UNIVERSITÀ DI TRENTO

DIPARTIMENTO DI

INGEGNERIA INDUSTRIALE

Assignment 2

Renewable Energy Conversion Systems

Giacomo Moretti

A.Y. 2024-2025

UNIVERSITÀ DI TRENTO
Dipartimento di Ingegneria Industriale

Energy analysis of a thermal solar system for DHW

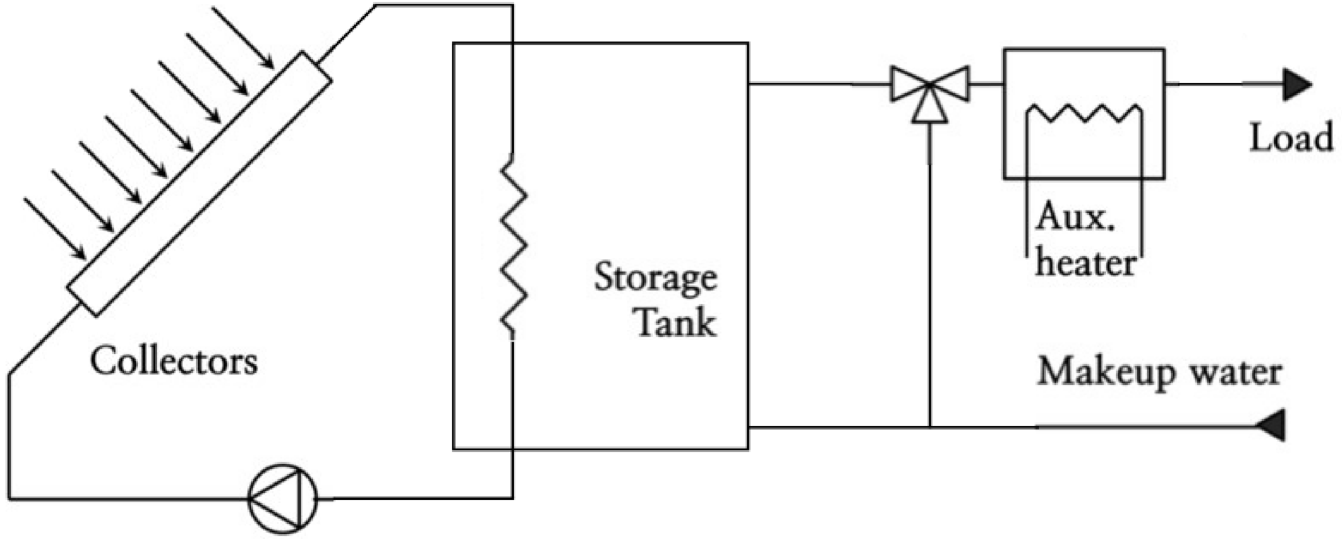
A two-person household in Trento has a flat plate collector installed on a rooftop, with a slope $\beta = 30°$ facing South. The collector has the features summarized in the table below (see also datasheet), and it is fed by an on-off pump, which either provides no mass flow rate (at night, or in those situations in which it could provide no positive power output), or a constant flow rate. The collector is coupled with a storage tank, according to the topology shown in the picture below.

Collector data

Active area	2.14 m^2
Flow rate	64.2 l/h
Efficiency params.	$\eta_0 = 0.802$ $U = 4.3$ W/(m^2 K)

DHW circuit data

Tank volume	200 kg
Tank loss coeffic.	2.5 W/K
Heat exchanger effectiveness, ε	0.6
Room temp (cellar)	18 °C



The tank is installed in a cellar, with an external ambient temperature that stays roughly constant over the year.
The collector circuit is a closed circuit, and it comprises a heat exchanging serpentine immersed into the tank. Water from the mains is fed directly into the tank, and domestic hot water (DHW) is directly extracted from the tank. The water from the tank is cooled down to the user desired temperature with a three-way valve or heated up with an auxiliary heater.
We assume that the volume of water in the tank stays constant, i.e., whenever water is extracted from the tank, an equal volume is fed back in from the mains.

Static analysis

- Assuming that the water temperature at the inlet of the collector is constant ($T_{in} = 30\,°\mathrm{C}$), calculate the *total thermal energy yield of the collector*, considering
  - Daily radiation profiles on the collector, for the reference location and the reference collector slope
  - Ambient temperature variations during the typical day of a month (note that the collector is installed outside, i.e., it subject to the external ambient temperature)
  - The average behaviour of the collector in a month is represented by the response in the 15th day of the month
  - Use numerical data from class 17 on PV systems simulation

Dynamic analysis

We now focus on the dynamic behaviour of the system in a couple of relevant prototypical days of the year (e.g., 15 January and 15 June), for which know profiles of the thermal power consumptions are given (see Matlab files). Thermal consumption profiles are provided in the form of time-series of the DHW flow rates and temperatures, for the two target days.

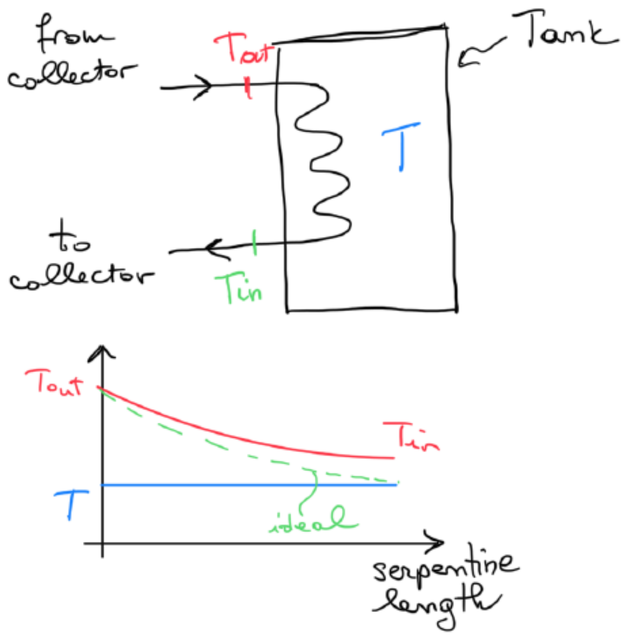
- Develop a *Simulink model of the system dynamics* (collector + tank + loads), which takes the solar radiation, ambient temperature profile, and consumption profiles as inputs, and calculates the time-series of the tank temperature (including the steady-state value at the beginning/end of the day), the inlet and outlet water temperatures of the collector, the profiles of the flow-rate in the collector, and the power supplied by the auxiliary heater. Assume that the mains water temperature is 12 °C in winter and 16 °C in summer.
- Use the dynamic model to determine what shares of the thermal energy demand are respectively covered by the solar collector and the heater in the two days.
- Perform a sensitivity analysis of the system behaviour (temperature profiles, consumptions, etc.) with respect to the tank volume, the external ambient temperature, and the heat exchanger effectiveness factor.

For the simulations, assume a reasonable initial value of the tank temperature (e.g., $30\,°\mathrm{C}$), and run a simulation on a timespan of a few days (assume all days identical to each other), until you find a periodic steady-state solution for the different profiles.

Make reasonable assumptions for all missing data.

Heat exchanger effectiveness

The effectiveness ε of a heat exchanger (involving two fluid streams) is a measure of how much power the device can exchange, compared to an ideal case, in which the minimum temperature difference between the 2 fluid streams becomes zero.



$$\varepsilon = \frac{\dot{Q}}{\dot{Q}_{ideal}} = \frac{\dot{m}c(T_{out} - T_{in})}{\dot{m}c(T_{out} - T)} = \frac{T_{out} - T_{in}}{T_{out} - T}$$