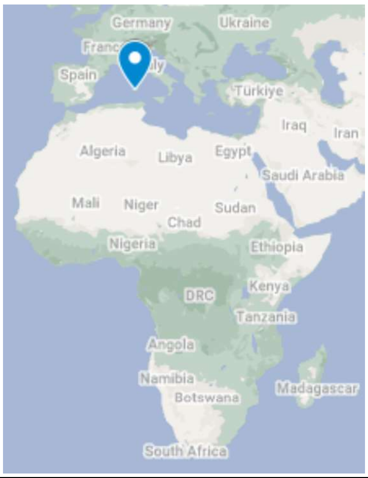
CASE STUDY 2-01: PATIO HOUSE | ITALY



GEOGRAPHICAL AND CLIMATE INFORMATION

Location	Via delle Mimosa 18, 09010 Portoscuso Sud, Sardinia, Italy
Latitude; Longitude	39.217703, 8.374674 (39°13'03.7" N, 8°22'28.8" E)
Climate zone (Köppen–Geiger classification)	Csa: Warm temperate climate with dry and hot summer

BUILDING INFORMATION

Building Type	Residential
Project Type	New construction
Completion Date	2017
Number of buildings	1
Number of storeys	1
Total Floor Area (m^2)	162 (patio 23 m^2 + porch 22 m^2)
Net Floor Area (m^2)	104
Thermally conditioned space area (m^2)	104
Spaces with Natural Ventilation (with or without Ceiling Fans) Only (m^2)	104
Total cost (€)	210 000
Cost /m^2 (€/m^2)	1 300
Performance Standards or Certification	Classe A4: 38,95 kWh/m^2
Awards	None

STAKEHOLDERS

Building Owner/ Representative	Vincenzo Fadda
Architect / Designer	Arch. Michele Ricci, Ing. Giovanna Nardini
Construction manager	Greenlab Srl
Environmental consultancy	Ing. Casu Gabriele
Structural Engineer, Civil Engineer	Ing. Claudia Conti

PROJECT DESCRIPTION

Figure 1 : Ground floor plan of the Patio House.

The project stems from the desire to create a sustainable and innovative building, in energy class A+ suitable for the Sardinian Mediterranean climate, made with natural materials. A safe, healthy and comfortable home: the client immediately requested a straw house.

The architectural design was therefore based on choices that would optimize not only the quality of the spaces but also energy efficiency and environmental sustainability.

The biggest problem was to create a building which, even if placed within a subdivision and therefore an urbanized area, managed to maintain its privacy. The fulcrum of the project therefore becomes the desire to create a private, intimate outdoor space. The traditional Sardinian house, especially that of the Sulcis area, had a courtyard or courtyard, an external but private space, hence the intention of resuming a classic typology typical of warm Mediterranean countries: the house with an internal courtyard. The courtyard house also plays a pivotal role in better controlling the bioclimatic aspects.

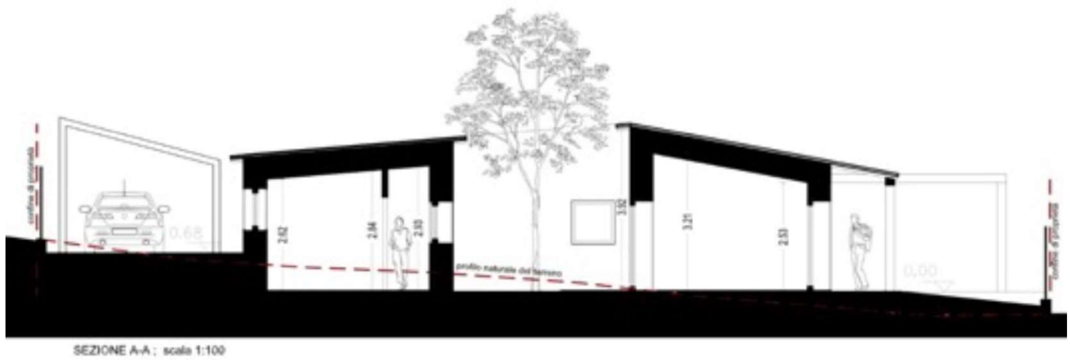


Figure 2 Section of the project.

SITE INTEGRATION

Figure 3 : (a) Aerial view (Source: Google Map) and (b) photograph of the geographical context of the project.

The building is located in Sardinia, in the Sulcis area in the province of Carbonia-Iglesias, on the outskirts of a small town of 5000 inhabitants close to the Tyrrhenian Sea, within an urban subdivision. The neighbourhood is surrounded by small trees and shrubs, typical vegetation of the "Macchia Mediterranea".

CLIMATE ANALYSIS

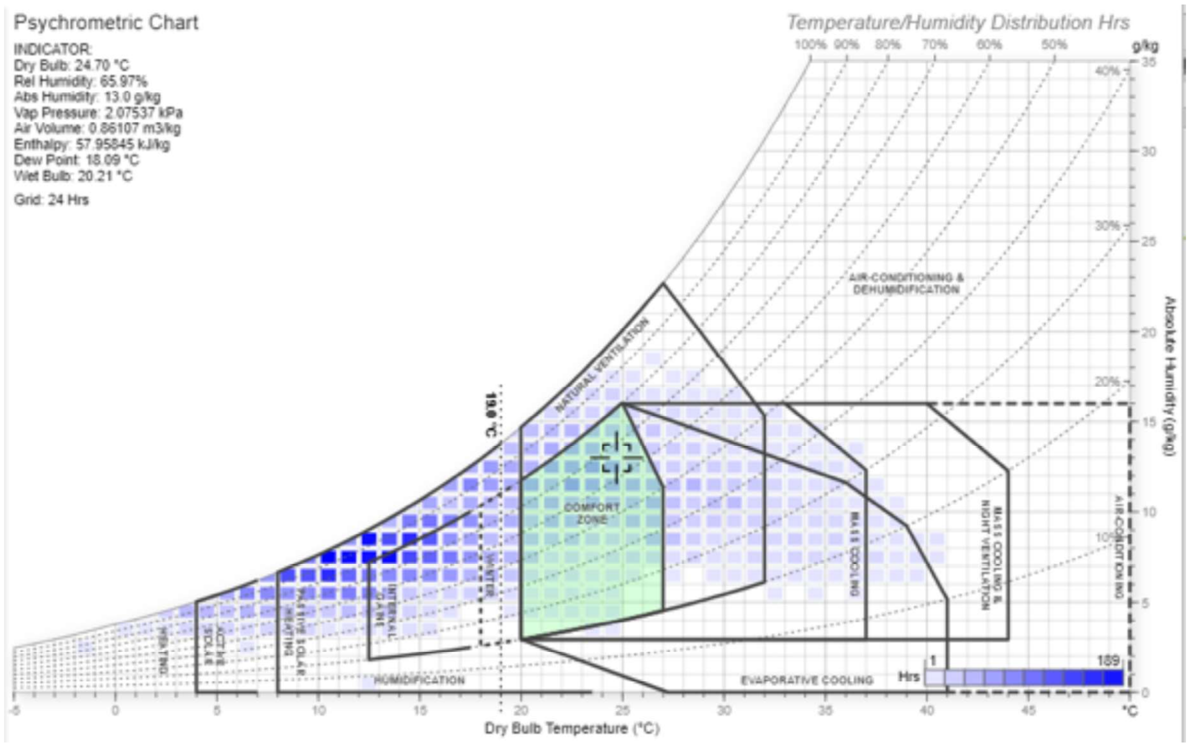


Figure 4: Givoni Bioclimatic chart for the climate of the region of Portoscuso, Sardinia, Italy using Andrew Marsh online tool [2]. Weather data are extracted from the PVGIS tool of the jrc for the 2005 – 2020 period.

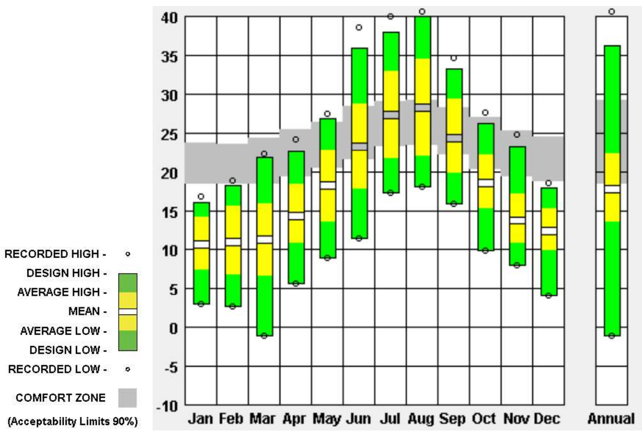


Figure 5: Temperature range by month for the region of Portoscuso, Sardinia, Italy (Source: Climate consultant – Adaptative Comfort model).

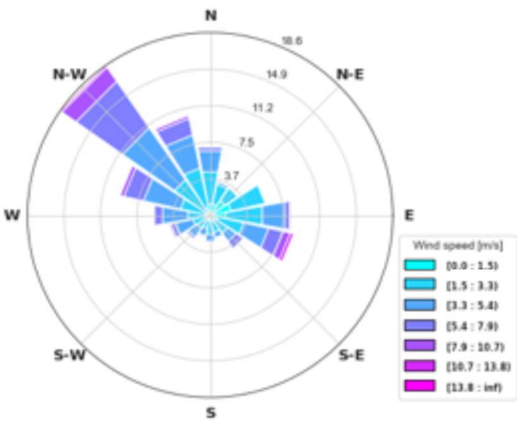


Figure 6: Wind rose for the region of Portoscuso, Sardinia, Italy

Global horizontal radiation (Avg daily total) Min (month) / Max (month)	Min: **1 987** Wh/m² (Dec.) Max: **7 776** Wh/m² (Jul.) Mean: **4 878** Wh/m²
Annual Degree-Days for weather classification according to ASHRAE Standard 169-2020	HDD 18°C: **1 149** CDD 10°C: **2 970**
Annual Degree-Days for the Adaptive Comfort Base Temperature according to the ASHRAE 55-2017	HDD: **1 297** CDD: **99**
Annual Degree-Days for a static comfort temperature approach	HDD 18.6ºC: **1 276** CDD 26º: **247**

ABC21 is funded by the EU's H2020 programme

KEY BIOCLIMATIC DESIGN PRINCIPLES	
Passive cooling strategy	**Comfort ventilation (**cross natural ventilation) **Nocturnal convective cooling** **High level of insulation** in straw bales Its **optimal and aerodynamic shape** allows to minimize the amount of heat in hot periods and enhance natural ventilation. The **inner courtyard** favours the formation of cool areas inside the house which create natural ventilation in summer, decreasing the perceived temperature. The building is plastered externally with a white natural lime plaster. The white colour was chosen for landscape and energy reasons, decreasing summer overheating. On the south-west side there is a small bio-pool which, in addition to having a recreational purpose, also has the function of creating a microclimate and cooling the hot summer air.
Passive heating strategy	**Solar radiation** **High level of insulation** in straw bales The **optimal shape** of the building involves the minimum heat loss in cold periods. Besides, **large glass windows on the south side and optimized solar protection** allow solar radiation to penetrate the building during the winter months. Another feature of the building is its positioning in the ground, which has a difference in height of about two meters in the north-south axis. The house tries to make the most of the morphology and remains buried for about 90 cm on the north side for two reasons: to use the ground as thermal insulation on the colder side (the ground has a constant temperature all year round) and to have a north facade lower than the others and therefore obtain a more aerodynamic shape and protected from the Mistral wind.

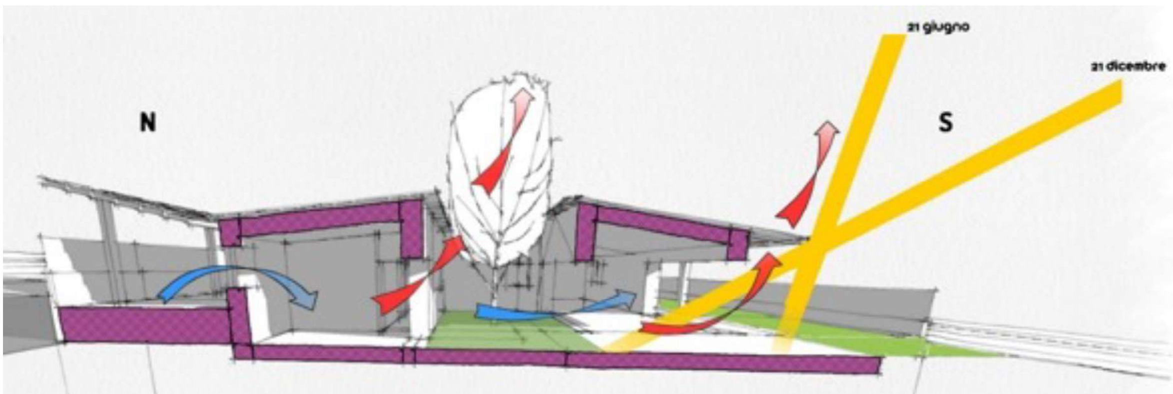


Figure 7: Section of the building showing the passive features set up.

Solar protection	The porch on the south side were designed to protect the building from direct solar during the summer period. Pergola on the East side for relaxation but also for lunch and dinner outdoors. A second pergola to the north instead has the dual function of carrying the solar and photovoltaic panels and covering the car park.

Building orientation	The main façades of the house are Est-West oriented.
Insulation	The high level of insulation in straw bales enables a thermal lag of the walls of 21 hours while the roof, which is ventilated and insulated with straw bales and raw earth, enables a thermal lag by no less than 16 hours.
Vegetation	The house is surrounded by small trees and shrubs, typical vegetation of the "Macchia Mediterranea". The vegetation does not contribute to shade the house, explaining why additional passive shading strategies had to be adopted.
Natural daylighting	The inner courtyard and the large glass windows provide natural light to the rooms of the building, especially the ones located in the northern part.
Use of local and embedded materials	**Straw bale and cork** The supporting structure of the building is made of wood, offering a " light “, flexible and highly resistant building. The masonry closure and thermal-acoustic insulation is made with **straw bales grown and built a few kilometres away**; the latter conceptually used as bricks, in addition to being a high-performance insulator, it guarantees breathability, durability, resistance to fire, earthquakes and environmental sustainability. Inside the house, the plasters will be made of raw earth. This natural material will contribute to a high internal comfort by acting as a hygro-regulator, avoiding condensation and mould; the use of raw earth for plaster and as a building material in general is part of the tradition of this region.
Water saving and flood management	The presence of small trees and shrubs, as well as pervious surfaces, in the courtyard and around the house allows to manage rainwater.
Waste management	Selective waste collection
Others features	Covered car park.


(a)


(b)

Figure 8: Exterior view of the (a) South and (b) West façades

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: **-**
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: **No**
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.: **NA** *It is not necessary since the building is a detached residential house and the users are aware how to use the building correctly.*

Figure 9: General sketch of the house

Figure 10 : Interior view of the living room

BUILDING FABRIC AND MATERIALS	
Roof	Composition: Ventilated wooden roof / Raw earth / Straw bale / Double wooden plank Thickness: 55 cm
Walls	Composition: Natural lime plaster / lime and sawdust mortar / Straw bale / Mortar and sawdust / Raw earth plaster Thickness: 55 cm
Windows	PVC
Basement floor	Insulation with expanded clay

Figure 11: The supporting structure of the building is made of wood.

Figure 12: The external walls are highly insulated with straw bales.

(a) (b)

Figure 13 : Construction of the roof: (a) step 1 and (b) step 2.

ENERGY EFFICIENT BUILDING SYSTEMS	
Low-energy cooling systems	5 split systems Cooling rated capacity of 2.43 kW and 8300 Btu/hr
Low-energy heating systems	5 split systems Heating rated capacity of 3.22 kW and 11000 Btu/hr
Ceiling fans	None
Mechanical ventilation / air renewal	None
Domestic Hot Water	None
Artificial lighting	LED lamps (150W in total)
Control and energy management	None

RENEWABLE ENERGY	
PV	None
Solar thermal	2 panels – South oriented
Wind	None
Geothermal	None
Biomass	None

ABC21 is funded by the EU's H2020 programme

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: **≥98%**
6. Percentage of time inside the Givoni comfort zone of 0m/s: **≈30%**
7. Number of hours within a certain temperature range

Hot period (1st Aug. to 30th Sep. 2022) Occupation time: 6:00pm to 8:00am	Living Room		Bedroom	
Range	Nb of Hours	Frequency	Nb of Hours	Frequency
Ta<22°C	0	0%	**0**	0%
22°C≤Ta<24°C	0	0%	**0**	0%
24°C≤Ta<26°C	**86**	8,3%	**176**	17,2%
26°C≤Ta<28°C	**801**	77,8%	**798**	77,8%
28°C≤Ta<30°C	**143**	13,9%	**52**	5,1%
30°C≤Ta<32°C	0	0%	**0**	0%
32°C≤Ta<34°C	0	0%	**0**	0%
34°C≤Ta<36°C	0	0%	**0**	0%
Ta≥36°C	0	0%	**0**	0%

Energy performance indicators

1. Energy needs for heating: **10.24** [kWh/m^2/year]
2. Energy needs for cooling: **12.90** [kWh/m^2/year]
3. Energy use for lighting: **-** [kWh/m^2/year]
4. Energy needs for Sanitary Hot water: **14.57** [kWh/m^2/year]
5. Total Primary energy use: **38** [kWh/m^2/year]
6. Renewable Primary energy generated on-site: **-** [kWh/m^2/year]
7. Renewable Primary energy generated on-site and self-consumed: **-** [kWh/m^2/year]
8. Renewable Primary energy exported to the grid: **-** [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) : **-** [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	Owners are very satisfied by the comfort conditions of the house.

LESSONS LEARNED AND RECOMMENDATIONS

Lessons learned	The data collected confirms that straw as a building material works better as thermal insulation than thermal inertia. The comfort conditions in all the indoor spaces are very good in summer with 99% of the temperature and humidity pairs inside the comfort zone of 1m/s. That means that without air conditioning and by creating air movements (natural cross ventilation and/or ceiling fans), the occupants feel comfortable. Unfortunately, AC is used in the bedrooms and no ceiling fans are installed. The patio does not seem to play its role of buffer space in summer as initially planned by the architects, mainly because of the lack of solar shading systems. The outdoor conditions inside the patio are very similar to the airport ones, i.e. hot and humid. We would point out, however, that in the original design a tree was planned on the patio.
Recommendations	Patio: we recommend to lower the outdoor temperature in summer to plant an endemic tree (acacia, deciduous tree, pergola with wine tree, olive tree), and to install a retractable shading system in textile or pergola with fixed of rotating louvres. Insert connection to a cold sink: earth to air heat exchanger, ground at 5 m depth (temperature at 5-6 m is = average air temperature over the year, hopefully < 20, possibly 16-17), radiation to the sky being hindered by humidity. Bedrooms and living room: to avoid or to reduce the use of AC, we recommend to install ceiling fans in all indoors spaces (one for each bedroom and 2 for the living room). The ratio is one ceiling fan/ 10 m^2. Increase the inertia of the straw wall: by increasing the thickness of the interior clay-based plaster or even through a single-row brick wall.

BUILDING STRENGTHS AND WEAKNESSES

Strengths

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

Weaknesses

REFERENCES

https://www.archetica.com/index.php?option=com_content&view=article&id=42:casa-a-patio&catid=12&Itemid=124