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Analysis of energy consumption for Algerian building in extreme North-African climates

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ABSTRACT

The objective of this study is to diagnose and quantify energy consumptions of a typical residential building with local materials. Three sites belong to different radiative regimes: Algiers on the southern Mediterranean shore, Tlemcen on the west and Ghardaïa in the Sahara of Algeria. The followed method is based on an approach for assessing heating and cooling energy needs, the solar gains, internal lighting loads, occupants and equipment are not considered. Annual heating and cooling requirements are calculated, according to climate data from 2014. We are also interested in a technical and economic study to have a monthly and annual estimation of heating and cooling needs in kWh and Algerian currency per m3 (DA/m^3).

The results show that this residential building is not affordable to live in. Facade walls, roof and ground are the major sources of heat losses in buildings (more than 70% of the total losses). The evaluation is devoted to adapt the construction to the region's climate. The integration of passive and active architectural concepts is an absolute necessity to improve the building's energy performance.

Keywords:

Degree days;
Energy consumption;
Diagnosis;
Loss of envelope;
Annual and monthly energy need;

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1. Introduction

In Algeria the building sector accounts for around 36% of the total energy consumption [1], so energy efficiency of buildings, which means providing minimum energy consumption in order to achieve the optimum comfort of living and use of the building, is very important. Energy consumption of a building depends on its characteristics (shape and structural materials), installed energy systems (heating system, cooling system, ventilation) [2]. However, prediction of energy consumption is a great challenge which will be related to the several factors including weather conditions, geographic location, and seasonal changes.

A well-conducted assessment of an annual heating or cooling needs for an existing residential building requires extensive data to accurately describe the building envelope weather conditions and building use. The diagnosis of energy performance of a building (DEP) provides information on the amount of energy actually consumed or estimated in terms of heating and cooling related to thermal comfort. This is done initially through the calculation of annual energy requirements using the heating and cooling degree days method [3]. The energy consumption depends not only on the thermal performance of the building envelope but also of the (comfort) temperature. As a consequence, according to buildings

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Nomenclature

Tcomf : Comfort temperature (°C)
Text: Monthly average of outdoor temperature (°C)
Dj: Number of degree-days in the heating and/or cooling season
DPenvelop: Heat loss (W/K).
Ui: Overall heat transfer coefficient (W/m2 K)
Si: Surface of the building element (m²)
bi: Heat transfer reduction coefficient
k: Thermal conductivity of the thermal bridge (W/m K)
lpb_i/m_j: Low floor i - wall j
lpi_i/m_j: Intermediate floor i - wall j
lph_i/m_j: Top floor i - wall j
lmen_i/m_j: Shear wall i - wall j
lrf_i/m_j: Shear wall i - wall j
hsp: Average ceiling height
N: Number of habitable space
niv: Number of levels
Sh : Living space (m2)
Sdep: Déperditive surface excluding low-floor (m2).
θconv: Conventional air flow extraction per unit of living space (m3/h/m²).
ηinf: Air flow due to infiltration caused by thermal draft phenomena (m3/h).
η4pa: Permeability under 4 Pa of the zone (m3/h).
η4pa_env: Permeability of the envelope (m3/h).
Smeconv: Conventional value of the sum of the inlet air modules under 20 Pa per unit of living surface (m3/h/m²).
η4pa_env/m²: Conventional value of permeability under 4 Pa (m3/h).

architectural requirements, an increase of the temperature of about 1 °C can cause an increase in the energy consumption from 6% to 20%. It is therefore necessary to quantify and analyze the meteorological parameters that influence energy requirements. The control of heat transfer is one of the most promising methods and important research areas in the field of thermal engineering for buildings which helps to orient building designers to respect the compromise between comfort and energy cost and to propose preferred solutions.

In the literature, several research studies on the best performing buildings show that the reduction of energy consumption requires an architectural design that uses appropriate technologies and design principles based on a reflection on climate and the environment [4] . Ekici and Aksoy [5] listed the parameters that influence the building's energy requirements as follows: physical and environmental parameters (daily outdoor temperature, solar radiation and wind speed and direction) and design parameters (shape factors, transparency of the surface, orientation, thermal properties of the building material and distances between buildings). In another work, Hongting *et al.* [6] have analyzed the main factors that may affect the characteristics of building energy consumption. The results led to conclude that the building envelop, lighting and air conditioning system are the main factors. In the literature, a few methods have been proposed to estimate the heating and cooling energy demands. An examination of the energy consumption characteristics proved that the shape of the building is one of the factors that affects the energy consumption of buildings [7]. On the other hand, M. Olfa [8] has shown that too much or poorly managed solarization can be uncomfortable, the orientation can have consequences on heating, cooling and lighting consumption. The building materials used must be effective against overheating.

Yang *et al.* [9] used the overall thermal transfer value (OTTV) method and the heating degree-days technique to analyze heating and cooling needs in five sites of China, representing the five major climatic zones. Different designs of the building envelope were studied and heat gains in the building during the four warmest months were estimated.

In the contribution [10], the proposed model of energy balance allowing to estimate the monthly and annual energy consumptions of an agricultural studio in the Saharan climatic conditions. The results indicated that the application of external insulation on facades and roofs can allow a 56.05% reduction in energy loads over a thickness of 6 cm. Priority has also been given to active concepts to reduce energy demand . Another work is to study the thermal behavior of a room located in Morocco. Through several simulations of the outer envelope taking into account the thickness of the envelope, insulating materials and glazed surfaces, the choice of insulation of the walls has a considerable influence on the energy requirements [11]. In the same context, Ozel [12] devoted part of his research work to enhance the thermal insulation properties according to cooling requirements during the hot period in the Antalya region. Tsikaloudaki *et al.* [13] take account of the influence of windows, in particular their thermophysical properties, to cover both heating and cooling needs. In the Mediterranean regions, windows with low thermal transmittance and controllable properties can assist significantly toward the enhancement of building energy performance especially during the cooling season [14]. However, building systems provide a significant increase in the energy efficiency of the building and the heating and cooling energy demand are associated with high energy efficiency potentials, for this purpose the influence of the envelope of the building on energy consumption was examined by Stojanovi *et al.* [15]. In another research, Ali-Toudert et al [16] describe the principal results obtained from a method applied to the estimation of the required energy demand of a multizone building for two regions with different climatic regimes, Algiers and Ghardaia. The found values confirm that the pilot's house can go to a reduction of 55% for cooling and 89% for heating if this low-energy building is located in Algiers. If this building is subjected to Ghardaia climate, the energetic consumption corresponds to a saving of 29% for cooling and 94% for heating . In the paper [17] Tronchin et al have analyzed the choice of the best energy efficiency measures derived from the Cost Optimal level methodology underlined the importance of the building typology, the reference market and also the building location in applying this methodology. The use of solar energy in buildings is an important contribution to reducing the consumption of fossil fuels and harmful emissions to the environment. An energy techno-economic assessment methodology is used by Ogundari et al [18]. They determine that the energy efficient lighting system is appropriate with 40% energy savings relative to the Conventional Lighting Systems. The study established the PV-energy-efficient lighting system as the most feasible off-grid electric power supply alternative for implementation.

For affordable and economical cost, most published publications [19,20] focus on the total energy consumption (heating and cooling) requirements for residential buildings in order to investigate all possible ways to reduce energy costs.

In this paper, the calculation method has as object a specific regulatory calculation of the conventional energy consumption of an existing building for heating, ventilation and cooling. The production of domestic hot water, free and internal loads related to lighting, occupants and equipment are not considered. The method refers to an integrated approach for assessing the heating and cooling energy performance of residential buildings.

2. Case study: building description, geographical location and climatic data

This section provides information related to the amount of energy actually consumed and to thermal comfort, starting with investigating the energy performance of the building according to the thermo-physical properties of its envelope, moving on to the classification of the selected climatic zones and lastly we trying to determine the comfort zone for each site.

2.1. Building description

The studied house is a multi-zone structure with three levels; it has an area of 293 m^2. (Fig.1) illustrates the geometry of the reference building, as well as the openings position. The Windows (1.55 x 2.10 m^2) and doors (0.92 x 2.65 m^2) contribute to the energy balance; depending on several parameters such as: properties of materials, local climate, orientation, frame and relative areas. Thermophysical properties of materials for each system element are presented in table 1. [21,22].

2.2. Geographical location and climatic data

As already mentioned, this study focuses on the evaluation of the energy consumption of the previous residential building when it is subjected to three climatic zones of Algeria. Algeria has a wide variety of climatic zones; the Köppen-Geiger map remains an update reference through its research on climate change scenarios. The northern part has a Mediterranean climate, while the rest of the country has mostly a desert climate. However, there are transition climates between these two main types of climate, in particular the semi-arid climate causing severe drought in some periods even outside the summer season.

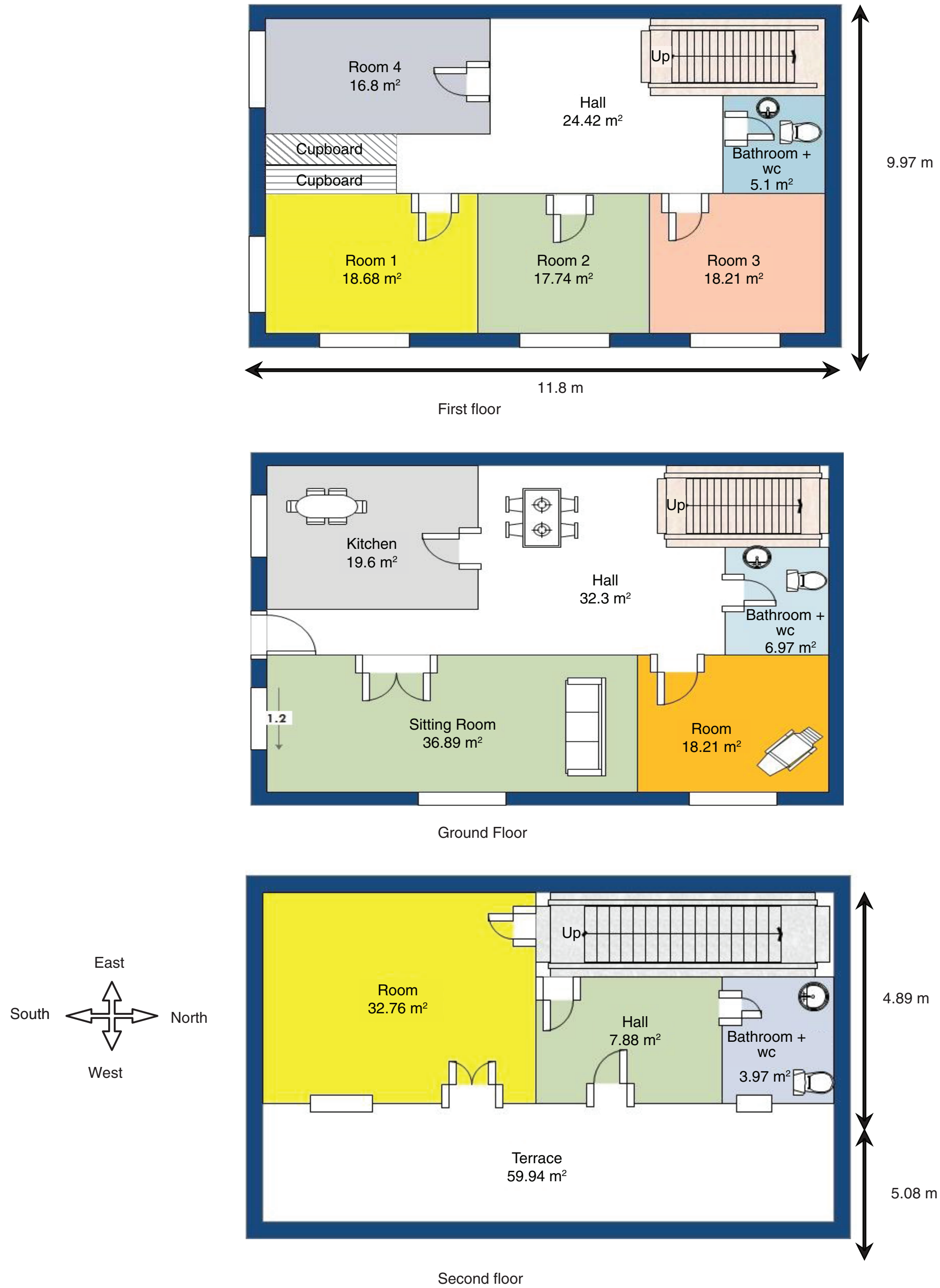

Figure 1: Geometry and descriptive plane of the residential building

Nevertheless, Algeria is a country in the subtropical zone where the prevailing climate is hot and dry. To cover all the possible cases, the choice of eligible areas was fixed on three zones (Fig.2) dispatched on the whole Algerian territory. The geographical coordinates of the selected cities are shown in the following Table 2:

Northern Algeria is a temperate zone; its climate is similar to that of other Mediterranean countries. The climate in the highlands is so dry that these plains are sometimes thought of as part of the Sahara. The temperatures in the Sahara desert, are daily variations of more than 44° C. The sunshine duration, average temperature and precipitation over the year are accessible by clicking on "Places in Algeria" on the indicated website [23]. Monthly temperature curves at three different locations are illustrated (Fig.3).

Table 1: Layer thickness, walls composition and thermal transmittance values of building elements

System element	Material and wall composition	Layer thickness m	Thermal transmittance values U (Wm^{-2} K^{-1})
Exterior walls	Mortar cement Stone Mortar cement Plaster	0.015 0.400 0.015 0.010	2.6096
Ground	Tiling Cement Stone heavy concrete	0.025 0.100 0.150 0.180	2.5654
Roof	Tiling Mortar cement Concrete Plaster	0.025 0.015 0.120 0.015	3.6955
Window with single glazing			5.3400
Wooden door			3.1959
Thermal bridges	Low floor – external wall Intermediate floor – external wall		2.3900

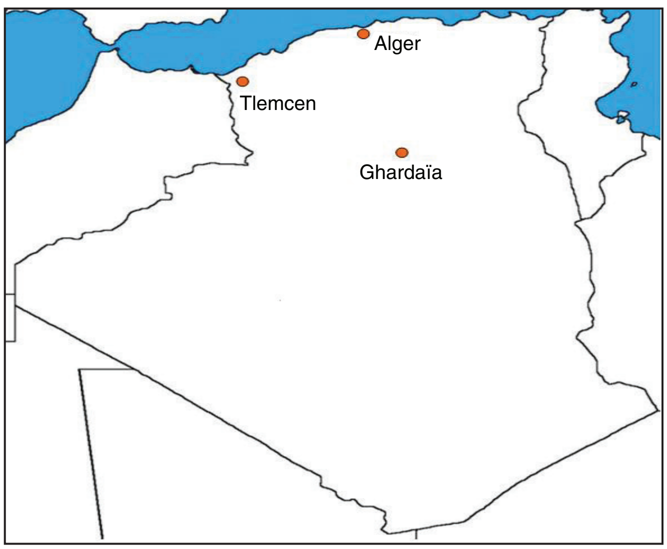

Figure 2: Geographic location of climate sites

2.3. Comfort zone

The comfort depends not only on the temperature but even more on the humidity of the ambient air. In 1991 Givoni [25] suggests a bioclimatic diagram located the comfort zone between 18 and 25 ° C in winter and between 20 and 27 ° C in summer for temperate climates in calm air conditions [26], with an increase of 2°C for the upper limit for hot regions. This diagram is based on an analysis method [27,28] to derive the area of thermal comfort from the climate data (Dry-bulb temperature DBT and absolute humidity AH). It not only helps the limits of thermal comfort for a given site but mostly to give recommendations on the choices of architectural and technical processes. In 2016, Bekkouche *et al.* had established a psychometric chart for Ghardaïa region dedicated to the identification of the corresponding comfort area Fig.4.

The monthly neutral temperature is obtained from the monthly mean temperature through Auliciems equation [28,30]: $Tn = 17,6 + (0,31 \times T_{mean})$ ° C

- For the Alger site, ambient comfort temperatures range from 21.1 ° C in winter to 25.9 ° C in summer. The comfort zone can be extended by +/- 2 ° C, which gives adaptive comfort range between 19.1 and 27.9 ° C.
- For the Tlemcen site, ambient comfort temperatures range from 20.8 ° C in winter to 25.1 ° C in summer. The comfort zone can be extended by +/- 2 ° C, which gives adaptive comfort range Between 18.8 and 27.1 ° C.
- For the Ghardaïa site, ambient comfort temperatures vary between 21.1 ° C in winter and 28.6 ° C in summer. The comfort zone can be extended by +/- 2 ° C, which gives adaptive comfort range Between 19.1 and 30.6 ° C.

3. Evaluation of the heat losses of the building envelope and quantification of energy consumptions

The aim of this section is to present the calculated results of total annual building energy consumptions. Needs in heating and cooling due to the envelope calculated for buildings, expressed in (kWh) are given as follows [29, 31]:

Table 2: Climate zoning and geographic coordinates of the three sites

Sites	Zones	Altitude	Longitude
Algiers (Bouzaréah)	zone **A**	36°47'24" North	3°1'4" East
Tlemcen	zone **B**	34°52'41" North	1°18'53" West
Ghardaïa	zone **D**	32°29'27" North	3°40'24" East

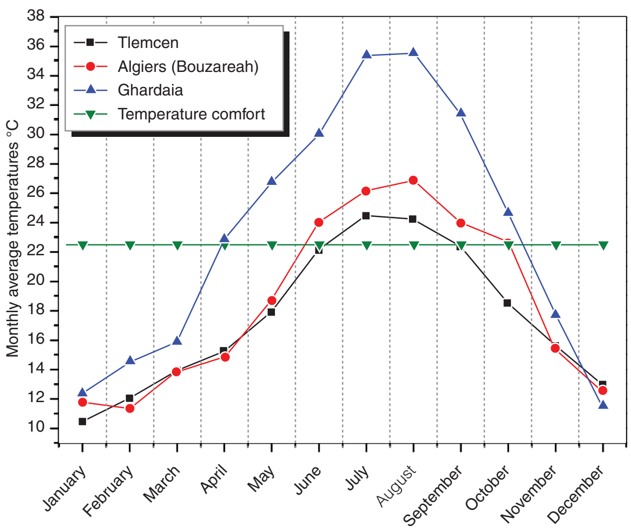

Figure 3: Monthly average temperatures for selected climatic regions [24].

$$C = 24Q_{needs}\ Dj = 24\ DP_{envelop}\ Dj / 1000 \qquad (01)$$

Dj: heating and cooling degree days

Degree days are a specialist type of weather data, calculated from readings of outside air temperature. They are used extensively in calculations relating to building energy consumption.

3.1. Calculation of envelope losses

For each piece the losses are to be calculated for each of the walls (wall, ceiling,windous). The input data are heat transfer coefficient U (W/m² K) and wall surfaces, Si (m²).

$$\mathbf{DP_{envelop} = DP_{ceilings} + DP_{walls} + DP_{windows} + DP_{doors} + DP_{floors} + DP_{thermal\_ridges} + DP_{ventilation}} \qquad (02)$$

$DP_{envelop}$: heat loss, (W/K).

The calculation of heat loss for each term is made from the following equations:

$$\mathbf{DP_{ceilings} = \sum_{i=1}^{i=n} b_{ceilings\_i} S_{ceilings\_i} U_{ceilings\_i}} \qquad (03)$$

$$\mathbf{DP_{walls} = \sum_{i=1}^{i=n} b_{walls\_i} S_{walls\_i} U_{walls\_i}} \qquad (04)$$

$$\mathbf{DP_{windows} = \sum_{i=1}^{i=n} b_{windows\_i} S_{windows\_i} U_{windows\_i}} \qquad (05)$$

$$\mathbf{DP_{doors} = \sum_{i=1}^{i=n} b_{doors\_i} S_{doors\_i} U_{doors\_i}} \qquad (06)$$

$$\mathbf{DP_{floors} = \sum_{i=1}^{i=n} b_{floors\_i} S_{floors\_i} U_{floors\_i}} \qquad (07)$$

S_i: loss surface (m²)

b_i: the heat losses reduction coefficient

U_i: the surface heat transmission coefficient per degree of difference between the inside and outside (W/m² K)

For the calculation of the heat losses reduction coefficient, a number of factors should be considered:

- the wall surfaces separating the unheated space from the heated zone, A_{iu} (m²)
- the wall surfaces separating the unheated area from the outside, the floor or other unheated space, A_{ue} (m²).
- the type of unheated space.
- the insulation state of the adjacent walls to the unheated space.
- the insulation state of the unheated space.

For a wall in contact with the outside, b = 1, b = 0.8 if the wall is buried or the floor is laid on a crawl space. The values of the heat transfer reduction coefficient should be given in references [29, 31] according to an area ratio and the overall heat transfer coefficient.

Thermal bridges usually happen at connections between building components and where a building structure changes its composition. For instance, a two-dimensional thermal bridge can occur at the connection of a wall and floor or the junction between wall and carpentry . Such phenomena have serious consequences: an increased heat flow rate and moisture problems. For the calculation of heat loss through thermal bridges, we use the following equation:

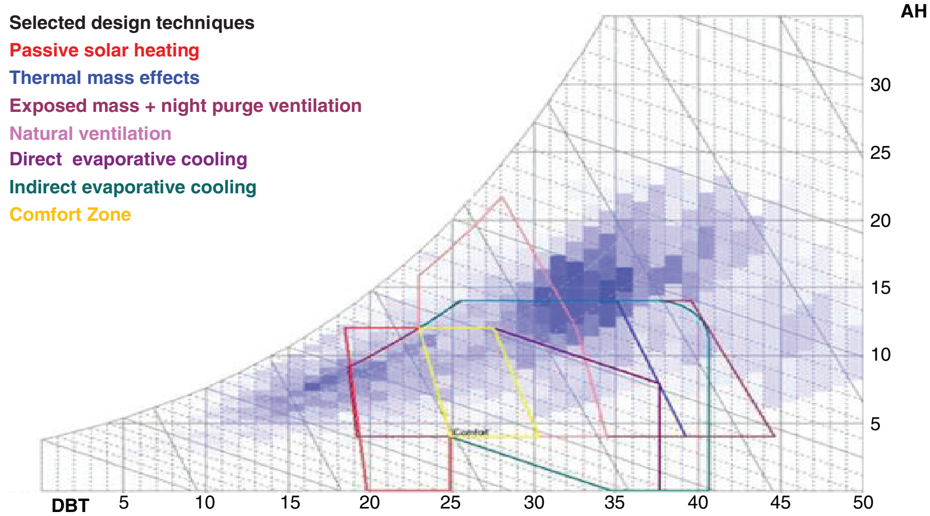

Figure 4: Psychometric "Szockoloy" chart: determination of passive and active control zones for Ghardaïa province [29]

k: thermal conductivity of the thermal bridge (W/m K), which depends both on the type of insulation and its link

$$\mathbf{DP_{thermal\_ridges} = \sum_{i,j} b_{pb\_i/m\_j} k_{pb\_i/m\_j} + 1_{pb\_i/m\_j} + \sum_{i,j} b_{pi\_i/m\_j} k_{pi\_i/m\_j} 1_{pi\_i/m\_j} + \sum_{i,j} b_{ph\_i/m\_j} k_{ph\_i/m\_j} 1_{ph\_i/m\_j} + \sum_{i,j} b_{rf\_i/m\_j} k_{rf\_i/m\_j} 1_{rf\_i/m\_j} + \sum_{i,j} b_{mrn\_i/m\_j} k_{men\_i/m\_j} 1_{men\_i/m\_j}} \quad (08)$$

type (as the length of the thermal bridge). The retained values are given in references [29,31].

l defines the length of the thermal bridge according the various links

lpb_i/ m_j : length of the thermal bridge, low floor i - wall j

lpi_i/m_j : length of the thermal bridge, intermediate floor i - wall j

lph_i/ m_j : length of the thermal bridge, top floor i - wall j

lmen_i/ m_j : length of the thermal bridge, carpentry i - wall j

lrf_i/m_j : length of the thermal bridge, shear wall i - wall j

l_{rf_i/m_i} = 2 hsp (N-niv) with hsp: the average ceiling height, N: number of apartments and niv: number of levels.

The ventilation in a building ensures the comfort of the occupants at the level of air quality. It involves the introduction of fresh air, which will have to be heated to obtain the desired temperature in the house. The losses generated by the air exchange, in W/K, is calculated by the following formula :

$$\mathbf{DP_{ventilation} = DP_{vent} + DP_{perm}} \quad (09)$$

DP_{vent} : heat loss through the air changes due to the ventilation system per degree in temperature difference between the inside and outside (W/K)

DP_{perm} : heat loss through the air changes due to the air permeability of the building per degree in temperature difference between the inside and outside (W/K)

$$\mathbf{DP_{vent} = 0.34\theta_{conv} S_h} \quad (10)$$

θ_{conv} : conventional extract air flow per unit of living space (m^3/h/m²).
S_h: living area (m²).

$$\mathbf{DP_{perm} = 0.34\eta_{inf}} \quad (11)$$

η_{inf} : air flow due to infiltration caused by thermal draft phenomena (m^3/h)

$$\mathbf{\eta_{inf} - 0.0146\eta_{pa} (0.7|19 - Tax_{mean}|)^{0.667}} \quad (12)$$

Tex_{mean} : the mean value of outside temperature (°C)

$$\eta_{4pa} = \eta_{4pa\_env} + 0.45 Sme_{conv} S_h \quad (13)$$

η_{4pa} : permeability under 4 Pa of the zone (m^3/h)

η_{4pa} : permeability of the envelope (m^3/h)

Sme_{conv} : conventional value of the sum of the inlet air modules under 20 Pa per unit of living surface ($m^3/h/m^2$)

$$\eta_{4pae\_env} = \eta_{4pa\_env/m^2} S_{dep} \quad (14)$$

η_{4pa_env/m^2} : conventional value of permeability under 4 Pa (m^3/h)

S_{dep} : deperditive surface excluding low-floor (m^2).

For a window without joint $\eta_{4pa\_env/m^2} = 2.5 m^3/h$, for other cases, it is equal to 1.7 m^3/h. In case of air exchange, we assume that the ventilation system is made in the high and low inlet openings, the corresponding values of Sme_{conv} and θ_{conv} are respectively 4 et 2,1450.

4. Diagnostic, quantification of energy losses, technical and economic studies

This section is devoted to calculate the annual heating and cooling requirements for the indicated house in (Fig.1). The first case concerns the study of a perfectly tight house, unlike the first and in the second case, the house is permeable to the air (ventilation). In this study, respiration and the human radiation, appliances and multimedia are also potential sources of energy supply that will not be considered. The estimated consumption is based on energy costs and readings of energy counters. Before any study and to quantify the major energy losses, we seek the percentage of heat loss of each element to properly target the greatest heat loss in this housing, this is announced in (Fig.5).

A preliminary investigation of heat loss through the envelope allows us to see that the roof, exterior walls and floor are the main sources of heat. On average, they include 77.1% of total losses. Therefore, experts have found that the best way to reduce energy consumption is to improve exterior thermal insulation in the building envelope. It is also worth to be interested in a technical and economic study to determine the cost of the corresponding energy. The procedure for calculating the relative cost per quarter is adopted in accordance with the method used by the Algerian state (SONELGAZ). SONELGAZ is a public company, responsible for the production, transmission, distribution of electricity and gas in Algeria. For a consumption less than 125 kWh, the unit cost is 1.779 DA (0.0169 EUR), above this threshold, and for a consumption greater than 125 kWh; The price will become 4.179 DA (0.0396 EUR) per kWh, ie that from 1 January 2016 the electricity and gas regulation commission will integrate two new consumption tranches: for consumption above 250 kWh, the unit cost is 4.812 DA (0.0388 EUR) and for consumption of more than 1000 kWh , the price will become 5.48 DA (0.0442EUR).

The following figures formally combine the predicted values given in Table 3 to maintain the minimum comfort in terms of temperature. Two situations must be analyzed from a house with and without air exchange.

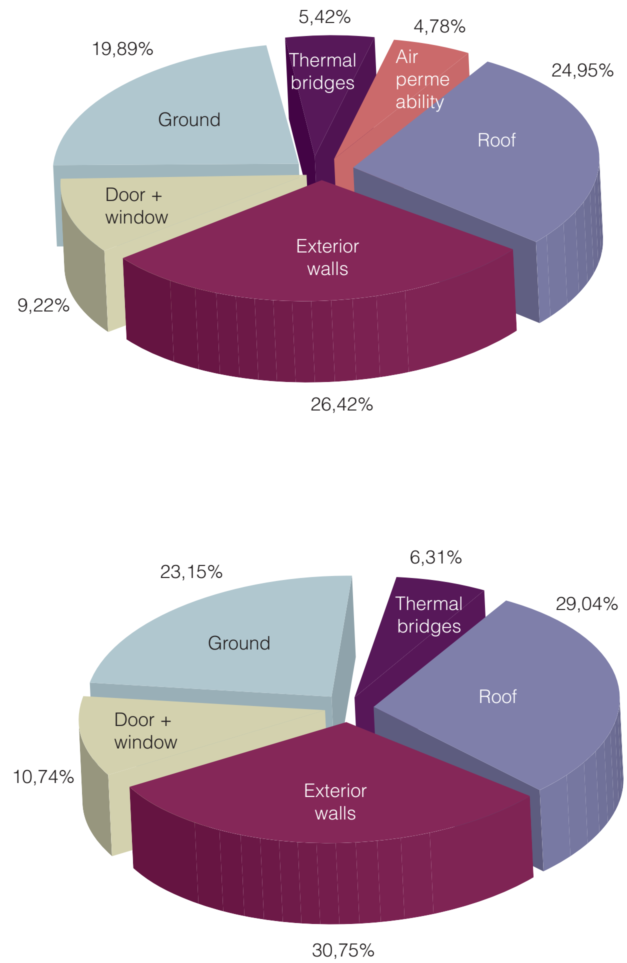

Figure 5: Share of total losses for the existing building : (a) permeable house to the air infiltration, (b) perfectly tight house.

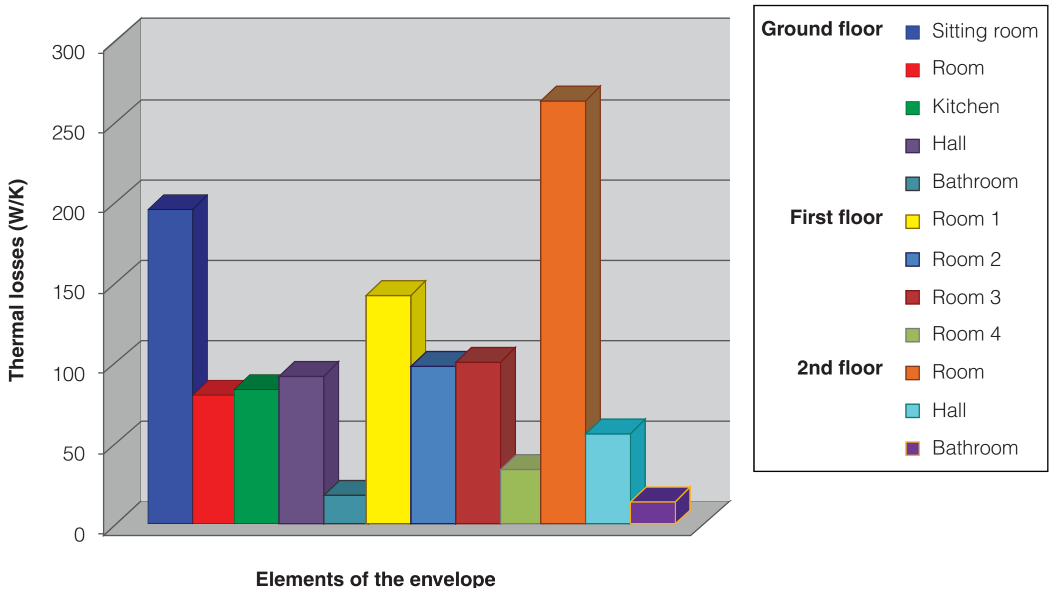

Figure 6: Losses due to heating of each room

Table 3: Required building energy consumption for each site

site	Month	Average outdoor temperature °C	Heating Cooling degree days Dj	Without air exchange C kWh	Without air exchange Cost DA/m³	With air exchange C kWh	With air exchange Cost DA/m³
Tlemcen	January	10.4	+374.1	11338.9	101.26	13209.5	118.22
	February	12.0	+293.7	8900.9	79.17	10352.2	92.32
	March	13.9	+266.6	8079.1	71.72	9376.2	83.47
	April	15.2	+219	6636.6	58.65	7689.5	68.19
	May	17.8	+142.9	4330.7	37.75	4996.6	43.78
	June	22.1	+11.7	354.5	2.35	411.6	2.88
	July	24.4	–60.7	1841.2	15.19	2137.8	17.87
	August	24.1	–52.3	1587.6	12.89	1842.7	15.20
	September	22.3	+3.6	09	0.65	126.3	0.70
	October	18.5	+124	3757.7	32.55	4329.5	37.74
	November	15.5	+208.2	6309.3	55.68	7306.8	64.72
	December	12.9	+296	8971.5	79.81	10423.5	72.97
Algiers (Bouzaréah)	January	11.7	+334.1	10127	90.28	11781.9	105.28
	February	11.3	+313	9486.4	84.47	11041.2	98.57
	March	13.8	+267.5	8107.3	71.97	9409.3	83.77
	April	14.8	+229.5	6954.8	61.53	8061.9	71.56
	May	18.6	+118.7	3598	31.11	4143.5	36.05
	June	24.0	–45.0	1363.6	10.86	1582.4	12.84
	July	26.1	–113.1	3428.9	29.57	3988.7	34.65
	August	26.9	–136.4	4133.5	35.96	4812	42.11
	September	23.7	–44.1	1336.4	10.61	1550.7	12.55
	October	22.6	–3.1	93.9	0.61	108.8	0.65
	November	15.4	+211.5	6409.3	56.59	7423.7	65.78
	December	12.5	+308.4	9347.3	83.21	10865	96.97

(continued)

Table 3: Required building energy consumption for each site *(continued)*

site	Month	Average outdoor temperature °C	Heating Cooling degree days Dj	Without air exchange C kWh	Without air exchange Cost DA/m^3	With air exchange C kWh	With air exchange Cost DA/m^3
Ghardaïa	January	12.3	+314	9516.4	84.75	11063.7	98.77
	February	14.5	+222.8	6754.2	59.71	7832.5	69.48
	March	15.9	+204.6	6200.2	54.69	7177	63.54
	April	22.8	–11.1	336.3	02.21	389.7	2.63
	May	26.7	–131.7	3992.5	34.68	4647.3	40.62
	June	30.0	–225.9	6845.7	60.54	7993.9	70.95
	July	35.4	–399.9	12118.6	108.33	14216.8	127.35
	August	35.5	–405.1	12278.4	109.78	14406.1	129.06
	September	31.4	–267.6	8109.4	72.00	9580.4	85.33
	October	24.6	–66.3	2010.3	16.72	2334.6	19.66
	November	17.7	+144	4363.8	38.05	5036.6	44.14
	December	11.4	+341.6	10352.5	92.32	12047.3	107.68

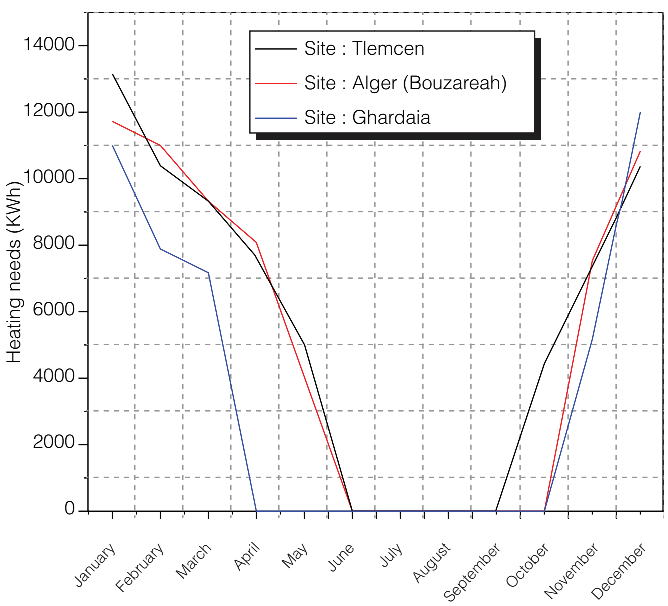

Figure 7: Net heating energy needs

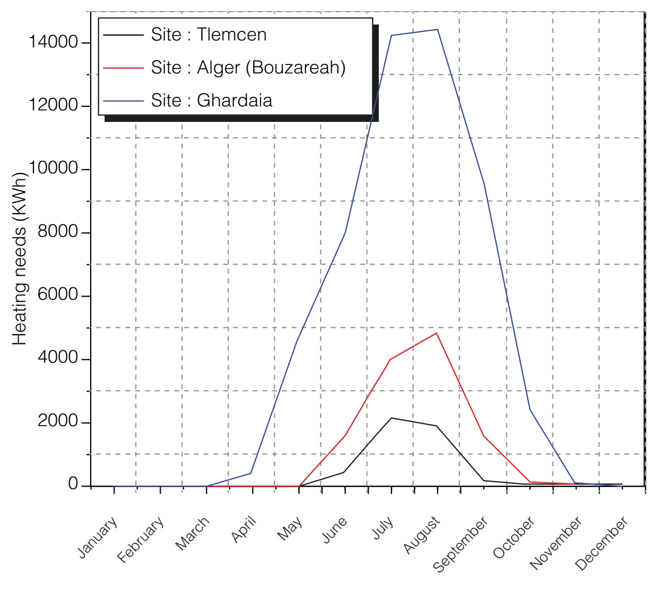

Figure 8: Net cooling energy needs

4.1. Discussion

Building heating extends from November to April, whereas annual heating needs are significant, representing about 51.76%, 53.65% and 69.06% of the annual heating and cooling needs for Tlemcen, Algiers and Ghardaia respectively. According to statistics, air infiltration cause an average increase in energy consumption of about 8.65% in Algiers, the minimum increase (8.1%) is observed in Tlemcen , while the maximum of 11.54 % is observed in Ghardaia. We note that the increase in energy consumption due to air infiltration reached record values during the summer months especially June, July and August. By finding, annual energy consumption in the three sites relative to the heating and cooling which keeps the temperature at 22.5° C, and in the case of an airtight house (including the kitchen, Baths, and room) throughout the year without breaking is estimated at 62218, 64387 and 82879 kWh/year for the sites of Tlemcen, Algiers (Bouzareah) and Ghardaia, respectively. However, depending on the chosen temperature, the financial estimate for the whole of the habitable volume

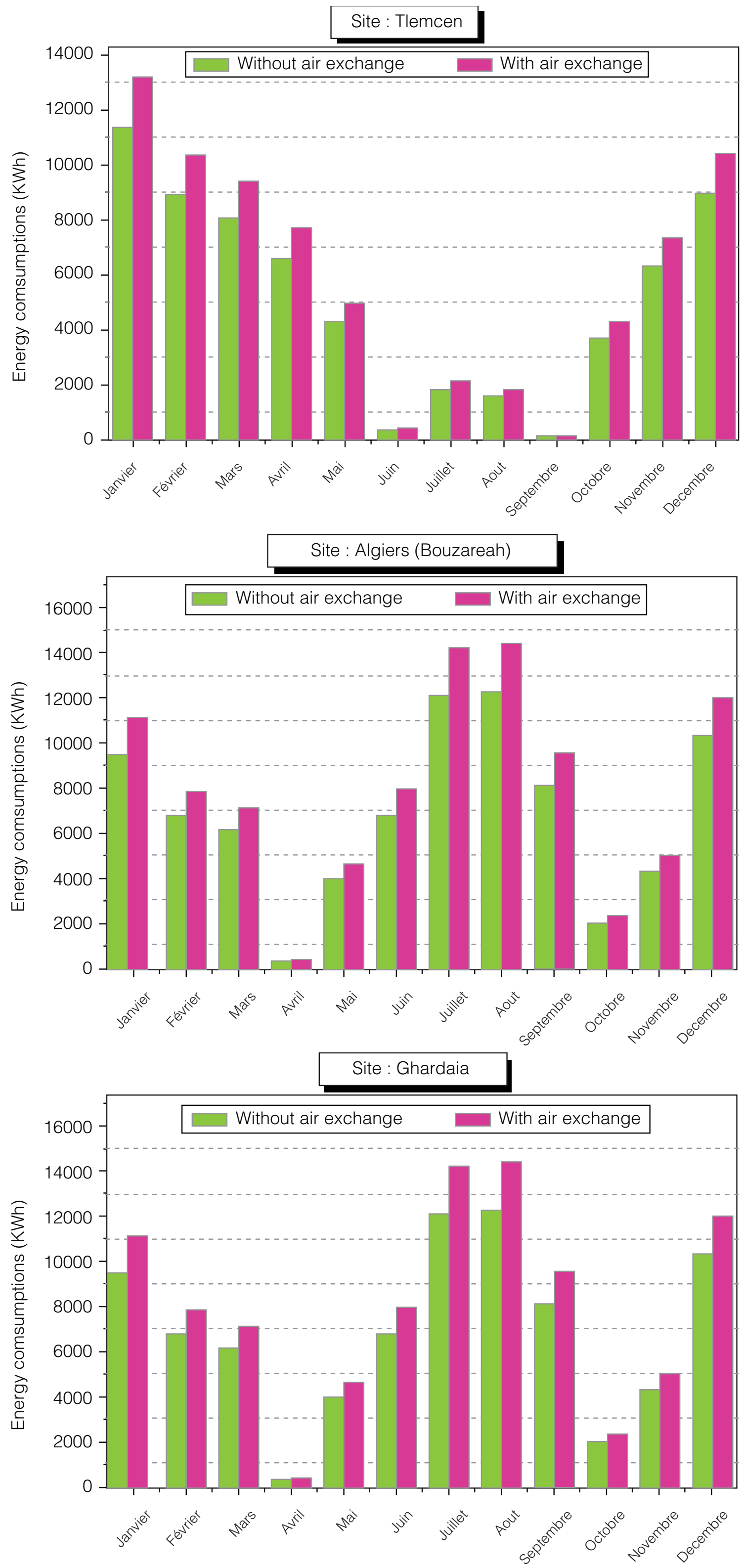

Figure 9: Monthly energy consumption for heating and cooling for each site.

and for the same order of sites is estimated at 407126, 421171 and 541852 DA / year, which is equivalent to 3171.30, 3280.70 and 4220.74 EUR/year.

In Algeria, the periodic quarterly payment of electricity bills is the imposed procedure. That is why we give results for a period of three months to have a valuable idea and to make them comparative with the real modalities of our lifestyle. If we limit our comfort perimeter only to the volume of room ($4.67 \times 3.9 \times 2.8$ m^3), and through an analysis on the total cost of the energy consumption which maintains a constant temperature of 22.5 °C in the third quarter (July, August, and September) in Ghardaia for example, we must invest an amount of 7518.96 DA (55.77 EUR). Now, if we want to maintain this internal temperature during all the year, this requires an investment corresponding to an amount of 12179 DA (90.10 EUR).We reiterate that Algerian state policy to support people in the South induced a reduction of 50% in electric energy consumption. It is for this reason that the unit price of the electric energy consumption is cheaper compared to the electricity bill cost in the majority countries of the world. This bill is very high and weighs heavily on the state budget, which is why we judged that an efficient integration of some passive solar constructive solutions appears as a mandatory process.

5. Conclusion

In this contribution, the energy needs diagnosis is generally quite positive and this low energy efficient residential building is not affordable to live in. There are many weaknesses in the buildings under investigation, they are summarize them as follows:

- the low level of thermal insulation.
- Other sources of heat loss as thermal bridges.
- Total absence of some bioclimatic design elements.

As consequences, it is necessary to decline our strategy to improve the indoor comfort. For a more suitable building, the reduction of energy consumption can be achieved by simple methods and techniques, using building design and energy efficient systems, such as passive and active solar systems.

The results show that the facade walls, roof and ground are the major sources of heat losses in the buildings , which can exceed the percentage of more than 70% of the total losses. Thermal insulation (opaque and transparent insulation) is required to reduce energy needs. The main intend of thermal insulation in winter is to conserve energy leading to a decrease in heating demand. To remove thermal bridges, it is convenient to choose the external thermal insulation. In addition, the use of brick in building walls in the Saharan regions has a potential in terms of improvement of indoor thermal comfort compared to heavy stone and cinder block and may be the main cause in reducing energy consumption [32]. On the other hand, night ventilation initially aims to reduce the need for cooling. The presence of openings in this house could be exploited to promote natural ventilation at night in summer. The air infiltration rate must not exceed 2.8 m^3/hour per linear meter in a differential pressure test of 75 Pa [33].

Degrees days of heating are much more important in the regions of Tlemcen and Algiers requiring larger heating needs. However, an active heating system using solar air collectors integrated into the building's façade is a promising solution in this case. The major inconvenience of this technique is often encountered in summer when temperatures exceed 27 °C (frequently in July and August). To ensure the reliability of this technique, it is necessary to control automatically the opening and closing the air ventilation valve[29].

The need for cooling in Ghardaia is more expensive than heating. It can be concluded that in terms of energy consumption, the climate of Algiers and Tlemcen is more favorable.

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