START-UP AND SHUT-DOWN COSTS IN GEP MODELS WITH A FULLY FLEXIBLE TEMPORAL RESOLUTION

TU Delft

Responsible professor:
German Morales-España

By: Uroš Gluščević
U.Gluscevic@student.tudelft.nl

Supervisor:
Maaike Elgersma

1. Background

Generation Expansion Planning models:

- find optimal investment plans for expanding energy systems
- to reduce computation time, they often sacrifice accuracy, by:
  - ignoring start-up and shut-down costs of thermal generators
  - lowering the temporal resolution (using larger timesteps)

Fully flexible temporal resolution (Fig 1)**:**

- allows less relevant information (for example, more distant countries) to be modelled with a lower resolution
- this can decrease computation time, while maintaining accuracy [1]

Tulipa energy model:

- GEP model with fully flexible temporal resolutions
- without start-up and shut-down costs

[1] Zhi Gao et al. Fully Flexible Temporal Resolution for Energy System Optimization. en. Nov. 2025. doi: 10.2139/ssrn.5214263.

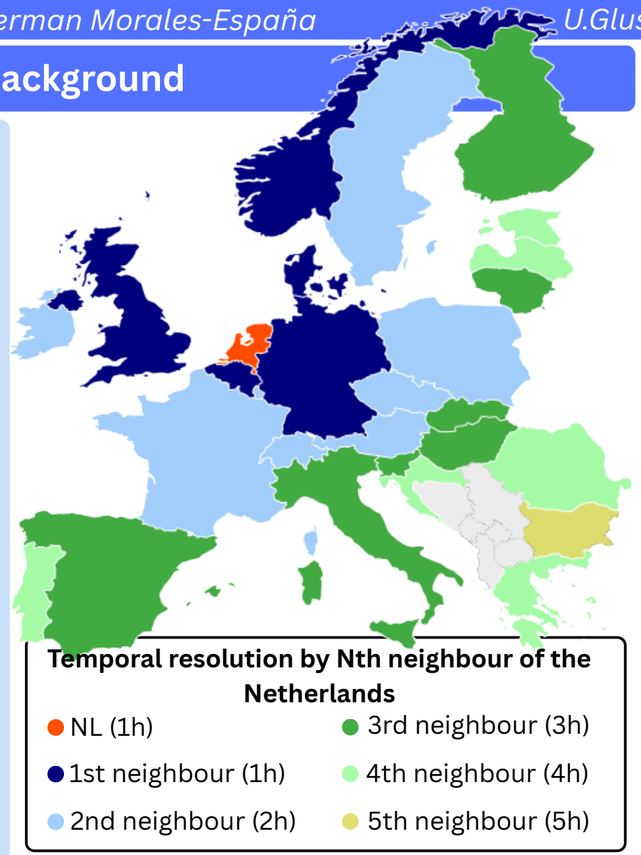


Figure 1: Example of a fully flexible temporal resolution, where countries further from the Netherlands are modelled with less temporal detail

4. Results

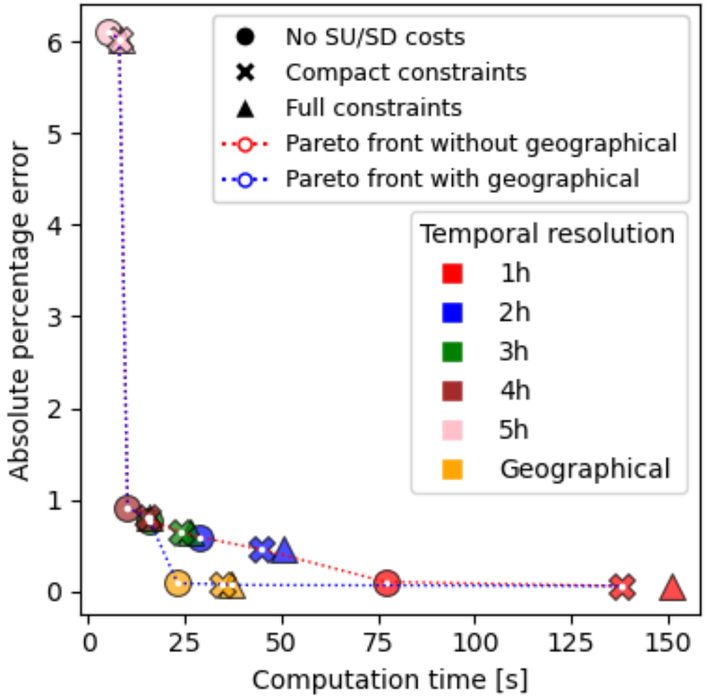


Figure 2: Trade-off between model runtime and error for the Dutch energy system compared to an hourly resolution with start-up and shut-down costs

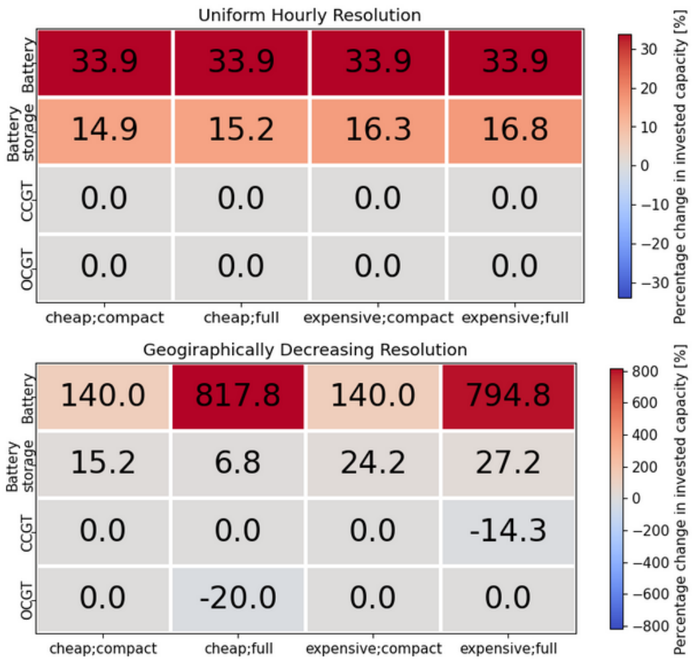
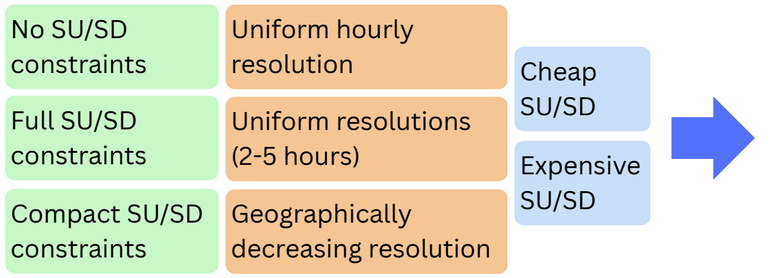


Figure 3: Percentage difference in invested capacity in the Netherlands caused by adding start-up and shut-down costs, for a uniform hourly resolution (top) and the geographically decreasing resolution (bottom)

2. Research Question

How does the addition of generator start-up and shut-down costs affect a GEP model with a fully flexible temporal resolution in terms of computation time, objective function value, and investment plan, compared to uniform temporal resolutions?

3. Experimental Setup



5. Conclusions

Computation time:

- Adding start-up and shut-down costs increases computation time
- Compact constraints perform better than full constraints

Objective function:

- Compact constraints exceed the Pareto front between runtime time and accuracy in the Netherlands
- Geographical resolution has the highest variance in cost

Investment plan:

- More batteries are purchased
- Sensitive to constraint set used