Improving Worst-Case Representative Day Clustering

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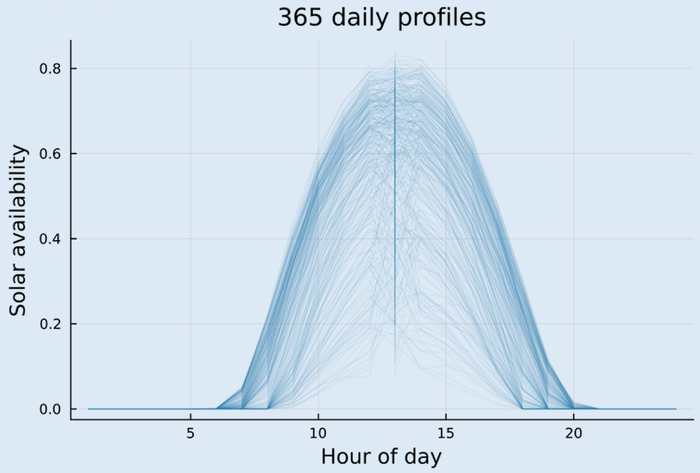
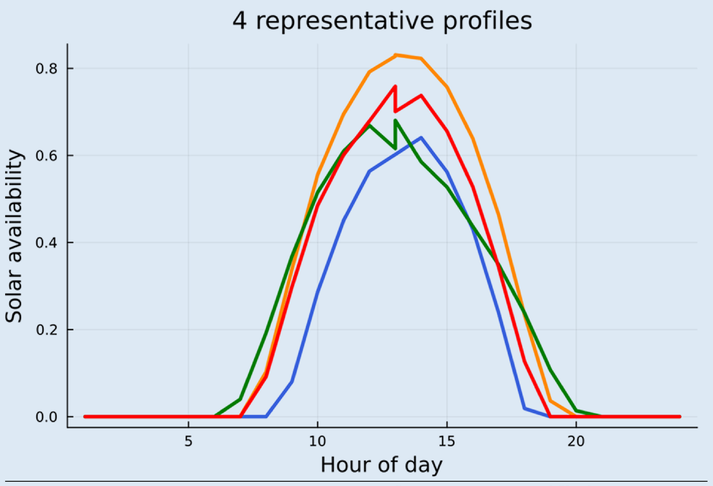
1. Background

Energy system optimization models are created in order to find an optimal investment and operation plan for the energy infrastructure.
Problem: they are computationally intractable for the full model.



Research found that clustering methods are effective in reducing the computational complexity of the model.



Problem: the current state-of-the-art artificial worst-case clustering provides an upper-bound to the total cost that is too high. In the real world, this can mean billions of euros!

2. Research Question

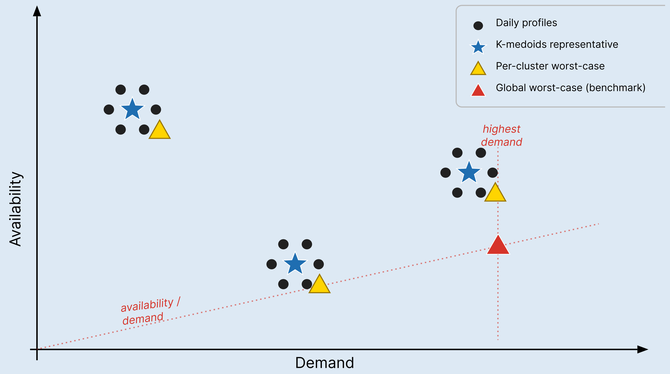
"How can we add an artificial worst-case representative day **after** existing clustering methods, and how does this affect performance?"

3. Methodology

Test appending strategies against synthetic 3-year data:

- No injection: normal k-medoids
- Global benchmark*: 1 worst-case for year
- Per-cluster reassign: 1 worst-case, reassign closest periods
- Per-cluster split*: 1 worst-case per cluster
- Selective per-cluster*: 1 worst-case in extreme clusters

* f = % weight assigned per representative



Evaluation metrics:

- Regret → important because it shows how much more expensive a solution is
- Loss-of-Load(LoL) → important because it shows if the system underinvests (high) or overinvests (low)

Aggregated path

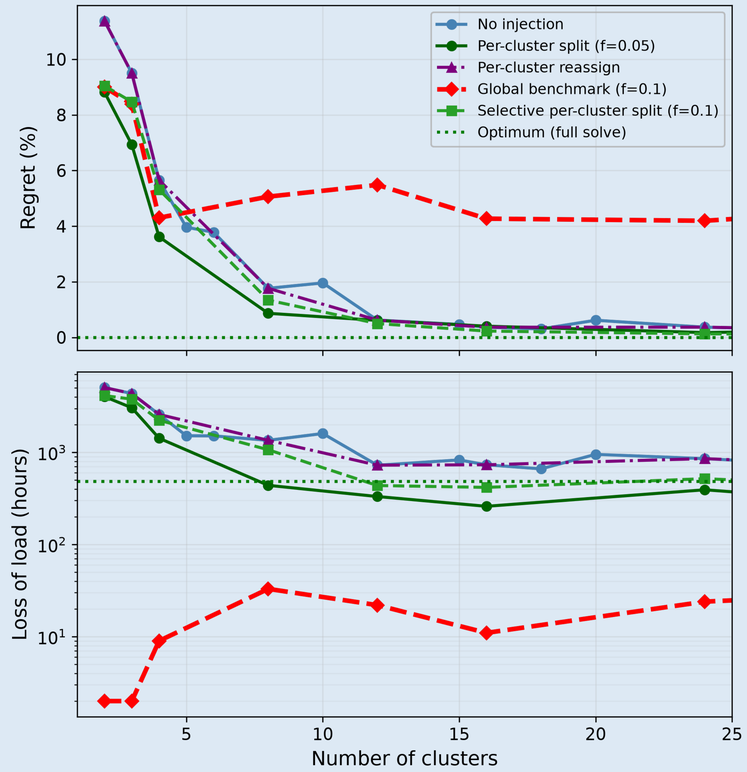
Energy model (reduced res.) → C^{inv}_{agg} → Investment (decisions fixed) → Operational (full res.) → C^{op}_{full} → $C^{inv}_{agg} + C^{op}_{full}$

Benchmark

Energy model (full res.) → C^{full} (optimal cost)

$$\textbf{Relative regret (\%)} = \frac{C^{inv}_{agg} + C^{op}_{full} - C^{full}}{C^{full}} \times 100$$

4. Experiment Results



Regret (top): Split methods beat the benchmark and the no injection baseline and converge to the optimum; benchmark stays at 4-5%.

Loss-of-load (bottom): Split methods reach the full-solve value; Selective lands on it. Global over-invests, no injection under-invests.

5. Key insights

Per-cluster split:

- **Outperforms the benchmark in regret at every cluster count**
- **Achieves a LoL value close to full-solve**

Selective per-cluster split:

- **Lands on the loss-of-load full-solve line**
- **Trades quicker solve for slightly higher regret**

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