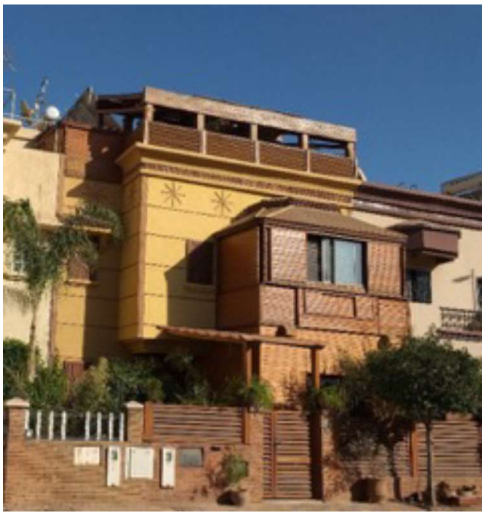
CASE STUDY 1-10: DAR NASSIM PROJECT | MOROCCO



GEOGRAPHICAL AND CLIMATE INFORMATION	
Location	35, Residence Nassim, Marrakech, Morocco
Latitude; Longitude	31.6497350, -8.0615803 Code Google Maps : JWXQ+V9 Marrakech
Climate zone (Köppen–Geiger classification)	BSh: Hot Semi-Arid

BUILDING INFORMATION	
Building Type	Terraced individual housing
Project Type	Renovation
Completion Date	2014
Number of buildings	1
Number of storeys	2
Total Floor Area (m²)	240m²
Net Floor Area (m²)	215 m²
Thermally conditioned space area (m²)	95 m²
Spaces with Natural Ventilation (with or without Ceiling Fans) Only (m²)	The whole building is naturally ventilated
Total cost (€)	240.000
Cost /m² (€/m²)	1000
Performance Standards or Certification	Moroccan Thermal Regulation of Construction [1]
Awards	None

STAKEHOLDERS	
Building Owner/ Representative	Abderrahim BRAKEZ
Architect / Designer	Al Omrane Holding
Construction manager	Al Omrane Holding
Environmental consultancy	-
Structural Engineer, Civil Engineer	-

ABC21 is funded by the EU's H2020 programme

Product Manufacturer	-
Certification company	-
Others	Ministry of Housing and Urban Policy as a stakeholder

PROJECT DESCRIPTION

The house was built in 2002 on a floor area of 70 m² (8.86 m in the East-West direction and 7.90 m in the North-South direction). The South and North facades are attached to the walls of terraced houses of the same type and of the same surface.

the renovation of the house was carried out in 2014. A monitoring of the house was carried out before and after the renovation. This renovation aimed to improve the energy performance of the house and to carry out an extension by adding a solar hammam and a dining room as well as a bedroom [2].

Much of the energy consumed in this building is achieved through renewable energy systems. Indeed, a large part electricity consumed is produced by photovoltaic panels. Solar thermal panels are installed to provide domestic hot water and heating the floor of a hammam installed in the house after renovation [3].

Ground floor

Vertical section of the house

First floor

West and East sides

Second floor Roofs

Figure 151: Different views of the house after refurbishment

SITE INTEGRATION

The studied house, named Dar Nassim, is considered in the terminology of housing in Morocco as an „*economic villa* “. It is a new concept of habitat to qualify a product intended for the middle class. This product borrows its morphology to the model of the villa, with savings in surface area and quality of services.

The house is located in a closed residence composed of 120 houses designed according to the same plan but with different orientations. The building is built on a floor area of 70 m² overlooking gardens of 30.6 m² and 25.8 m² respectively.

The South and North facades are attached to the walls of terraced houses of the same type and of the same surface.

Figure 152 Aerial view of the residence and photo of the house in its close neighbourhood

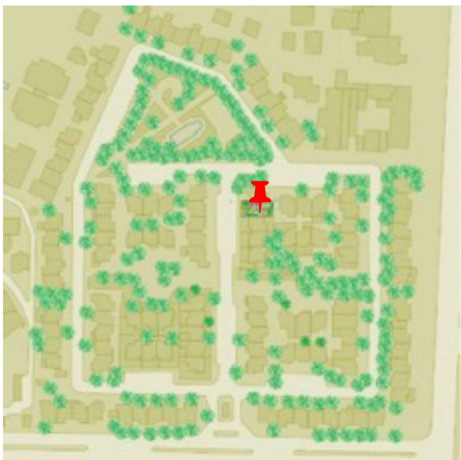


Figure 153 : Situation of studied house inside the residence

CLIMATE ANALYSIS

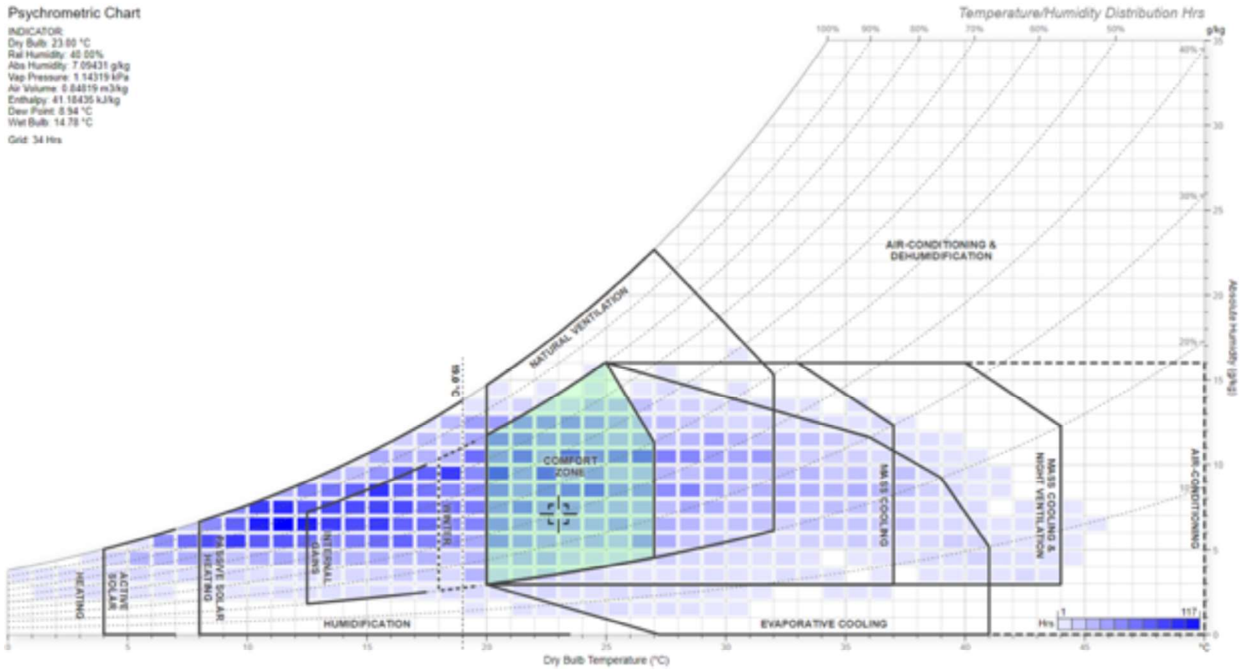


Figure 154: Givoni Bioclimatic chart for the climate of Marrakesh using Andrew Marsh online tool [4]. Climate data are extracted from http://climate.onebuilding.org/WMO_Region_1_Africa/MAR_Morocco/MS_Marrakech-Safi/MAR_MS_Marrakesh-Menara.AP.602300_TMYx.2004-2018.zip

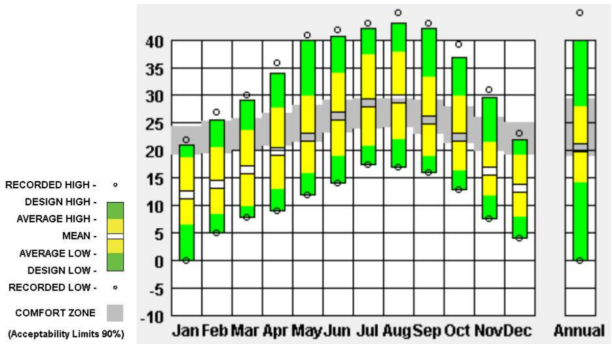


Figure 155: Temperature range by month for Marrakech. Source: Climate consultant – Adaptative Comfort model [5]

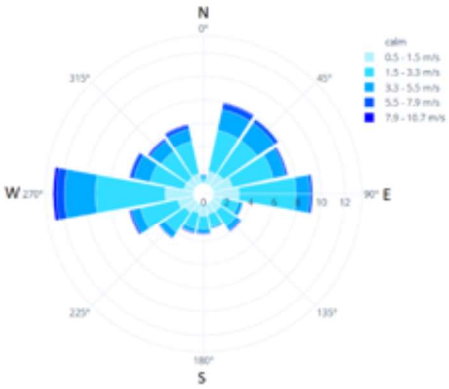


Figure 156: Annual Wind rose for Marrakech (Beaufort wind scale) [5]

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**

ABC21 is funded by the EU's H2020 programme

KEY BIOCLIMATIC DESIGN PRINCIPLES	
Passive cooling strategy	**Comfort ventilation**: Natural ventilation strategy is activated through the manual opening of windows. **Nocturnal convective ventilation**: The natural ventilation (cross ventilation) is exploited during the night-time. Some of the techniques are already integrated the house (Insulation of facades by an air gap of 5 cm, ground coupling), while the others will be considered for retrofitting (thermal insulation of the roof and thermal insulation of external walls of west facade)
Passive heating strategy	Ground coupling on thermal load and double-glazed windows.
Solar protection	The shading of the west side of the roof is achieved by a mobile device. (Fig 3)
Building orientation	The main facades are East and West. The North and South walls are adjoining walls.
Insulation	The walls of East and West facades are insulated by an air gap of 5 cm. A thermal insulation by 4 cm extruded polystyrene (XPS) for the roof.
Vegetation	The main facades overlooked gardens of 30.6 m² and 25.8 m² respectively. The northwest-facing corridor of the 1st floor is shaded by the plants and trees of the west garden.
Natural daylighting	The house faces East-West. The street facade receives the sun in the afternoon. The back facade of the house is in the morning sun. This double exposure makes it possible to benefit from solar contributions all day long. The first challenge of the renovation was to create a layout with interior openings on each floor. This made it possible to create a natural light crossing to take advantage of the double East-West exposure of the house.
Use of local and embedded materials	N/A
Water saving and heat recovery on hot water drain	N/A
Waste management	N/A
Others features	N/A

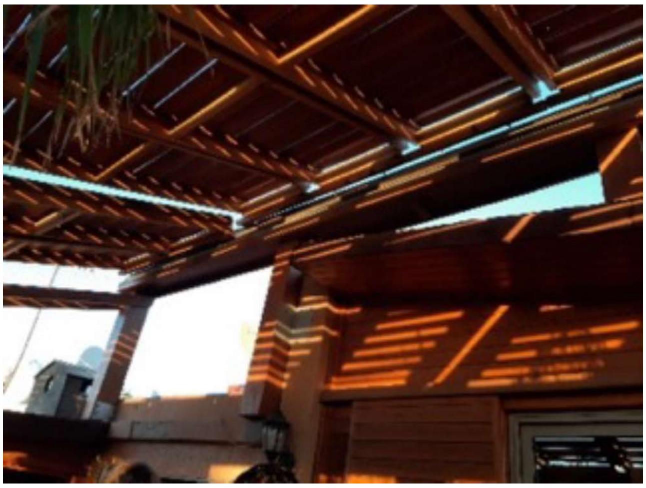


Figure 157 : Mobile shading device of the west side of the roof

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	**No**
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: **Yes**
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	
Roof	• 1 cm of plaster • 16 cm hollow bricks with steel beams • 4 cm of reinforced concrete • 10 cm of cement mortar • 2 cm of ceramic tiles
	Overall R-value : 1.69 [m^2 K W^{-1}] U-Value : 0.59 [W m^{-2} K^{-1}]
Windows	Double glazing
	Window-to-wall ratio (WWR) (see Tableau 1)
	U-value = 2.95 [W m^{-2} K^{-1}], g-value =64 %
	Visual transmittance: -

Walls	• 1.5 cm of cement mortar • 10 cm red clay brick • 5 cm of air gap • 10 cm red clay brick • 1.5 cm of cement mortar
	U-value : 0.72 [W m^{-2} K^{-1}] Overall R-value : 1.388 [m^2 K W^{-1}]

Table 1 : Window-to-wall ratio of the Nassim house after renovation

Walls	Ground floor			1st floor		Terrace		
	West	East	South	West	East	West	East	South
Glass surface (m^2)	2.50	2.27	2.90	3.4	4.95	2.46	1.9	0.5
Total surface area of facades (m^2)	22.12	19.00	12.30	22.12	22.12	18.30	19.44	5.30
Overall rate of bay windows (%)	11.3%	11.9%	23.6%	15.4%	22.4%	13.4%	9.8%	9.4%

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. Typically, the thermal inertia of the ground can reduce the annual heating / cooling thermal load by about 8%. . Smart reversible air conditioners equipped with Inverter technology allow 25% energy savings (all devices are in energy class A ++)
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. . Smart Inverter air conditioners with a high COP.
Ceiling fans	N/A
Mechanical ventilation / air renewal	The air renewal strategies are: ▪ Natural ventilation ▪ Nocturnal ventilation
Domestic Hot Water	Domestic hot water is produced by a closed-circuit solar water heater with a 200 liters storage tank. To maximize the self-consumption of the solar photovoltaic production we use a smart diverter to ensure deviation of surplus solar production electricity towards the resistance of the domestic hot water tank.
Artificial lighting	The whole building is equipped with high-efficiency LED lighting. (100 lumens/Watt)
Control and energy management	An advanced home automation system based on an open-source software can control temperature and lighting based on time of day and occupancy, reducing energy consumption around the home.

ABC21 is funded by the EU's H2020 programme

	Individual thermostats in each room ensure the house is never over heated or over cooled and allow temperatures to be reduced when the room is not occupied (Figure 158).

Figure 158 : Screenshots of the home automation management interface

RENEWABLE ENERGY	
PV	. PV system (2 kW peak electric power) is installed in the south-orientated roof part of the building and on the sloped roof. The slope chosen for the solar panels is 15 degrees to promote summer photovoltaic solar production and for aesthetic reasons (Fig. 5). . 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	. A 1.6 square meter solar thermal panel with a 200 liters tank ensures the production of domestic hot water (Fig 5). . Two thermal solar panels of 2 square meters each (Fig. 5) to heat the floor of a Hammam installed in the terrace of the

	house. The system of solar floor heating mainly consists of flat-plate collectors, pump and an active layer (heating serpentine) integrated to the Hammam floor (Fig. 6 and Fig. 7).
Wind	N/A
Geothermal	N/A
Biomass	N/A

Figure 159 Solar thermal and photovoltaic panels installed on the roof of the house

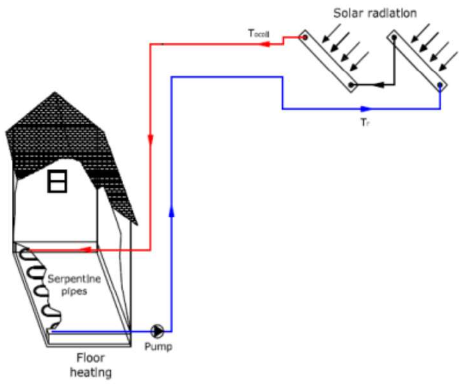


Figure 160 Scheme of the floor heating system

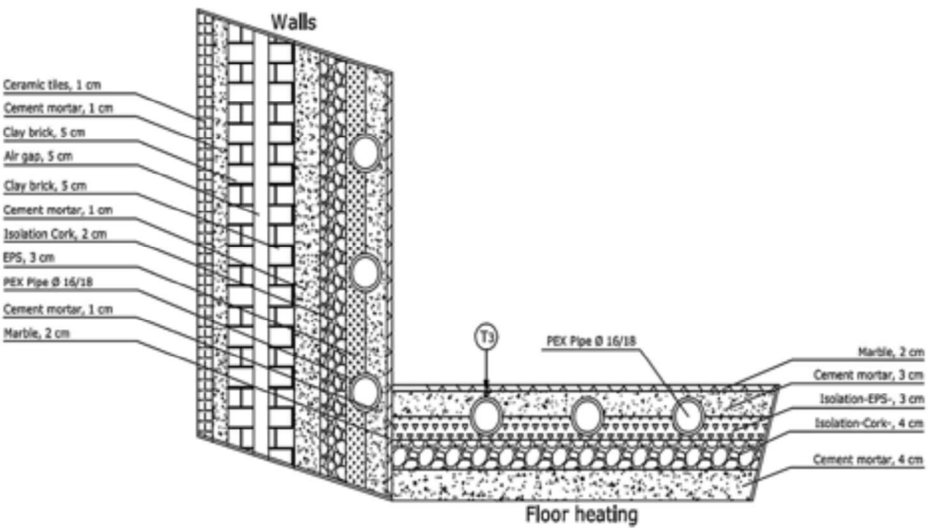


Figure 161 Floor and walls heating system (T3: temperature sensor)

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: **2** [kWh/m^2/year]
	2. Energy needs for cooling: **3.5** [kWh/m^2/year]
	3. Energy use for lighting: **2** [kWh/m^2/year]
	4. Energy needs for Sanitary Hot water **1.5** [kWh/m^2/year] Unconsumed photovoltaic production (mainly during autumn and winter) is routed by a solar power diverter to the resistance of the solar water heater.
	5. Total Primary energy use: **28** [kWh/m^2/year] (Total Primary Energy Factor (PEF) equal to 2.63 for electrical energy from the grid)
	6. Renewable Primary energy generated on-site: **11.5** [kWh/m^2/year]
	7. Renewable Primary energy generated on-site and self-consumed: **7** [kWh/m^2/year]
	8. Renewable Primary energy exported to the grid: **4.65** [kWh/m^2/year]
	9. Ratio of renewable primary energy over the total primary energy use (with and without compensation): **25%**
	10. Delivered energy: **8** [kWh/m^2/year] (see Fig. 8)
Acoustic comfort indicators	1. Airborne sound insulation: N/A
	2. Equivalent continuous sound Level: N/A
	3. HVAC noise level: **28 dB**
	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): No

ABC21 is funded by the EU's H2020 programme

	7. Hazard material: No
Users' feedback	The air temperature inside the building was decreased by 3 to 5 ° C, enhancing the thermal comfort of the occupants who are very satisfied with this renovation.

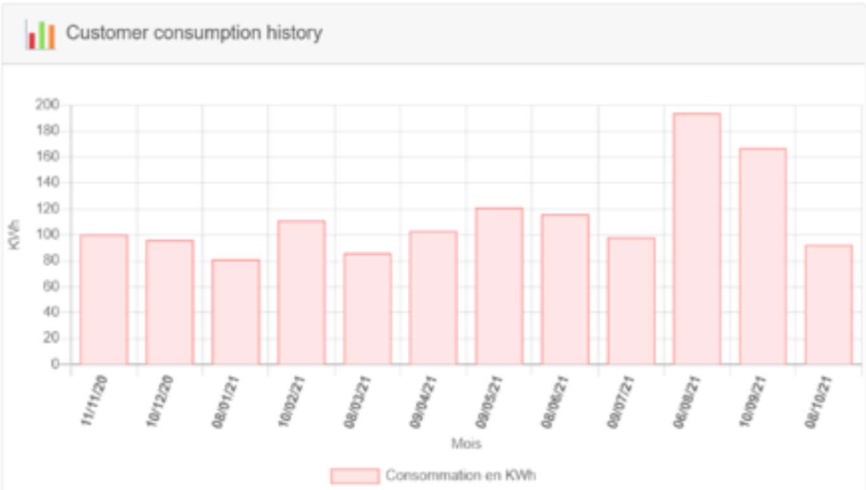


Figure 162: Monthly delivered energy of the house over one year (from November 2020 to August 2021)

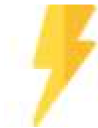
LESSONS LEARNED AND RECOMMENDATIONS	
Lessons learned	The analysis of temperature and humidity measurements inside and outside the building before renovation gave us a general idea of the thermal behaviour of the house, as well as the strengths and weaknesses of its envelope. On the other hand, the measurements we made after renovating the house with and without occupancy showed us the positive effect of integrated systems on their thermal performance of the house. These bioclimatic solutions studied within the framework of this thesis are: orientation of the building, thermal inertia, thermal insulation of the envelope with its thickness and its optimal position, double glazing, shading devices, natural ventilation, underfloor heating and the integration of renewable energy systems for the production of hot water and for heating the Hammam space of the house. An optimal combination was applied to the house and was the basis for said renovation. Faced with the East-West orientation of the house which is the most unfavourable and that we cannot change it, we have played on other aspects which are summarized in the combination of roof insulation by 4 cm of extruded polystyrene, insulation of the walls with a 5 cm air gap, use of double glazing, use of mobile shading devices on the roof and windows, take advantage of natural night ventilation in summer. This combination has reduced the air temperature inside the building by 3 to 5 ° C, and it has increased the thermal comfort of the occupants who are very satisfied with this renovation.
Recommendations	To consume the maximum amount of photovoltaic energy produced instantly, in addition to the correct sizing of the installations, it is important to control and be able to predict production and consumption. Specialized regulations must emerge for thermal electrical equipment, in order to recover production predictions, analyse consumption, prioritize energy uses by being able to control devices, and finally, directing towards storage if necessary.

The IoT is presented as a real level for energy flexibility. It enables, through smart energy, the development towards the energy transition and the emergence of digital uses for smart bioclimatic buildings, using fossil fuels such as gas as little as possible, and sufficiently autonomous to claim self-consumption. .

BUILDING STRENGTHS AND WEAKNESSES

Strengths

Passive Design



Energy Efficiency

Renewable Energy

Weaknesses

-

REFERENCES

[1] Moroccan Thermal Regulation for Construction, RTCM, https://www.amee.ma/fr/reglementation-thermique, Accessed October 20, 2021.

[2] Sobhy, I., Brakez, A., and Benhamou, B., 2017, “Analysis for Thermal Behaviour and Energy Savings of a Semi-detached House with Different Insulation Strategies in Hot Semi-arid Climate,” J. Green Build., 12(1), pp. 78–106.

[3] Sobhy, I.; Brakez, A.; Benhamou, B. Energy performance and economic study of a solar floor heating system for a Hammam. Energy Build. 2017, 141, 247–261

[4] Andrew Marsh Psychrometric Chart. Available at: https://drajmarsh.bitbucket.io/psychro-chart2d.html.

[5] Climate Consultant tool. Available at: https://climate-consultant.informer.com/6.0/