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Impact of rural housing energy performance improvement on the energy balance in the North-West of Algeria

M. Missoum [a,*], A. Hamidat [b], L. Loukarfi [a], K. Abdeladim [b]

[a] Université Hassiba Benbouali de Chlef, Chlef, Algeria
[b] Centre de Développement des Energies Renouvelables, CDER, Algiers, Algeria

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ABSTRACT

Forty-two percent (42%) of Algerian primary energy was consumed by the building sector and it is still in expansion, due to mainly on an exceptional growth of population and urbanism. In order to reach the increase demand of housing and to keep the rural areas' inhabitants in their lands, the Algerian state has launched a huge plan of rural housing construction without taking into account the energy performance level which is too bad. The main objective of this work is to analyze the energy performance of rural housing built in the district of Chlef for the three construction programs, besides study their impact on the overall energy balance in the district of Chlef. There are two ways to improve the energy performance of a typical rural house. First, a passive one through the integration of a set of efficiency measures to reduce the need for heating and air conditioning. The efficiency measures include the adequate orientation of the house, insulation of the envelope house, efficient glazing and increased windows size with the use of shading device in summer.

Second, an active one using solar PV to supply the house with electricity. The results show that at the end of the last construction's program, more than 219 GW h of electricity and 26,508 t of butane gas could be saved annually at the energy balance level of the district. The annual cost savings associated to these energy savings was estimated at 1281,933$ for butane gas and at 5110,431$ for electricity.

1. Introduction

Building construction industry is one of the most consuming energy sectors, thus contributing significantly to the greenhouse effect and climate change, and has a serious environmental impact. Worldwide, buildings are responsible for approximately 40% of annual total energy consumption. In Algeria, buildings, with about 35% in the residential sector and 6% in the tertiary sector, use approximately 42% of total energy consumption [1]. The reasons that led to the increase in energy demand are: (a) substantial increase of population and housing, (b) low prices of conventional energy, (c) increase number of electrical equipment in each house, (d) use of non-economic electrical equipment such as incandescent lamps and cheap air conditioners, (e) absence of awareness and lack of culture on the energy control, (f) growing desire of people to comfort.

The Algerian thermal regulation of residential buildings was released in 1997. In the framework of this thermal regulation, three Regulatory Technical Document were developed (DTR).

- The DTR.C3-2 which establishes the rules for calculating of winter heat losses for residential buildings [2].
- The DTR.C3-4 includes the rules for calculating of the summer heat input for residential buildings [3].
- The 3-31 DTR.C deals with the natural ventilation of residential premises [4]. The implementation of this regulation should allow a saving of 20 to 30% on energy consumption for heating homes.

Algeria must establish its development based on other types of energy and try to control its energy consumption by implementing an appropriate energy efficiency policy. For this reason, 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 [5]. 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% [6]. Thus, a pilot project of 600 houses with high energy

* Corresponding author. Tel.: +213 772 020858; fax: +213 27 72 17 88.
E-mail address: missoum1976@hotmail.fr (M. Missoum).

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Nomenclature

AC	alternating current (A)
C	energy cost ($/kW h)
cs	cost saving ($)
DC	direct current (A)
EC	annual electricity consumption (kW h)
EEM	energy efficiency measure
EG	energy gain (kW h)
EN	total energy needs (kW h)
EP	annual electricity energy purchased from the electricity grid (kW h)
EPV	annual electrical energy generated by the PV system (kW h)
ES	annual electricity sold to the electricity grid (kW h)
f	usage frequency (h)
F	derating factor
G	solar radiation (kW/m^2)
IC	investment cost (%)
LSL	social rented housing
LSP	participatory social housing
S	area (m^2)
t	time (h)
YI	yearly income (J)
N	equipment number
P	power (kW)
ΔP	Pressure drop (Pa)
PV	photovoltaic
q	air mass flow rate (kg/s)
Q	heat flux density (W/m^2)
RH	reference house
ROI	return on investment (years)
SS	state subsidy ($)
T	temperature (°C)
a	temperature coefficient (%rc),

Subscript

ar	array
c	ceil
d	daily
el	electricity
3	gas
inv	inverter
ins	insulation material
sc	space cooling
sh	space heating
STC	standard test conditions
t	total
y	yearly
w	windows

performance (HEP), as demonstrative operation, was launched. It incorporates the principle of energy conservation in the design and construction of buildings. The promotion and development of renewable energies including solar, enshrined in the Law on Renewable Energy 2004 [7]. By 2030, the Renewable Energy and Energy Efficiency Program expected to reach a 40% share of solar and wind energy in the balance of the national electricity [5]. The choice to use renewable energy is strengthened by its geographical location. Indeed, Algeria holds one of the largest solar potential in the world. Sunshine duration in almost all the country exceeds 2000 h annually and can reach 3900 h (highlands and Sahara). The energy received daily on a horizontal surface of 1 m^2 is about 5 kW h on most territory of the country (1700 kW h/m^2/year at North and 2263 kW h/m^2/year in the South [8].

During the last few years, the Algerian authorities have made development of rural housing one of their priorities. Since 2005, Algeria has launched a programme for the construction of one million housing units. Nearly half of this programme (450,000 unit) is devoted to housing in rural areas in order to keep rural populations in place and to encourage their return from urban areas [9]. The construction of a rural house, beneficed by a state subsidy (SS) of 7000$, aimed to encourage families to build a self-construction with a decent house in rural environment.

However, the construction of these houses whose level of energy performance is very bad, surely leads to a significant increase in energy consumption, since the government has built them without taking into account the climatic conditions and the required thermal performance level.

The main objective of this paper is to analyze the impact of energy efficiency and solar PV integration on the overall energy balance in rural housing. In addition an economic analysis was performed. These actions will help decision-makers to use renewable energy in the building sector and implement policy packages which deliver a deep path of energy consumption reductions and associated CO_2 emissions mitigation from buildings.

2. Energy situation in the district of Chlef

2.1. Geographical location

The district of Chlef is located in the Northwestern region of Algeria (see Fig. 1). It is 208 km far from the capital Algiers, at latitude 36.13°, longitude of 1.20° and an altitude of 133 m. It extends over an area of 4791 km^2 and a population of around one million inhabitants with a density of 194 inhabitants/km^2. It occupies a strategic place due to its geographical location. It is characterized by a Mediterranean climate: sub-humid in the North and continental in the South, cold in winter and hot in summer.

2.2. Energy situation

Electricity and natural gas are the most common energy sources used by the households in the region. The electricity is used for lighting, household appliances running and space cooling, while natural gas is used for cooking, space heating and production of sanitary hot water. In the zones where houses are not connected

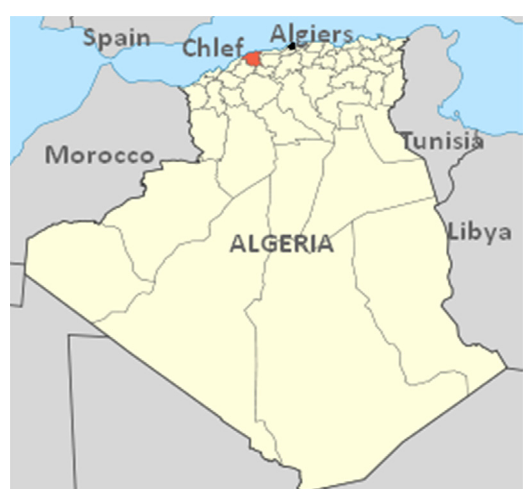

Fig. 1. Geographical situation of the district of Chlef.