance: n/a
Walls	The wall is structured as Figure 8: 1. Hollow brick (30 cm) 2. Internal plaster (3 cm) 3. Rockwool insulation (20 cm) 4. External plaster (1 cm)
	U-value: 0.127 [W/m^{2}K] Overall R-value: 7.87 [m^{2}K/W]

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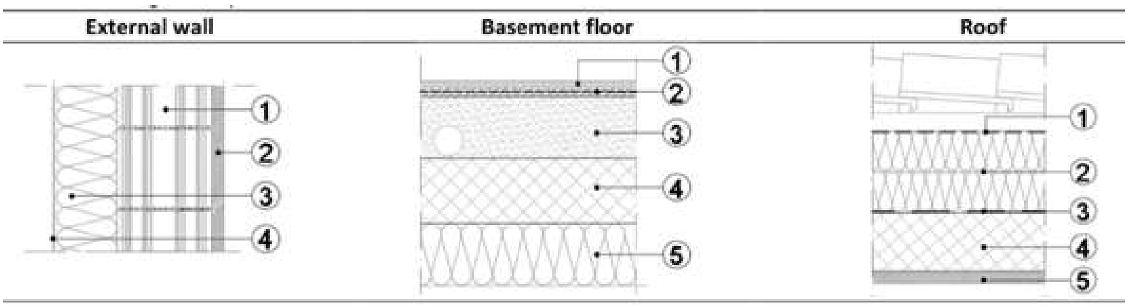

Figure 8: Main building envelope solutions [4]

ENERGY EFFICIENT BUILDING SYSTEMS [3,4,7]	
Low-energy cooling systems	The building is served by a reversible heat pump (air-water 6 kW) and an EAHE (Earth-to-Air Heat Exchangers) which provides the possibility for pre-heating or pre-cooling the handled air. This latter may then pass through a heat recovery unit before being processed by the heating/cooling coils and distributed to the bedrooms and the living room.
Low-energy heating systems	An electrical air to water reversible heat pump (6 kW) serves the heating/cooling coil in the main inlet ventilation duct. The climatization is realized by an all-air system in which the main air-inlet is connected to the heat exchanger EAHE (Earth-to-Air Heat Exchangers) and a heat recovery unit (air-air, cross-flow). The purpose of the EAHE is to pre-heat the handled air.
Ceiling fans	N/a
Mechanical ventilation / air renewal	The air renewal strategies are: ▪ Natural ventilation ▪ Nocturnal ventilation ▪ Mechanical ventilation with the exploitation of cross-flow heat recovery unit. The windows are equipped of sensors able to send signals to the BMS (bus Konnex). The mechanical ventilation is automatically unactive when the windows are open and vice versa.
Domestic Hot Water	The building is served by: ▪ Electrical air to water heat pump (the one over-mentioned for heating system) ▪ Solar thermal The thermal energy provided for domestic hot water system is generated by an integrated system: a water storage of 500 litres connected to the solar thermal system (7 m^2 of flat collectors) and the electrical heat pump (air-water).
Artificial lighting	The whole building is equipped with high-efficiency LED lighting.
Control and energy management	The connection of BMS with the room's sensors and the systems allows to exploit and monitoring in real time the comfort and the energy performance. The management is based on Konnex standard on the first part and secondly on BACnet communication protocol (*BACS class A realized with home automation KNX / connection for control, supervision and monitoring*).

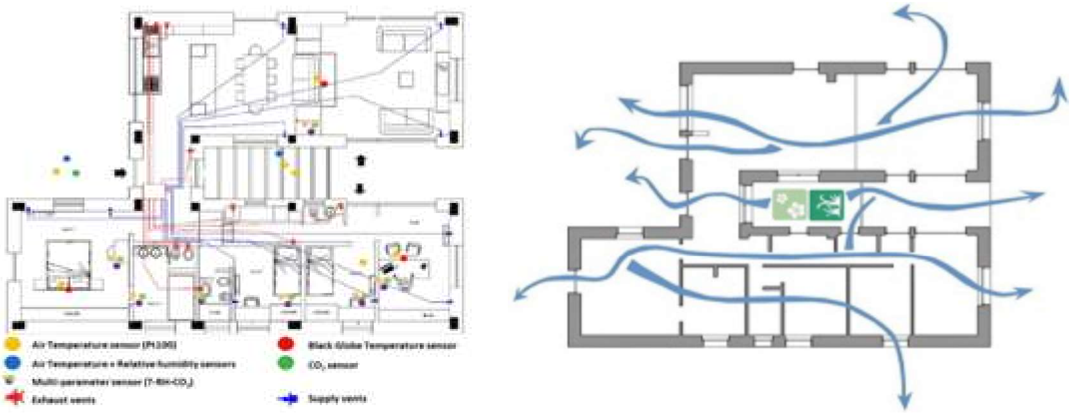

Figure 9: Botticelli Project view plan (on the left: sensors location, on the right: natural ventilation)[3]

Figure 10: Pictures of installed systems (on the left: thermal solar collectors, on the right Earth to Air Heat Exchanger) [3]

RENEWABLE ENERGY [3,4,7]	
PV	PV system (8.14 kW peak electric power) is installed alongside the building and on the sloped roof (both are mainly south-orientated). The electricity production by the PV panels is continuously monitored and compared with the instantaneous energy use of the building and the delivered energy (from the grid).
Solar thermal	Thermal solar panels are installed on roof and are part of an integrated system. (7 m^2 of flat collectors).
Wind	N/A
Geothermal	The EAHE (Earth-to-Air Heat Exchangers) provides the possibility for pre-heating or pre-cooling the ventilation air. The EAHE has been designed considering the geometric limits of the lot and the soil type and it can be excluded from the ventilation system by means of a by-pass duct, when required, according to the chosen control strategy.
Biomass	N/A

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Figure 11: Pictures of photovoltaic System and solar thermal collectors [3]

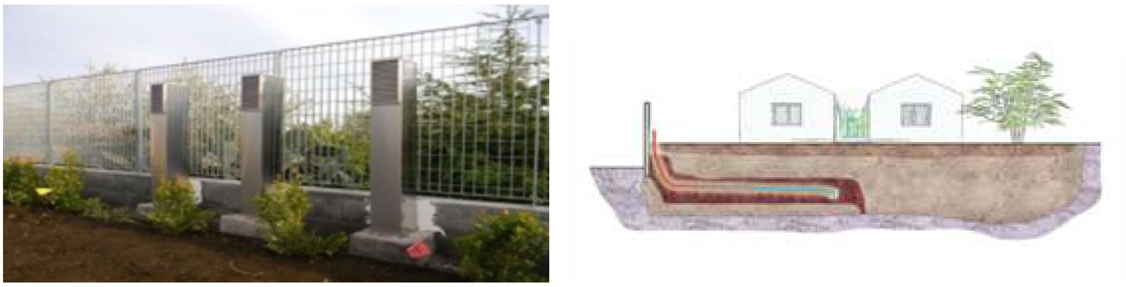

Figure 12: Pictures and schema of Earth to Air Heat Exchanger [3]

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): **3.9%**
2. Percentage of time outside an operative temperature range (Fanger, II category EN16798-1, heating season): **23.3%**
3. Degree-hours (Adaptive, II category EN16798-1, cooling season): **108**
4. Degree-hours (Fanger, II category EN16798-1, heating season): **303**

4. Percentage of time inside the Givoni comfort zone of 1m/s:

   Whole year: **88%** (Figure 15)

   Cooling season: **96%**

5. Percentage of time inside the Givoni comfort zone of 0m/s:

   Whole year: **44%** (Figure 15)

   Cooling season: **41%**

6. Number of hours within a certain temperature range (Figure 13):

Heating season (15th-11 to 31th-03)		
Range	N° of Hours	frequency
T≤19	26	0.8%
19≤T<24	3201	98%
T≥24	38	1.2%

Cooling season (1st-04 to 14th-11)		
Range	N° of Hours	Frequency
T≤20	0	0%
20≤T<26	3526	64%
T≥26	1969	36%

Energy performance indicators

1. Energy needs for heating: **7.21** [kWh/m^2/year] [4]
2. Energy needs for cooling: **10.25** [kWh/m^2/year] [4]
3. Energy use for lighting: **27.72** [kWh/m^2/year] [4]
4. Energy needs for Sanitary Hot water: **2.38** [kWh/m^2/year] [4]

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	5. Total Primary energy use: **144.5** [kWh/m^2_{net}/year] (total Primary Energy Factor (PEF) equal to 2.42 for electrical energy from the grid)
	6. Renewable Primary energy generated on-site: **76** [kWh/m^2/year] [4] (Figure 16)
	7. Renewable Primary energy generated on-site and self-consumed: **17.09** [kWh/m^2/year] [7]
	8. Renewable Primary energy exported to the grid: **56.02** [kWh/m^2/year] [7]
	9. Ratio of renewable primary energy over the total primary energy use (with and without compensation): **11.82%** [7]
	10. Delivered energy: **43.04** [kWh/m^2/year] [7]
Acoustic comfort indicators	1. Airborne sound insulation: N/A
	2. Equivalent continuous sound Level: N/A
	3. HVAC noise level: N/A
	4. Reverberation time: N/A
	5. Masking/barriers: N/A
Visual comfort indicators	1. Light level (illuminance): *YES*
	2. Useful Daylight Illuminance (UDI): N/A
	3. Glare control: N/A
	4. Quality view: YES
	5. Zoning control: YES
Indoor Air Quality indicators	1. Organic compound: N/A
	2. VOCs: N/A
	3. Inorganic gases: *YES (CO_2)*
	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	n/a

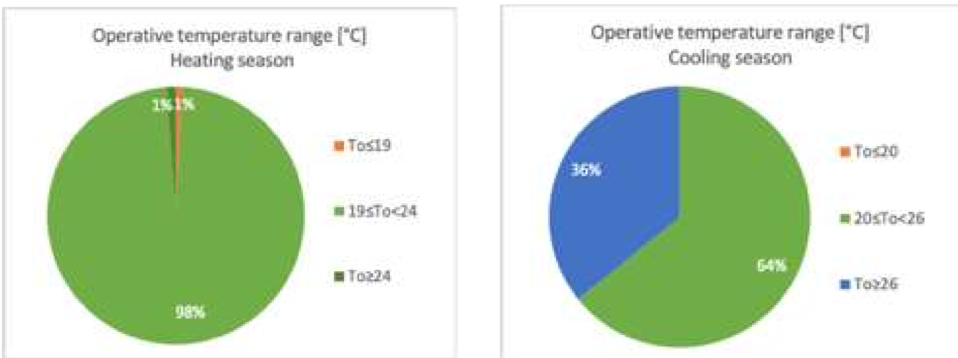

Figure 13: Percentage of hours within comfort range of operative temperature

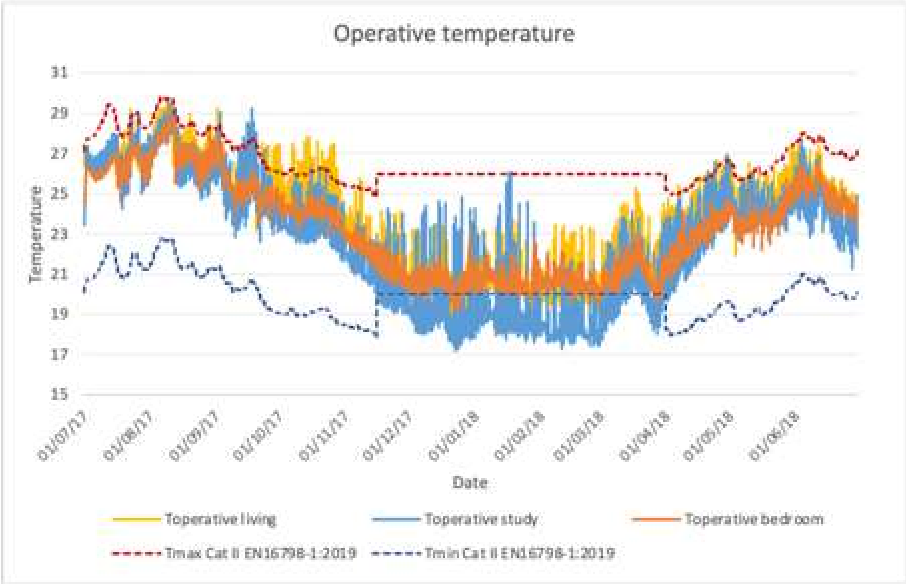

Figure 14: Operative temperature and comfort boundaries (EN16798-1:2019) (Fanger comfort model for heating season from 15/11 to 31/03 and adaptive comfort model the cooling season from 01/04 to 14/11, II comfort category)

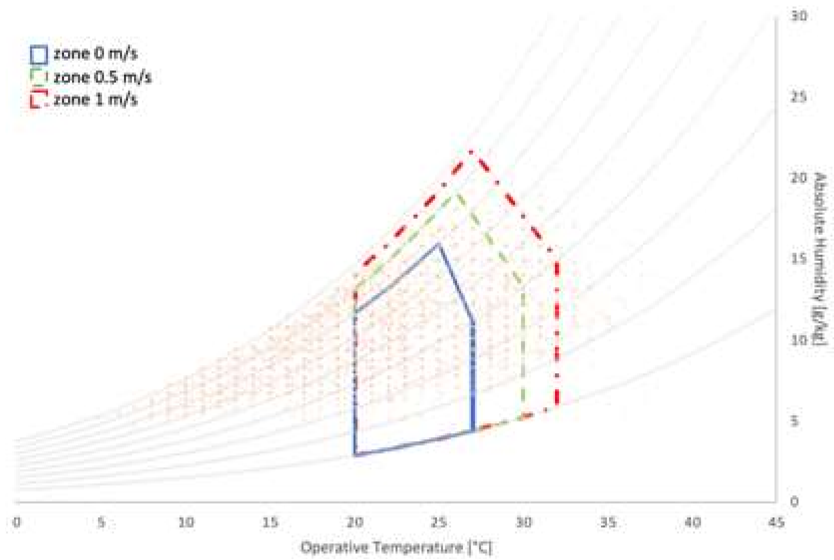

Figure 15: Givoni bioclimatic chart – distribution of hourly operative temperature of the monitored year (2017/2018)

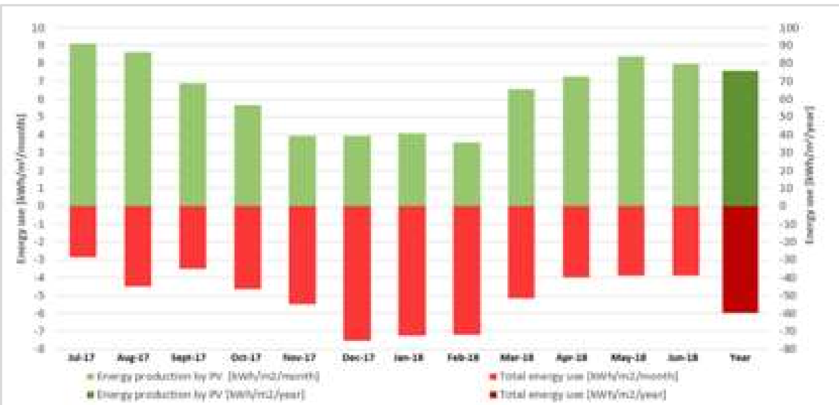

Figure 16: Monthly and yearly energy production by PV (green) and total energy use (red) during the investigated year (2017/2018)

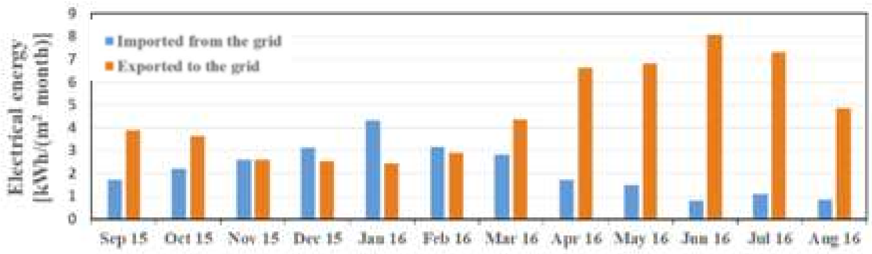

Figure 17: Comparison between the monthly electrical energy imported/exported (monitored year: 2015/2016)[7]

LESSONS LEARNED AND RECOMMENDATIONS

Lessons learned	The analyses highlight that even under challenging outdoor temperatures without an active conditioning thanks to the building geometry, highly insulated envelope and external movable solar protections automatically controlled, the building remains in comfort zone. The presented comfort indexes allow verifying both how many degrees and how long the building is outside the comfort zone. During the cooling season, even though the percentage of hours in which the operative temperature higher than 26°C is 36%, the calculated operative temperature is just slightly higher than the comfort threshold.
Recommendations	The analysis of the building energy performance is important in terms of load-management strategies to optimize the use of renewable energy and to improve the balancing between production and use. Figure 17 shows that on a monthly basis the renewable energy generated on site is lower than the energy use for some months, therefore should be explored all the possibilities for shifting (on a daily basis) part of use of energy to hours where PV generation takes place, in order to reduce the daily mismatch, even without installation of electrical storage. Long term, inter-seasonal storage (e.g. storing for using in winter the energy generated by renewables in summer) remains a challenge both in terms of available spaces and cost, possibly to be addressed at district scale.

BUILDING STRENGTHS AND WEAKNESSES

Strengths

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

Weaknesses

As reported in the previous analysis the building shows generally high energy and comfort performance though out the year. However, the north-facing rooms may exceed the comfort thresholds (as shown in the Figure 14) because of their unfavourable position.

There is a small garden surrounding the building with only one tree, which is not sufficient to have a favourable impact from the point of view of the climatic comfort inside the building.

Artificial materials such as insulation mineral wool rock is used. There is no information about sustainable materials; this shows a lack in the design process.

This is not a low tech design that can be easily reproduced in parts of the world where there is not the same availability of materials, means and technical knowledge.

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