The Influence of the Envelope Color on Energy Consumption

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Abstract

The housing stock in the world and in Algeria is constantly growing, with a sharp increase in energy consumption. An intervention on this park, trying to reduce energy use passively by designing and building energy-efficient housing, can generate significant savings.

Indeed, it is possible to act either on the building envelope, or on the heating and air-conditioning equipment, and in Algeria, there is no normative environment for determining the yields and the power of heating or air conditioning appliances. So, in our study, we will opt for an analysis of the behavior of the building, by acting on the building envelope and more particularly on the color of the horizontal and vertical walls (facades and roof) to see its effect on energy consumption. It has been found that the color of the outer wall has an influence on the energy consumption especially for the albedo values which exceed 0.5 (absorption <0.5).

Keywords: Park housing, color envelope, energy consumption, albedo

1. Introduction

Our planet has been warming since the last century. This warming is mainly reflected in climatic upheavals such as the risk of floods and storms, the uncertainty concerning wind regimes and drought episodes. The city which is a dense environment, does not escape the influence of this warming and the most known manifestation of the microclimate generated by the cities following this rise in temperature is the urban heat island "UHI". Indeed, the urban heat island is a microclimatic phenomenon mainly nocturnal, characterized by summer temperatures in an urbanized area higher than the surrounding rural area, with differences that vary by 2°C for small towns of a few thousand inhabitants to 10°C and sometimes more for large cities of several million inhabitants as shown in Figure1.

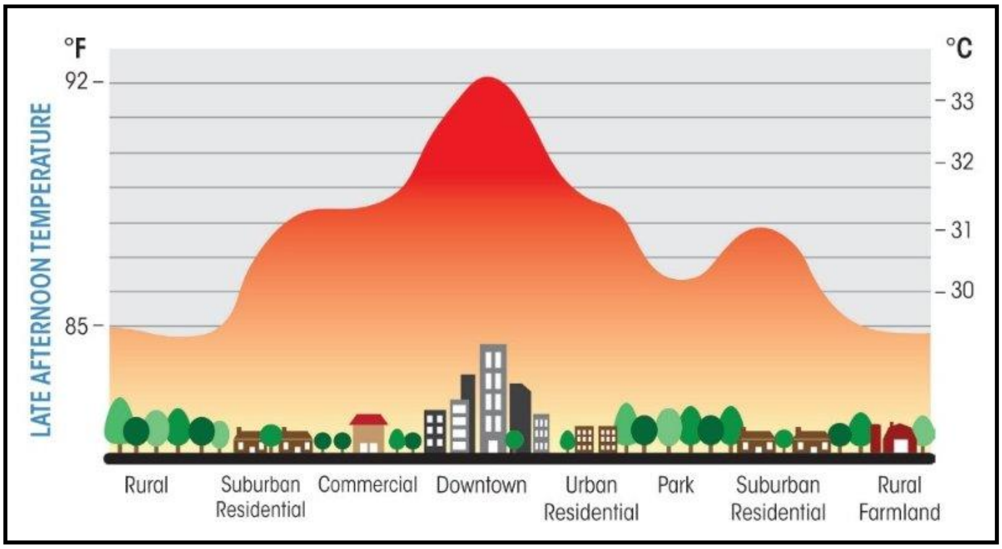

Figure1. The urban heat island profile (URL1)

The causes of the phenomenon of UHI are multiple, the most intervening are: industrialization, the extension of residential buildings, waterproofing of surfaces and low vegetation, the noticeable increase in the number of cars and low albedo (the fraction of solar radiation reflected from the surfaces by relation to incident solar radiation). Thereby, the mineralization of urban spaces and the reduction of green spaces that were replaced by pavements, roofs and facades whose materials absorb heat and increase long-wave discharges, cause the warming of urban centers (Figure2), where the effects have reached proportions that worry scientists.

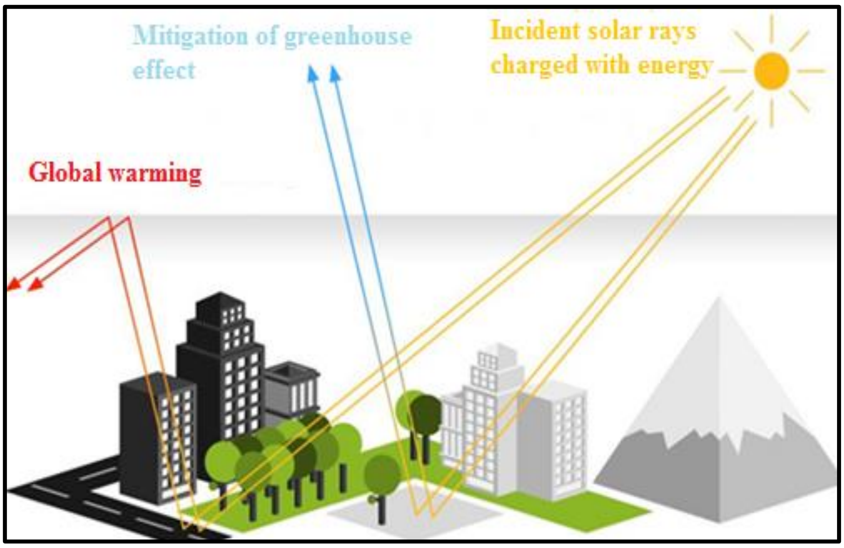

Figure2. Effect of incident solar radiation on different types of soil

In addition, the residential building proves to be an energy-intensive building for which energy consumption becomes a topical subject, a political discourse and an economic and social priority, Especially since the majority of the world population lives today in cities, therefore, it is legitimate to take an interest in the living environment of this population.

The intense use of energy and its ever-increasing consumption cause several problems, both to nature and to its occupants. The search for passive strategies to reduce this consumption remains inevitable, especially after the energy crises. Altering the "albedo" reflectivity of urban surfaces characterized mainly by their color is an integral part of the strategies followed.

2. Literature review

The color of the outer shell of the building determines the impact of solar radiation on the building. Indeed, a fraction of the solar energy striking the building is effectively absorbed by the building envelope, which affects its heat gain and its indoor temperature, and a fraction is reflected, without having any effect on the thermal conditions building (Givoni, 1998).

In the following, a brief quote from some research that targeted the assessment of energy consumption by changing the color of the external surfaces of the building. For example, Taha et al., (1988) simulated the reduction of building cooling loads to 18.9% for summer days in Sacramento, California, for an increase in roof albedo and walls from 0.30 to 0.90 respectively. Another example, the application of high-albedo coatings on the roofs of six houses in Florida (Parker et al., 1994) has led to a reduction in the electrical consumption of air conditioning which was estimated between 11% and 43% with an average saving of 9.2kwh/day and a reduction in peak demand which was 0.4 to 1.0kw with an average reduction of 0.7kw.

Akbari et al., (1997) controlled the peak power and cooling energy savings of high albedo coatings in one home and two school bungalows in Sacramento, California. They found savings of 2.2kwh/d for a home, and a reduction in peak demand of 0.6kw. In school bungalows, cooling energy was reduced by 3.1kwh/d and peak demand by 0.6kw.

Other research around the world has shown that increasing the solar reflectivity of the roof, for example by applying a "cool" coating, reduces the cooling loads, the maximum temperatures and the number of hours of discomfort depending on the varied climatic conditions (Synnefa et al., 2007, Zinzi et al., 2008, Jaber & Ajib, 2011).

Cheung et al., (2005), for their part, investigated the effect of six passive design strategies, such as the color of exterior walls, thermal insulation, thermal mass, type of glazing, the glazing index and external shading devices on annual cooling energy requirements and peak cooling load for a high-rise building in Hong Kong. They found that savings of 31.4% for annual cooling energy requirements and 36.8% for peak cooling load for the base case were achieved by this approach.

3. Methodology

Our study took place in the coastal town of Skikda (Figure3), located in northeastern Algeria (Longitude: 6° 52 ', Latitude: 36° 54' and Altitude: 12m), characterized by the semi-humid Mediterranean coastal climate (hot and humid in summer and mild and very rainy in winter). The average temperature is 26.09°C recorded in August which is the hottest month and 12.07°C in February which is the coldest month of the year. Monthly mean relative humidities range from 67.1% to 70.83%. For winds, they are generally weak with an annual average of 3.43m/s (Skikda Weather Station, 2015). The solar radiation is intense, the maximum incident energy on a horizontal plane is 8010W/m² during the month of July (Capderou, 1985).

Figure 3. Situation of Skikda city (URL2)

More precisely in the south of the city, in the district Houari Boumediene, which consists of buildings of G+ 4, where the choice was focused on a housing F3 located in the upper floor.

The study consists of a series of numerical simulations carried out using the software TRNSYS17 (Klein et al., 2010) which is a highly efficient and highly flexible dynamic thermal simulation environment used to simulate the behavior of transient systems, in order to evaluate the influence of the change in the color of the external surfaces of the building (facades and roofs) on energy consumption.

The building, subject of our research is built according to the traditional post-beam system with a lightweight envelope consisting of a double wall cinder block with an air gap of 5cm thick as an insulating layer for the vertical walls and a hollow roof with insulation of expanded polystyrene of 4cm thick, an average color or albedo of 0.6 for the walls and 0.2 for the roof.

We proceed in our work by studying the effect of the variation of the color of the building envelope (exterior wall and roof color), which is represented by the solar reflectivity or albedo and its impact on the needs annual energy of our building.

Indeed, albedo is an important factor affecting the opaque outer wall. In what follows, we will test the effect of different colors ranging from very dark to very light with albedo values (reflectivity) which varies between 0.1 (absorption = 0.9) and 0.9 (absorption = 0.1), with an interval in an odd number, namely the following values (0.1, 0.3, 0.5, 0.7, 0.9) which respectively reflect very dark, dark, medium, light and very light colors. Noting that the upper storey will undergo in addition to changing the albedo of the exterior wall that of the roof, which will be modified at the same time and in the same way.

4. Results and discussion

Before changing the value of the reflectivity of the external surfaces of our building, we first start by estimating the energy needs of the existing case. Our building is painted a light color of an average albedo of 0.6 for the walls and a value of 0.2 for the roof.

The annual energy requirements for heating, air conditioning and the total needs of our building are shown in Figure 4.

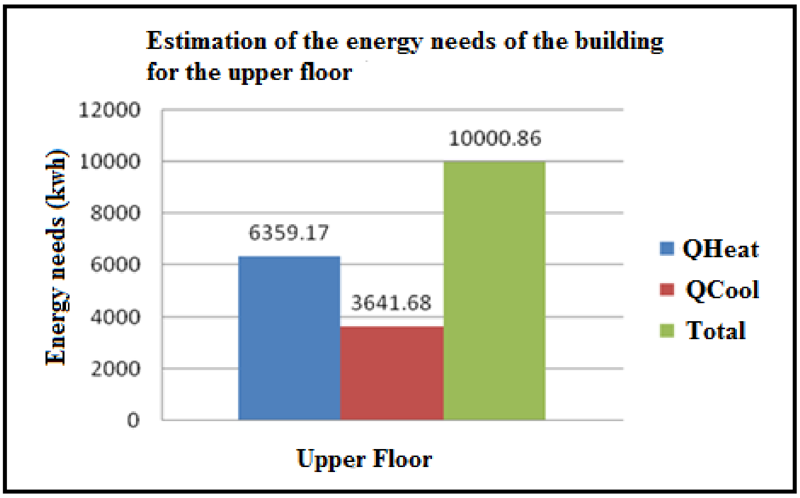

Figure4. Estimation of energy needs for existing building (Authors)

The energy requirements for heating exceed those of air conditioning, with an annual total of 10,000kwh.

After changing the albedo value of the facades and the roof by varying the color from lighter to darker, we obtained the results shown in Figure 5.

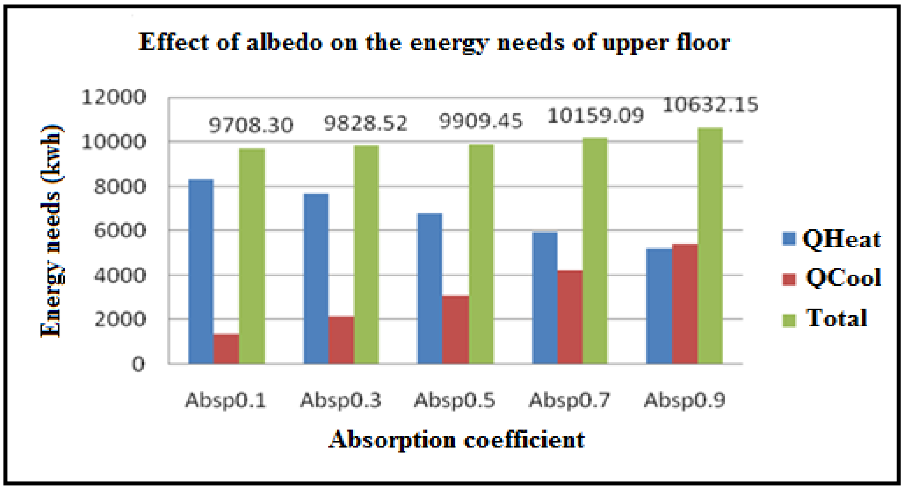

Figure5. Effect of albedo change on energy requirements (Authors)

The results of the color change are expressed from the histogram by the absorption which is the inverse of the albedo, that is to say that if the absorption value is 0.1, the value of albedo is 0.9. It is noted that the absorption values of 0.5 and less corresponding to light reflective colors give the best results with lower energy requirements.

To broaden our field of study, we have tested the effect of thermal inertia (which consists of thermal mass and thermal insulation) and its combination with color on the energy demand of our building. It appears that the double brick wall with a glass wool insulation layer for light reflective colors which have an absorption value of 0.1, gives the lowest energy requirements as shown in Figure 6.

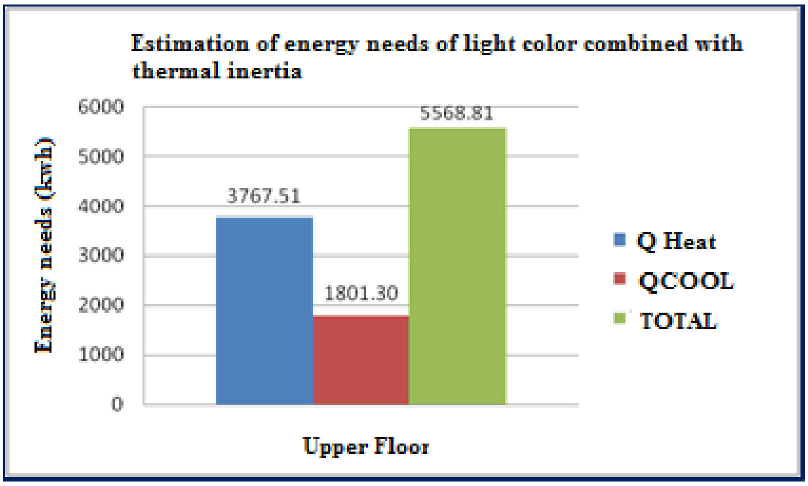

Figure6. Effect of the combination of light color with thermal inertia on energy requirements (Authors)

The fact of combining the light color with the parameters of the thermal inertia studied has given interesting results with a reduction in energy requirements of around 44% compared to the existing building.

5. Conclusion

The dominance of mineral and impervious surfaces in urban spaces is part of the main causes of the phenomenon of ICU.

It turns out that the reflectivity of surfaces commonly called "albedo" plays a major role in the modification of the micro climate outside and has an impact on the interior too.

Our research focused on assessing the color of the building's external surfaces on energy consumption. It has been found that light colors have an effect on the lowering of energy needs, this decrease is accentuated more if we combine the light color of our outer envelope with the thermal inertia by choosing a good material with good thermal insulation.

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