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Economic and environmental analysis of a solar thermal heating system for residential buildings in Algeria

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***Abstract*— In this work, the economic aspect and environmental impacts of an integrated solar heating system under Algerian climatic conditions have been probed. We considered two types of solar heating installation; the first is a real individual system, which is integrated in a bioclimatic single-family house located in Algiers region. However, the second is a virtual collective system serving to provide hot water and heating for a multi-family building. The equity payback and GHG emissions have been estimated by means of a numerical simulation using the powerful tools of the RETScreen free software program. The obtained results showed that the equity payback is strongly dependent on the fuel type that is used by the auxiliary and the kind of the installation. In the case of the studied real system, where the auxiliary is assured by the gasoil, the equity payback is around the half of the project lifetime. However, from the environmental standpoint, the solar application is entirely advantageous. Furthermore, the natural gas is the most favorable environmental resource as an auxiliary, with a minimum yearly GHG emissions compared with electricity and gasoil for both studied cases.**

***Keywords*— Solar heating; economic study; environment impacts; residential building; Algeria**

I. Introduction

In Algeria, nearly 43 % of energy consumption is owed to the building sector [1]. An important part of this energy consumption is due to loads of domestic hot water (DHW) and space heating (SH). Therefore, building sector has a significant contribution in the rationalization of energy consumption. In the other hand, the country has an enormously solar potential. Therefore, the integration of the solar energy in buildings to meet the needs of DHW and SH is a useful method to contribute in the reduction of fossil-energy usage within environment protection. Solar combisystems (SCS) are solar heating systems for combined domestic hot water preparation and space heating [2]. A combisystem uses at least two energy sources to supply hot water and heating: a solar collector and an auxiliary energy source. The auxiliary energy source could be natural gas, electricity or gasoil.

In a previous study [3], we demonstrated the viability of an integrated SCS in a bioclimatic dwelling under Algerian climatic conditions. However, the need to take an integrated approach about this system requires a multidimensional analysis of the project, among them, the economic aspects.

In order to probe the economic aspects, as well as, the environmental impacts of a solar heating system for residential buildings in Algeria; a numerical study by means RETScreen software program [4] is carried out considering two types of installation. The first is a real individual system, which is integrated in a bioclimatic house located in Algiers, however, the second is a virtual collective installation, which is integrated in a multi-family house; where the size of the system and the number of occupants is ten times that of the individual case.

II. Description of the Prototype Bioclimatic House and the Integrated SCS

The studied solar heating system consists of an integrated SCS in a bioclimatic prototype. The prototype owns a surface of 90 m² and is located in the Algiers region, more precisely in the village of Souidania. This region is part of the climate zone A (latitude 36.70 N, longitude 03.20 E) is characterized by a cool winter and hot-humid summer. This prototype house has some characteristics of a passive solar house, including a large south facing window area, enhanced wall insulation and high thermal mass. Fig.1 displays the pilot house (top) and the SCS serving to domestic hot water supply and space heating (bottom).

Concerning the active solar heating system, it contains the following elements:

- Solar collectors mounted on the roof of the dwelling;
- The storage tank, the solar collector field exchanges energy with the solar storage through an internal heat exchanger;
- The auxiliary energy supply maintains the upper section of the tank at a set temperature. The auxiliary heat is connected to the solar tank by an immersed heat exchanger in the top of the tank.

For the considered SCS in our study, four (04) flat-plate collectors (FPC) within parallel arrangement are adopted, which gives 8 m^2 of total collector surface. The storage tank is an insulated tank with a total volume of 300 l. The Auxiliary heat exchanger is located in the top of the tank and is of sufficient capacity that it can supply all of the DHW and SH energy needs if necessary. Furthermore, the auxiliary energy supply maintains the upper section of the tank at 50 °C.

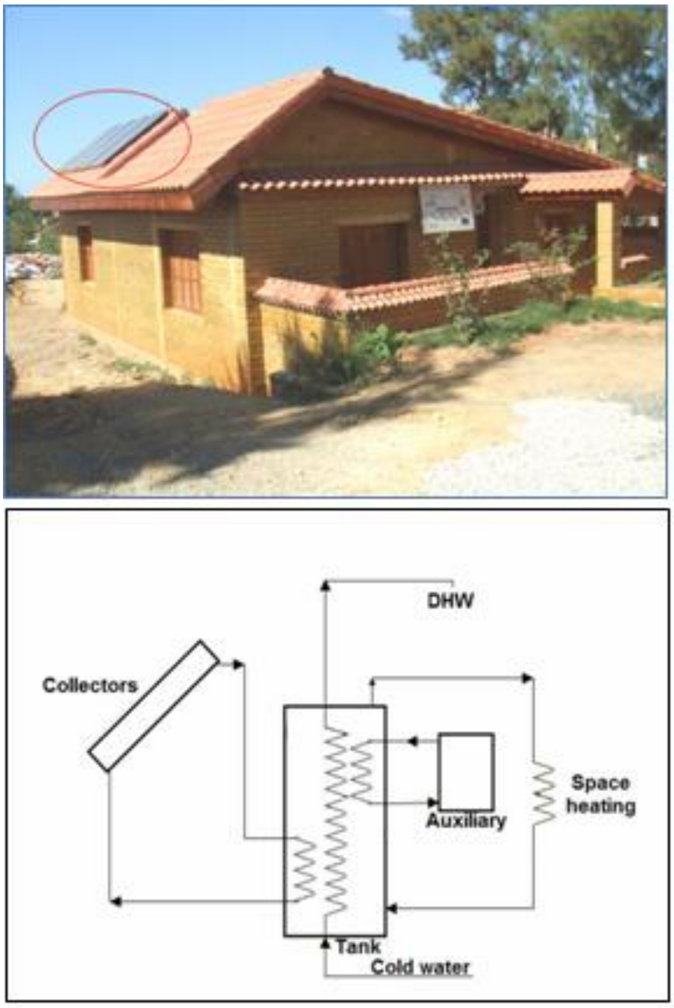

Fig. 1 Top; the pilot house, flat plate solar collectors are installed on the roof of the house facing south (red contour). Bottom; schematic illustration of the solar combisystem serving to domestic hot water supply and space heating

Five (05) persons represent the members of an Algerian family occupy the building. The need on the DHW is considered 50 l per day per occupant at 50 °C. The house set temperature is set within 20 °C at wintry period i.e. January, February, March, April, October, November and December. However, at outside of this period the SH system turned off.

Based on the provided data through the energetic study [3], the required energetic parameters, namely; total system load (E_{load}), space heating load (SH load) and the auxiliary energy required by the solar system (E_{aux}) are illustrated in Table 1.

TABLE I

TOTAL LOAD, SPACE HEATING LOAD AND THE AUXILIARY ENERGY REQUIRED BY THE SOLAR SYSTEM FOR THE STUDIED ECONOMIC HOUSE (IN MWH) [3].

E_{load}	SH load	E_{aux}
9.79	5.01	3.85

III. COST PARAMETERS CONSIDERED IN THE CALCULATIONS

Like any other software, RETScreen is characterized by the three functions: input, processing and output data. Among required settings to perform an economic study, the rates of the auxiliary power and the electricity for the site. As part of our study, the auxiliary is provided by a fossil source, namely; natural gas, electricity or gasoil, their rates are shown in Table 2. However, Table 3 bellow shows the costs of main considered inputs.

TABLE II

BASIC PRICING OF A KWH, THERM AND GASOIL IN ALGERIA.

Currency	The first 125 kWh*	KWh beyond*	Natural gas*	Gasoil**
DZD	1.779 DZD/kWh	4.179 DZD/kWh	0.168 DZD/therm	13.7 DZD/l
USD ($)	0.0165 $/kWh	0.0388 $/kWh	0.0016 $/therm	0.1278 $/l

Source: * Distribution Company of Electricity and Gas in Algiers, October 2015. ** Ministry of Commerce, October 2015.

TABLE III

THE PRINCIPLE COSTS AND PARAMETERS CONSIDERED IN THE CALCULATIONS.

Cost/parameter	Unit	Value	Source
Initial costs	$	2240	Project owner
Solar collector	$	280	Project owner
Inflation rate*	%	5.13 (in late September 2015)	-
Yearly maintenance cost of the heating system	% of investment cost	1	[5]
Expected project life	Year	25	-

Source: * Ministry of Finance, December 2015.

IV. RESULTS AND DISCUSSION

Table 4 illustrates the equity payback and the greenhouse gas (GHG) emissions for both considered installations. As

Table 4 shows, the equity payback exceeds the project lifetime in these cases: the individual system within natural gas or electricity auxiliary and in the case of the collective installation within gas-based auxiliary; this is due to the grant of natural gas. In the case of the individual installation where the auxiliary is provided by the gasoil, as well as, for the collective installation within electrical power auxiliary and the collective installation based on the gasoil auxiliary, the equity payback is around 12 year, 13 year and 17 year respectively. Indeed, the individual installations are profitable in the case of gasoil-based auxiliary; however, the collective installations are profitable for both electricity and gasoil-based auxiliary from economic point of view.

Fig. 2 displays graphically the evolution of cumulative cash flow for interesting cases, namely, collective installation with electric-auxiliary, individual system with gasoil-based auxiliary and collective system with gasoil auxiliary.

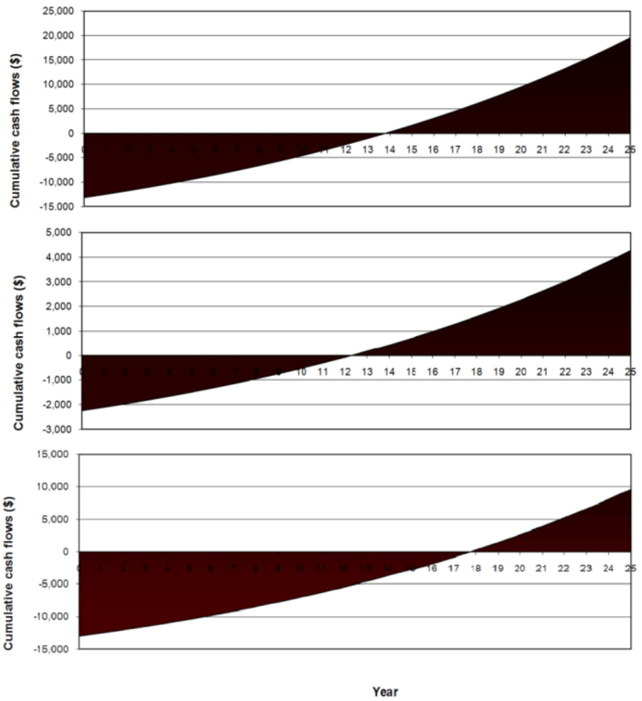

Fig. 2 Cumulative cash flows graphs; top: collective installation with electric-auxiliary, middle: individual system with gasoil-based auxiliary, bottom: collective installation and gasoil auxiliary

TABLE IV

EQUITY PAYBACK (EP) AND EMISSIONS ANALYSIS CONSIDERING THREE TYPES OF FUEL-BASED AUXILIARY; NATURAL GAS (NG), ELECTRICITY (ELEC.) AND GASOIL (GO). THE ABBREVIATION PL MEANS PROJECT LIFE.

	Kind of installation					
	Individual			**Collective**		
Auxiliary	NG	Elec.	GO	NG	Elec.	GO
EP (year)	>PL	>PL	12.3	>PL	13.8	17.7
GHG emission (tCO_2)	3.2	9.3	4.5	30.2	88.1	45.3

V. CONCLUSION

In this work, the economic aspect and environmental impacts of an integrated solar heating system on a residential building under Algerian climatic conditions has been studied through a numerical approach using RETScreen. The obtained results outlined that the equity payback shows a strongly dependence on the auxiliary fuel-type and the installation kind. In the case of the studied real system, where the auxiliary is assured by the gasoil, the equity payback is around the half of the project lifetime. From an environmental standpoint, as expected, the solar application is entirely advantageous; because, the solar system contributes to the reduction of the fossil-energy consumption.

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