# ENERGY CONSUMPTION OF PUBLIC HOUSING: PERFORMANCE, CHARACTERISTICS AND HOUSEHOLD BEHAVIOR

# إستهلاك الطاقة بالعمارات الجماعية: الآداء، الخصائص و تصرفات الأسر

# LA CONSOMMATION ENERGETIQUE DANS LES IMMEUBLES COLLECTIFS: PERFORMANCES, CARACTÉRISTIQUES ET COMPORTEMENT DES MENAGES

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## Abstract :

It is widely recognized that the residential energy consumption is not only influenced by the characteristics of construction, but also by household's behavior and characteristics. Compared to the impact of building characteristics on energy consumption, little research that consider the behavior of households exist.

Thus, this study aims to get a glimpse on the effect of the characteristics and behaviors of residents on energy consumption. The search starts from the assumption that there are differences in energy consumption between three categories of dwellings (colonial, social and promotional types of housing) that are chosen in the city of Setif (Algeria).

The main differences between these types of neighborhoods are:

- Building characteristics: urban density, age and building materials of the housing types.
- Householder's characteristics: The difference in age, income and personal preferences of residents.

First, a difference between the energy performances of housing is found.

Then, the impact of occupants is checked: do they contribute to maintain it, improve it or increase it?

To define the energy performance of the three categories of selected houses, the study uses: First, a thermal analysis and energy simulation "Ecotect Analysis 2010" software: with which the internal temperature curve is compared to thermal comfort boundaries Then, The simulator EPD "energy performance diagnosis": that gives: Energy class housing and consumption per m² per year. And, $CO_2$ emissions calculated in kilograms per m²with the corresponding letter of the label climate.

To explore the impact of occupants a survey was conducted in terms of heating, cooling, bath, cooking, lighting, appliances and ventilation.

The survey questionnaire includes questions on household characteristics, building, energy consumption, and occupant behavior.

Results show that, promotional house is most energy efficient than colonial and social ones.

Moreover, survey results points out that the energy consumption is significantly correlated with: floor area, age of household head, number of air conditioner, and household income.

**Keywords:** Thermal performance – Households – Behavior- building characteristics

**Résumé** :

Il est largement reconnu que la consommation d'énergie résidentielle n'est pas seulement influencée par les caractéristiques de la construction, mais aussi par le comportement et les caractéristiques du ménage.
Par rapport à l'impact des caractéristiques du bâtiment sur la consommation d'énergie, il existe peu de recherches portant sur le comportement des ménages. Ainsi, cette étude vise à avoir un aperçu de l'effet des caractéristiques et comportements des habitants sur la consommation d'énergie.

La recherche part de l'hypothèse que il y a des différences de consommation d'énergie entre trois catégories de logements (types de logements coloniaux, sociaux et promotionnels) qui sont choisis dans la ville de Sétif (Algérie). Les principales différences entre ces types de quartiers sont:
- Caractéristiques du bâtiment: densité urbaine, âge et matériaux de construction des types de logements.
- Caractéristiques du maître de maison: La différence d'âge, de revenu et de préférences personnelles des résidents.
Tout d'abord, on constate une différence entre les performances énergétiques des logements. Ensuite, l'impact des occupants est vérifié : contribuent-ils à le maintenir, l'améliorer ou l'augmenter?

Pour définir la performance énergétique des trois catégories de maisons sélectionnées, l'étude utilise: Tout d'abord, une analyse thermique et une simulation énergétique par le logiciel "Ecotect Analysis 2010": avec laquelle la courbe de température interne est comparée aux limites de confort thermique. Ensuite, le simulateur EPD "diagnostic performance énergétique": ça donne: Logement classe énergie et consommation par m² par an. Et, les émissions de $CO_2$ calculées en kilogrammes par m² avec la lettre correspondante du label climat.
Pour explorer l'impact des occupants, une enquête a été menée en matière de chauffage, refroidissement, bain, cuisine, éclairage, appareils et ventilation.

Le questionnaire d'enquête comprend des questions sur les caractéristiques des ménages, bâtiment, consommation d'énergie et comportement des occupants. Les résultats montrent que la maison promotionnelle est plus économe en énergie que les maisons coloniales et sociales.
De plus, les résultats de l'enquête indiquent que la consommation d'énergie est significativement corrélée avec : la surface de plancher, l'âge du chef de ménage, le nombre de climatiseurs et le revenu du ménage.

**Mots clés** : performance thermique, ménages, comportements, caractéristiques du bâtiment

## INTRODUCTION

In 2025, primary energy demand could be multiplied by 1.5 in the Mediterranean countries, South and East Mediterranean countries (SEMC) experiencing growth in their energy demand four times higher than the North (PNM). They represent then 42% of the total energy demand in the Mediterranean basin, against 29% in 2006. Algeria that is a part of it, also has a perpetual and continuous increase of energy demand. Algeria is mainly dependent on non-renewable energy, as the resources are currently on the national territory. Despite suitable geographical and climatic context for the development of renewable energies, is still neglected and untapped. The energy needs of Algeria are increasing rapidly, still its vast natural resources promise to provide a sufficient energy supply for many years to come but it's time to think about regulating and consume properly.( fig 1)

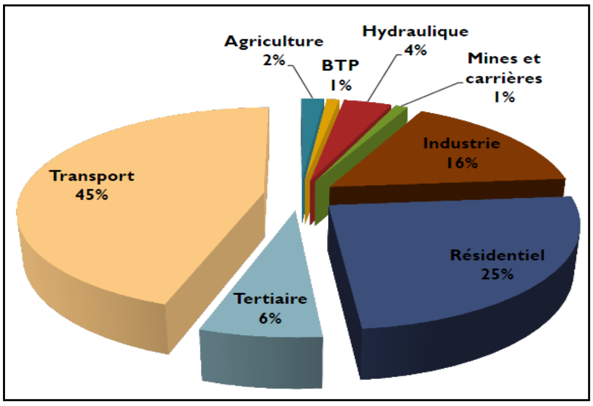



Fig 1 : Répartition de la consommation finale par secteur d'activité "année 2010 (Source : APRUE, 2013)

Since 1999, Algeria has defined a law to control energy consumption ( Amirat et El Hassar, 2005). It has set up regulations for energy management w
hich set a national energy plan. That model defines a general framework for different actions to rationalize the use of available energy and better control of energy consumption. The existing housing sector is particularly concerned. When we know that the residential and service sector represents over 46% of final energy and 28% of primary energy (Fezzioui et al,2008) we understand the challenge that it has to intervene in this sector to improve energy conditions. Indeed, consumption in this sector is constantly rising. An average annual growth rate (AAGR) of the residential sector - Tertiary is of the order of 6.28%. The average annual energy consumption of a dwelling is 1,050 tep. The final energy consumption per capita is 0.48 TOE in 1990, its evolution will increase from 0.71 in 2000 to 1.35 PET in 2010 and 1.88 in 2020.

The evolution of energy consumption in residential sector represents 35% of the National final energy consumption. The existing housing are not subject to any regulations on energy savings. Faced to a constant increase in consumption of electrical energy favored by both population growth improvement of life style and the extension of the use of electrical appliances in Algeria, the concept of energy efficiency arises today with acuity of especially as the Algerian market is full of products “highly energy” consumer.
It is well established that housing is a key factor of the emission of greenhouse gases. Energy consumption in the residential sector includes space heating and water heating, cooling, lighting and the use of devices (Kim et al, 2013).

Consequently, with the colossal boom experienced by Algeria in recent years in terms of residential construction including the last decade program of building 2 millions of dwellings, the amount of which has failed in the quality of building constructions (Kadri et Mokhtari, 2011). The development of such housing is necessarily accompanied by a substantial increase in energy needs for heating, cooling and electricity; because the spread of a new modern comfort depends on high electricity consumption, which often leads to power cuts in peak hours due to maximum use.

The present consideration aims to study the impact of household characteristics and construction on residential energy consumption, by answering these questions:
Is there any difference in the energy performance of three choosen dwellings types : colonial housing, social housing and promotional housing ? What will be the most efficient type of housing?
Could the characteristics and household behavior explain the variation of the actual energy consumption of housing?

## I. Materials and methods

### 1. Presentation of three case studies:

This section presents multistory buildings selected for the study, and they are representative of different periods and methods of construction in the city of Setif (Algeria).

***The first case study: The legacy of the 19$^{th}$ century (the apartment building of the neoclassical style) built before 1930***

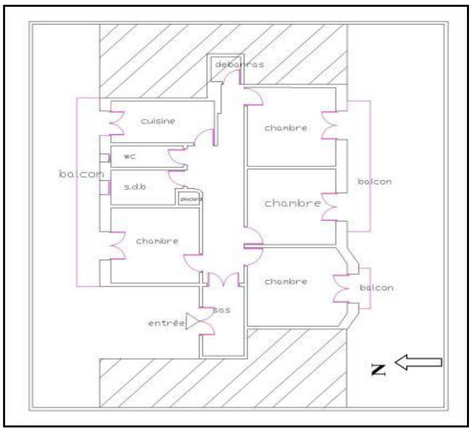


**Figure 2.** Interior shot – building Henry – (Source: author, 2014

***The second case study: social housing:***

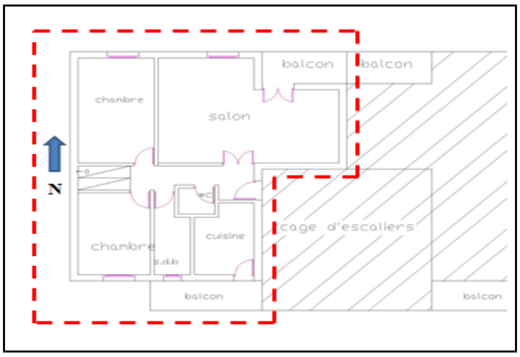


**Figure 3.** Interior shot - social housing - les 600 logements (source: author, 2014)

***The third case study: promotional housing***

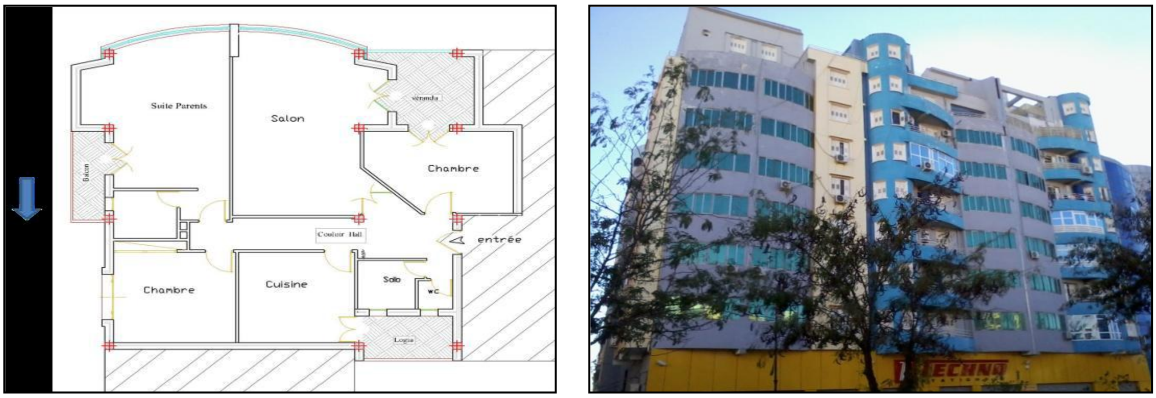



**Figure 3**. Interior shot –promotional apartment- (source: author, 2014)

### 2. Investigative Tools

The methods used were structured around two (02) parts: technical work simulation followed by investigative work. I. The Technical Working simulation: which defines the energy performance of three categories of accommodation chosen for the study is based on two programs: a) thermal analysis software and energy simulation "Ecotect Analysis 2010": this software provides the temperature inside curve free evolution (no heating or air conditioning) compared to the outside temperature and comfort limits (summer / winter ). Reflecting an evaluation of the thermal behavior of housing. b) The energy performance diagnostic simulator (DPE) DPE An online simulation tool that provides: - The energy class housing and consumption per m² per year. II. The investigative work of investigation: to determine the effect of the characteristics and occupant behavior on energy consumption. The questionnaire aims to collect information on housing characteristics, its occupants and energy consumption behavior in terms of heating, cooling, bath, cooking, lighting, use of household appliances and ventilation.

## II.RESULTS AND INTERPRETATION

### 1. Analysis of the results obtained by the simulation via software "Ecotect"

The purple line is the lower limit of the comfort zone The green line is the upper limit of the comfort zone.

***Thermal behavior was***

In summer heat, good performance are recorded in descending order for the colonial housing, promotional, and social. (Figure 4) The colonial home is the most powerful in summer, good behavior is generally explained by a reduction of solar gain during the day and night cooling, thanks to: high inertia of the walls, openings ratios adapted to the orientation of facade, systematic cross local (internal organization) and natural ventilation.

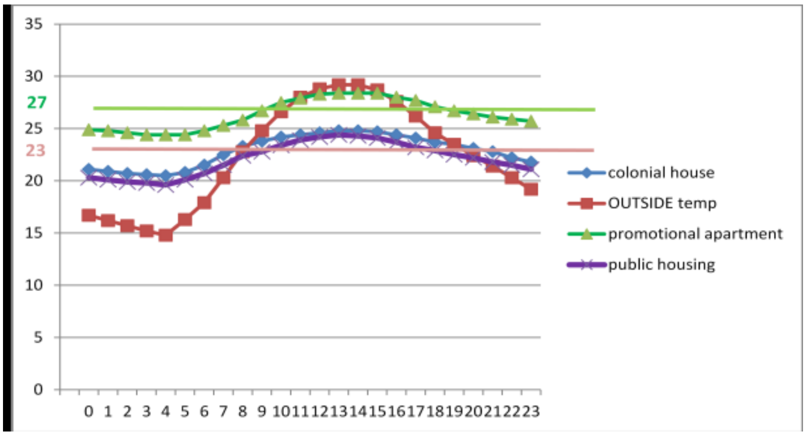



**Figure 4.** Hourly temperature profile in free evolution compared to summer comfort limits (source: author, 2014)

### *Thermal behavior in winter*

In winter heat, the best performance is recorded in promotional housing, then comes the colonial housing and social housing but with a small difference in the performance of the latter two types of housing. (Figure 5)
Promotional housing is the most efficient in winter (five to six months), with its layout features that are in the form of a large island closed, formed by the adjoining buildings, which generates a large courtyard. and also thanks to the correct orientation of interior spaces, and the existence of a "thermal" veranda.

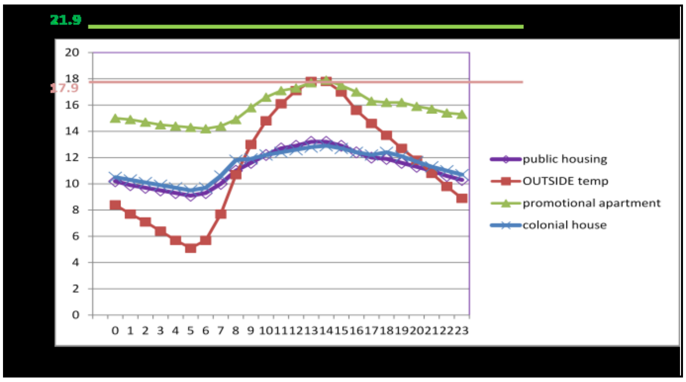
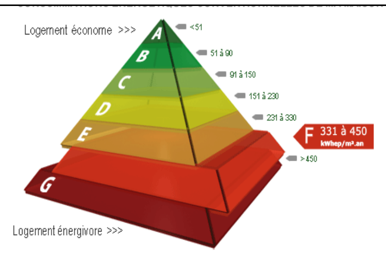
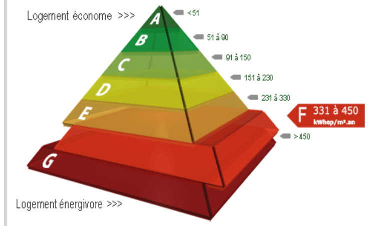
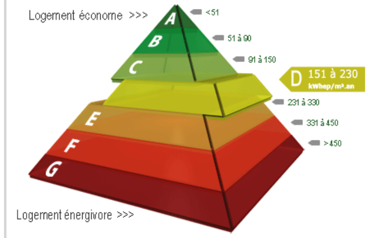



Figure 5- Hourly temperature profile in free evolution compared to winter comfort limits (Source: author, 2014)

### *Result of DEP simulation software*

| Type of accommodation | Energy consumption Energy Label | Energy Label |
|---|---|---|
| Colonial housing | 365kwhep / m².year (class F) "Housing with high energy consumption |  |

| | | |
|---|---|---|
| public housing | 414kwhep / m².year (class F). "Housing with high energy consumption |  |
| Promotional accommodation | 185kwhep / m².year (class D) "A medium-energy housing ' |  |

### 2. Interpretation of the survey results.

Interpretation of the results of the investigation discovers that the energy consumption is significantly correlated with: the floor area (r = 0.6326, r is to 1); age of household head (r = -0.9319, r is close to -1); number of air conditioner (r = 0.7748, r → 1) and household income (r = 0.7138, r → 1)

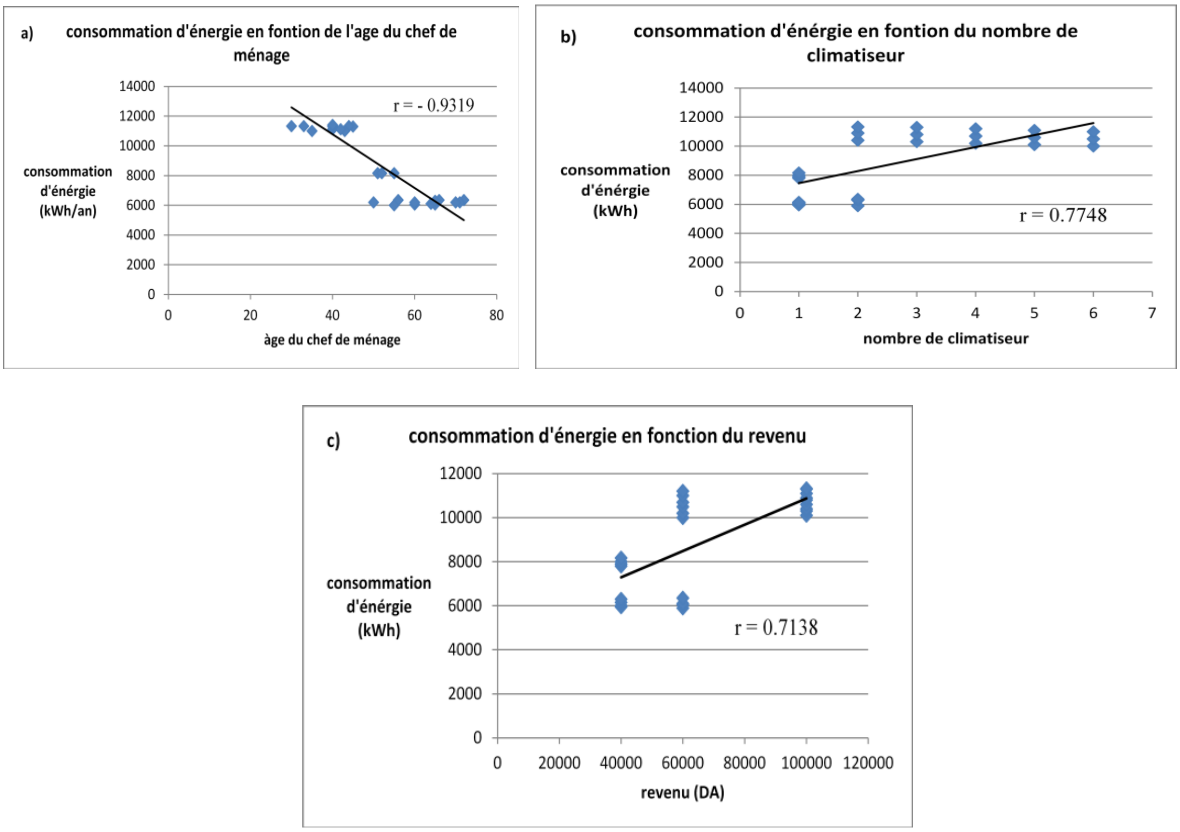



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**Figure 6. Scatter** and trend line of energy consumption based on age (a), based on the number of air conditioner (b) and by income (c). (Source: author, 2014)

**CONCLUSION**

What we remember from this study is that residential energy consumption is not only influenced by the characteristics of the building, but also influenced by household characteristics, occupant behavior, and effectiveness Service Systems. Thus, households are a very important target group in efforts to increase energy efficiency in housing. And the objective of fighting against climate change undoubtedly require immediate and substantial changes in the way we live our lives every day. Indeed, the sustainability of development that respects the environment in terms of housing can be divided into two main categories: technical viability and behavioral sustainability. Continued technical sustainability will not, by itself, make the most energy-efficient home, but progress in behavioral sustainability will also be needed. Behavioral Sustainability refers to the attitudes and behavior of households. So residents must have knowledge, a good attitude and good skills on how to be environmentally and efforts should focus on reducing their energy consumption and carbon footprint as well.

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