Thermal Performance Function

Let T_t be the representative temperature at timestep t and let N be the total number of timesteps in the episode. We define three out-of-comfort zones:

$$\text{zone}(t) = \begin{cases} 1, & 27.0 < T_t \leq 27.7℃ \\ 2, & 27.7 < T_t \leq 28.5℃ \\ 3, & T_t > 28.5℃ \end{cases}$$

The fractions of time spent in each zone are:

$$f_k = \frac{1}{N} \sum_{t=1}^{N} \mathbf{1}[\text{zone}(t) = k], \qquad k \in \{1, 2, 3\}.$$

The fraction of time within the ASHRAE comfort range $[18, 27]$ is:

$$C = f_0 = 1 - \sum_{k=1}^{3} f_k.$$

The weighted severity of out-of-comfort exposure is:

$$S_{\text{zone}} = w_1 f_1 + w_2 f_2 + w_3 f_3, \qquad w_1 \ll w_2 \ll w_3.$$

Peak temperature penalty (optional). Let

$$T_{\max} = \max_t T_t, \qquad o_{\max} = \max(0,\, T_{\max} - 27.0),$$

and

$$P_{\text{peak}} = \exp(\lambda o_{\max}) - 1.$$

Thermal performance objective. The thermal objective maximized during ES training is:

$$F_{\text{temp}} = C - \alpha S_{\text{zone}}$$

and, if post-training analysis reveals temperature spikes,

$$F_{\text{temp}} = C - \alpha S_{\text{zone}} - \beta P_{\text{peak}}.$$

Energy Performance Considerations

With variable GPU loads, simple energy averaging metrics can be misleading. We analyze several alternatives.

Naive Metrics (to avoid).

Simple average (non-robust).

$$\bar{E} = \frac{1}{N} \sum_{t=1}^{N} E_t$$

Issue: An episode with 1 hour of idle GPUs and 1 hour at full load will have a very different $\bar{E}$ than one with 2 hours at medium load, even with identical HVAC efficiency.
Total sum (horizon-dependent).

$$E_{\text{total}} = \sum_{t=1}^{N} E_t$$

Issue: Longer episodes always have larger E_{total}, even if more efficient.

Our Energy Performance Function. Let $E_{\text{HVAC}}(t)$ denote the total HVAC energy consumption at timestep t, and $Q_{\text{load}}(t)$ the total thermal load imposed on the system (including IT equipment, occupancy, and external gains).
Energy Efficiency Ratio. We define the episode-level Energy Efficiency Ratio (EER) as:

$$\text{EER} = \frac{\sum_{t=1}^{N} Q_{\text{load}}(t)}{\sum_{t=1}^{N} E_{\text{HVAC}}(t)}.$$

A higher EER corresponds to higher energy efficiency, analogous to the classical Coefficient of Performance (COP). The ratio is invariant to episode length and naturally accounts for temporal variations in thermal load intensity.
Energy performance objective. Since Evolution Strategies maximize the fitness, we define:

$$F_{\text{energy}} = \text{EER}.$$

Combined Fitness Function

The total fitness function optimized by Evolution Strategies is:

$$F_{\text{total}} = \gamma_T \, F_{\text{temp}} + \gamma_E \, F_{\text{energy}},$$

where $\gamma_T, \gamma_E > 0$ control the relative importance of thermal comfort and energy efficiency.