Le 3ème Séminaire International sur les Energies Nouvelles et Renouvelables
The 3nd International Seminar on New and Renewable Energies
Unité de Recherche Appliquée en Energies Renouvelables, Ghardaïa – Algérie 13 et 14 Octobre 2014

Effect of integrating bioclimatic designs in rural housing on energy consumption of Chlef district (north-west of Algeria)

M.Missoum[#1], A.Hamidat, [*2] L.Loukarfi[#3]
[#]Faculty of technology, Hassiba Benbouali University of Chlef, Algeria
[1]Missoum1976@hotmail.fr

[#]Centre de Développement des Energies Renouvelables, CDER,*
BP 62, Route de l'Observatoire Bouzaréah – 16340 Algiers, Algeria

***Abstract*— The residential sector is responsible for an important part of the energy consumption in Algeria. Most of this energy is used in space heating and cooling. Implementing bioclimatic designs in building sector is one of the best methods to improve energy efficiency and reduce energy consumption. In the present paper, the effect of integrating bioclimatic designs in rural housing on energy consumption of Chlef district is discussed. To reach this goal, the integration of bioclimatic designs in a typical rural house is analyzed. The bioclimatic designs include the adequate house orientation, optimal thermal insulation of the house envelope, using of efficient glazing, and increased windows size to increase direct solar gain, external shading and nocturnal cooling. In order to show the energy saving reached by the integration of bioclimatic designs, a comparison between the energy requirements in house with and without bioclimatic designs, is made. To model the airflow rates in the house and the house energy modeling, the CONTAM airflow modeling tool was incorporated into the TRNSYS energy analysis program. The resultant models were then run for different building pressurization conditions and outdoor air ventilation rates. The results show that bioclimatic designs have a large potential to reach significant levels of energy saving.**

Keywords*— *Bioclimatic designs, Rural housing, TRNSYS software, Energy requirement, Energy saving.

I. INTRODUCTION

The energy consumed in buildings accounts for more than 42% of the final energy consumption in Algeria **[1]**. The reasons that led to the increase in energy demand are substantial increase of population and housing, low prices of conventional energy, increase number of electrical equipment in each house, use of non-economic electrical equipment such as incandescent lamps and cheap air conditioners, absence of awareness and lack of culture on the energy control, growing desire of people to comfort.

For a few years now, the Algerian state has made development of rural housing one of their priorities by lunching a program for the construction of one million housing units. Nearly half of this program – 450,000 units–is devoted to housing in rural areas in order to keep rural populations in place and to encourage their return from urban areas **[2]**. According to the direction of housing and public facilities of the district of Chlef, the rural housing program has practically tripled in the last ten years, rising from 7350 to 23 700 Aid for the program 2010-2014.

The integration of bioclimatic designs in building construction are increasing in popularity as an intelligent way to design and construct more energy efficient buildings, to minimize consumption of conventional energy as well as to increase indoor comfort inside the house over the entire year.

In this context, the **Algerian State,** has adopted a Renewable Energy and Energy Efficiency Program, published in 2011, including an ambitious energy efficiency program particularly in the residential sector **[3]**. Proposed measures to achieve energy efficiency in this sector include the introduction of thermal insulation of buildings, which will reduce energy consumption related to home heating and cooling by about 40% **[3]**.

Energy efficiency refers to the reduction of energy consumption without causing a decrease in the level of comfort and service quality in buildings **[4]**. The goal of energy efficiency, therefore, is to produce the same goods or services, but using the lowest energy possible. **Samar and Salman [5]** have demonstrated that the application of energy efficiency measures at the design stage of the home under the Mediterranean climatic conditions can provide thermal comfort to the occupants by unless prices. The results show that about 27.59% of the annual energy consumption can be saved by choosing optimal orientation, window sizes and use of sun protection during hot season, in addition to the insulation of walls and roof by 0.13m and 0.20 m respectively. **Nathan et al. [6]** analyzed the effect of a set of measures energy efficiency for residential houses in a semi-arid climate. The energy efficiency measures include insulation panels for exterior walls, control of natural light (daylight), increase of windows surfaces, glazing effective, and various combinations of these. This model has determined that the energy consumption is reduced by 6.1% when several energy efficiency measures are combined. **Danielle et al. [7]** studied the interaction between various measures of energy efficiency and thermal comfort in residential buildings in Salamanca (Mexico) using a detailed simulation and optimization procedures. The results show that a combination of efficient appliances, increased levels of roof and wall insulation, heating system water efficient is necessary to save about 52% of the annual energy for new homes. **Jordi L at al. [8]** demonstrate that an important reduction in energy consumption (80%) has been achieved through careful planning and further improvements made during the operation of the building, compared to typical housing standards of the area in Andorra.

The main goal of this work is to analyse the effect of integrating bioclimatic designs in rural housing on energy consumption in Chlef district (north-west of Algeria). The program chosen to model the airflow rates in the house is CONTAM and the program chosen for the house energy modeling is TRNSYS 16 **[9]**. The resultant models were then run for different outdoor air ventilation rates and house designs.

II. ENERGY CONSUMPTION IN CHLEF DISTRICT

In **Fig.1** are represented the evolution of the overall electricity consumption in the residential sector, of the district of Chlef. It is noticed that the electric energy demand is growing sharply from one year to another. An increase of approximately 30% is recorded from 2006 to 2011 which is due to the increase in housing stock, estimated at 189,708 units at the end of 2011. This trend of increase was experienced in recent years.

Fig. 1. Evolution of the overall electricity consumption and of the residential sector, in Chlef.

The evolution of butane gas consumption shows that the demand on the butane gas is decreasing significantly from 2006 to 2009, as shown **Fig.2**. This evolution is due to an increase in the number of subscribers to the natural gas network.

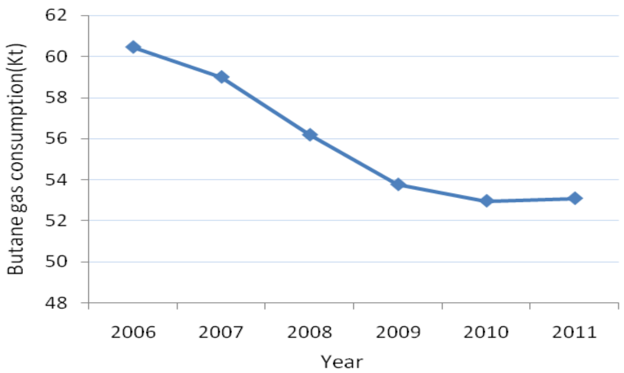

Fig. 2. Evolution of the butane gas consumption in Chlef

These data are provided by the *"Société Nationale de Distribution d'Electricité et du Gaz"* (Sonelgaz) of the district of Chlef.

III. METHODOLOGY

In this analysis, first the climatic conditions of the Chlef district are analysed. Then, the basic characteristics of a typical rural house are described. Finally, the effect of several bioclimatic designs on heating and cooling energy requirements of the reference house (RH) is investigated, separately and in combination.

For the calculation of energy assessment, different effects are taken into account, the heat conduction through the walls, windows and doors, solar transmission through windows, the heat due to the presence of the occupants, the heat dissipated by the electrical equipment and lighting. Each occupant is a heat source, an average power of 80 W is assumed.

The scenario considers the presence of four occupants from 18h to 7h, two occupants from 11 h to 13 h and one occupant the rest of the time. For Fridays and Saturdays, the presence of 4 persons is assumed throughout the day. The heating setpoint is 20°C and cooling setpoint is 28°C.

3.1 Weather data analyses

Representative Chlef weather data are analyzed in the aspect of solar radiation and average monthly temperatures, as shown in **Fig.3**. Based on data from the hourly global irradiation on horizontal surface, we can see that the Chlef region has a higher average annual daily to 4.61 kWh/m^2/day. It can be noticed that the winter has less solar potential whose average daily monthly global radiation varies between 2 kWh/m^2/day and 3 kWh/m2/day. Solar radiation becomes very important between March and October when the average daily monthly global radiation varies from 5 kWh/m^2/day to 7 kWh/m^2/day. The average monthly temperature varies between 10.5°C in January and 30.5°C in July.

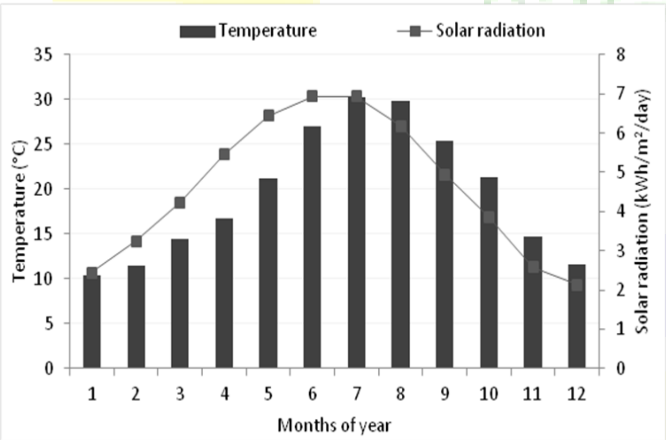

Fig.3. Average daily monthly irradiance and temperature of Chlef district.

3. 2. Reference house characteristics

A representative rural house (RH), located in Chlef (southern of Algeria), with a total heated floor area of 80m^2 and suitable for replication within the framework of Algeria's rural housing program, is selected as reference house in this study.

It is common that rural houses in Chlef do not have cooling equipment. In addition to natural night cooling in summer; inhabitants use mechanical ventilation such as ceiling fans for space cooling. Thus, electricity consumption is due to miscellaneous equipment, large appliances and lighting while the butane gas use is associated with domestic hot water (DHW) , space heating and cooking. Since the house is locating in a rural area where district heating is not available, a mobile heating system operating with propane gas or butane gas is used for space heating.

TABLE 1
Wall characteristics of the reference house

Construction	**Material**	**Thermal transmittance (W m^{-2} K^{-1})**
Exterior wall	Cement plaster (2.5cm) hollow brick (15cm) plaster coating (2.5cm)	2.303
Interior wall	Cement plaster (1.5cm) hollow brick (10cm) plaster coating (1.5cm)	3.395
Roof	heavy concrete (10cm) slabs (15cm) plaster coating (1.5cm)	2.338
Floor	Heavy concrete (5cm)mortar (4cm) tiling (2cm)	3.466
Window	single glazing	5.68

The construction materials for the rural houses are also very similar, hollow clay brick and the windows are all clear, single pane glazing with an wood frame. The simulation model and materials construction specifications of the house are shown in **Fig.4** and **Table 1**.

3.3. Bioclimatic designs

Bioclimatic designs include:

House orientation : Orientation is one of the most important parameters that intervene in the passive solar design and one that has been most frequently studied **[10]**. It is generally

agreed that a southern orientation is optimal for gaining heat in the winter and for controlling solar radiation in the summer.
As occupants spends most of time in the living room and kitchen, the sensitivity of heating and cooling demand for the reference house to variations in house orientation is investigated by rotating the house such that these two areas (living room and kitchen) was changed to face South, North, East and West. The best orientation is determined.

Windows size and shading devices: South oriented windows constitute an effective passive solar heating system in heating season. However, windows and shading should be jointly considered, in hot season, in order to effectively control the heat gain. The use of mobile shading systems is more beneficial in regards to natural illumination and to lower energy consumption **[11]**.
In this analysis, the optimum windows size is studied technically to gain maximum benefit from solar radiation in heating season. The effect of shading devices on cooling demand of is also studied. The existing windows area of the reference house represents only 14% of the total wall.

Thermal insulation: A house envelope is the key factor that determines the quality and controls the indoor conditions irrespective of transient outdoor conditions. The introduction of an insulator permits a lowering important of the interior temperature that with the blade of air **[12]**. The insulation thickness in the walls and roof are parameters that are optimised in this study. The optimal thermal insulation thickness is determined by estimating the annual heating and cooling needs for different thermal insulation thickness for walls and roof.

Window glazing type: Window glazing is one of the weakest thermal control points in building interiors. In a standard family residence, 10–20% of all heat loss occurs through the windows **[13]**.Two glazing types are compared in this analysis, single glazing and double glazing.

Nocturnal cooling: Nocturnal cooling cools the structural mass of the building by means of nocturnal ventilation. Research has shown that the mean temperature of a building can be reduced by up to 3 ◦C with this type of ventilation **[14]**.
In order to study the impacts of the nocturnal cooling on the energy usage of house during summer, two opening windows scenarios are considered. The first scenario considers that the windows are opened during night time, from 11h to 6h, and the second scenario during day time, from 8h to 17h.

VI. SIMULATION RESULTS

4.1 Effect of the house orientation

The simulated space heating and cooling demand is shown in **Fig.5**. Thanks to exterior shading devices (blinds, overhangs) in living room and kitchen windows, the reference house shows little variation of the cooling demand with orientation; therefore, the best orientation will be determined by the ability to collect useful solar gains during the heating season.

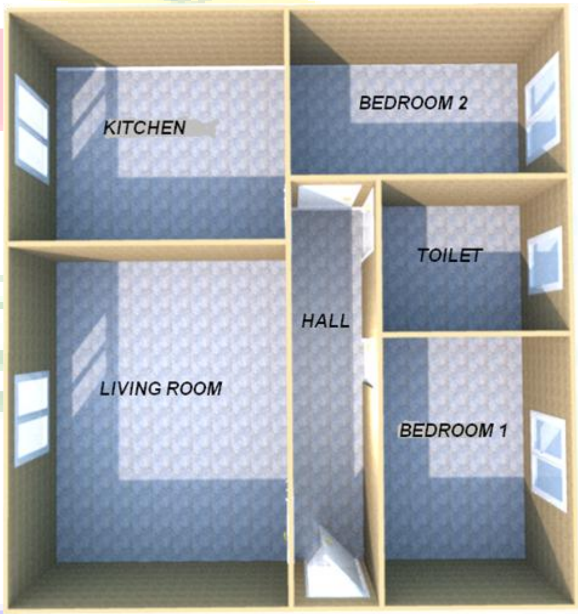

Fig.4. The simulation model for rural house in Chlef district

Fig.5 shows that the total energy needed to provide comfort in these two areas throughout the heating season is about 6983 kWh 6926 kWh, 7158 kWh, and 6701 kWh for West, East, North, and South house orientation, respectively. We can detect that living areas facing south is the best orientation for energy saving

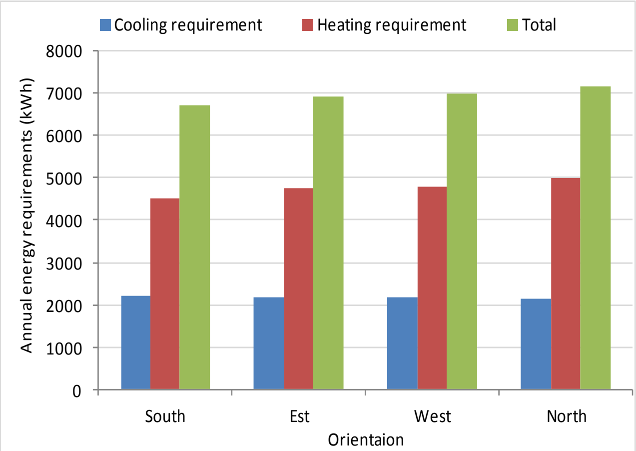

Fig.5. Annual heating and cooling demand at different orientation

Table.2 shows a comparison between the monthly cumulated heat fluxes contributed by houses south-facing windows. The heat gain decreases/ increase from month to month, due to the decrease/increase of the incoming solar radiation flux.

The monthly heat gain due to the radiation energy flux passing through windows ranges from 142.6 to 251.6 kWh in the RH and from 63.25 to 322.6 kWh in the RH with increasing the windows size. The minimum heat gain value is reached during the summer months in the insulated house, thanks to the exterior shading devices which allow only diffuse solar radiation to enter the house. However, during the heating months, heat gain in the RH with increasing the windows size is higher than those in the reference house. Larger heat gain values occur in October to May, when the exterior shading devices are lifted, due to the increasing of windows area.

4.2. Effect of windows size and shading devices

The effect of windows size on heating load is estimated for different windows size from the total façade area. From **Fig.6**, it can be concluded that the optimum windows size is 10% for North façade and 40% South façade. As can be seen in **Fig.7**, due to the use of shading device, the increasing of cooling needs result in the increasing of windows size of the southern façade, can be avoided. Increasing the windows size of the southern facade by 40% compared to the originally windows size (12%) with the use of external shading device in summer provides significant energy savings by reducing the total energy needs of 5.40%.

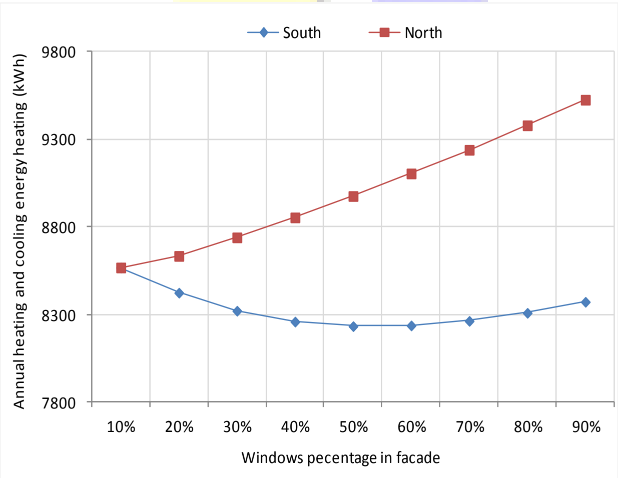

Fig.6. Annual heating energy at different windows size

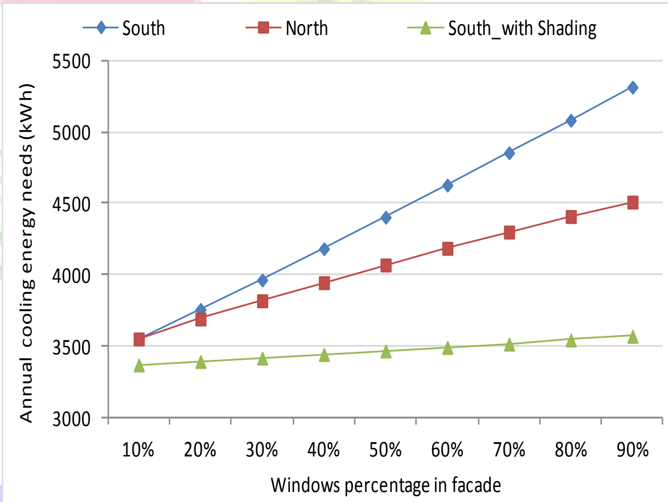

Fig.7. Annual cooling energy at different windows size

We conclude that the passive solar system is very useful during the heating season and can be controlled reasonably well by the exterior shading devices to diminish the solar heat gains during the warm season.

4.3. Effect of thermal insulation

As shows in **Fig.8**, a reduction of 49% in total energy needs is recorded when increasing the thermal insulation thickness of only (0.08 m). This is due to the reduction in heat loss through the walls and roof. Beyond this thickness, the impact on total energy needs strongly attenuates with a reduction of about 6%, for an increase of the insulation thickness of 8 cm to 20 cm.

Table 2
Monthly cumulated heat flux contributed from house windows

Months	**Reference house** (kWh/month)	**RH with increasing the windows size** (kWh/month)
Jan	216.9	286.2
Feb	226	292.1
Mar	227.4	284
Apr	185.7	223.2
May	165.6	198.5
Jun	142.6	65.5
Jul	156.6	67.86
Aug	194.2	71.83
Sep	239.8	63.25
Oct	251.5	322.6
Nov	215.7	282.6
Dec	246.9	310.3

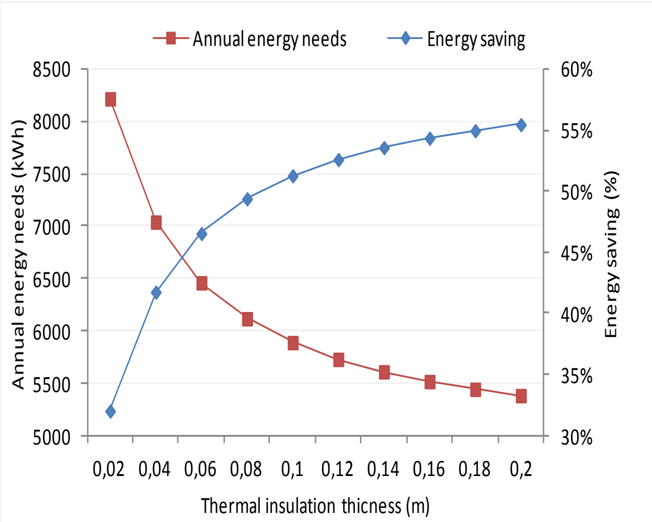

Fig.8. Energy saving at different insulation thickness for ceiling and walls.

Table 3
Effect of the glazing type

	RH	**Insulated house**
Single glazing	12065	6118
Double glazing	11485	5326
Energy saving rate	4.8%	12.94%

4.4. Effect of efficient type

The impact of the glazing type on the house energy needs is presented in **Table 3**. The interaction between the glazing type and insulation level is also illustrated through the simulation of two configurations. For the RH, the impact of double glazing windows on the house energy needs is low (4.80%). In the case of an insulated house, the impact is significant (12.94%).

4.5 Effect of nocturnal ventilation

Fig.9 shows the evolution of the temperature in function of time in the model house for the hottest week in July. We can noticed that the maximum temperature of the air indoor housing reach up to 30◦C when the windows are opened during day time. However, the opening of windows during night time maintains the temperature of the air indoor housing less than 26°C.

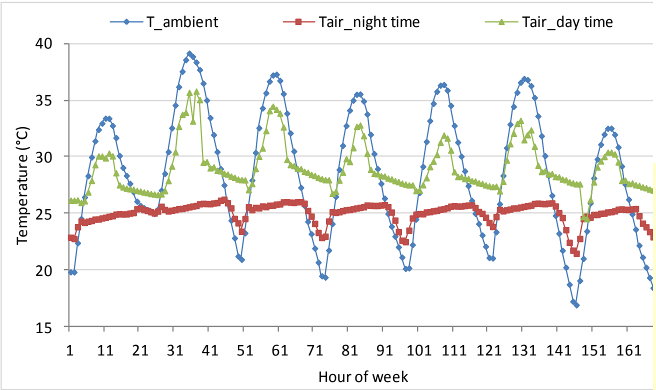

Fig.9. Evolution of the temperature in function of time in model house.

It can be concluded that the nocturnal ventilation contributes to maintain the house within the comfort during the warm season by using the thermal mass of the house as an intermediate storage medium, which enables us to us during the day the coolness stored during the previous night.

4.6. Effect of the bioclimatic designs in combination

In order to illustrate the effect of the different bioclimatic designs in combination, a comparison between two houses with and without bioclimatic designs in energy needed for heating and cooling is made, as shown in **Fig.10** and **Table 4**.

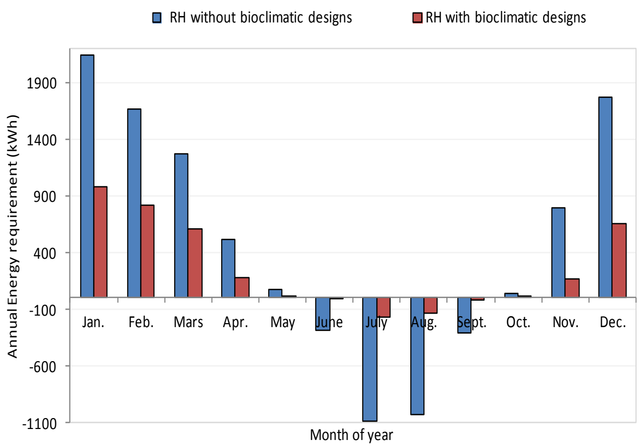

Fig.10. Monthly energy requirement comparisons between two houses without and with bioclimatic designs

The positive values represent the monthly heating requirements and the negative values are the monthly cooling requirements.

It can be seen that the integration of bioclimatic designs provides a useful mean of decreasing the energy demand all over the year especially in interseason.

Table 4
Difference between RH with and without bioclimatic designs

	RH without bioclimatic designs	**RH bioclimatic designs**
Parameter design		
Orientation	Unspecified orientation	South
Insulation of external walls	Without insulation	80mm expanded polystyrene
Insulation of flat roof	Without insulation	80mm expanded polystyrene
Window distribution of Facades	14%-S/14%-N	40%-S/10%-N
Glazing type	Single glazing	Double glazing
Energy requirement kW h/ (m^2. y)		
Space heating energy requirement	106	42
Space cooling energy requirement	34	04
Total energy requirement	140	46
Energy saving kWh/(m^2. y)	-	94

In the heating season (from October-April), the specific energy requirements for space heating of the RH with bioclimatic designs is 42 kWh/(m^2 y). However, RH without bioclimatic designs has a space heating requirements of about 106 kW h/ (m^2 y), so 60% reduction has been achieved. While, during cooling season (from May to September), the cooling energy requirements are 34 kWh/(m^2 y) for the RH without bioclimatic designs and only 04 kWh/(m^2 y) for the RH with bioclimatic designs, so 88% reduction has been achieved. The total heating and cooling energy requirements of the RH with bioclimatic designs are 46 kWh/(m^2 y). These values are rather low compared to the total heating and cooling energy requirements of the RH without bioclimatic designs (140 kW/(m^2 y)), with a reduction in total energy requirements of 67% (94 kWh/(m^2 y)).

V. CONCLUSION

Introducing the concept of bioclimatic designs for rural housing in Chlef district was discussed in this paper. The results show that space heating and cooling energy requirements of a typical rural house can be reduced by 67%. This goal can be achieved through the adequate house orientation to the true south, increasing windows size of façade facing south, using double glazing and shading devices in summer, in addition to insulate the roof and wall by 0.08 m. Thanks to nocturnal cooling, the energy requirement for space cooling is reduced to the point of eliminating the need for an auxiliary cooling system as the indoor temperatures fall largely within the thermal comfort zone. The energy requirement for space heating is reduced by 60%. If the optimum annual energy savings for the typical rural house is applied to all rural houses built during the program 2010-2014 in the Chlef district (23700 houses) , the district has the potential of saving 178,224 MWh of electricity and gas annually.

REFERENCES

[1] MEM, Ministère de l'énergie et des mines. Agence Nationale pour la Promotion et Rationalisation de l'Utilisation de l'énergie (APRUE). Consommation Energétique Finale de l'Algérie, 2009. WWW.aprue.org.dz

[2] MED-ENEC- Energy Efficiency in the Construction Sector, Project for energy efficiency in the building sector, FEATURE STORY No12-2008. http://www.med-enec.com/

[3] MEM, Ministère de l'Energie et des Mines. Programme des Energies Renouvelables et de l'Efficacité Energétique. Algérie, 2011.

[4] P, Daniela et al,. Impact of energy efficiency measures on the economic value of buildings. Applied Energy 89 (2012) 454–463.

[5] S. Jaber, S. Ajib. Optimum, technical and energy efficiency design of residential building In Mediterranean region. Energy and Buildings 43 (2011) 1829–1834.

[6] H, Nathan et al,. Dynamic modeling of potentially conflicting energy reduction strategies for residential structures in semi-arid climates. Journal of Environmental Management 97 (2012) 148-153.

[7] G, Danielle et al,. Optimization of energy efficiency and thermal comfort measures for residential buildings in Salamanca, Mexico. Energy and Buildings 54 (2012) 540–549.

[8] L, Jordi et al,. Design and performance of energy-efficient solar residential house in Andorra. Applied Energy 88 (2011) 1343–1353.

[9] TRNSYS, User's Manual, 2006, A Transient System Simulation Program. Version 16, Solar Energy Laboratory, University of Wisconsin-Madison, WI, USA.

[10] Morrissey J, Moore T, Horne RE. Affordable passive solar design in a temperate climate: An experiment in residential building orientation. Renewable Energy 2011;36:568–77.

[11] Tzempelikos A, Athienitis AK. The impact of shading design and control on building cooling and lighting demand. Solar Energy 2007;81:369–82.

[12] Yu, et al., " Astudy on optimum insulation thickness of external walls in hot, summer and cold winter zone of China," Applied Energy vol. 86 (2009) 2520-2529.

[13] Roos A, Karlsson B. Optical and thermal characterization of multiple glazed windows with low U-values. Solar Energy 1994;52:315–25.

[14] R. Pacheco, J. Ordónez, G. Martínez. Energy efficient design of building: A review. Renewable and Sustainable Energy Reviews 16 (2012) 3559– 3573.