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# Design, construction and performance testing of a new system for energy saving in rural buildings

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ABSTRACT

Drying fruit, heating residential buildings and providing a hot water supply in villages all consume energy. Using fossil fuel for these purposes creates pollution and costs too much. In contrast, the use of solar energy in these applications leads to a noticeable decrease both in pollution and investment costs. In this study, a new solar system was designed and tested in order to reduce energy usage in rural residential buildings and the food drying industry. As the peaks of energy consumption in the proposed system are not simultaneous, this new system is very effective in reducing energy consumption, controlling energy peaks and reducing environmental pollution. This system has the ability to provide the required energy in both summer and winter modes. In the summer mode, the energy supply is used for providing hot water and drying agricultural products, while in winter mode it is used for rural residences heating and hot water supply. Drying time has been varied between 51.23 and 42.45 h according to type of application, and average temperature difference between room and ambient is almost nearly 10 °C with different air heaters. The system includes energy supply and storage equipment, solar dryers, water collectors and rectangular, triangular, trapezoidal and double-pass with longitudinal fins air heaters. The system was tested in Iran for drying apricots, heating rural residential buildings and supplying hot water for domestic use, meanwhile, the energetic and exergetic efficiency of the system was calculated 37.3–61.3 and 3.2–9.7 respectively for different types of installations.



## 1. Introduction

As a process in food industries, fruit drying requires a high level of energy. Since there is a high cost to heating houses and providing hot water, the new solar system was designed to decrease the use of energy in houses and the food industries. Since the energy peak is not synchronized in the system, the new system is very effective in reducing energy consumption and controlling energy peaks. It can help to decrease the energy consumption in rural food industries and in house heating applications. It also lowers the system cost by the synchronization of energy peaks, which is an advantage that comes from the unified design of this system. Economizing on fossil fuels; reducing environmental pollution as well as sanitary drying of agricultural products are among other useful applications of this system. In developed countries, energy consumption in the building sector represents a major part of the total energy budget. Most of the amount is spent for hot water production and space heating.

Hot water is required for bathing and washing clothes, utensils and other domestic purposes not only in the rural areas under discussion but also in urban areas. Water is generally heated by burning noncommercial fuels, namely, firewood in the case of the rural areas and commercial fuels such as kerosene oil, liquefied petroleum gas (LPG), coal and electricity in urban areas. In this regard, utilization of solar energy through solar water heating (SWH) systems can play a big role in the amount of energy required. Solar energy is a well-proven and readily available technology which can directly substitutes renewable energy for conventional water heating methodologies. Various systems are available which are suitable for different applications. Small systems are used for domestic hot water applications while larger systems can be used in industrial process heat applications. There are two types of water heating systems defined by the type of the water circulation involved: natural circulation and forced circulation. Natural circulation solar water heaters are simple in design and low in cost. Forced circulation water heaters are used in colder climates and for providing heat in commercial and industrial processes.

Karatasou et al. [1] designed a method to calculate the mean radiation in collectors inclined towards the south (that is, the method is useful in the northern hemisphere). Safaripur and Mehrabian [2] using another method, in Iran, predicted the amount

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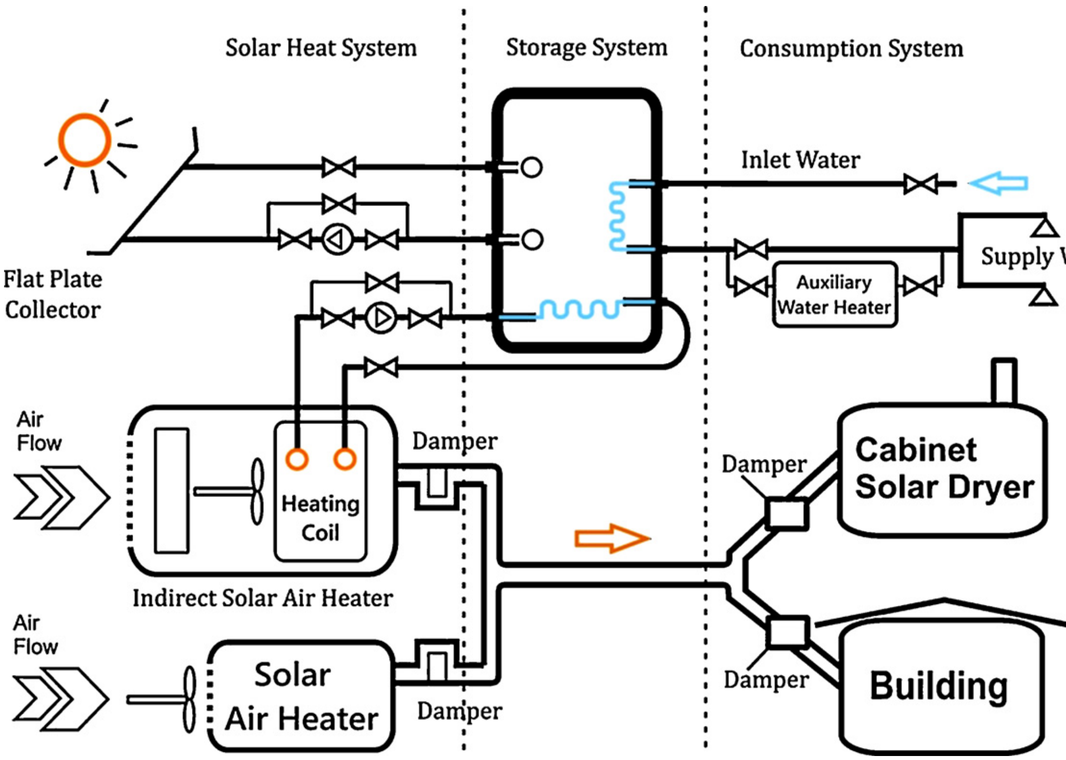


**Fig. 1.** Schematic diagram of a combined solar air handling unit and solar dryer.

of solar radiation using geometrical and astrological features along with geographical and meteorological data. Gunerhan and Hepbasli examined parts of the solar water-heating system for energy consumption and exergy and studied water-heaters in daily hours, in Izmir, and reported the results [3]. Badescu figured out the optimum current in flat-plate solar collectors [4]. Mittal et al. [5] Signal suggested some relationships for air-heater, and some formulas between roughness and their heat transfer. Hatami and Bahadorinezhad [6] conducted research on the application of vertical flat-plate solar air-heaters, suggesting a formula for heat transfer and thereby calculating Nuselt number. Bales and Persson [7] analyzed and compared eight water-heating systems, cross-comparing against a reference system. Chua and Chou [8] investigated low-cost rural dryers, pointing out the advantages and disadvantages for each, and mentioned some points on their application in developing areas as well as Asian countries. Montero et al. [9] designed and tested a solar dryer in Spain. In 2008, Amer et al. [10] designed a solar hybrid dryer for banana. In addition, the equations of heat and mass transfer for tropical fruit dryers were solved by Karim and Hawlader [11] the dynamic behavior of dryers was studied. Furthermore, the models of Newton, Page, Modified page Wang and Shung were investigated by Ceylan et al. in order to find out the degree of moisture in a solar dryer [12]. Abu-Hamdeh [13] proposed a model for the air-heater behavior, comparing gas and solar energy required for such a dryer. Moyls [14] studied the solar dryer with air heater and a rock tank for heat storage. Khollive et al. [15] investigated the use of dryers to dry apricots, grapes and apples. Kholliev et al. [16] showed that the solar dryer has other applications such as planting vegetables as well as the drying usage. Fadhel et al. [17] compared the simulation results in natural and forced convection systems. Golneshan et al. [18] Shiraz University, used the newly design solar collectors for pre-heating large spaces. Also, in a computer program Lund [19] analyzed the effect of various factors for calculating required heat load in order to decrease costs through dimensional optimizing of system parts. Concerning the use of solar energy for heating spaces, Kara et al. [20] used solar system for heating the administrative section of the solar institute in Turkey. Tchinda reviewed and classified various mathematical models of solar air heaters based on the shape, the number of cover and model of absorber [21]. Ho et al. investigated about efficiency of double-pass flat plate solar air heaters with fin attached and proposed a mathematical model for this solar air heater [22]. Hans et al. investigated the effect of artificial roughness in different forms, shapes and sizes for improving heat transfer in solar air heaters [23]. Hartnett and Minkowyez studied the heat transfer characteristics and the performance of flat plate solar air heaters by numerical methods [24]. The entropy generation in solar air heater with rib-grooves roughness was studied numerically by Layek et al. [25] Kumar and Saini has analyzed the performance of a solar air heater duct that provided with artificial roughness by using Computational Fluid Dynamics [26]. Pottler et al. has optimized finned absorber geometries for different solar air collectors [27]. The double pass-finned plate solar air heater was investigated theoretically and experimentally by El-Sebaii et al. [28]. Tronchin et al. has developed three different numerical models that calculate energy performance of rural buildings for single-family house in Italy [29]. Zhuang et al. has studied a thermal and airflow model for a Kang (special rural buildings used widely in China) with a simply consideration of heat transfer in building [30].

There are various industrial drying systems as well as solar heating systems for houses, which have been designed and analyzed individually. However, simultaneous designing of the two systems has not taken place, because the drying in rural areas is generally done through traditional and unsanitary processes resulting in high cost of energy consumption, the simultaneous use of both systems is suggested in some rural applications. Since each family generally dries its individual products and fruits in the house, the system is designed in such a way as to both dry the products through solar energy and to supply heat for domestic use. Thus, the system uses