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Viability of integrating Solar Water Heating systems into High Energy Performance housing in Algeria

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ABSTRACT

In the framework of the new Algerian energy policy, we investigate in this contribution the energetic and the economic viability of the integration of Solar Water Heating (SWH) systems into High Energy Performance (HEP) housing in Algeria. The case studies are houses situated in four different locations each one representing a distinct Algerian climatic zone. In order to efficiently design the SWH systems to be installed, we use a simple method based on the determination of the optimum collector area that minimizes the costs of the installation via considering both economic factors and system parameters. The solar fraction, needed for this analysis, has been calculated using the F-Chart method with monthly meteorological data characterizing each region. The results revealed very promising high values of the solar fraction in almost all the studied regions and that an adequate funding policy will permit to establish a good balance between system performance and system design resulting in a higher competitiveness of solar energy against conventional energy.

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1. Introduction

The economic development which occurred in Algeria during the last decade has led to a noticeable improvement in living standards of Algerians and thus a significant increase in energy requirements. Additionally encouraged by the subsidy policy of electricity and gas implemented in Algeria since 1962, the national energy needs reached 55.9 *Mtoe* in 2014, representing an increase of 7.8% as compared to 2013 [1]. However, the economy of Algeria heavily depends on hydrocarbons export (oil and natural gas) and the current fall in oil prices caused an economic crisis which prompted the government to review its energy policy in a new program that encourages and promotes the use of renewable energy.

The average sunshine duration in Algeria is about 2560 h/year for coastal regions, 3000 h/year for highlands regions and 3500 h/year for desert regions. Therefore solar energy, whose use is still very limited in Algeria, presents an enormous potential for several applications among which water heating. Indeed, in many regions in the world, particularly Mediterranean countries, the utilization of Solar Water Heating (SWH) systems for domestic use have proven their huge potentiality both from the energetic and the economic sides [2–7]. However, an adequate design of SWH systems is important to ensure the maximum benefit to the user, especially for domestic utilization. This involves proper sizing of the different components of the system, in particular the collecting area, on the basis of the predicted solar fraction and hot water demand.

A number of workers have investigated methods for optimizing SWH systems based, among other things, on the determination of optimal collector area which minimizes the cost of the system. The earliest methods concerned direct computer dynamic simulations of the solar system using numerical softwares such as TRNSYS [8], SIMSHAC [9] and SIMPLEX [10]. More recent methods, simpler to use for designers, concern iterative methods which are characterized by lengthy calculations repeated iteratively [11–13] and direct methods, which are presented as simple mathematical formulas suitable for a rapid computation [14–21].

Optimization methods of SWH systems have been performed in several different contexts. For instance, Abou-Zeid and Hawas [2] studied the economic viability of using SWH systems in the town of Benghazi in Libya. The obtained results permit a

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Nomenclature

P_T	annual operating cost of the solar system (DA, $1DA \approx 0.0092$ USD) P_c cost of the collector per unit of area (DA/m^2)	N_p	number of person in the apartment
		N_a	number of apartment in the building
		V	hot water demand per building per day (l/day)
		ρ	density of water = 1 kg/l
		c_p	heat capacity of water = 4181.3 ($J/kg.°K$)
P_t	cost of the storage tank per unit of volume (DA/m^3)	N_k	number of day in kth month
P_1	other costs related to collector (DA)	T_d	desired hot water temperature ($°C$)
P_f	cost of the conventional energy unit (DA/J)	T_{ik}	monthly average temperature of the inlet cold water in kth month ($°C$)
P_2	other costs not related to the collector (DA)		
b	proportionality constant between storage volume and collecting area (m)	T_{ak}	monthly average ambient temperature in kth month ($°C$)
S	collector area (m^2)	T_a	annual average ambient temperature ($°C$)
R	capital recovery factor	F_R	heat exchange coefficient of the collector
E	auxiliary energy (J)	U_L	collector overall loss coefficient ($W/m^2.°C$)
r	annual interest rate	Δt_k	total number of seconds in kth month
n	number of payment years	$(\tau\alpha)$	weighted average transmittance-absorbance product
F	fraction of the annual heating load supplied by solar energy (J)	H_k	monthly average daily radiation incident on collector surface per area unit in kth month (J/m^2)
L	annual heating load for water heating (J)	E_0	auxiliary energy needed for S = 0 (J)
M	hot water demand per person and per day (l/per/day)	α	auxiliary energy consumption decay constant

generalization applicable to other locations in Lybia. In the work of Lewis [22], the utilization of three different methods to estimate the optimum collector area of SWH systems in Nyanga, Zimbabwe, led to comparable values making the solar system utilization as a viable proposition. Under meteorological conditions of Singapore, Hawlader et al. [23] showed that both life cycle saving and annual life cycle cost based methods lead to similar values of the optimum collector area. In Akinoglu et al. [3], the authors determine the optimal surface and the storage capacity for several sites in Turkey while comparing low and high performance solar collectors. In Jordan, Kablan [4] made a comparative study for the economic feasibility between SWH systems and gas geyser systems. They demonstrated that under typical Jordan weather conditions the solar systems are more economical and have much longer optimal operation life. Kalogirou [5] showed that the use of passive SWH systems under Mediterranean weather conditions can provide a considerable fraction of domestic hot water needs with in addition a very promising financial attractiveness. Al-Badi [24] demonstrates that using SWH systems in all the cities in Oman can save up annually an energy which is equivalent to the annual energy produced by a power station of 212 MW size. However, the study shows that the diffusion of SWH systems in Oman requires setting policy that motivates people to use them. A detailed long-term dynamic performance and thermo-economic studies by Hazami et al. [6,25] revealed that the utilization of domestic SWH systems in Tunisia is very efficient and profitable in terms of life cycle savings. The techno-economic analysis done by Nikoofard et al. [26] in Canadian context showed that with the help of an encouragement policy from the government, it is possible to make SWH systems economically attractive resulting in a significant diminution in conventional energy use with an associated reduction of greenhouse gas (GHG) emissions of about 2%. In accordance to the latest Greek regulation on the energy performance of buildings, Martinopoulos et al. [27] performed a techno-economic evaluation of solar space and water heating system for isolated housing utilization and showed the possibility of a subsequent minimization of energy costs as well as gas emissions. In their energy analysis, Allouhi [7] have proven the significant potential of using SWH systems in Morocco for six different climatic zones. However, in order to support their results, the authors recommend a complementary economic and financial analysis. Based on the results of their techno-economic feasibility study, Abd-ur-Rehman et al. [28] presented the optimum selection criteria for SWH systems to be used in domestic sector in ten different cities in Saudi Arabia. In particular, the authors pointed out the importance of the minimization of the initial cost in order to preserve the economic viability of the project. A more detailed bibliography concerning studies related to technical and economical aspects of SWH systems and their applications can be found in the recent review by Gautam et al. [29].

In Algeria, to our best knowledge there is no published work dealing with the feasibility of integrating SWH systems into residential sector taking into account typical characteristics of the different climatic zones. This kind of studies is a crucial prerequisite to any solar investment project in order to guaranty its technical and economical viability. In this perspective, the present work enters in the framework of the new Algerian energy policy and concerns the design and optimization of flat-plate collector SWH systems (Fig. 1) integrated to High Energy Performance (HEP) buildings. The buildings are part of the ECO-BAT program [30,31] which aims the realization of 600 energy efficient housing to help

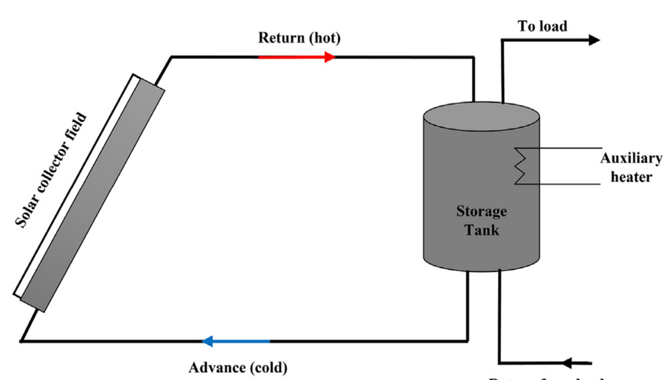

Fig. 1. Schematic diagram of Solar Water Heating (SWH) systems. It consists of flat-plate solar collectors field connected to a hot water storage tank. The tank is in turn connected to an electric auxiliary heater which heats the water in the tank when the solar contribution from the collectors is insufficient.

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