

Part 1

Exercise 1 of 2

Consider a greenhouse composed by two independent adjacent sectors, as reported by the plant below.



The walls, including the separation between the two modules, are made of glass, and their thermal transmittance<sup>1</sup> is the one defined by a single glazing:  $5.7 \text{ W}/(\text{m}^2 \cdot \text{K})$ . As a simplifying approach consider the greenhouse empty and perfectly insulated with the soil.

- 1) Taking into account the “cooling cheese” exercise defined in class, define a simplified model to evaluate the evolution of the temperature in the next 24 hours taking into account:
  - a. The forecasted external temperature as available for weather forecast site for Genova
  - b. The forecasted sun radiation. This aspect has not been modelled in the “cooling cheese” problem. In this case, as simplifying hypothesis, we suppose that the sun radiation is just entering by the flat roof, also made by glass, at 95% (while the rest is reflected).
- 2) Verify the model copying forecasted values for 24 hours for temperature and sun radiation from a web site (for example <https://it.tutempo.net/>, <https://it.tutempo.net/genova.html?dati=allora>)
- 3) Suppose now to have one heat pump for each module. In the first module the heat pump has a maximum electric power of 10kW and 10kW in the second one (please verify on the web or by AI tools how to transform it in thermal power by proper COP). Suppose also to be able to perfectly measure the temperature in the second module. Define control laws in discrete time (on samples of 1 s) for the two heat pumps based on:
  - a. Relay
  - b. PID

and evaluate them according to their ability to track the following temperatures (row 1 h of the day, row 2 desired T in °C in module 1, row 3 desired T in °C in module 2 (13 °C in the rest of the day for both greenhouses):

10	11	12	13	14	15	16	17	18	19	20	21
25	25	30	30	30	30	30	30	24	23	22	22
18	18	25	25	25	23	24	24	18	18	15	14

- 4) Evaluate the two methods taking into account separately, for each module:
  - a. the quadratic deviation from the desired temperature over one day
  - b. the power consumed by the heat pumps over one day

<sup>1</sup> [https://en.wikipedia.org/wiki/Thermal\\_transmittance](https://en.wikipedia.org/wiki/Thermal_transmittance)