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What is the effect of optimum independent parameters on solar heating systems?

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ABSTRACT

Researchers are rather closely involved in Solar Combisystems recently, but there is lack of study that presents the optimum design parameters. Therefore, in this study the influence of the four major variables, namely; outside, inside temperature, solar radiation on horizontal surface and instantaneous efficiency of solar collector on the energetic, exergetic and environmental efficiencies of Solar Combisystems are investigated and system optimization is done by a combination of response surface methodology. Measured parameters and energetic–exergetic and environmental performance curves are found and statistical model is created parallel with the actual data. It is found that statistical model is significant and all "lack-of-fit" values are non-significant. Thus, it is proved that statistical model strongly represents the design model. Outside temperature, solar radiation on horizontal surface and instantaneous efficiency of solar collector are the decisive parameters for all responses but instantaneous efficiency of solar collector is not for environmental efficiency. Maximum exergetic efficiency exceeded 11%, maximum environmental efficiency reached up to 95% at optimized process. The optimum value of the outside temperature and solar radiation are found as 22 °C and 773 W/m^2 for all responses, on the other hand optimum collector efficiency is found around 60% for energetic and exergetic efficiency values. Inside temperature is not a decisive parameter for all responses.

1. Introduction

Solar heating systems are all related with the purpose of an action to reduce the energy consumption in buildings and even in industry [1]. Energy consumption in industry has an important role with respect to sustainability and competitivity in the market [2]. Each system design aims to increase the fractional solar consumption value (FSC) and to reduce the consumed auxiliary energy which are usually selected as fossil fueled sources. The energy consumption values in buildings should be underlined in order to present the importance of the role any system which is designed to decrease the energy consumption in buildings and/or provide heating demand via renewable energy sources.

Distributed energy consumption values can be seen in Fig. 1 and final energy consumption in residential areas occupies an important place [3].

It is reported that approx. 40% of final energy consumption occurs in buildings in EU members. This ratio means that 36% of greenhouse gas emissions are released from buildings in 2013 [4]. The percentage of final energy consumption in buildings is above the critical threshold value for future projection of the EU. That is why European Commission created future projections for 2020 energy efficiency target of EU with respect to energy efficiency investments as a financial action.

Energy consumption value in buildings were reported as 20–40% of total energy consumption for developed countries in 2004 [5]. This increment can be explained by population growth, rising urbanization and energy intensity in central places [6].

Nearly same values were announced from U.S. Energy Information Administration (U.S. EIA), 41% of total U.S. energy consumption was consumed in residential and commercial buildings in 2014 [7].

For Turkey, one third of total energy consumption occurs in buildings and 85% of this energy consumes for heating purpose in 2010 [8]. As we consider Turkey as a developing country, energy consumption in buildings has a vital interest for both developing and developed countries [9].

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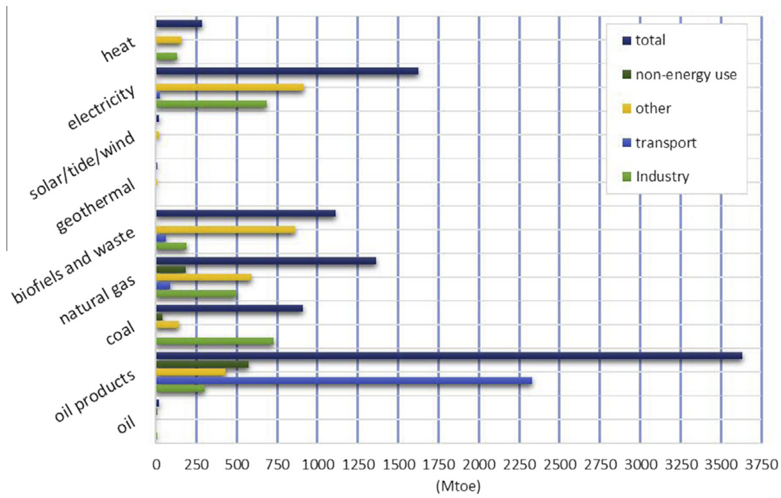

Fig. 1. Sectorial distribution of total energy consumption in the world [3].

1.1. A simple solution for high energy consumption in buildings; SCS

As it is underlined above, high energy consumption in buildings is an important problem for sustainable future and many researcher tried to solve this problem via different heating and/cooling systems. Solar Combisystem is one of these systems which were created to reduce the fossil fuel demand for heating and/or cooling purposes. Solar energy is used as a primary energy source and supported by an auxiliary energy source when solar and/or stored energy is not enough to provide the heating demand of the selected space.

The experimental studies showed that SCS are capable of providing energy demand from 10% to 100% depends on the climatic conditions, system components, system efficiencies and energy demand [10].

1.2. Studies about SCSs

Solar heating systems are long been research topic, therefore there are numerous papers published in the literature. But new generation heating systems which are called SCSs are relatively new topic. However, the first samples are done at the end of 20th century, researches are triggered by the TASK-26 Project which was in the framework of Solar Heating and Cooling Programme (SHC) of International Energy Agency (IEA) and many reports are presented at the end of the time-schedule of sub-projects [11,12] (Table 1).

Beyond these major studies listed above, there are some other studies related with solar heating systems. For instance, Suter et al. provided information about general status of SCS in 2000 and presented technical specifications of all established SCS in the context of TASK-26 [35]. Leconte et al. investigated the performance test procedures of SCS and new procedure named as "grey box" model is presented in the aforementioned study [36].

After Literature survey, it is considered that the optimization studies are not illustrative enough to design the system in the highest efficiency conditions. There is an absence of "*determination criteria*" while an engineer design a SCS in energetic, exergetic and environmental aspects. However, Kacan optimized the efficiency values of system components which are the most common elements used in the market such as "solar collector", "heat exchanger" and "heating system" [33]. These components are dependent to the measured values, therefore the independent parameters that affects the efficiency of system components are need to be optimized. The independent parameters are selected as, outside temperature (t_1), inside temperature (t_2), solar radiation on horizontal surface (I) and instantaneous collector efficiency ($\eta_{\text{coll.}}$). The main target is to determine the effect of these independent parameters on energetic, exergetic efficiency of overall system and greenhouse emission reduction by using Central Composite Design Method (CCD).

Kacan et al. presented the system efficiencies in Ref. [37] but the behavioral specifications needs a numerical solution in design action. Below questions still need to be answered,

"What are the optimum values of outside-inside temperature, solar radiation and efficiency of solar collector as a decisive parameter for maximum efficiency of the system?"

"How does the energetic, exergetic and environmental efficiency of SCS reacts when all decisive parameters set to the optimum value?"

"What is the influence of double interaction effects of the decisive parameter that the third one set to the optimum value on the energetic, exergetic and environmental efficiency of the system?"

Finding the actual optimum values for independent parameters has a vital importance for design engineer with respect to select the proper system component. Also it will eliminate the uncertainty of the operating range of the system components which will rise the sensitivity of control units. Therefore, prior and complementary target of the study is to find an answer these questions and to find the numerical solution that will increase the efficiency of the SCS in the market.

2. Material and method

2.1. Dependent and independent parameters of a SCS

As it is underlined above, the most common system design consists of two closed flow cycles that one includes solar collector, pump and heat exchanger in solar loop and the other flow includes heat exchanger, pump and heating system. These are the dependent system components which were optimized in Ref. [33] and all are located inside part of the system. The working parameters of these components are dependent to the inside-outside temperatures and solar radiation data which are measured in the outside part of the system as seen in Fig. 2.