ISSN: 1000-3673

Mechanism Design and Operation Analysis of Bilateral Spot Market in Gansu Province Under High Renewable Energy Integration

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ABSTRACT

The energy consumption of the building sector in Algeria represents the largest part of the energy produced in the country. Action to reduce the impact of this sector on the economy and the environment must be taken. The use of thermal insulation to reduce the energy needs of the building sector represents an effective and sustainable solution.

The objective of our work is to conduct a study using the TRNSYS 17 software on the influence of the use of thermal insulation in different climates in Algeria. A typical apartment is chosen to run the calculations under three different climates of Algeria. The simulation results obtained for the city of Annaba show that the use of rock wool, cork, expanded polystyrene and airgel insulation allows a reduction of 42.81%, 43.08%, 43.31% and 50.90% respectively. While for the city of Setif the reduction obtained is 34.15%, 34.70%, 35.13% and 52.25% respectively for the same insulation. For the city of Biskra the reduction is 32.07%, 32.28%, 32.45% and 38.72% respectively for the same insulation. The improvement of the thermal performance of the structure and the glazed surfaces according to the Passivhaus standard allows a significant reduction of heating and air conditioning needs estimated at 72, 78.21 and 65.21% respectively for the cities of Annaba, Setif and Biskra. A low energy consumption building is obtained for the city of Annaba and Setif.

1. INTRODUCTION

In Algeria, the building sector consumes 22.4 Mtep of final energy (according to statistics of 2018) which represents more than 40% of national energy production [1]. Commercial consumption of electrical energy increased from 6 MTep in 1970 to 40 MTep in 2005 [2-3]. These statistics tend to increase due to the enormous development of the building stock and the increase in comfort requirements in recent years. Power cuts are observed in the summer period due to the increased use of air conditioners.

This high consumption leads to a deficit to cover the needs by 2030 [1]. Indeed, Algeria is a petrifying country that produces and exports a significant amount of oil and gas, but experts consider that according to the growth in energy consumption, such resources would not meet national energy needs by 2030.

In this sense, the Algerian government launched in 2011 an ambitious program that aims to produce energy from renewable sources and increase the energy efficiency of constructions. The latter, revised in 2015, aims to produce 22,000 MW of electricity from renewable sources by 2030. Another important part of this program aims to increase energy efficiency in the building sector by using renewable energies and efficient equipment, as well as thermal insulation [1]. To achieve such goals, some alternatives might be adopted [4-6]: (A) reducing the energy consumption of new buildings by 40 to 50%; (B) The reduction of 15 to 25% of the energy consumption of existing buildings. Edwin Rodriguez-Ubinas et al. [7] present in their studies different stages and procedures to achieve such objective. Among these methods are thermal insulation.

From a thermal point of view, the building envelope is the most stressed component in the building because it's directly exposed to external conditions. It must therefore fulfill its role, which is to provide the occupant a maximum comfort with a minimum energy consumption. The integration of passive strategies in the building envelope effectively improves its energy contribution, as is the case of apartments in Hong Kong, where savings have reached 31.4% just by inserting thermal insulation and using paint white to minimize the absorption of solar radiation [8].

The envelope is characterized by several parameters including the heat transmission coefficient U. Codes and certifications have been developed to reduce the value of this coefficient [9]. For a typical building, U-values of roof, floor, walls, and exterior windows are respectively 0.16, 0.25, 0.30, and 2.00 $W/m^2.K$ [10]. These standards differ from one country to another. The Passivhaus standard set out by the Passivhaus Institute of Darmstradt in Germany requires that the values of the U-value must not exceed 0.15 $W/m^2.K$ for the envelope and 0.85 $W/m^2.k$ for the doors and windows, in order to obtain an annual consumption of the building in heating lower than 15 kWh/m^2 [10].

Many research on manufacturing, modelling, life cycle assessment of thermal insulators and particularly nano insulators has been carried out in recent years [11-18]. Super-insulation is defined by a thermal conductivity lower than that of air, i.e., a thermal conductivity lower than $\lambda = 0.025$ W/(m.K). The development of innovative and high-performance insulating materials is crucial for the needs of the building sector, from an environmental point of view but also from an economic point of view. Consequently, significant research efforts have focused on developing new thermal super-insulating materials that meet the requirements of sustainable development. SiO2 airgel is an extremely porous synthetic material, capable of offering high levels of thermal insulation [19]. This solid material with a three-dimensional network structure, very low density and low thermal conductivity belongs to a family of super-insulators with very promising prospects [20]. In this context, super insulating materials, whose thermal conductivity is much lower than that of commonly adopted products, have received increasing attention in recent years. While common insulating materials have typical thermal conductivity values around 0.05 W/m.K, materials with thermal conductivity well below 0.02 W/m.K have been consistently presented recently [21]. The preparation of concrete incorporating silica airgel aggregates in a high strength cement matrix has been proposed recently by Ng et al. [22] and Fickler et al. [23]. These studies made it possible to obtain mixtures having a thermal conductivity and a compressive strength of 0.26 W/m.K and 8.3 MPa, 0.55 W/m.K and 20 MPa and 0.17 W/m.K and 2.7 MPa respectively.

Windows can represent up to 60% of the total energy loss in buildings, the introduction of aerogels in window glazing has achieved superior thermal performance associated with high light transmission. The emergence of airgel-based glazing systems on the market in recent years have demonstrated impressive thermal capabilities [24]. The thermal conductivity of perlite and airgel-filled insulating bricks using a shielded hotplate configuration and thermal simulations. The results showed the decrease in thermal conductivity from 91 to 59 W/m.K, which corresponds to a U-value of these "aerobics" of 0.157 W/(m^2.K). Thus, with an airgel filling, the thickness of the insulating bricks can be reduced. This implies space savings and new architectural possibilities [24-26]. The results of the thermal studies showed that the thermal conductivity and the mechanical resistance increase linearly, the products in airgel enriched decrease when the quantity of airgel added to the mixtures increases. Nevertheless, the final compositions exhibit an appropriate balance between thermal and mechanical properties. For example, plasters and mortars with a thermal conductivity of 0.06 W/m.K and 0.20 W/m.K were obtained respectively [27]. There is still work to be done to optimize aerogel-based products in such a way that their cost-effectiveness can support wider adoption in the market. The effect of adding nano-silica (SiO2) on the mechanical and thermal properties of concrete is discussed by Alaa N. Saleh et al. [28]. Replacing 1, 2, and 3% of the cement with Nano-silica increased the insulation capacity of concrete by 41.8%, 53.15%, and 65.57% respectively. The thermal conductivity obtained for this doping varies from 0.5–0.92 W/m °C. The maximum values of the compressive strength are obtained at a rate of 3% (32.45% increase) which coincides with the low value of thermal conductivity.

Karim Aliakbari et al. [29] studied the impact of the use of a novel transparent nano-insulation in building windows on the energy consumption and thermal comfort of a house build according to ASHRAE 2004 standard in five Iranian climates. The modeling is carried out by the combination of Rhinoceros 5 and Grasshopper software. The results obtained show a reduction in energy consumption of 2.23%, 7.61%, 5.45%, 5.68%, and 6.25% respectively in the cities of Bandar Abbas, Yazd, Mashhad, Rasht, and Tabriz.

Dong Li et al. [30] studied the thermal performance of glass window composed of glass, silica airgel and phase change material (PCM) under cold climate in China. The latter combines important characteristics such as storage and restitution of heat, super thermal and acoustic insulation and daylighting to the interior environment. Different parameters are studied such as thickness, density, specific heat and thermal conductivity of aerogel and the results obtained show that the addition of silica airgel to PCM material positively influences the performance of the latter in a cold climate. 30 mm thickness of Silica airgel and a thermal conductivity of 0.014W/(m K) gives the best result. The authors find that the density and the specific heat have minimal influence on thermal comfort and PCM material.

Muhammad Abdul Mujeebu et al. [31] studied the influence of the use of a nano airgel glazing and nano vacuum insulation panel on the performance of an office building located in the Dhahran region of Saudi Arabia. Modeling and simulation are carried out by Revit and Ecotec software. The results obtained show a reduction in annual energy requirements of 14% when using nano airgel glazing instead of double glazing. However, the use of nano vacuum insulation panel reduces these needs by 0.8% (0.5% compared to polystyrene foam). The authors find that the combination of nano airgel glazing and polystyrene foam insulation in walls and roof gives the best result of consumption and cost.

Umberto Berardi [32] studied the influence of the use of airgel materials for the energy renovation of an educational building located in Toronto. The results obtained from the model constructed from various audits and measurements carried out show that a reduction in energy consumption of 34% is possible by installing thin aerogel-enhanced products in the opaque and transparent envelope. The study also presents a state of the art of the results obtained for different configurations.

In this sense, we propose a study on the energy behavior of a typical apartment built in Setif under several climates. The influence of thermal insulation will be highlighted. Three climates are chosen for the calculations representing a Mediterranean climate (Annaba), a semi-arid climate (Setif) and an arid climate (Biskra).

2. CHOICE OF CLIMATE AND DESCRIPTION OF THE STUDIED APARTMENT

2.1. Choice of climate

According to thermal regulations DTR 3.2 and DTR 3.4 [33], Algeria is divided into four climatic zones A, B, C and D with 2 sub-zones for heating needs calculation and into 4 climatic zones with 4 sub-zones for air conditioning needs calculation. In this study, three cities are chosen, namely: Annaba (zone A) characterized by a Mediterranean climate, Setif (Zone B) characterized by a semi-arid climate and Biskra (zone D1) characterized by an arid climate. The characteristics of the selected cities are shown in Table 1

Table 1. Geographical and climatic characteristics of the different zones chosen for the calculation.

Climate zone	**City**	**Horizontal monthly global radiation (kWh/m^2)**	**Horizontal monthly diffuse radiation (kWh/m^2)**	**Monthly direct radiation (kWh/m^2)**	**Basal temperature (°C)**
Zone A Annaba	Alt: 25 m Long:3.1E Lat: 36.4N	Max: 227 Min: 65 Total annual: 1651	Max: 87 Min: 32 Total annual: 730	Max: 208 Min: 73 Total annual: 1507	Tbe winter: 6 Tbe summer: 34 average annual 17.4
Zone B Setif	Alt: 694 Long:6.37 E Lat:36.17 N	Max: 227 Min: 53 Total annual: 1649	Max: 90 Min: 34 Total annual: 733	Max: 208 Min: 40 Total annual: 1496	Tbe winter: 01 Tbe summer: 37 average annual 15.4
Zone D1 Biskra	Alt: 141 Long:5.4 E Lat: 31.9 N	Max: 248 Min: 111 Total annual: 2192	Max: 60 Min: 18 Total annual: 498	Max: 265 Min: 175 Total annual: 2738	Tbe winter: 05 Tbe summer: 44 average annual 23.7

The case studied is a typical apartment of ordinary shape and plan built practically in all Algerian cities. This choice is based on the fact that the Algerian government has launched in the past years thousands of housings in different forms (social, promotional, LPA etc.) which are built practically with the same architectural form.

The apartment is located on the 5th floor of a building (figure 1). It has two bedrooms, one living room, a kitchen and a toilet block (figure 2).

Figure 1.Situation of the studied apartment

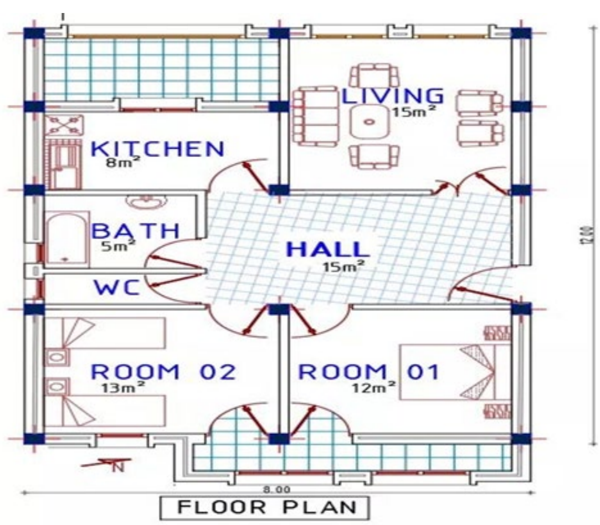

Figure 2. Top view of the studied apartment

The characteristics of the walls, doors and windows of the apartment are given in table 2.

The modeling of the apartment is carried out under the TRNSYS 17 software. The meteorological data is generated by the METRONOME 7 software. Figure 3 illustrates the TRNSYS model used. The building is modeled in multizone model.

Table2: Characteristics of the construction of the apartment (reference case)

Walls/Floor Roof/Window Door	Composition	U value ($W/m^2.K$)
North/East/South/ West wall	Cement mortar, 2 cm. Brik, 15 cm. Air layer, 5 cm. Brik, 10 cm. Interior plaster, 2 cm	0.583
Floor on the ground	Tiling, 2 cm. Concrete mortar, 4 cm. Dry sand, 5 cm. Tar paper, 0.5 cm. Solid concrete, 16 cm. Heavy Stone, 20 cm	0.949
Roof	Concrete mortar, 4 cm. Ground clay, 20 cm. Solid concrete, 3.5 cm. Dry sand, 2 cm. Multilayer Waterproofing, 1 cm. Slope form of heavy Concrete aggregate, 10 cm. Dry sand, 2 cm. Insulation (compensated cork), 4 cm. Concrete slabs, 20 cm. Interior plaster, 2 cm	1.46
Window	Single glazing	5.74
Door	Wood	2.58

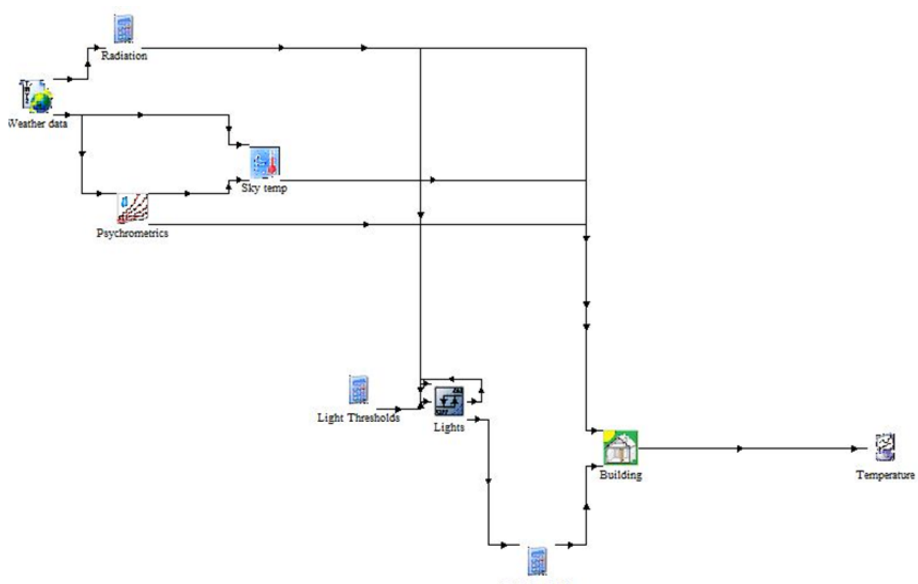

Figure 3. Modeling of the apartment under TRNSYS 17

3. RESULTS AND DISCUSSION

3.1 Determination of the energy needs of the apartment (reference case)

The energy needs of the apartment are evaluated under different climates of Algeria in the case without thermal insulation (reference case). The heating and cooling set-point temperatures are 20°C and 26°C respectively.

Figure 4 illustrates the variation in heating and cooling needs of the apartment under the climate of the city of Annaba. Heating needs present high values with a maximum obtained in January estimated at 240 kWh and a minimum in November estimated at 20 kWh with an annual total of 700 kWh, the heating period extends between November and April. While for air conditioning, the needs are spread between May and October with a maximum obtained in August estimated at 687 kWh and a minimum of 110 kWh in May and an annual total estimated at 2437 kWh. Heating needs represent 3.48 times more than air conditioning needs. The annual consumption is 3137 kWh which represents 70 kWh/m^2.year (for an apartment surface of 63 m^2).

Concerning the city of Setif shown in figure 5, heating needs begin from November to April with a maximum in January estimated at 571 kWh and a minimum in April estimated at 98 kWh with an annual total of 2236 kWh. An increase of 3.2 times compared to the city of Annaba is obtained. While air conditioning needs range from May to October with a maximum in July estimated at 704 kWh and a minimum in May estimated at 80 kWh with an annual total of 2179 kWh. The annual consumption is 2834 kWh which represents 70 kWh/m^2.year. A considerable increase compared to the city of Annaba is obtained.

For the city of Biskra (Figure 6), heating needs range from December to February with a maximum in January estimated at 151 kWh and a minimum in November estimated at 62 kWh and a total annual estimated at 306 kWh. As for air conditioning needs, the period runs from March to October with a maximum for the month of July estimated at 1398 kWh and a minimum for the month of October estimated at 137 kWh with an annual total air conditioning estimated at 6405 kWh. The annual consumption of the apartment is 6711 kWh which represents 106.52 kWh/m^2.year. Despite the decrease in heating needs compared to other climate zones, cooling needs are higher.

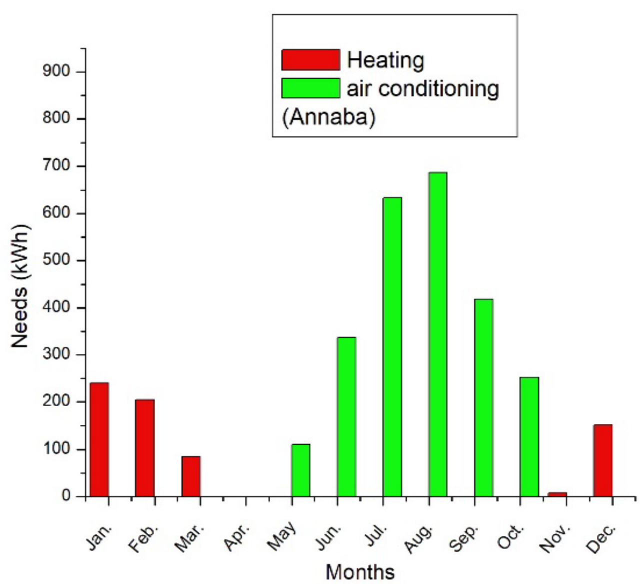

Figure 4. Heating and cooling needs of the apartment under the climate of Annaba (reference case)

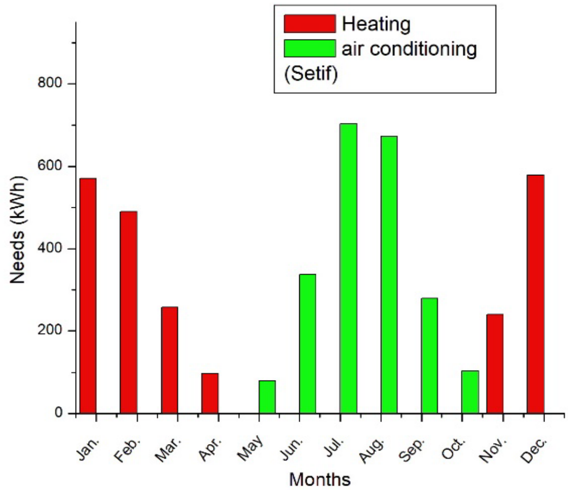

Figure 5. Heating and cooling needs of the apartment under the Setif climate (reference case)

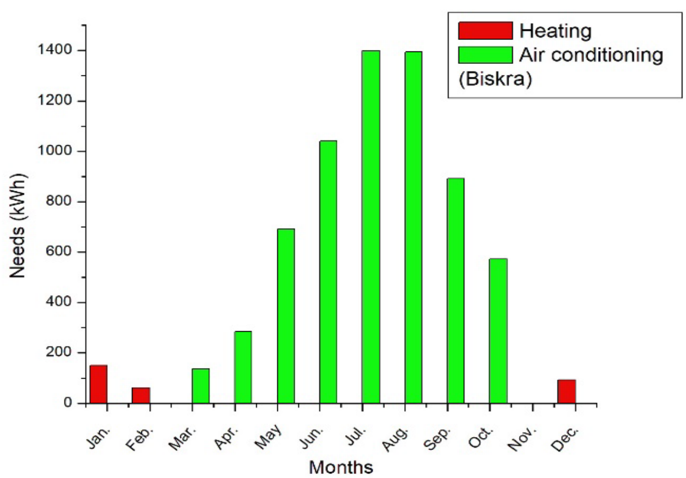

Figure 6. Heating and cooling needs of the apartment under the climate of Biskra (reference case)

3.2. Improvement of the thermal insulation of the apartment

Before proposing the improvements made to the envelope, a thermographic study is carried out by a FLIR One thermal camera. The objective is to analyze failures of the structure under a cold climate. The measurements are taken at the city of Setif for the day January 3, 2022. Figure 7 illustrates the thermographic image obtained which shows the presence of certain thermal bridges. The latter can represent 20% of the heat loss of the apartment according to the DTR [28].

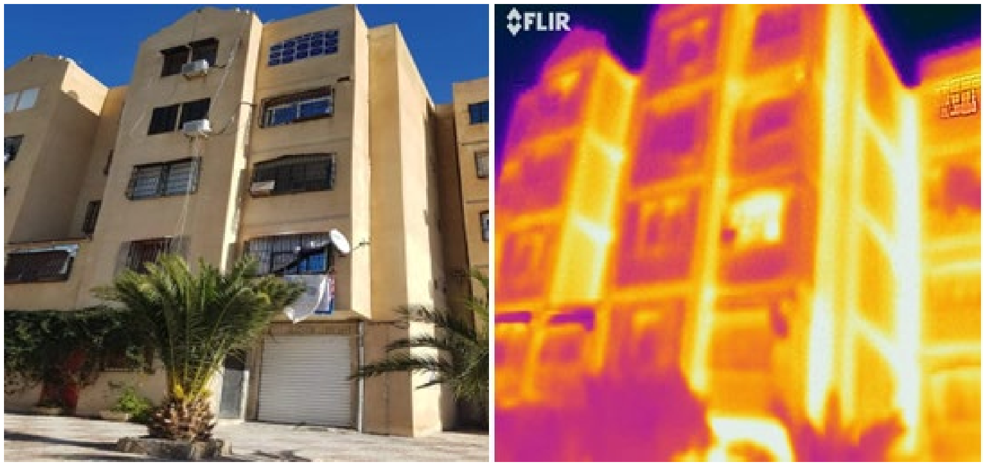

Figure 7. Thermographic image of the apartment studied under a climate of the city of Setif (January 3, 2022)

The analysis of the previous results shows that certain improvements are necessary in order to reduce the energy consumption of the apartment and to increase the thermal comfort in the latter. In what follows, we will study the influence of thermal insulation on the energy behavior of the apartment. Thermal insulation is placed on the exterior face to eliminate thermal bridges. Four types of thermal insulation are used, namely: Rock wool (mineral insulation with λ=0.032 to 0.040 W/m.K), cork (natural insulation with λ=0.032 to 0.042 W/m.K), expanded polystyrene (synthetic insulation with λ= 0.029 to 0.038 W/m.K) and airgel (new generation insulation with λ=0.011 to 0.013 W/m.K). Table 3 illustrates the variation in the total energy consumption of the apartment for each type of insulation.

Table 3. Variation in total apartment consumption for different types of thermal insulation in different climates

Cities **Types of insulation**	**Annaba**	**Setif**	**Biskra**
Real case	3138	4415	6712
Rockwool	1795	2907	4559
Cork	1786	2883	4545
Expanded polystyrene	1779	2864	4534
Airgel	1541	2108	4113

The results obtained show a decrease in total energy needs for the three cities. Indeed, for the city of Annaba, these needs go from 3138 kWh for the non-insulated case to 1795 kWh, 1786 kWh, 1779 kWh and 1541 kWh respectively for thermal insulation: Rock wool, cork, expanded polystyrene and airgel i.e., 42.81 %, 43.08%, 43.31% and 50.90% reduction respectively for the same thermal insulation.

Regarding the city of Setif represented in the same table, we note an increase in total needs compared to the city of Annaba. The latter goes from 4415 kWh for the non-insulated case to 2907 kWh, 2883 kWh, 2864 kWh and 2108 kWh, i.e., a reduction of 34.15%, 34.70%, 35.13% and 52.25% respectively for the same thermal insulators. We notice that the airgel insulation presents the highest reduction compared to the other thermal insulation.

For the city of Biskra, the needs of the apartment are much higher compared to other cities and this is due to the increase in air conditioning needs. The latter goes from 6712 kWh for the non-insulated case to 4559 kWh, 4545 kWh, 4534 kWh and 4113 kWh, i.e. 32.07%, 32.28%, 32.45% and 38.72% reduction respectively for the same thermal insulation.

The addition of thermal insulation considerably influences the thermal behavior of the apartment under the three climates. Reductions up to 52.25% in thermal requirements are obtained. The consumption of the apartment under the climate of the city of Annaba approaches low energy consumption while high consumption is obtained for the city of Biskra.

Improvement of the thermal performance of the apartment according to the Passivhaus standard.

According to the Passivhaus standard set out by the Passivhaus Institute in Darmstadt, Germany, a building must be constructed so that the U-value for the envelope does not exceed 0.15 W/m^2. K and 0.85 $W/m^2.K$ for doors and windows. We are going to apply this standard to the apartment with the addition of super insulation for the exterior walls with the use of more efficient windows (table 4).

Table 4. Characteristics of walls and windows according to the passivhaus standard

Walls/Window	**Composition**	**U value ($W/m^2.K$)**
All walls	Exterior plaster, 2 cm Brick, 25 cm Airgel insulation, 5 cm Brick, 10 cm Interior plaster, 2 cm	0.133
Window	Type ASH.A17.47B	0.71

Figure 8 represents the heating and cooling needs of the apartment under the climate of the three cities. Concerning the city of Annaba, a consequent reduction in heating needs is obtained for the case of the Passivhaus improvement. These needs have decreased from 701 kWh for the initial case to 2 kWh for the modified case and consequently the use of heating for this climatic zone no longer becomes really necessary. The same is true for air conditioning needs, which drop from 2437 kWh for the initial case to 876 kWh (i.e., a reduction of 64%). As for the annual needs, they decrease to 877 kWh, i.e., a reduction of 72%. A significant reduction (from 50 kWh/m^2.year to 14 kWh/m^2.year) of the annual consumption is obtained by the use of the Passivhaus standard, an apartment with low energy consumption is obtained by the use of passive means for the city of Annaba.

For the city of Setif, the heating needs have decreased from 2235 kWh for the initial state to 117 kWh for the modified case, i.e., 94.76% reduction for the case of the Passivhaus improvement. As well as for air conditioning needs, which drop from 2179 kWh for the initial case to 844 kWh (i.e., a reduction of 61%). A reduction in annual needs of up to 962 kWh, i.e., 78.21%, is also obtained by using this standard. Annual consumption also decreases from 70 kWh/m^2.year to 15 kWh/m^2.year. Thus, for the city of Setif, an apartment with low energy consumption is obtained by the use of passive means.

For the city of Biskra represented in the same figure, a very significant reduction in heating needs is also obtained for the case of the Passivhaus improvement. Requirements have decreased from 306 kWh for the initial state to 2 kWh.

For air conditioning needs, they go from 6405 kWh for the initial case to 2333 kWh, i.e. a reduction of 63%. It should also be noted a reduction in annual needs of up to 2334 kWh (i.e., 65.21%). The annual consumption decreases from 106.52 kWh/m^2.year to 37 kWh/m^2.year.

Thus, although for this climatic zone, an apartment with low energy consumption has not been obtained by the use of passive devices, significant energy savings are nevertheless achieved.

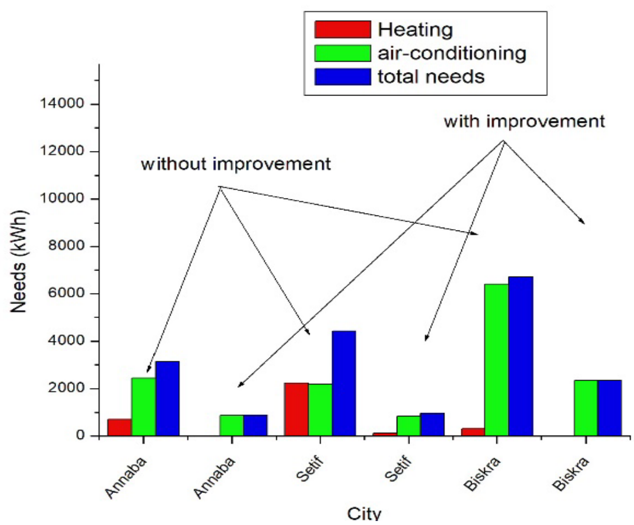

Figure 8. Variation in heating and cooling needs of the apartment with and without passivhaus improvement

4. CONCLUSION

The building envelope constitutes the major part of the latter. It provides the occupant with maximum comfort with minimum energy consumption. Particular attention must be paid when studying and sizing the latter. In this context, the objective of our work is to evaluate the impact of the use of several types of insulating materials on the energy balance of buildings in different climates. Five cases are considered with the use of new super insulating materials based on nanotechnology. A standard apartment built in Setif city is used for the calculation. The influence of the climate is studied by the choice of three different cities, the city of Annaba characterized by a Mediterranean climate, the city of Setif characterized by a semi-arid climate and the city of Biskra characterized by an arid climate.

The analysis of the heating and air conditioning needs of the apartment for the three cities shows that these needs are low for the city of Annaba compared to the other two cities. The air conditioning needs for the city of Biskra are excessively high.

The contribution of the thermal insulation is evaluated and shows that the latter considerably reduce the heating loads for the three chosen climates. Reductions in annual energy needs for the city of Annaba of 42.81%, 43.08%, 43.31% and 50.90% respectively for rock wool, cork, expanded polystyrene and Aerogel insulation. While for the city of Setif the reduction obtained is 34.15%, 34.70%, 35.13% and 52.25% respectively for the same insulation. For the city of Biskra the reduction is 32.07%, 32.28%, 32.45% and 38.72% respectively for the same insulation. An improvement of the apartment according to the passive house standard shows that a house with low energy consumption is obtained for the two cities namely Annaba and Setif. The annual needs of the apartment under the climate of the city of Biskra are significantly reduced. Reductions of 72, 78.21 and 65.21% respectively for the cities of Annaba, Setif and Biskra are obtained. The use of insulating materials based on nanotechnology leads to a considerable influence on the energy needs of the apartment studied. Passive houses are obtained with the improvement of the insulation of the walls. The results obtained show that obtaining high energy performance in several Algerian climates is possible. The investment due to the insulation can be amortized by reducing the consumption of heating and air conditioning. In addition to the economic advantages that this type of insulation offers, the preservation of natural resources in gas and oil and the protection of the environment by reducing the greenhouse gases released into the atmosphere constitutes a great motivation for the use of super insulators in the field of construction in Algeria.

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