CASE STUDY 1-11: DAR AMYS VILLA | MOROCCO

GEOGRAPHICAL AND CLIMATE INFORMATION	
Location	Marrakech, Morocco
Latitude; Longitude	31.61685854559842, -8.033311845423265
Climate zone (Köppen–Geiger classification)	BSh: Hot semi-arid steppe
BUILDING INFORMATION	
Building Type	Terraced individual housing, Villas
Project Type	New construction
Completion Date	N/A
Number of buildings	1
Number of storeys	2
Total Floor Area (m²)	1st floor:167 m² 2nd floor: 117 m² [1]
Net Floor Area (m²)	284 m²
Thermally conditioned space area (m²)	284 m² (The whole building is thermally conditioned)
Spaces with Natural Ventilation (with or without Ceiling Fans) Only (m²)	284 m² (The whole building is naturally ventilated)
Total cost (€)	667 044 (7 000 000 MAD)
Cost /m² (€/m²)	2 348.8 (24 647 MAD/m²)
Performance Standards or Certification	-
Awards	-
STAKEHOLDERS	
Building Owner/ Representative	Pr. Amine Bennouna
Architect / Designer	Mohamed El Anbassi
Construction manager	Mohamed El Anbassi
Environmental consultancy	Mohamed El Anbassi

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Structural Engineer, Civil Engineer	Mohamed El Anbassi
Product Manufacturer	_
Certification company	_

PROJECT DESCRIPTION

Figure 163: Exterior view of the Dar Amys Villa

The building is a villa type house located in the Marrakech (Morocco). The house is constituted of two floors and was designed to be energy efficient by integrating some passive techniques: overhangs, an Earth-to-Air Heat Exchanger (EAHX), thermal insulation of the roof and external walls. Water is provided from an in-site well and managed with smart drip irrigation techniques. Biodegradable wastes are recycled and used as compost for fertilization. A solar water heater is installed on the roof of the building.

(b) (b)

Figure 164: Dar Amys plan view: (a) 1st floor level and (b) second floor level [2]

SITE INTEGRATION

Figure 165 : Aerial view of the Dar Amys Villa and its' surrounding

Dar Amys is a family detached house, located in a hot semi-arid steppe region. The villa is constructed in a green land of 300 m^2 area. The building is located in a suburb of Marrakesh constituted by luxury constructions villas.

CLIMATE ANALYSIS

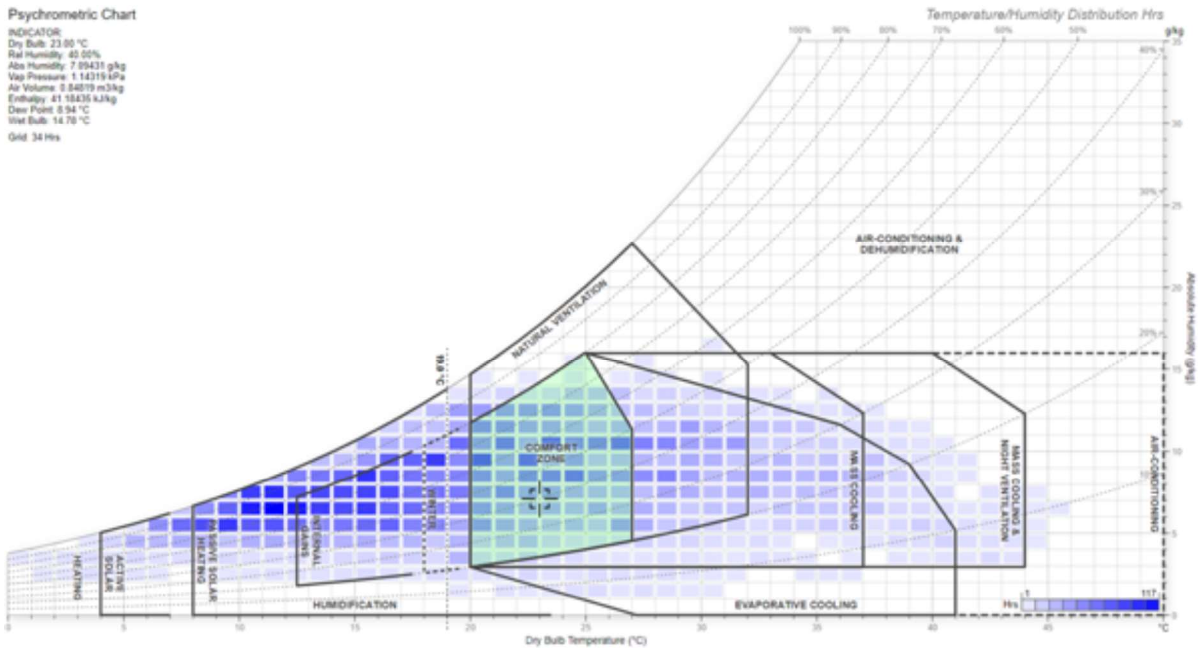

Figure 166: Bioclimatic chart for the climate of Marrakesh using Andrew Marsh online tool [3]. Climate data are extracted from http://climate.onebuilding.org/WMO_Region_1_Africa/MAR_Morocco/MS_Marrakech-Safi/MAR_MS_Marrakesh-Menara.AP.602300_TMYx.2004-2018.zip

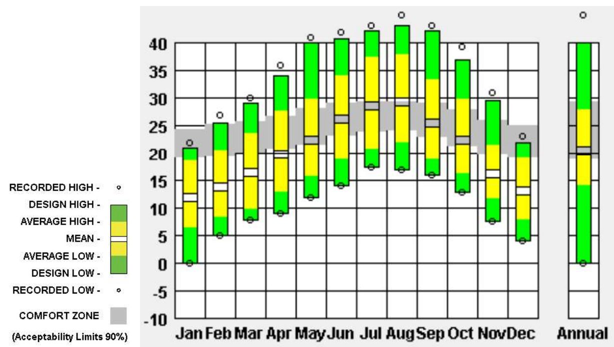

Figure 167: Temperature range by month for Marrakesh. Source: Climate consultant – Adaptative Comfort model [4]

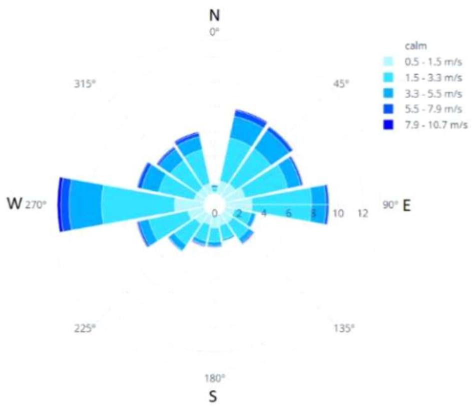

Figure 168: Annual Wind rose for Marrakesh (Beaufort wind scale) [4]

Global horizontal radiation (Avg daily total) Min (month) / Max (month)	Min: **2959** Wh/m² (Dec) Max: **7517** Wh/m² (Jul) Mean: **5237,42** Wh/m²
Annual Degree-Days for weather classification according to ASHRAE Standard 169-2020	HDD 18°C: **768** CDD 10°C: **3896**
Annual Degree-Days for the Adaptive Comfort Base Temperature according to the ASHRAE 55-2017 for 80% of acceptability	HDD: **1032** CDD: **245**
Annual Degree-Days for a static comfort temperature approach	HDD 18.6ºC: **863** CDD 26º: **498**

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KEY BIOCLIMATIC DESIGN PRINCIPLES	
Passive cooling strategy	**Comfort ventilation**: Natural ventilation strategy is achieved through the manual openings.
Passive heating strategy	High level of insulation of the roof and the walls. Double-glazed windows.
Solar protection	Overhangs and shadowing are following the standards to have the shadowed portion of the glazed area should be as large as possible in summer and as low as possible in winter. Horizontal solar protection of 1.20m on the Southern façade.
Building orientation	Oriented east-west so that its large dimensions face south (a disorientation of 17 ° was tolerated) [1]
Insulation	The roof and the exterior walls of the villa are highly insulated. The different thermal resistances are given below: Envelope walls or exterior walls = 2.55 m².K/W Intermediate floor = 2.37 m².K/W Roof = 2.67 m².K/W
Vegetation	The villa is surrounded with planted trees, providing shadowing cool air to the house. Deciduous trees provide shading only when needed, i.e., in summer.
Natural daylighting	The house is provided with large glazed façade South-oriented which allows natural daylighting during the day.
Use of local and embedded materials	Fired earth bricks are used for the exterior walls.
Water saving and heat recovery on hot water drain	Water is provided from an in-site well and managed with smart drip irrigation techniques.
Waste management	Biodegradable wastes are recycled and used as compost for fertilization.
Others features	Line drying spaces are available.

Figure 169 : Passive principles set up: (a) Overhangs and shadowing and (b) Natural daylighting [2]

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**

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Protected bike parking and showers	**Yes**
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: **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.: **No** It is not necessary since the building is a detached residential house and the users are aware of how to correctly use the building.
BUILDING FABRIC AND MATERIALS [1]	
Roof	The roof is structured as follows (from inside to outside): 1. Plaster (1 cm) 2. “Hourdi” (16 cm) 3. Pre-stressed concrete (5 cm) 4. Polystyrene (6 cm) 5. Cement mortar (6 cm) 6. Ceramic tile (2 cm)
	Overall R-value: **2.67** [m^2K/W] U-value: **0.37** [W/m^2K]
1st floor slab	The 1st floor slab composition is similar to that of the roof without insulation.
	Overall R-value: **2.37** [m^2K/W] U-value: **0.42** [W/m^2K]
Walls	The **external walls** are structured as follows (from inside to outside): 1. Plaster (1 cm) 2. Concrete block (15 cm) 3. Glass wool (10 cm) 4. Earthenware brick (15 cm) 5. Cement mortar (1.5 cm)
	Overall R-value: **2.55** [m^2K/W] U-value: **0.39** [W/m^2K]
Windows	Tempered glass.
	Window-to-wall ratio (WWR):

1st floor				2nd floor			
W	E	**S**	N	W	E	**S**	N

7%	8%	**36%**	10%	2%	6%	**19%**	9%

U-value: -

Visual transmittance: -

ENERGY EFFICIENT BUILDING SYSTEMS	
Low-energy cooling systems	▪ **The soil as a cooling source**: The coupling between the building and the ground is very beneficial, especially in summer. Indeed, in an arid climate like that of Marrakech what matters most is the cooling load. ▪ Earth-to-Air Heat Exchanger (EAHX): The house is air conditioned by an EAHX formed of 3 down tubes up to 3.50 m deep which provides 500 m³/h of air at 24 ° C in summer and 19 ° C in winter [1].
Low-energy heating systems	Free solar gains are widely used in winter provided that the building is protected against excess gains in summer via shading systems, so as not to cause overheating inside the building.
Ceiling fans	None
Mechanical ventilation / air renewal	**Natural ventilation.** Earth-to-Air Heat Exchanger (EAHX): The house is air conditioned by an EAHX formed of 3 down tubes up to 3.50 m deep which provides 500 m³/h of air at 24 ° C in summer and 19 ° C in winter.
Domestic Hot Water	Two solar water heaters with exchanger (due to limestone and risk of frost) totalling 4 m² ensure the supply of hot water in bathrooms and from the kitchen
Artificial lighting	The whole building is equipped with high-efficiency LED lighting (3 W/m^2)
Control and energy management	N/A

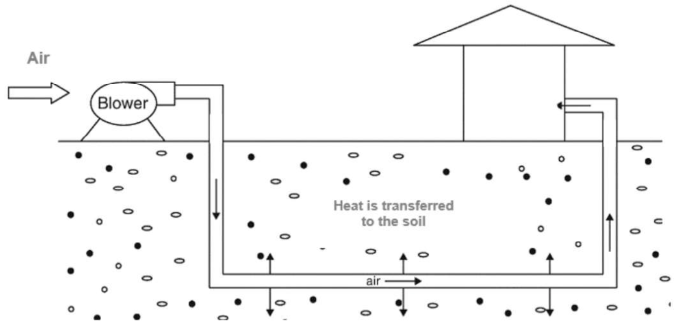


Figure 170: Earth-to-Air Heat Exchanger principle (a) and construction (b) [2]

RENEWABLE ENERGY	
PV	Not used

Solar thermal	Two solar water heaters with exchanger (due to limestone and risk of frost) totalling 4 m² ensures the supply of hot water in bathrooms and from the kitchen.
Wind	Not used
Geothermal	The house is air conditioned by a Earth-to-Air Heat Exchanger (EAHX) of 3 down tubes up to 3.50 m deep which provide 500 m³ / h of air at 24 ° C in summer and 19 ° C in winter.
Biomass	Not used

Figure 171: Solar water heaters installed on the rooftop of the Dar Amys Villa.

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
	6. Percentage of time inside the Givoni comfort zone of 0m/s
	7. Number of hours within a certain temperature range
Energy performance indicators	1. Energy needs for heating: **15** [kWh/y/m^2]
	2. Energy needs for cooling: **23** [kWh/y/m^2]
	3. Energy use for lighting: **-** [kWh/m^2/year]
	4. Energy needs for sanitary hot water: **-** [kWh/m^2/year]
	5. Total Primary energy use: **-** [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]
	1. Airborne sound insulation

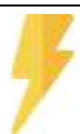
Acoustic comfort indicators	2. Equivalent continuous sound Level
	3. HVAC noise level
	4. Reverberation time
	5. Masking/barriers
Visual comfort indicators	1. Light level (illuminance)
	2. Useful Daylight Illuminance (UDI)
	3. Glare control
	4. Quality view
	5. Zoning control
Indoor Air Quality indicators	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	-

LESSONS LEARNED AND RECOMMENDATIONS [1][2]

Lessons learned	This case study shows that the passive features set up allowed to reach their main objectives: to reduce energy needs for heating and cooling while maintaining comfortable indoor conditions. The villa can not only accumulate solar heat gain when needed through the south-oriented windows but also regulate rooms temperature thanks to its high thermal inertia. The insulation of the roof and the external walls is a key performance measure so as to reduce heat loss and solar gain. The roof insulation allowed to reduce the cooling load by 42% and the energy needs for heating by 18%. In winter, the indoor temperature was very stable with 18°C±0.5°C while the outside temperature ranged from 7°C to 23°C. In summer, the room temperature of the 1st floor was around 28.3°C±0.3°C and around 29,6±0,3°C for the 2nd floor while the outside temperature ranged from 23°C to 41°C. The Earth-to-Air Heat Exchanger (EAHX) was not very useful in winter since the temperature difference was not significant.
Recommendations	Roof insulation is highly recommended for the climate of Marrakech. Indeed, this passive feature has a great beneficial effect all year long.

BUILDING STRENGTHS AND WEAKNESSES

Strengths


Passive Design	Energy Efficiency	Renewable Energy
	Weaknesses	
	-	

REFERENCES

[1] B. Benhamou et A. Bennouna, « Energy Performances of a Passive Building in Marrakech: Parametric Study », Energy Procedia, vol. 42, p. 624-632, janv. 2013, doi: 10.1016/j.egypro.2013.11.064.

[2] « Dix cas de bonnes pratiques au Maroc ». [En ligne]. Disponible sur: http://www.archi.ac.ma/images/publications/Catalogue%20web.pdf

[3] « Bioclimatic chart for the climate of Marrakesh ». [En ligne]. Disponible sur: http://climate.onebuilding.org/WMO_Region_1_Africa/MAR_Morocco/MS_Marrakech-Safi/MAR_MS_Marrakesh-Menara.AP.602300_TMYx.2004-2018.zip

[4] « Climate Consultant », Software Informer. https://climate-consultant.informer.com/6.0/ (consulté le nov. 03, 2021).