International Information and Engineering Technology Association
Advancing the World of Information and Engineering

Instrumentation Mesure Metrologie
Vol. 18, No. 2, April, 2019, pp. 171-180
Journal homepage: http://iieta.org/journals/i2m

Evaluation Study of Energy Performance and Conformity to Regulations for Ordinary and HEP Housings: Case Study Based on Measurements at Djelfa City, Algeria

Mostefa Mouffok[1*], Lakhdar Aidaoui[2], Noureddine Zemmouri[3]

[1] Département de Génie Civil, Université Ziane Achour Djelfa, BP 3117 RP, 17000, Algérie
[2] Laboratoire de Développement en Mécanique et Matériaux LDMM, BP 3117, Université de Djelfa, Algérie
[3] Département d'Architecture, Université Mohamed Khider Biskra, BP 145 RP, 07000, Algérie

Corresponding Author Email: mostefamouffok@yahoo.be

https://doi.org/10.18280/i2m.180212

Received: 15 January 2019
Accepted: 3 April 2019

Keywords:
energy performance, Algerian thermal regulatory, high energy performance housing HEP, regulatory technical document RTD C3-2

ABSTRACT

The aim of this study is to evaluate the constructions quality in addition to the energy consumption at a residential sector in a cold region. Djelfa is a medium sized town located at the centre of Algeria and characterized by cold climate for more than six months a year and high seasonal temperature variation. Consequently, citizens must adapt their constructions depending to this hostile climate. During the period 2013-2017, MNO (Meteorological National Office) data at Djelfa station revealed a cold period with measured temperatures in January goes from -0.6 to 13.6 °C. In this project, experimental study, calculation, questionnaire and numerical simulation were performed. Considered buildings are two standards housings: HEP housing (High Energy Performance) and an ordinary housing, both buildings have the same architectural context. Obtained results from real measurements demonstrate that only 1.3 % increase is recorded in the gas consumption for ordinary housing compared to HEP. While the computation based on the Algerian thermal regulatory show that the HEP can save up to 48 % of heating energy compared to ordinary housing, which is different to real measurements. Besides, the difference in electricity consumption is 35 % saving in favour of the HEP due to the use of economical instruments. Finally, several propositions such as; the use of solar panels, trompe wall can be investigated in order to obtain more performed buildings in terms of energy.

1. INTRODUCTION

Energy efficiency in buildings is a prime objective for energy policy at regional, national and international levels at the present time. The global energy consumption by residential and commercial sectors has exceeded other major sectors such as industrial and transportation and has steadily increased by 20 % to 40 % in developed countries [1]. Moreover, the energy demand is expected to be continue in the future because of several reasons as; growth in population, increasing demand for building services in addition to comfort levels, together with the rise in spent time inside buildings. According to the International Energy Agency IEA (2006) [2], consumption will be increased very likely for the growth in HVAC systems, where energy use is particularly significant (50% of building consumption). Statistically, the energy uses in residential sector estimated about 13 % of the total world delivered energy consumption in 2040. Delivered energy consumption in the residential sector grows by an average of 1.4 %/year from 2012 to 2040, with a total increase of 48 % over the entire period [3]. The International Energy Agency IEA (2006) has collected a scary data on energy consumption trends, where forecasts show that energy consumption in underdeveloped countries will exceed that of developed countries by 2020 with an average annual rate almost equal to 3.2 %. Besides, CO_2 emissions during the previous two seasons 1984-2004 are increased by 43 %, with an average annual increase of 1.8 % [2]. Consequently, the world is seriously concerned about the difficulties of supply, the depletion of energy resources and the heavy environmental impacts (depletion of the ozone layer, global warming, climate change, *etc.*).

In the last decades, energy efficiency of buildings is at the top of interest by different researchers. Multiple methodologies are invested in order to make the building less energy consuming. In the next section, a recall of some experiences and investigations will be addressed.

Statistical data on the socio-economic, constructive and climatic aspects gives a possibility of decision-making related to the actions of the policy-making and the modernization of the energy of the houses [4]. The statistics also help to improve the energy performance of buildings and redistribute heating costs more equitably, overcoming the contrast between the principles of accountability and equity [5].

Performed study by Elsharkawy and Rutherford (2018) showed how the awareness and behaviour of occupants influence energy consumption, according to a study done on 150 houses before and after energy retrofitting. Finally, the experience resulted a minimal energy saving, these results are largely attributed to people's well-established habits of energy use, higher comfort levels, lack of awareness, and inadequate information to help residents manage better their energy consumption after the renovation [6]. Calderón and Beltran

(2018) conducted a two-year empirical study of the effects of insulation on a social housing building in Newcastle upon Tyne (United Kingdom). The results show that users are influenced by the benefits of energy efficiency like additional heat form rather than energy savings [7]. Cauvain and Karvonen (2018) explained their agency's approach to advancing the carbon reduction agenda, starting with the influence of decision-makers and funders, as well the owners and occupants of the building. As a result, they were able to directly modify their housing stock, so they influenced their peers in the broader social housing sector [8].

Moreover, several experimental studies were realized in this field. For example, Kolokotroni et al. (2018) demonstrated that cold paint on the roofs of low-income homes in solar-intensive areas will significantly improve thermal comfort through natural ventilation and reduce the demand for cooling energy [9]. Sánchez-Reséndiz et al. (2018) have illustrated the behaviour of living walls and their beneficial effects in semi-arid environments of central Mexico. The results show that the design with such a wall contributes to the phase shift (loss/gain) of heat of the enclosure, increase the green surfaces and promote social interactions [10]. Liu et al. (2018) presented a hybrid solar heating system including a solar kang system, a Trombe wall and a direct gain window for a building located on the Qinghai - Tibetan Plateau. The study outcomes show that these systems play an important role in improving comfort and indoor temperature [11].

Control strategies and technologies can be a useful tool in energy optimization. Seeam et al. (2018) demonstrated that the use of a building energy management system (BEMS) can save energy by 50 % in terms of reducing heating time compared to scheduling [12]. The cloud-based system can be connected to home energy management systems (e.g. Wi-Fi smart plugs and wireless temperature sensors), these recent systems that make a smart and technological home, actually are considered as a cheap and affordable [13].

On the other hand, insufficient understanding of heating and ventilation equipment and the lack of proper commissioning of heating and mechanical ventilation with heat recovery (MVHR), leads to overconsumption of energy and affects the quality of the air [14].

Also, Zahiri and Elsharkawy (2018) have studied the correlations between the patterns of occupancy and energy consumption, thermal comfort and energy performance of buildings. Their results confirm that the socio-demographic characteristics, the habits of the occupants as well as the insufficient thermal envelope have a considerable influence on their theories [15]. Karatasou et al. (2018) have shown that high electricity consumption and high energy consumption for household space and water heating are related to different factors. Firstly, The high electricity consumption is related to the socio-demographic characteristics of the occupants and the nature of the building (such as household size, number of bedrooms, total floor area, building age and the existence of the electric water heating system).On the contrary, high-energy consumption for space and water heating is only related to building characteristics [16]. San Miguel-Bellod et al. (2018) indicates that housing consumption is related to socio-economic characteristics, building systems and heating systems, the result is based on a study carried out on 112 dwellings built in 40s and 80s in Spain. It shows that households connected to district heating networks maintained indoor air temperatures above 18 °C on a continuous basis. Whereas 54 % of households outside these heating systems had indoor air temperatures below this threshold at night in the bedrooms. While 25 % had temperatures below 18 ° C during the periods occupied during the day and the night [17]. Gonçalves et al. (2018) studied the combined effect of thermal inertia, exterior shading and controlled natural ventilation on thermal comfort in hot areas, based on their experience and the strategy adopted, they were able to record stable indoor thermal conditions. The air temperature oscillating between 24 °C and 26 °C when the outside temperature reached 32 °C [18]. Colcough et al. (2018) identified the potential of PH (passive house) typology as a solution to nZEB by investigating, construction costs, indoor environmental conditions, energy consumption, and heating and ventilation costs [19]. Ioannou et al. (2018) presented by real-time in situ measurements of thermal comfort and perception of thermal comfort in 17 residential dwellings in the Netherlands, the results show that if indoor temperatures were within the comfort bandwidth of the adaptive model, Occupants have often reported feelings of comfort to there than neutral. The results explain an ambiguity and that they are an indiscrimination between the different levels of thermal sensations or that allihésie plays a role and that the neutral sensation is not comfortable or that many actions take place by habit and not in the aim to improve thermal comfort [20].

Furthermore, few studies used survey methodology to investigate occupant perceptions and behaviours in social housing settings [14], through survey method, Pérez-Fargallo et al. (2018) evaluated the degree of adaptive comfort in housing. It is possible as result to apply international standards to social housing for low-income families [21]. DellaValle et al. (2018) identified a range of context-specific variables that can be used as levers to align behaviour to retrofit interventions. For example, ventilation behaviour is recognised as a social practice and scarce level of education affect him [22].

The building simulation approach is also used in other studies to examine the effect of technical, behavioural and urban design interventions [14]. Souliotis et al. (2018) presented two innovative solar water heating systems integrated on the facades (Hybrid Photovoltaic/Thermal (PV/T) solar systems) and the roof (Integrated Collector Storage (ICS) solar water heaters) of a social housing building in the municipality of AgiosDometios, Nicosia, Cyprus and is evaluated through Life Cycle Assessment. The results show that the thermal behaviour of the building is improved by 10 %, while the electric hot water and space heating requirements have been reduced by up to 80 % and 50 %, respectively [23]. Petidis et al. (2018) studied the existing building of the student hall of the Technical University of Crete, by method of help of surveys and simulations. They used five energy reduction scenarios, namely thermal insulation of the envelope, green roofs, LED bulbs, window replacement and a combination of all were chosen, the scenario resulted in a reduction of up to 36 %. The photovoltaic of the roof made it possible to save 62 % compared to the initial energy consumption, a very satisfactory result for the energy performance objective target of near-zero [24]. In the project of Santangelo et al. (2018) they explored the role of occupant behaviour modelling in assisting decision-makers in designing home renovation strategies. The authors recommend that for retrofit strategies to be effective, appropriate informative tools must be developed at an early stage to promote behavioural change for responsible energy use [25]. Sosa et al. (2018) investigated the thermal behaviour and energy consumption of different urban scenarios for low-density social housing neighbourhoods in Mendoza, Argentina. The results show that, Energy savings depend on a suitable layout and street orientation, urban trees, and the albedo of the building materials [26].

Policy development, technological advancement and behavioural changes should go hand in hand for achieving energy efficiency and comfortable conditions for the low income household sector [14].

In 2008, Algeria initiated a pilot program of 1500 HEP housing, for the purpose to keep up with the current world thought approach, this program is divided on several cities. Djelfa has benefited from 80 housing, and the approach is to build housings with energy efficient.

The methodological advance in the current study can be summarized; from one hand, assessment of two housings different by four methods. One of the two housings is built according to the so-called principle HEP and the other is ordinary housing. The methodology adopted for the analysis is as follows; calculation note, field's measurements, building simulation and occupant survey. Besides, the present study evaluating the Algerian government's decision on the techniques used and the financial process.

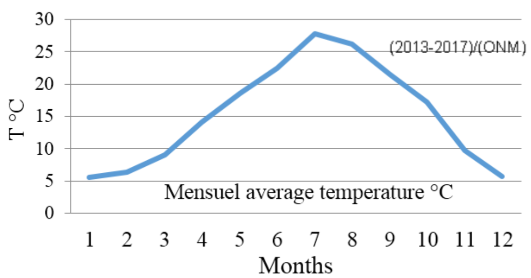
2. PRESENTATION OF THE STUDY AREA

2.1 Natural morphology

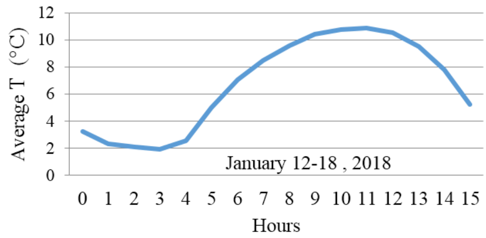
Algeria is the biggest country in Africa, with more than two millions kilometre square of extended land. In this immense territory, different landscapes and climates are distinguished. Algerian climate is changing between cold and wet during wintertime and between hot and dry during summer time. The city of interest is in the middle of the territory, it is specified by a wintertime very cold and little temperate, in addition to hot and dry summer climate. The city has an altitude of about 1180m above the sea level and prevailing winds from the northwest direction.

The selected region is characterised by a particular climate; very cold during winter in which the minimum temperature can reach 0 °C. In addition, a very hot climate during the summer time, from where a maximum temperature of 39 °C is recorded sometimes (Figure 1.a).

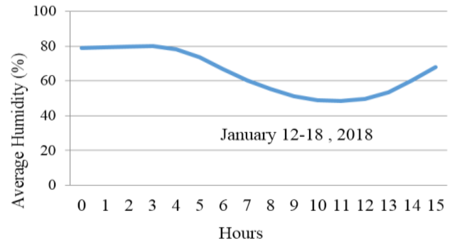
A week period during the coldest time is selected based on the available data from the MNO weather station at Djelfa city [34]. During these days a temperature rising and falling is observed, the variation of the average temperature T_m gives an upward aspect during the day and it can reach the value of 11 °C. From the other hand, during the evening the T_m declines and it records the values of 2 °C, with 50 % of humidity during the daytime and 80 % during the night time (Figure 1.b/c).



a) MNO measurements of temperature monthly mean variation (2013-2017) [34]



b) MNO hourly average temperature variation in January, 12-18-2018 [34]

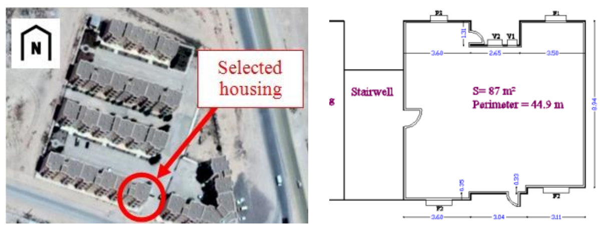


c) MNO hourly average humidity variation in January, 12-18-2018 [34]

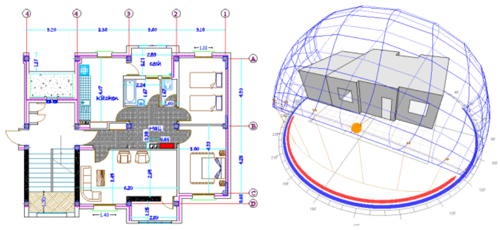
Figure 1. Meteorology conditions variation in Djelfa city

2.2 HEP housing

The urban morphology of the 80 HEP housings takes in consideration the microclimatic aspect in addition to the urban requirements. Where, the gables projection is on the north-west side and the blocks are aligned on two perpendicular boulevards (Figure 2.a-d).



a) Selected housing on the last floor; b) Envelope outer and housing's surface



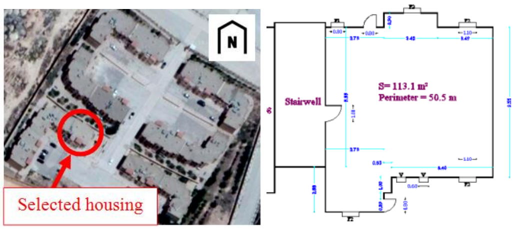
c) Housing plan; d) Housing orientation

Figure 2. HEP housing

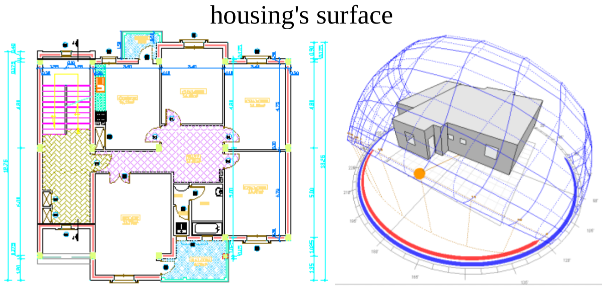
The typology of the 80 HEP housings is arranged in 14 blocks, where 11 of them are planted along the North/South direction. The orientation choice is according to an experimental study made on similar region of the same latitude. This direction is considered as the most favourable for the arid regions [27]. For this purpose HEP housings take maximum advantage of the solar radiations during winter and summer periods, with such a solar azimuth almost vertically. It's easily to get protected, against solar rays by using awning and occultation [27, 28]. Following the same urban concept, the interior layout of the housing follows the North/South orientation. So the accommodation is divided into two sections according to a structuring axis. In the north side is the kitchen, the bathroom, the toilet and a bedroom, while in the south facade, there is a large living room, a bedroom and a loggia to promote the phenomenon of the capture/diffusion of solar energy by the system of the trombe wall. Moreover, the used insulation techniques can be summarised by the next points; a Double hollow brick walls (15 cm + 10 cm) with polystyrene insulation inside of 5cm.besides, windows are in PVC frame with a single 5 mm thick glazing, the last floor (terrace) is an ordinary hourdis floor and the insulation has a thickness of 12cm in polystyrene.

2.3 Ordinary housing

The urban morphology of all 50 housings are arranged to create only closed islands (Figure 3a), housed in thirteen blocks, six of them have been arranged north-east/south-west, one block oriented to the east-south/north-west direction, and the rest have only a liaison role (angle blocks).



a) Selected housing on the last floor; b) Envelope outer and housing's surface



c) Housing plan; d) Housing orientation.

Figure 3. Ordinary housing

Also, housing interior typology is divided into two entities following a virtual structuring axis, the kitchen and two bedrooms are on a side, on the other side is a large living room, the bathroom and a bedroom. It must be remembered that the disposition of the blocks is sometimes directed at one direction, sometimes in the opposite sense according to the requirement of forming an island. The apparent idea is that the typology of this housing has no bioclimatic basis, either in terms of the housing internal distribution or the level of urban planning. The outer envelope technique is summed up; Double hollow brick walls (15 cm + 10 cm) with inside, an air gap in 5cm thick, windows in wood frame with a single 5mm thick glazing, the last floor (terrace) is an ordinary hourdis floor and the insulation has a thickness of 5 cm in polystyrene.

3. USED METHODOLOGIES

During the current study a week period in the early January 2018 is chosen (from 12 to 18). The selected duration is considered by the MNO station as the coldest period in the region during 2018 **(***Cf.*Figure 1) [34]. Moreover, two housings types were taken for the thermal comfort analysis, HEP housing and Ordinary housing.

3.1 Energy consumption using experimental and survey analysis

According to EIA (2016), the energy consumption in the residential sector comprises all energy consumed by households, excluding transportation uses. It includes energy used for heating, cooling, lighting, water heating, and consumer products. Energy consumption in the residential sector is affected by income levels, energy prices, location, building and household characteristics, in addition to weather, efficiency and type of equipment, energy access, availability of energy sources, energy-related policies and so on. Consequently, the energy type and amount consumed by households can vary significantly within and across regions and countries [3].

Table 1. Global questions about HEP & Ordinary housing families

HEP housing								
Age by years		<5	>5,<10	>10,<15	>15	<35	>45	>50
Grandparents age		-	-	-	-	-	-	-
Parents age		-	-	-	-	XX	-	-
1st child age	Boy	X	-	-	-	-	-	-
	Girl	-	-	-	-	-	-	-
2nd child age	Boy	-	-	-	-	-	-	-
	Girl	X	-	-	-	-	-	-
Ordinary housing								
Grandparents age		-	-	-	-	-	-	-
Parents age		-	-	-	-	X	X	-
1st child age	Boy	-	-	-	-	-	-	-
	Girl	-	-	-	-	-	-	-
2nd child age	Boy	-	-	-	-	-	-	-
	Girl	-	-	-	X	-	-	-
3rd child age	Boy	-	-	-	-	-	-	-
	Girl	-	-	X	-	-	-	-
4th child age	Boy	-	-	-	--	--	-	-
	Girl	-	X	-	-	-	-	-
5th child age	Boy	-	-	-	-	-	-	-
	Girl	X	-	-	-	-	-	-

Concerning the consumed energy analysis from the electricity and gas in case of the two housings types, the research is based on:

- The analysis by survey method based on the composition of the two families, in which the HEP family consists of two parents and two grandchildren (<5years), and the ordinary housing family is composed from two parents and four children with different ages(<5, >5<10, >10<15, >15) (Table 1)
- The experimental analysis of the gas consumption is carried by the verification of the consumption quantity before and after the experiment (January 12-18). So the survey method gives us a vision on all the instruments of the two families that works with gas and checking their operating times and power during the use.

In the electrical energy consumption case, the same approach as the gas consumption is adopted.

3.2 Simulation

The objective of this step is to visualize and analyse by simulation the thermal comfort in a built space (Table 2). The model Autodesk Ecotect (2011) offers a wide range of thermal performance analysis features [29].

The operating conditions of the used model are well affected by several parameters such as: Internal design conditions; Occupancy and operation; HVAC and Material assignments for modelling.

Table 2. Simulation protocol for HEP & Ordinary housings

Simulation protocol			**HEP housing**	ORDINARY housing
Internal design conditions		Clothing *[0~3][1≈light business suit]*	1	*1*
		Humidity *[%]*	60	60
		Air speed *[m/s]*	0.5	0.5
		Lighting level *[Lux]*	26	75
Occupancy and operation	Occupancy	Number	4	6
		Position *[40W~200W]*	70	70
	Internal gains	Sensible gain *[W/m²]*	5	5
		Latent gain *[W/m²]*	2	2
	Infiltration rate	Air change rate *[Air changes/hr]*	0.5	0.5
		Wind sensitivity *[0.1ach ~1.5ach]*	0.25	0.25
HVAC	Active system	Type of system	Heating only	Heating only
		Comfort band *[C°]*	18 ~ 26	18 ~ 26
		Hours of operation *[0 ~ 24]*	24	24
Material assignments for modelling	Wall	Vertical insulation by 5 *[cm]*	polystyrene	Air blade
		R $[m^2.C°/W]$	1.43	0.17
	Windows	Material type	PVC	WOOD
		R $[m^2.C°/W]$	0.42	0.42
	Doors	Glazing proportion	<30 %	<30 %
		R $[m^2.C°/W]$	0.25	0.25
	Ceiling	Horizontal insulation by polystyrene *[cm]*	12	5
		R $[m^2.C°/W]$	3.43	1,44

3.3 Calculation and reference regulations

The used reference equations in the theoretical methodology are made according to the RTD C3-2 of the Algerian regulations. The regulatory requirement on which this RTD is based is by setting a threshold that should not be exceeded to limit building's energy losses. Respecting this threshold should allow saving from 20 to 30 % of the global energy consumption for the housing heating [30].

Objectives of the RTD application can be cited as follow; Determination of buildings heat losses, Verification of buildings compliance with thermal regulations, Dimensioning of buildings heating systems and thermal design. Present method is divided into two stages; the first step is to calculate the reference losses D_{ref}. While the other step is calculating the actual heat losses D_t about walls, floor, windows and doors.

After the calculation of the reference heat losses D_{ref} $(W/C°)$ and the real heat losses D_t $(W/C°)$ of different surfaces, the regulation requires that: $D_t < D_{ref}$ with a tolerance of 5 % overrun, should be respects the following formula.

$$D_t / D_{ref} < 1.05 \tag{1}$$

3.3.1 Reference losses

This step permits to define the regulatory threshold that should not be exceeded:

$$D_{ref} = a\,.S_1.+b\,.S_2 + c\,.S_3 + d\,.S_4 + e\,.S_5 \tag{2}$$

With S_1, S_2, S_3, S_4, S_5. represent the surfaces of the upper floor, lower floors, outer walls and the outer doors & glazing, respectively.

And the coefficients *a, b, c, d, e* attribute to the region of Djelfa.

$$D_T = (D_{pr})_i + (D_{plh})_i + (D_{pv})_i + (D_p)_i + (D_{lnc})_i \tag{3}$$

3.3.2 Real losses

Heat losses through the outer walls:

The lost heat through the exterior walls is computed with the next formula:

$$(D_{pr})_i = \sum[(k_{ow} \times A_{ow}) + (K_{ow} \times L_{ow})] \tag{4}$$

where outer walls' coefficients are;

k_{ow}: Surface Thermal transmission coefficient ($W/m^2.C°$), A_{ow}: Area (m²), K_{ow}: Linear thermal bridges ($W/m.C°$) and L_{ow}: Length of thermal bridges (m).

Heat losses through the roof:

The lost heat through the high can be computed, using the following expression:

$$(D_{plh})_i = \sum[(k_r \times A_r) + (K_r \times L_r)] \tag{5}$$

where the roof's coefficients are;

k_r: Surface thermal transmission coefficient (W/m². C°), A_r: Area (m²), K_r: Linear thermal bridges (W/m. C°), and L_r: Length of thermal bridges (m).

Heat losses through the windows:

In the windows case, the heat losses are determined as follow:

$$(D_{pv})_i = \sum[(k_w \times A_w) + (K_w \times L_w)] \tag{6}$$

where windows' coefficients are;

k_w: Surface thermal transmission coefficient ($W/m^2.C°$), A_w: Area (m²), K_w: Linear *thermal* bridges ($W/m.C°$), and L_w: Length of thermal bridges (m).

$$R = \frac{1}{k_w} = \frac{1}{k_{vn}} + r_v + r_{rid} + r_{occ} \tag{7}$$

where,

k_{vn} ($W/m^2.C°$) is the thermal conductivity of glazing (conventional table);

r_v ($m^2.C°/W$) is Additional thermal resistance of the potential sheers, r_v = 0,025 $m^2.C°/W$;

r_{rid} ($m^2.C°/W$) is the thermal resistance of possible curtains, $r_{rid} = 0{,}03\ m^2.C°/W$;

r_{occ} ($m^2.C°/W$)is the thermal resistance of occultation (no occultation).

Heat losses through exterior doors:

$$(D_p)_i = \sum[(k_{ed} \times A_{ed}) + (K_{ed} \times L_{ed})] \tag{8}$$

where exterior doors' coefficients are;

k_{ed}: Surface transmission coefficient ($W/m^2.C°$), A_{ed}: Area (m²), K_{ed}: Linear *thermal* bridges ($W/m.C°$), and L_{ed}: Length of thermal bridges (m).

Heat losses through unheated walls:

$$D_{lnc} = \boldsymbol{Tau}(\sum[(k_{uw} \times A_{uw}) + (K_{uw} \times L_{uw})]) \tag{9}$$

where unheated walls' coefficients are;

k_{uw}: Surface transmission coefficient ($W/m^2.C°$), A_{uw}: Area (m²), K_{uw}: Linear *thermal* bridges ($W/m.C°$), and L_{uw}: Length of thermal bridges (m).

$$Tau = \frac{t_i - t_n}{t_i - t_e} = \frac{d_e}{d_e + a_c} \tag{10}$$

(1). t_i (°C) is the indoor temperature.

(2). t_n (°C) is the temperature of the unheated space.

(3). t_e (°C) is the outside temperature.

(4). a_c (W/ °C) Represents the heat gains of various heated rooms to the unheated room.

(5). d_e(W/ °C) Represents the heat losses of the unheated room to the outside.

4. RESULTS AND DISCUSSION

4.1 Regulations check

Calculations illustrate that HEP housing is well complies with the reference regulations mentioned above, the computed real heat losses (D_t) is found to be less than its reference value (D_{ref})with 48 %. On the other hand, in the ordinary housing case, the D_t value exceeds the reference D_{ref} with almost 9,7 % (Table 5). Whatever, the difference between computed and reference values in the ordinary housing is minimal, while the HEP housing results is widely accepted and theoretically it can improve the energy efficiency in a considerable way. It is noted that several researchers assessed that the intervention concerning the building envelope is among the strategies that can reduce the heating energy consumption [15-18, 24, 26].

Table 3. Regulatory verifications of heat loss according to RTD.C3-2 reference values (Regulatory Technical Document) for HEP & Ordinary housing [30]

Heat losses		HEP housing	Ordinary housing
Real heat loss D_t	Exterior walls$(D_{pr})_i$	74,43	168,94
	High floor$(D_{plh})_i$	36	75,95
	Windows $(D_{pv})_i$	15,28	16,58
	Exterior doors$(D_p)_i$	17,09	18,23
	stairwell wall's (D_{lnc})	18,66	24,39
	Total (D_t)	161,46	304,09
Reference heat losses D_{ref}		238,98	276,95
Regulation verifications $D_t/D_{ref} < 1.05$		*admitted* 0.67	*no admitted* 1.1

4.2 Measured and simulated energy consumption

4.2.1 Gas consumption

During the considered period from 12 to 18 January2018, the gas consumption amount by HEP housing is 126.71 m^3 (with 3.5753 DA/m^3), which gives a total consumption price equal to 453.04 DA. During the same period, the ordinary housing consumed about 128,365 m^3 (+ 1.3 % compared to the HEP), with a total consumption price equal to 458.94 DA. The percentage value of 1.3 % is recorded as a difference between the two typologies (+5.9 DA) (Figure 4/Table 4).

Besides, the gas energy gap between the two housings types; HEP and ordinary is minimal. This rapprochement between the two values is maybe due to a compensation of the produced heat in the ordinary housing by a compound energy, which is the resultant of:

- More family numbers (+2 members),
- The characteristics of the building envelope (No insulation, *Cf.*Table 2) affect the gas energy consumption; this explanation is confirmed by Karatasou et al. (2018) [16].
- At the socio-cultural and economic level of the two families, according to San Miguel-Bellod et al. (2018) [17] whom indicate that housing consumption is related to socio-economic characteristics, building systems and heating systems.
- The use of tungsten bulbs which are energy-consuming bulbs (75W), compared to economic bulbs (26W)

(*Cf.*Table 2);

- The ordinary housing tenant is working as a teacher and researcher, who invested a lot of time at home with his family. While the occupant of the HEP housing is a doctor at the hospital, who invested less time at home, because of the profession's obligations (work during the day and sometimes the guard during the nights). As a consequence, the degree of thermal comfort in the ordinary housing is ranged between 18 and 26 °C in a continuous way during the experiment whole period, which reduces the gas consumption but increased the electricity consumption.

According to the findings of the different methods in this study, the socio-demographic characteristics like the occupancy patterns, the habits of the occupants as well as the insufficient thermal envelope have a considerable influence on energy consumption, thermal comfort and energy performance of buildings, current results is also confirmed by Zahiri and Elsharkawy (2018) [15].

It can be seen that, despite the energy production offsets of the ordinary housing looks acceptable, the HEP housing profile is always remains the best in terms of energy efficiency (Figure 4).This reasoning is confirmed, if we proceed to a scenario of six months period (26 weeks) for 50 houses, the difference will be significant, worth of 27,422.5 DA (231.39 US $) as a difference. So, it is obvious that HEP housing consumes less compared to ordinary housing, this is perfectly clear over a long period.

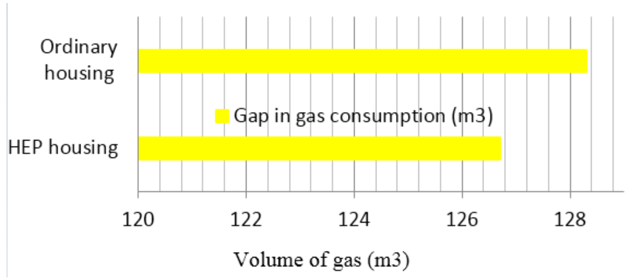


Figure 4. Gas consumption volume (m^3) In HEP &ordinary housing

Table 4. Global questions about the Gas appliances for HEP & Ordinary housing

Gas appliances			HEP housing	Ordinary housing
Water heater	Location		kitchen	kitchen
	Capacity / Power		5L	5L
	Make / Model		Junkers	Superflic
Gas stove, single burner gas	Location in (kitchen / loggia of kitchen / loggia of living room)		-	Loggia of kitchen
Cooker	60 cm		60 cm	60cm
	90 cm		-	-
Gas stove for heating	Number		1	1
	Make / Model		Condor	Free air
	Power during the experiment		Max (5-6)	Max (6)
	Location	Close to the front door	-	-
		In the middle	X	X
		At bottom of the house	-	-
		Other	-	-

4.2.2 Electricity consumption

Electricity becomes an important increasingly energy source for the residential sector during the upcoming years. The electricity share of the world residential energy consumption grows from 39 % in 2012 to 43 % in 2040, and by 2025 electricity surpasses natural gas as the leading source of residential delivered energy [3].

During the period January 12-18, 2018, the HEP housing had an electricity consumption of about 40Kwh, (for 4.2002 DA/Kwh), with a total of 168.01 DA as electricity consumption. During the same period, the ordinary housing consumed 54Kwh (+35 %), with a total of 226.81DA consumption. A difference of 35 % is recorded between the two typologies (+58.8DA), while, if we proceed to a scenario of a one year period (52 weeks) for 50 housings, the difference will be significant and the gap will be 152880DA (US$1290) (Figure 5/Table 2/5).

The difference of the electricity energy between the two housings; HEP and ordinary is considerable (+ 35 %). The ordinary housing exceeds is mainly due to the use of tungsten bulbs (75W), while in the HEP housing a sodium bulbs (26W) are used (*Cf.*table 2/5), the high consumption gap of electricity is related also to the socio-demographic characteristics of the occupants in addition to the building nature, as; the household size (+2 member), number of bedrooms (+1 room) and total floor area (+26.1m²).These parameters are further confirmed by several researches such as; Karatasou et al (2018) and Petidis et al. (2018) [16, 24] (Table 5).

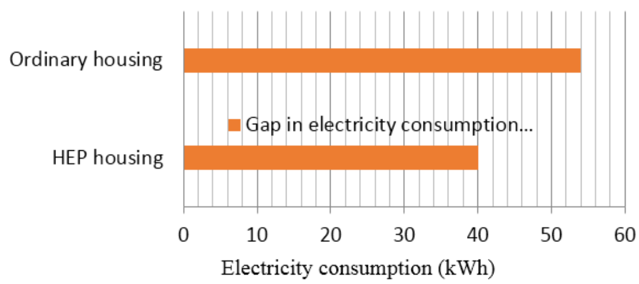


Figure 5. Electricity consumption (kWh) for HEP & ordinary housing

Table 5. Electric bulbs and electrical outlets for HEP & Ordinary housing

	HEP housing					**ORDINARY housing**				
Spaces	Bulb number	Bulb types	Bulb Brand	Bulb power (W)	Number of electrical outlets	Bulb number	Bulb types	Bulb Brand	Bulb power (W)	Number of electrical outlets
Living room	2	*S*	*R*	26	2	1	t	-	75	2
Parent's room	1	*S*	*R*	26	1	1	t	-	75	2
Boys room	1	*S*	*R*	26	1	1	t	-	75	2
Girls room	-	-	-	-	-	1	t	-	75	2
Corridor	2	*S*	*R*	26	-	1	t	-	75	-
Hall	-	-	-	-	-	1	t	-	75	-
Kitchen	1	*N*	-	30	2	1	N	-	75	2
Bathroom	2	*T* *N*	- -	75 30	1	2	t n	- -	75 30	2
Toilet	1	*T*	-	75	-	1	t	-	75	-
Kitchen Loggia	1	*T*	-	75	1	1	t	-	75	-
Loggia of living room	1	*T*	-	75	-	1	t	-	75	-

S: Economy sodium bulb, *N*: Neon Bulb, *t*: Tungsten Bulb, *n*: Neon Bulb for wall, R: Brand Bulb "RIOTO"

4.2.3 Energy consumption simulated

In the considered region, the outside temperature is variable and can reach a minimum value of 3.7 °C in the morning, where the maximum value is below 3 °C during the afternoon. This cold period is considered as an extreme compared to the Algerian territorial climate, while inside buildings there is a different behaviour. Based on Figure 6, it is observed that the temperature variation in the two housing types behave in the same way with a non-important difference during the early morning and during the evening, while in the midday we notice a concordance visible between the two graphs.

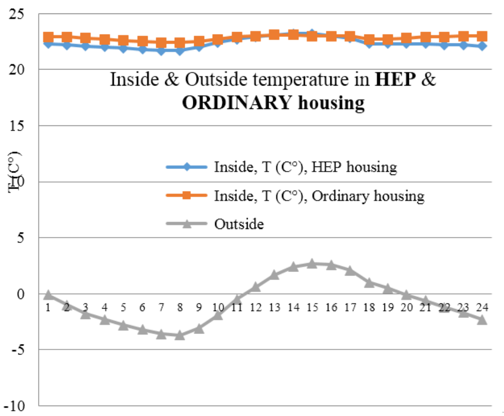


Figure 6. Simulation of both temperatures (°C) inside & outside the housings types HEP & Ordinary in January, 15th [29, 34]

It is noted that the heating energy efficiency recorded in the ordinary housing exceeded the one of HEP housing. Current energy performance is justified according to the following points:

- The nature of the HEP bulbs produce only 26W (Sodium bulbs), whereas the standard housing bulbs produce 75W (Tungsten bulbs) (*Cf.*Table 2/5);
- The family number of ordinary housing exceeds the family number of HEP housing by two (02) persons, and their range of age exceeds the one of HEP housing children. (*Cf.*Table 1), it can be noted that, a human can produces between 60W ~ 80W in the sitting state and this energy can be doubled according to the age and the activity [31].
- The software could not give the hand to develop certain aspects such as thermal bridges or building defects for ordinary housing. It can be said that the perfect non-configuration of the reality of the parameters penalizes the analysis of the actual comfort of the HEP housing, and changes the behaviour of the housing envelope, because the housing envelope has huge consequences on energy consumption for heating, according to a lot of research [15-19, 24, 26].

5. CONCLUSION

In the present project, experiment, theoretical, numerical and survey investigations were performed in order to study the energy performance and conformity to regulations for two different types of housings; ordinary and HEP housings, by taking Djelfa city (Algeria) as a case study.

According to the literature, researchers provide many strategies to be applied in order to improve the energetic performances of the residential sectors. It is well known that various process should be respected while the conception and realization of buildings, such as:

- Architectural and urban design by orienting housings to the south for maximum capture during the winter, this orientation also facilitates protection against the sun's rays during the summer [27, 28]. This hypothesis is also proved by the research of Sosa et al. (2018) and Montarry (2005), where they reflect that the architectural and urban design is the primary element for a better energy efficiency [26, 32]. Also energy savings in addition to the thermal comfort are depends on a suitable layout and street orientation, urban trees, and the albedo of the building materials.
- The outer envelope such as walls, floor, windows and loggias doors in addition to the limit of thermal bridges. Current design choice is proven by numerous researches, where the effect of the building envelope performances on the energy efficiency is proved [15-19, 24, 26].

A cold region for more than six months a year, in addition to its high seasonal variation of temperature min and max is selected in this study. Two building types are considered for examination (HEP housing and ordinary housing), the mentioned housings are located in two different sites with the same architectural context (orientation & disposition in elevation).

Findings from experiment (real measurements) demonstrate that only 1.3 % increase is recorded in the gas consumption for ordinary housing compared to HEP housing. While the computation based on the Algerian thermal regulatory show that the HEP housing can save up to 48 % of heating energy compared to ordinary housing, which explain clearly the big difference between the real findings and what should be found. Besides, the difference in energy consumption in electricity is 35 % saving in favour of the HEP housing based on the experiment results. This gain is mainly due to the use of economical electric instruments in buildings with high energy efficiency HEP.

Based on the mentioned scenarios, the Algerian government did not really invest much in this pilot project, the financial impact compared to ordinary housing is estimated at only 187500 DA (1581,28 USD) per surface housing of 69m². However, many solutions can be applied at the same time to have optimal energy performance such as; the use of solar panels (photovoltaic or hot water) installed on the facades or on the roofs, trompe wall, kang system, living wall, etc. In addition, other materials and techniques can be used to improve thermal and sound insulation or increase natural ventilation in homes in order to have a comfortable and healthy indoor environment with less energy consumption [14, 24, 23, 31, 33].

REFERENCES

[1] Pérez-Lombard, L., Ortiz, J., Pout, C. (2018). A review on buildings energy consumption information. Energy and Buildings, 40: 394-398. http://dx.doi.org/10.1016/j.enbuild.2007.03.007

[2] International Energy Agency (IEA). (2006). Key world Energy Statistics, Energy Statistics Division, Paris, France.

[3] Energy Information Administration (EIA). (2016). International Energy Outlook, Department of Energy, USA.

[4] Sánchez, G.S., Gonzalez, F.J.N., Hernandez, A. (2018). Energy poverty methodology based on minimal thermal habitability conditions for low income housing in Spain. Energy & Buildings, 169: 127-140. https://doi.org/10.1016/j.enbuild.2018.03.038

[5] Dell'Isola, M., Ficco, G., Canale, L., Frattolillo, A. andBertini, I. (2018). A new heat cost allocation method for social housing. Energy & Buildings, 172: 67-77. https://doi.org/10.1016/j.enbuild.2018.05.004

[6] Elsharkawy, H., Rutherford, P. (2018). Energy-efficient retrofit of social housing in the UK: Lessons learned from a Community Energy Saving Programme (CESP) in Nottingham. Energy & Buildings, 172: 295-306. https://doi.org/10.1016/j.enbuild.2018.04.067

[7] Calderón, C., Beltrán, R.M. (2018). Effects of fabric retrofit insulation in a UK high-rise social housing building on temperature take-back. Energy & Buildings, 173: 470-488. https://doi.org/10.1016/j.enbuild.2018.05.046

[8] Cauvain, J., Karvonenb, A. (2018). Social housing providers as unlikely low-carbon innovators. Energy & Buildings, 177: 394-40. https://doi.org/10.1016/j.enbuild.2018.08.012

[9] Kolokotroni, M., Shittu, E., Santos, T., Ramowski, L., Mollard, A., Rowe, K., Wilson, E., Filho, J.P.D.B., Novieto, D. (2018). Cool roofs: High-tech low-cost solution for energy efficiency and thermal comfort in low-rise low-income houses in high solar radiation countries. Energy & Buildings, 176: 58-70. https://doi.org/10.1016/j.enbuild.2018.07.005

[10] Sánchez-Reséndiz, J.A., Ruiz-Garcíaa, L., Olivieri, F., Ventura-Ramos, E. (2018). Experimental assessment of the thermal behavior of a living wall system in semi-arid environments of central Mexico. Energy & Buildings, 174: 31-43. https://doi.org/10.1016/j.enbuild.2018.05.060

[11] Liu, Z., Wu, D., Yu, H., Ma, W., Jin, G. (2018). Field measurement and numerical simulation of combined solar heating operation modes for domestic buildings based on the Qinghai-Tibetan plateau case. Energy & Buildings, 167: 312-321. https://doi.org/10.1016/j.enbuild.2018.03.016

[12] Seeam, A., Laurenson, D., Usmani, A. (2018). Evaluating the potential of simulation assisted energy management systems: A case for electrical heating optimization. Energy & Buildings, 174: 579-586. https://doi.org/10.1016/j.enbuild.2018.06.063

[13] Bruce-Konuah, A., Jones, R.V., Fuertes, A., Messi, L., Giretti, A. (2018). The role of thermostatic radiator valves for the control of space heating in UK social rented households. Energy & Buildings, 176: 206-220. http://dx.doi.org/10.1016/j.enbuild.2018.05.023

[14] Rajagopalan, P., Dimoudi, A. (2018). Editorial note for low energy social housing. Energy & Buildings, 180: 29-31. https://doi.org/10.1016/j.enbuild.2018.09.027

[15] Zahiri, S., Elsharkawy, H. (2018). Towards energy-efficient retrofit of council housing in London: Assessing the impact of occupancy and energy-use patterns on building performance. Energy and Buildings, 174: 672-681. https://doi.org/10.1016/j.enbuild.2018.07.010

[16] Karatasou, S., Laskari, M., Santamouris, M. (2018). Determinants of high electricity use and high energy consumption for space and water heating in European Social Housing: Socio-demographic and building characteristics. Energy & Buildings, 170: 107-114. http://dx.doi.org/10.1016/j.enbuild.2018.04.019

[17] Miguel-Bellod, S., Gonzalez-Martînez, J., Sanchez-Ostiz, P. (2018). The relationship between poverty and indoor temperatures in winter. Determinants of cold homes in social housing contexts from the 40s-80s in Northern Spain Energy & Buildings, 173: 428-442. https://doi.org/10.1016/j.enbuild.2018.05.022

[18] Gonçalves, J.C.S., Dolce, M., Roberta, C., Mulfarth, K. (2018). Revealing the thermal environmental quality of the high-density residential tall building from the Brazilian bioclimatic modernism: The case-study of Copan building. Energy & Buildings, 175: 17-29. https://doi.org/10.1016/j.enbuild.2018.06.054

[19] Colcough, S., Kinnane, O., Hewitt, N., Grifths, P. (2018). Investigation of nZEB Social Housing built to the Passive House Standard. Energy & Buildings, 179: 344-359. https://doi.org/10.1016/j.enbuild.2018.06.069

[20] Ioannou, A., Itard, L., Agarwal, T. (2018). In-situ real time measurements of thermal comfort and comparison with the adaptive comfort theory in Dutch residential dwellings. Energy & Buildings, 170: 229-241. https://doi.org/10.1016/j.enbuild.2018.04.006

[21] Pérez-Fargallo, A., Pulido-Arcas, J.A., Rubio-Bellido, C., Trebilcock, M., Piderit, B., Attia, S. (2018).

Development of a new adaptive comfort model for low income housing in the central-south of Chile. Energy & Buildings, 178: 94-106. https://doi.org/10.1016/j.enbuild.2018.08.030
[22] DellaValle, N., Bisello, A., Balest, J. (2018). In search of behavioural and social levers for effective social housing retrofit programs. Energy & Buildings, 172: 517-524. https://doi.org/10.1016/j.enbuild.2018.05.002
[23] Souliotis, M., Panaras, G., Fokaides, P.A., Papaefthimiou, S., Kalogirou, S.A. (2018). Solar water heating for social housing: Energy analysis and life cycle assessment. Energy & Buildings, 169: 157-171. https://doi.org/10.1016/j.enbuild.2018.03.048
[24] Petidis, I., Aryblia, M., Daras, T., Tsoutsos. (2018). Energy saving and thermal comfort interventions based on occupants 'needs a students' residence building case. Energy & Buildings, 174: 347-364. https://doi.org/10.1016/j.enbuild.2018.05.057
[25] Santangelo, A., Yan, D., Feng, X., Tondelli, S. (2018). Renovation strategies for the Italian public housing stock: Applying building energy simulation and occupant behaviour modelling to support decision-making process. Energy & Buildings, 167: 269-280. https://doi.org/10.1016/j.enbuild.2018.02.028
[26] Sosa, M.B., Correa, E.N., Cantón, M.A. (2018). Neighborhood designs for low-density social housing energy efficiency: Case study of an arid city in Argentina. Energy & Buildings, 168: 137-146. https://doi.org/10.1016/j.enbuild.2018.03.006
[27] Givoni, B. (1978). L'homme l'architecture et le climat, éditions du moniteur, France.
[28] Oke, T.R. (1990). Boundary Layer Climates Second edition, London.
[29] Autodesk Ecotect Analysis (2011). Autodesk Inc.
[30] National Center for Integrated Building Research and Studies (NCIBRS). (1997). Regulatory Technical Document-RTD. Thermal regulation of residential buildings - Rules for calculating heat losses - Fascicule 1, Algiers.
[31] Dutreix, A. (2010), Bioclimatisme et performances énergétiques des bâtiments, Eyrolle édition, France.
[32] Montarry, D., Platzer, M., (2005), La Technique du bâtiment- Tous Corps d'Etat (TCE), Le Moniteur éditions, 4ème édition, France.
[33] Földváry, V., Bukovianska, H.P., Petráš, D. (2015), Analysis of energy performance and indoor climate conditions of the Slovak housing stock before and after its renovation. Energy Procedia, 78: 2184-2189. https://doi.org/10.1016/j.egypro.2015.11.314
[34] Meteorological National Office (MNO), (2018). Djelfa Station.

NOMENCLATURE

A	Area, m^2
D	Heat loss, $W.C^{\circ-1}$
K	linear thermal bridges, $W.m^{-1}C^{\circ-1}$
L	Length of thermal bridges, m
R	thermal resistance, $m^2.C°.W^{-1}$
k	surface thermal transmission coefficient, $W.m^{-2}C^{\circ-1}$
a	heat gains, $W.C^{\circ-1}$
r	heat losses, $W.C^{\circ-1}$
t	Temperature, C°