A thermo-economic model for objective solar collector choice and sizing of a solar water heating system

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Abstract

In this paper, a thermo-economic model is developed for the computation of suitable metrics that can aid in choosing the most cost-effective collector to use in a solar water heating system and to determine the optimal sizing of the solar water heater components once the choice collector has been picked. An approach to calculating the energy-per-dollar is introduced and used for comparing cost-effectiveness of different solar collectors. For the determination of the optimal sizing of the solar water heating system, the Net Present Value of Solar Savings was used as the objective function. Ten (10) different models of liquid solar thermal collectors, which are rated under the OG-100 collector certification program of the Solar Ratings & Certification Corporation (SRCC), were first ranked according to the energy-per-dollar criterion. By making the Net Present Value of Solar Savings the objective function to maximize, the optimal area of the choice-collector to be used in the solar water heating system was then determined using the thermo-economic model. The required hot water storage volume decreases exponentially as the deployed collector area increases while the solar fraction increases, with diminishing marginal rate, as it approaches unity solar fraction. By the energy-per-dollar criterion, one collector model of the flat plate technology was ranked as best among its competitors at the study site in Zimbabwe, when applied for heating water to 50^{o}C. The optimal size of this collector model to deploy in the solar water heating system at the location is 17 m^2 per m^3 of daily hot water demand; with a hot water storage volume of 910 l/m^3; at an optimal solar fraction of 91%. The energy-per-dollar as used in this study is an objective criterion to select from among different solar collector models for deployment at specific sites and for a specified temperature of application.

Key Words

Energy-per-dollar; Thermo-economic model; Collector selection; Optimal sizing; Diminishing marginal returns; SRCC-rated