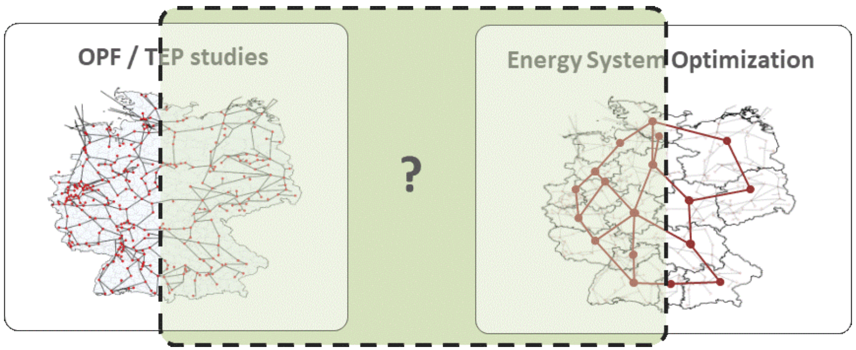
High Performance Computing vs. Heuristic

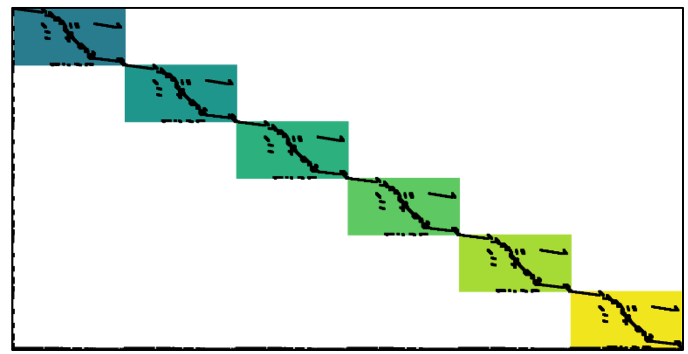
A performance benchmark for optimization problems with linear power flows

by Karl-Kiên Cao & Manuel Wetzel

Background: Solving Energy System Models is associated with high computing times



Methodology: Benchmark analysis of two speed-up approaches based on parallelization

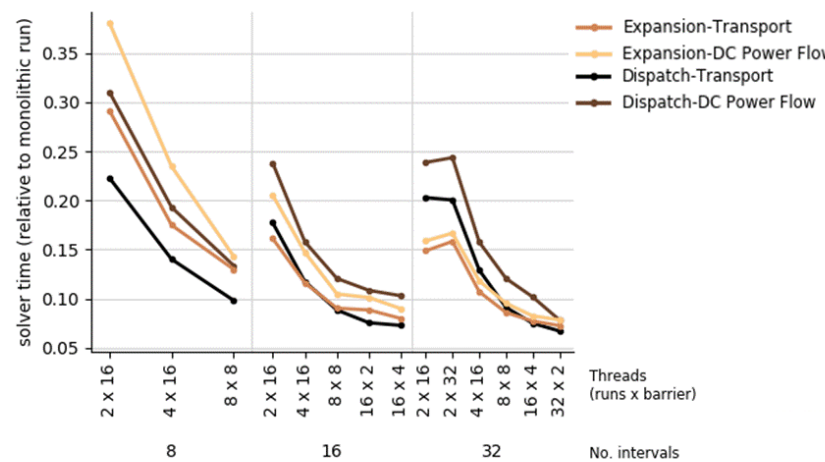


Key results:

- Speed-up factor: 10
- Heuristic outperforms parallel solver for medium-sized models

Outlook

- Benchmarks for large-scale models
- New PIPS-IPM++ version: more stable, MIP



Deutsches Zentrum
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German Aerospace Center

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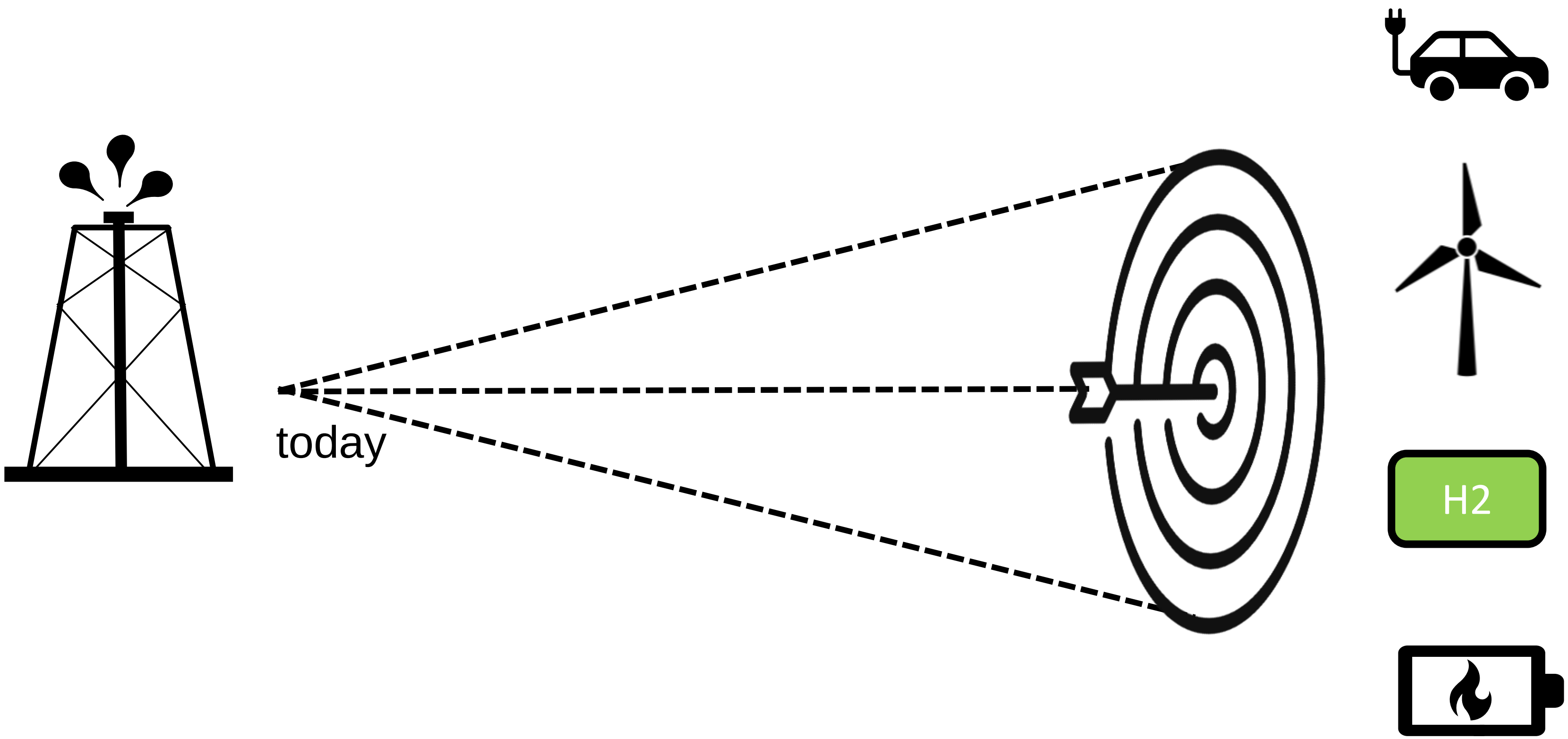
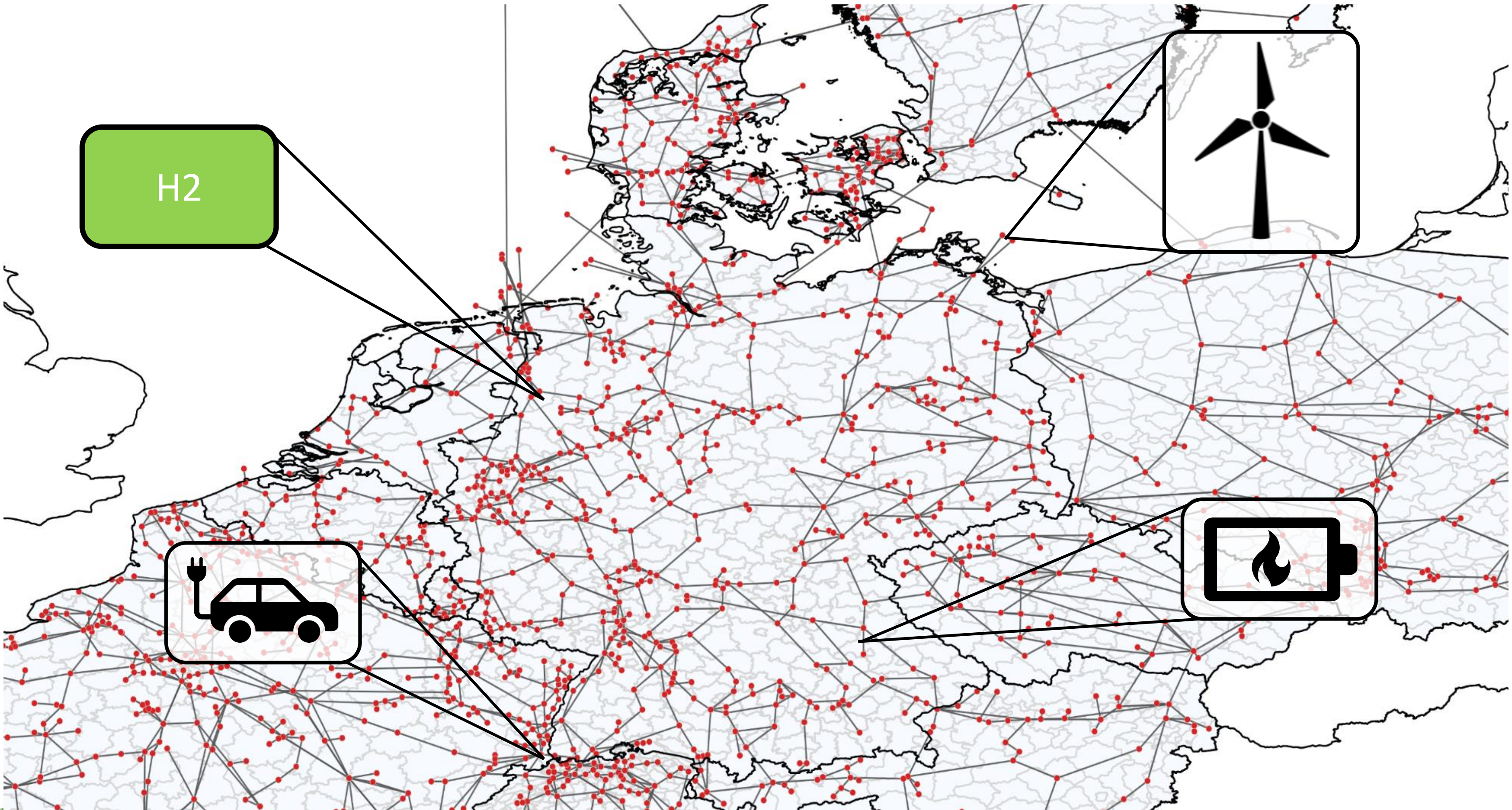
MOTIVATION

Energy System Transition

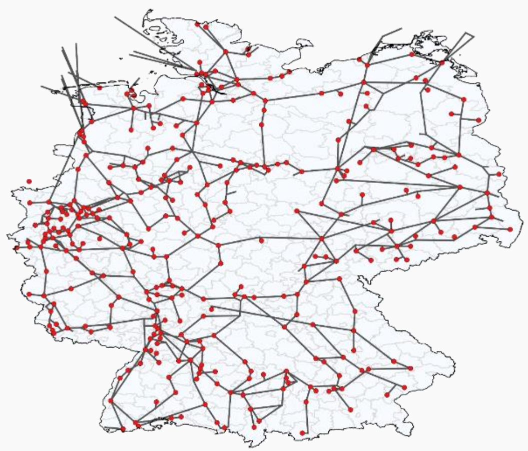


What needs to be modeled

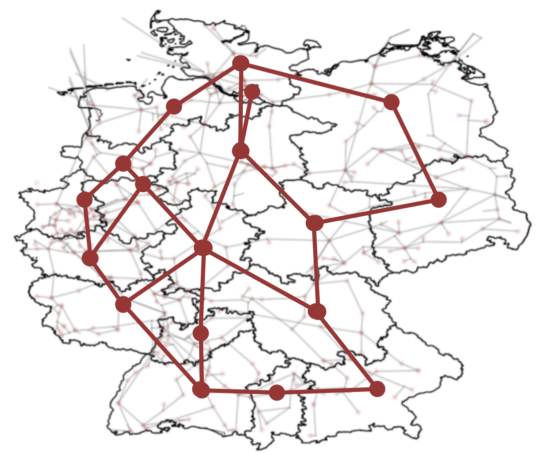


What can be modeled

OPF / TEP studies



Energy System Optimization

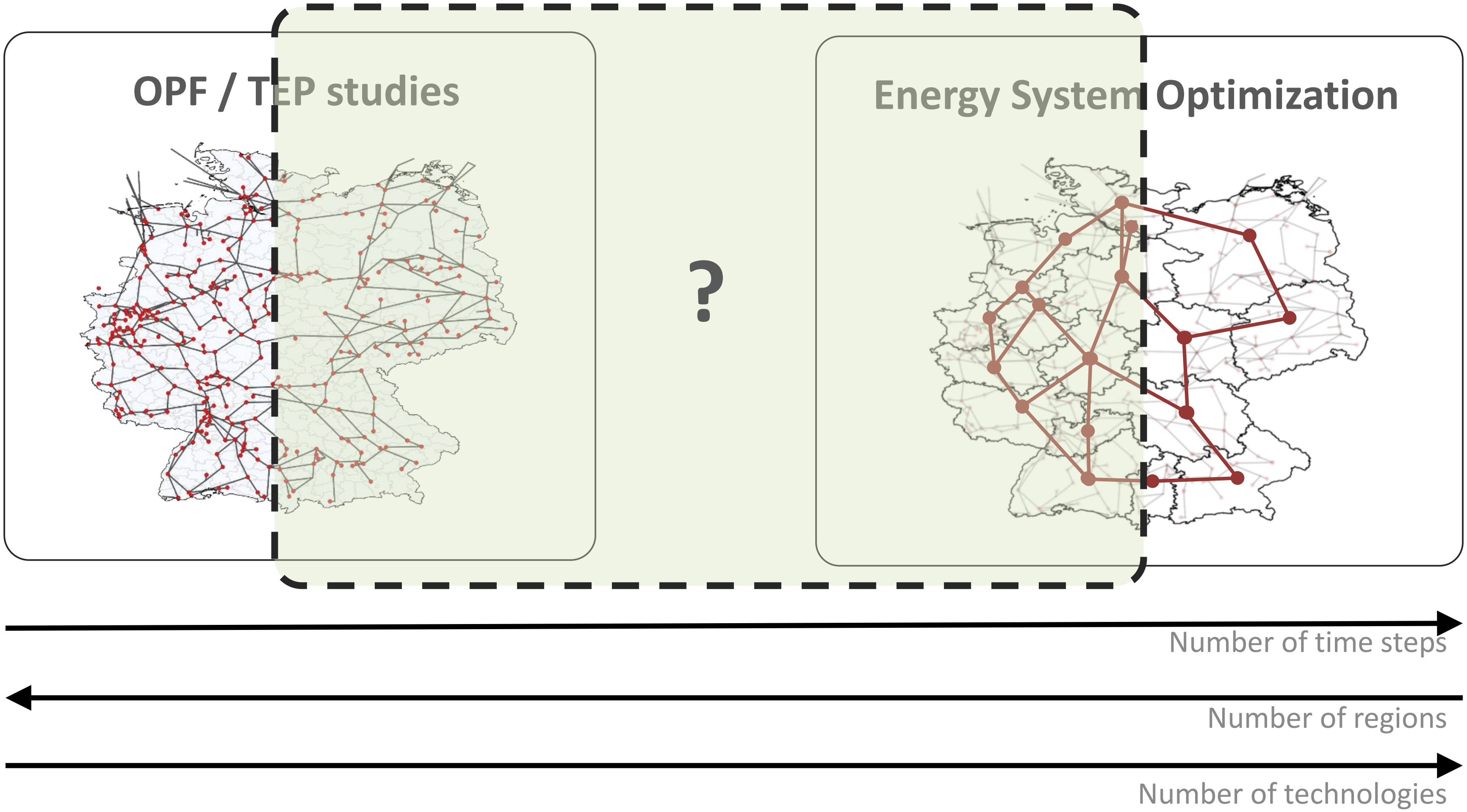


Number of time steps →

← Number of regions

Number of technologies →

What can be modeled



Solving large optimization models

$$\min c^T x$$

$$\text{s.t.}:$$

$$Ax \leq b$$

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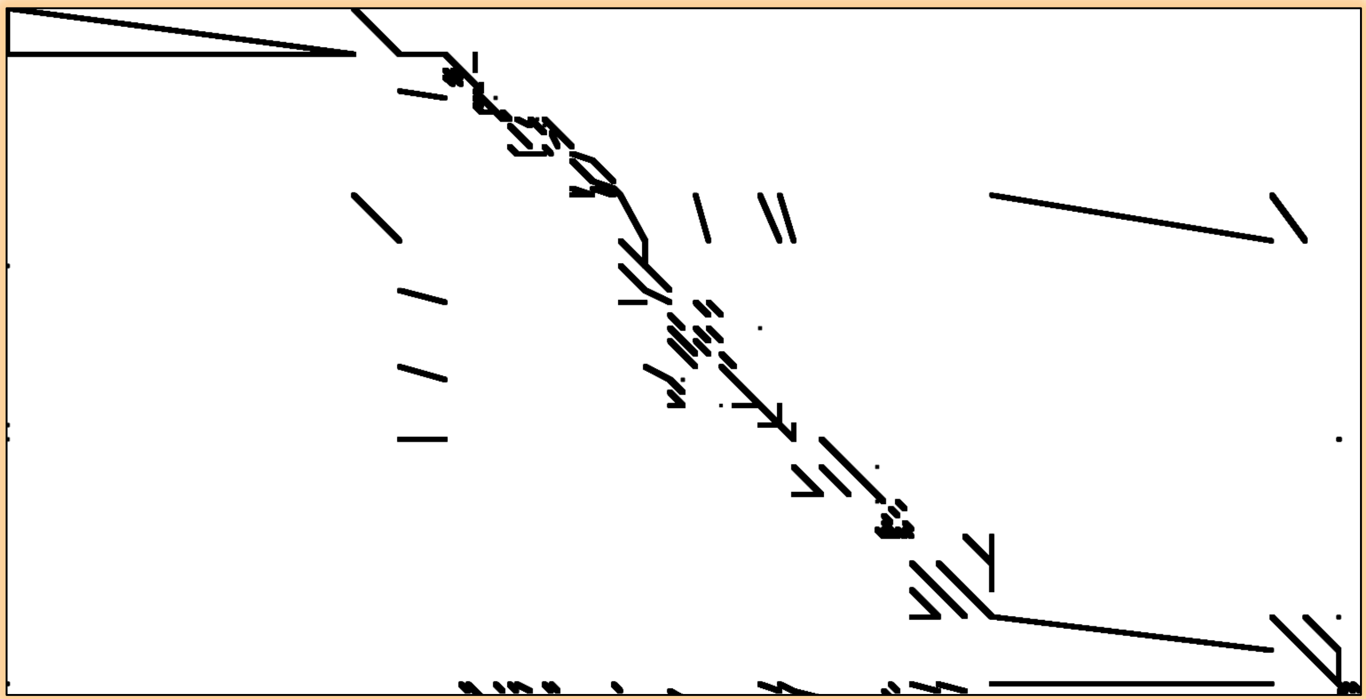

Solving large optimization models

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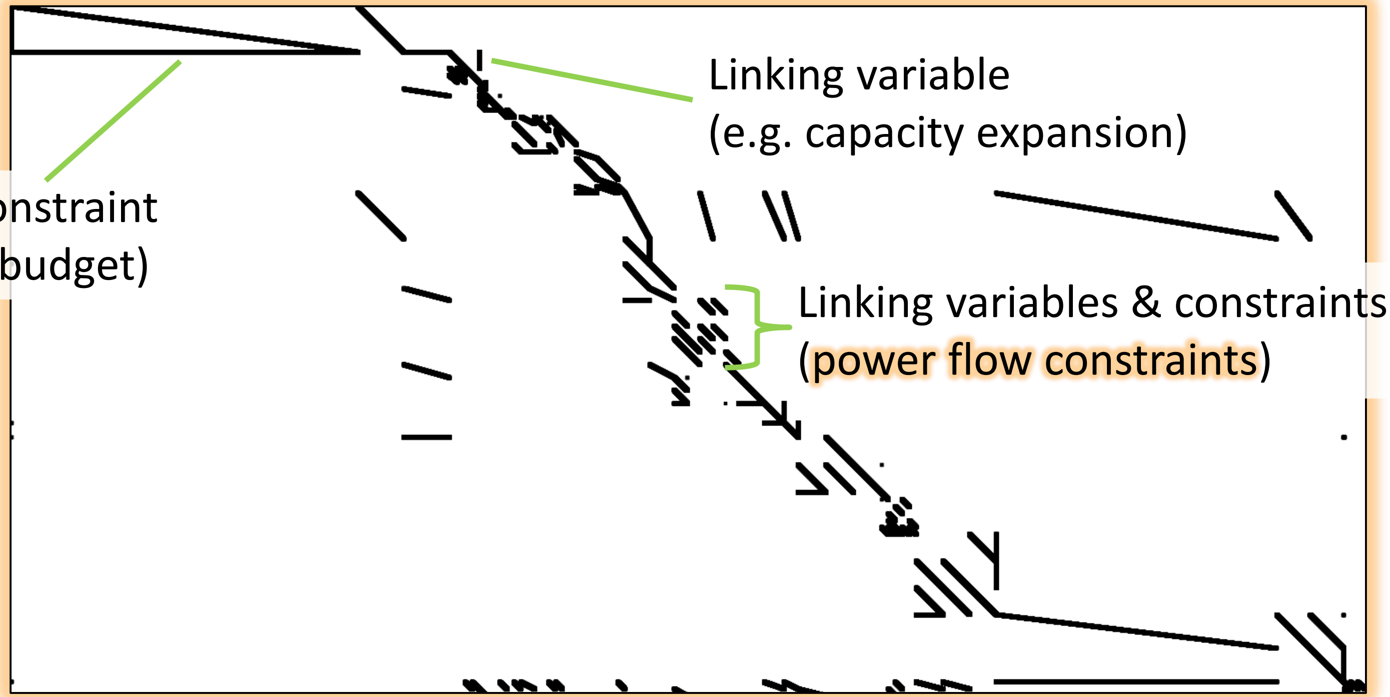

Objective

?

How to deal with
increasing computing times?

!

Speed-up approaches
(parallelization)

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?

How to deal with
increasing computing times?

!

Speed-up approaches
(parallelization)

?

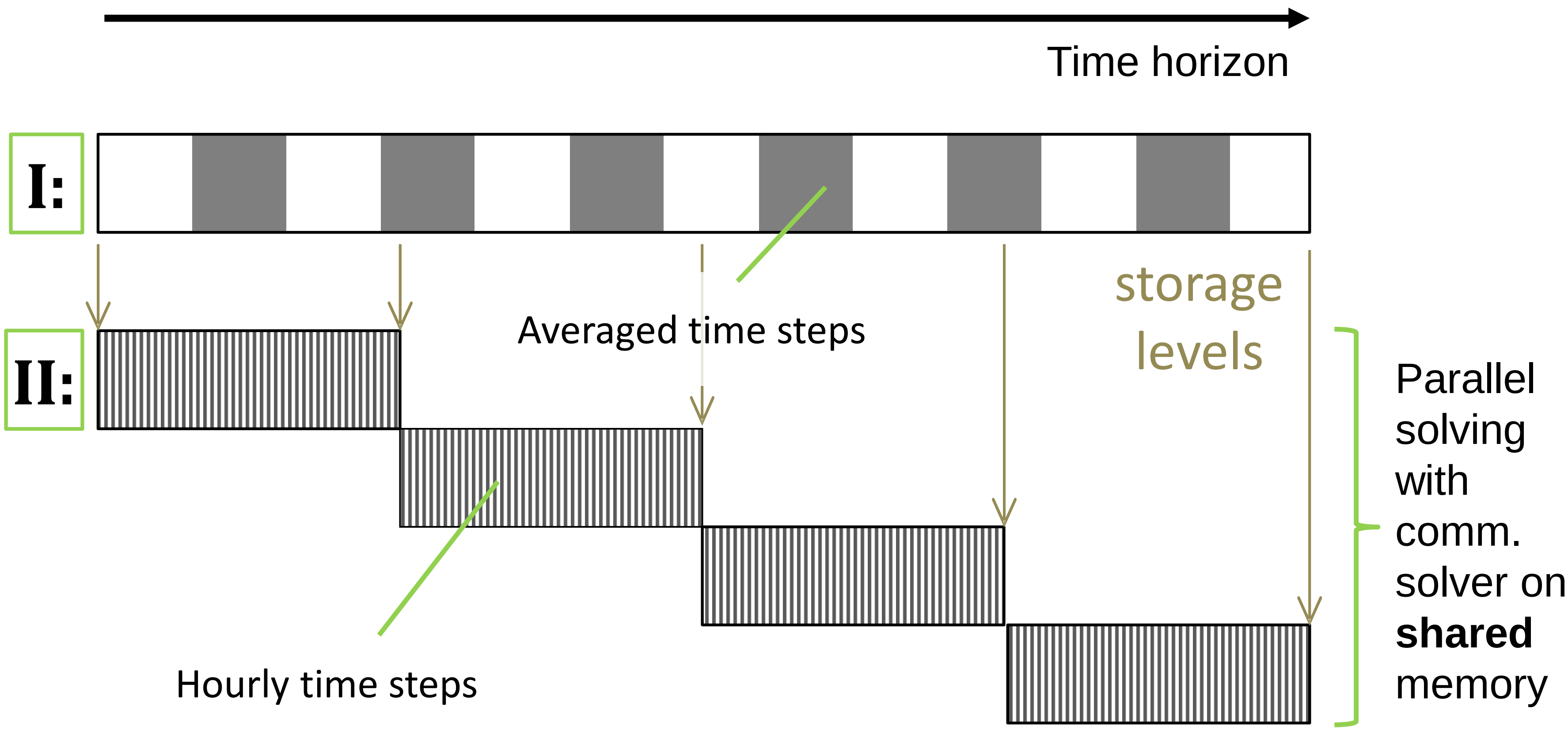
Which approach performs better?
High performance computing
or heuristics ?

METHODOLOGY

Model factsheet

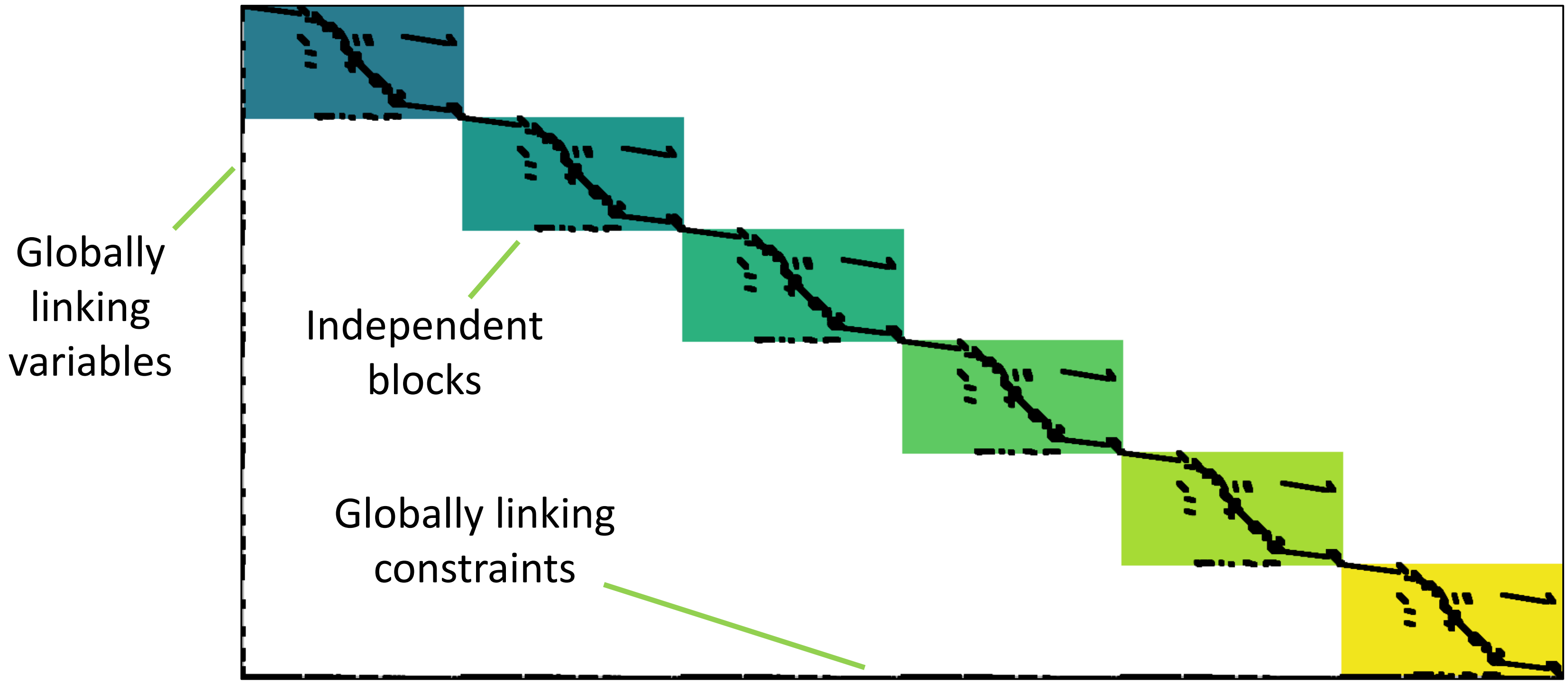
<table>
<tr><td>Model type</td><td colspan="3">Energy System Optimization Model
• Multi-regional Economic Dispatch
• (Transmission and storage expansion planning)</td></tr>
<tr><td>Number of regions (zones)</td><td colspan="3">120</td></tr>
<tr><td>Number of time steps</td><td colspan="3">8760</td></tr>
<tr><td>Scope</td><td colspan="3">Scenario of the German power system</td></tr>
<tr><td rowspan="3">4 Model instances and reference computing times</td><td></td><td>Cap.-constrained transport</td><td>DC power flow</td></tr>
<tr><td>Dispatch</td><td>15 min</td><td>20 min</td></tr>
<tr><td>Expansion</td><td>75 min</td><td>127 min</td></tr>
</table>

Approach I: Heuristics

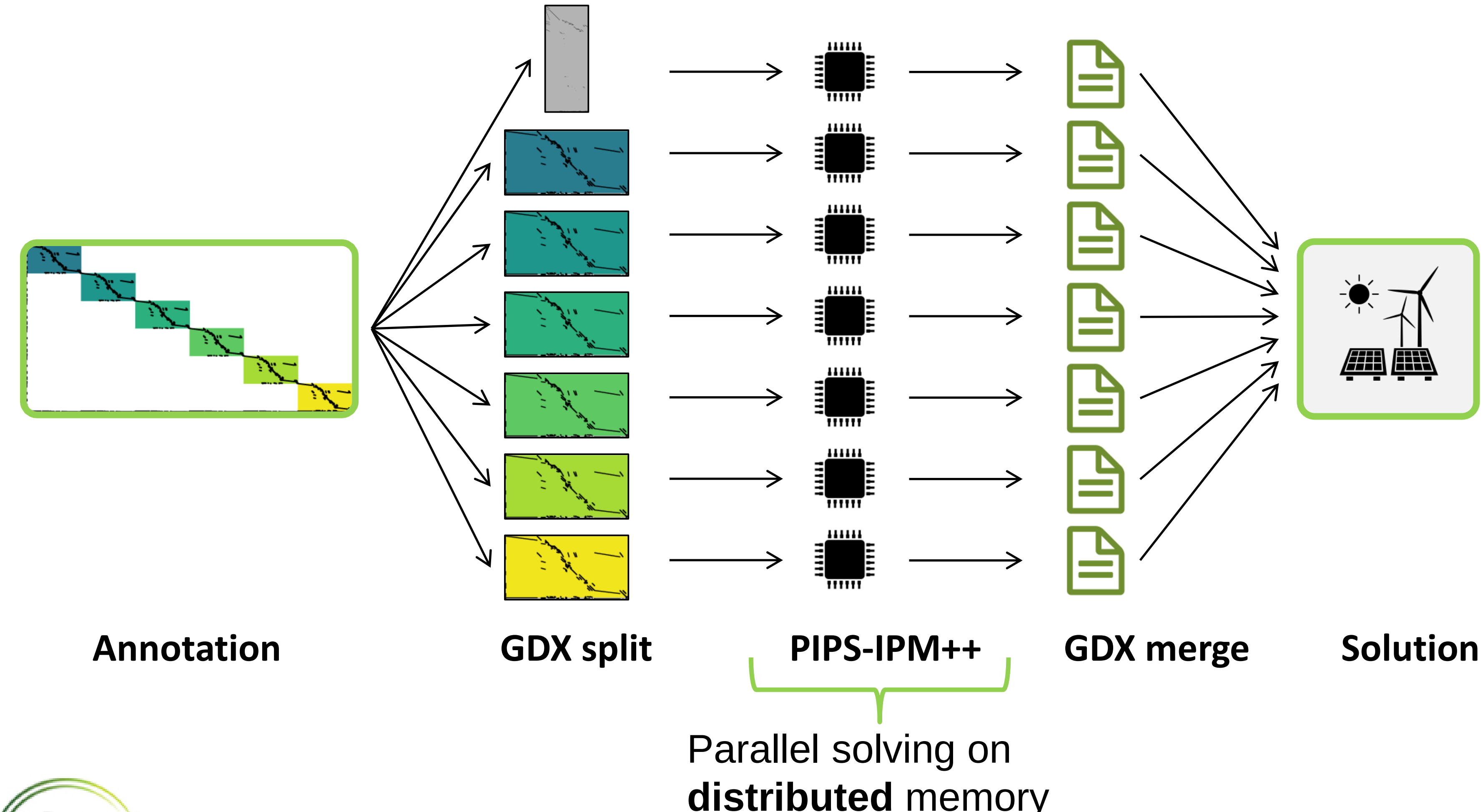


Approach II: PIPS-IPM++

Model annotation

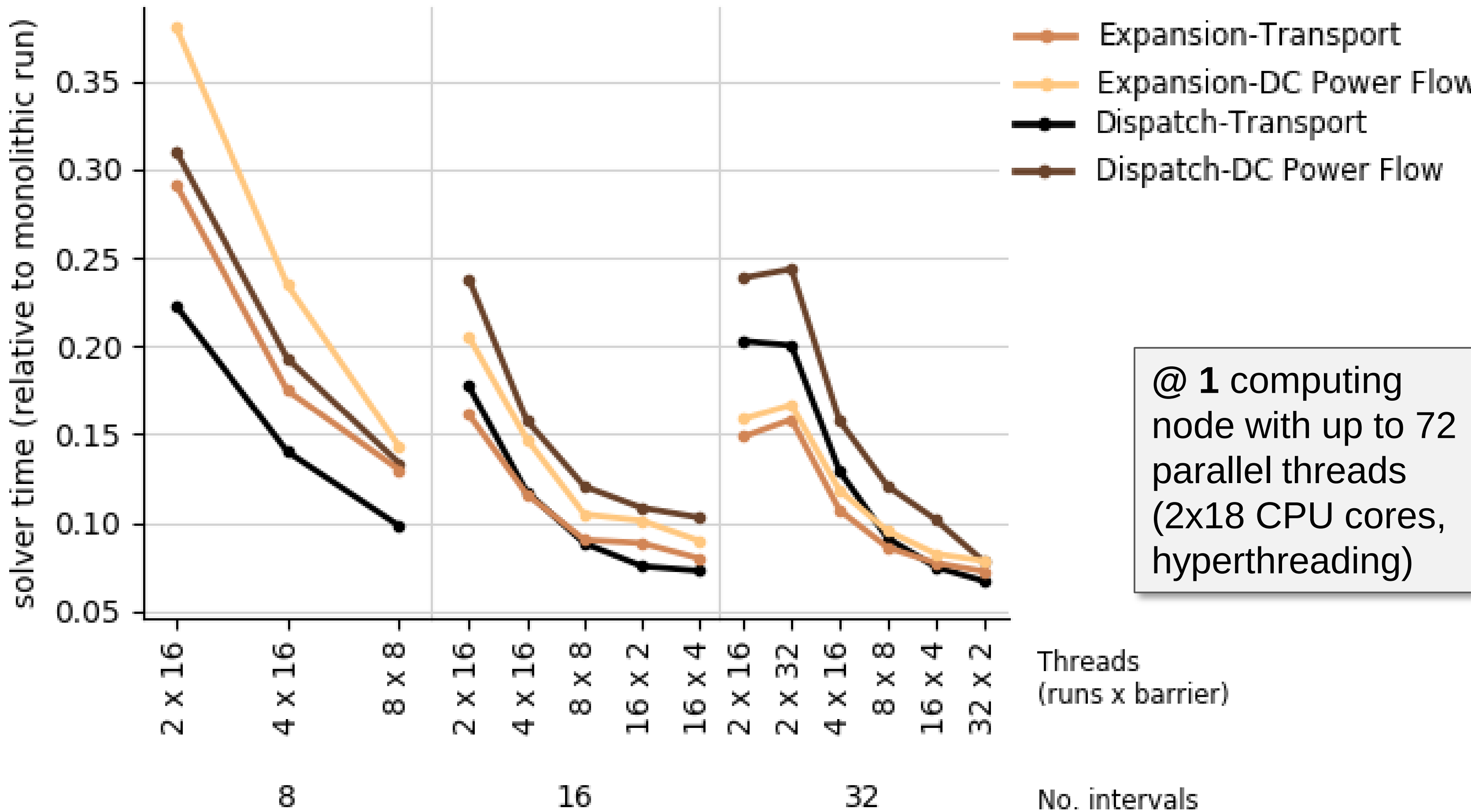


Approach II: PIPS-IPM++



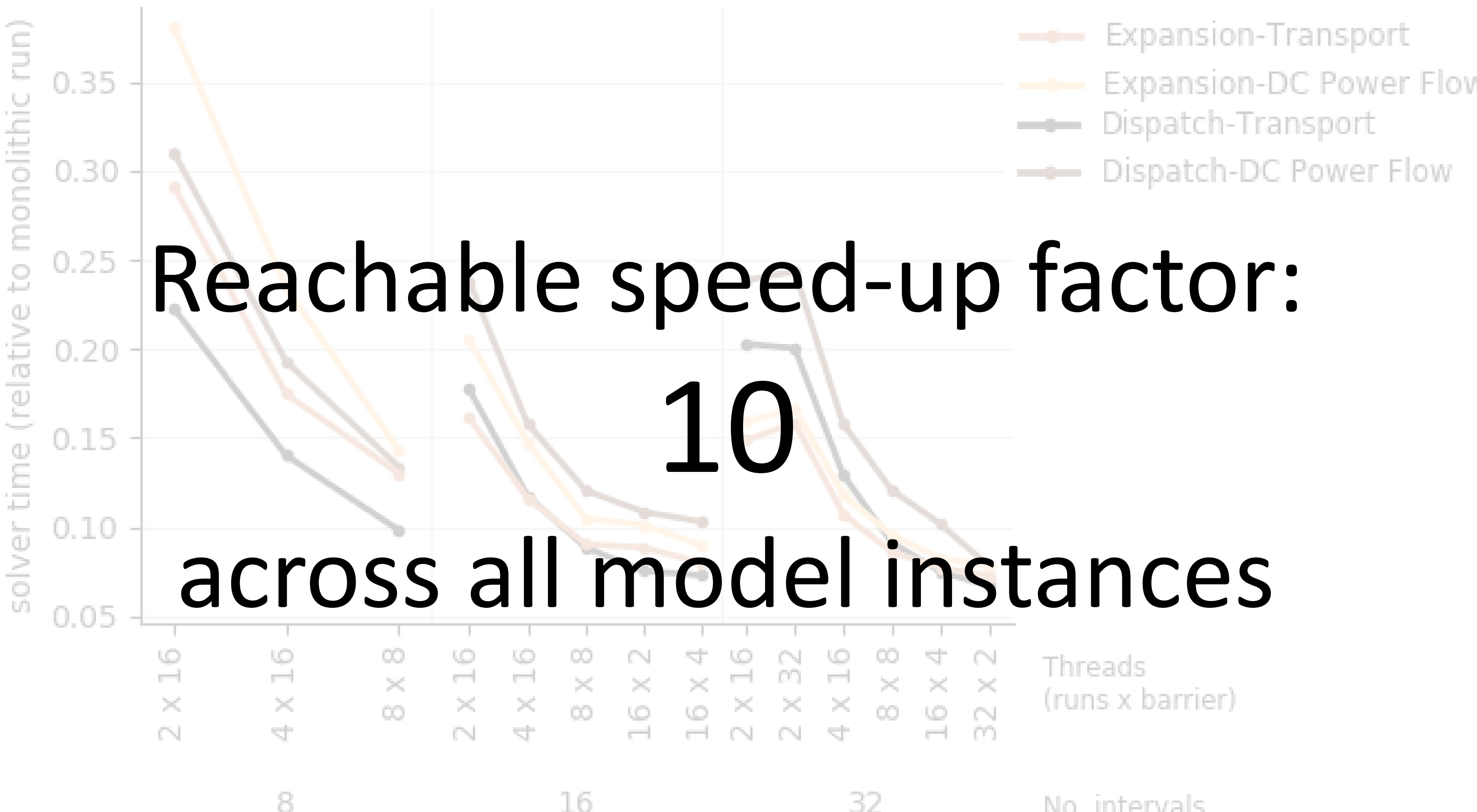
RESULTS

Heuristics



@ **1** computing node with up to 72 parallel threads (2x18 CPU cores, hyperthreading)

Heuristics

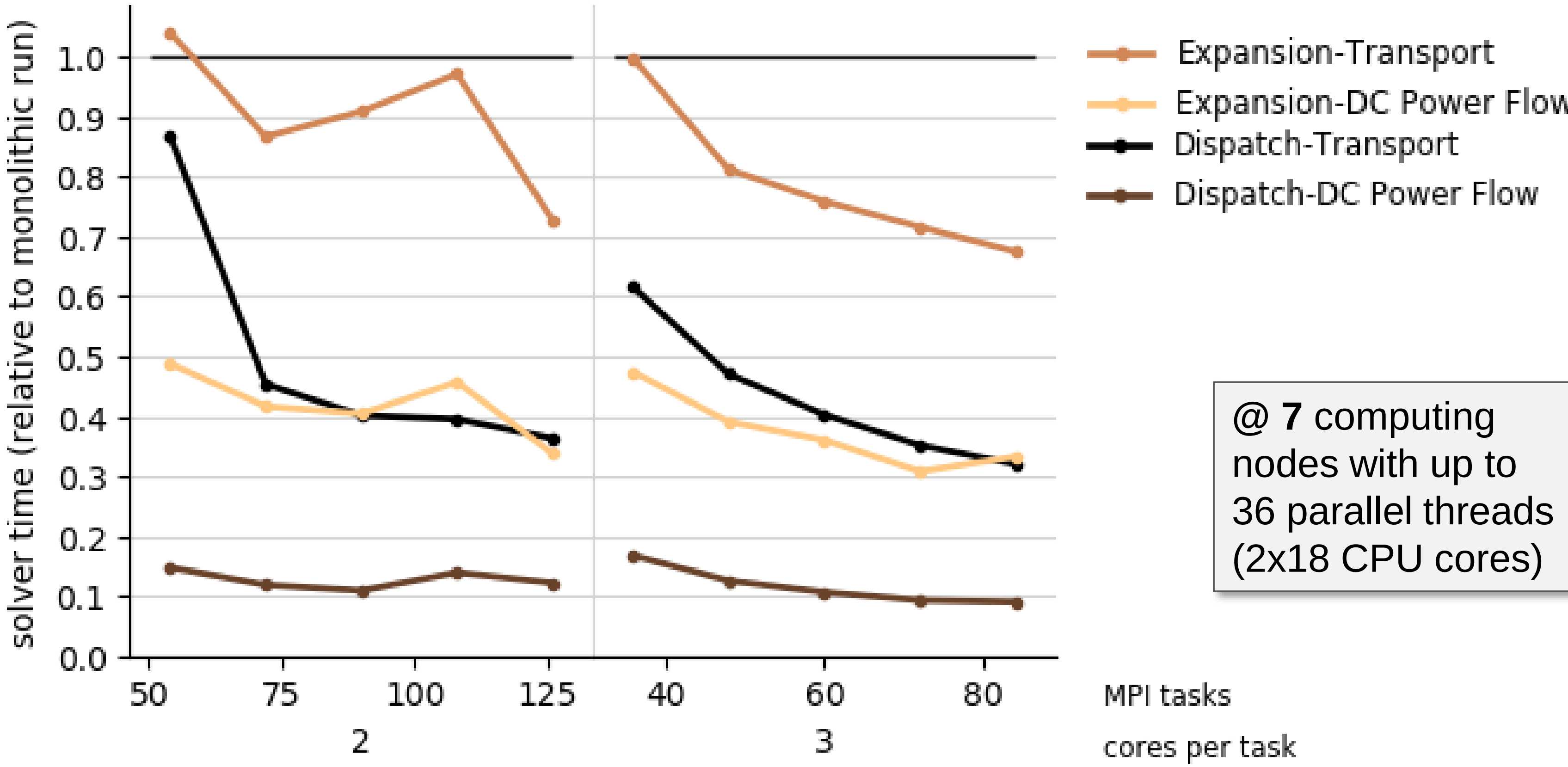


Reachable speed-up factor:

10

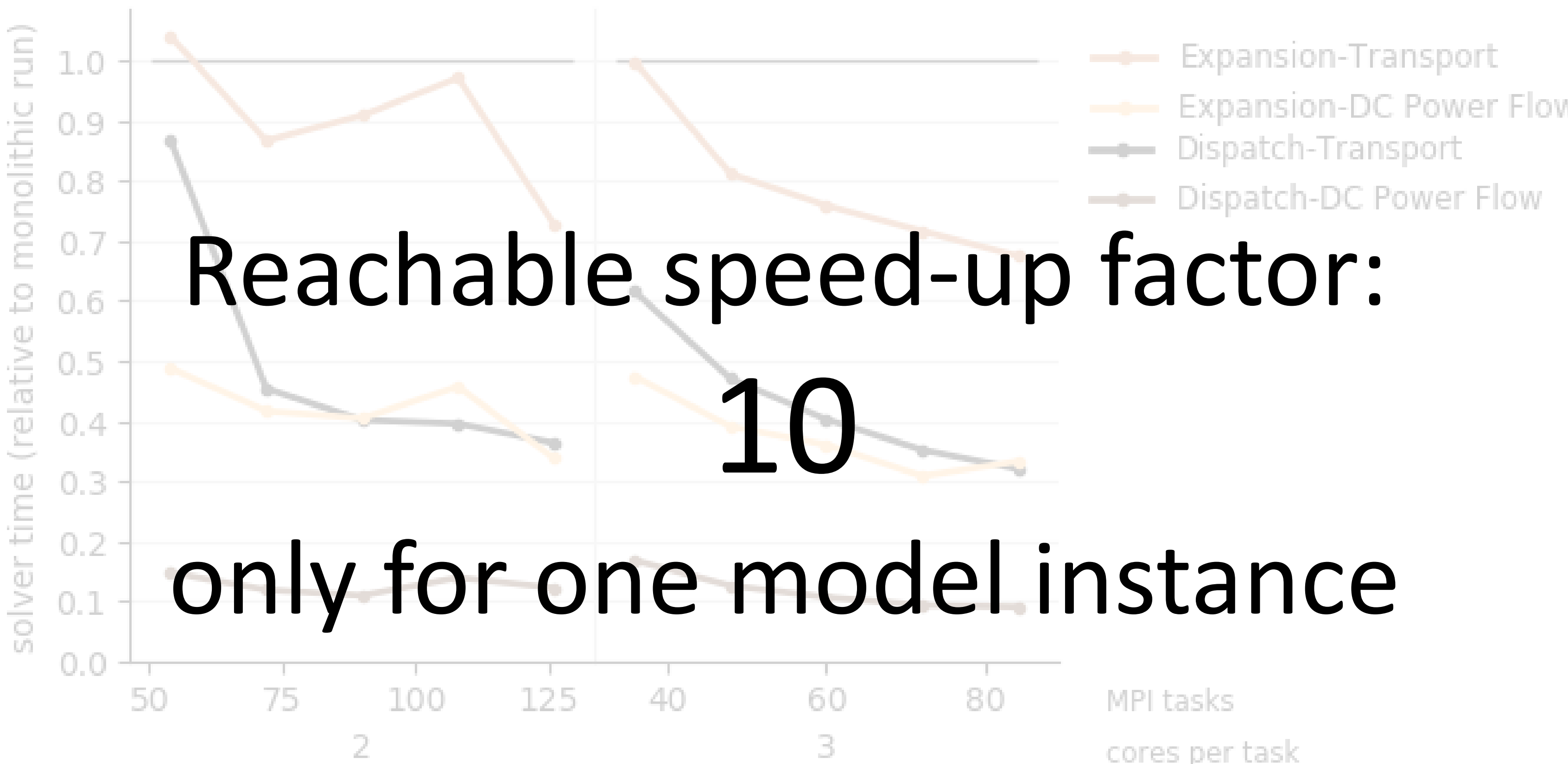
across all model instances

PIPS-IPM++



@ **7** computing nodes with up to 36 parallel threads (2x18 CPU cores)

PIPS-IPM++



Reachable speed-up factor:

10

only for one model instance

CONCLUSIONS

Discussion

- Heuristic beat PIPS-IPM++
  - Faster and more stable across model instances
- But
  - Accuracy loss: up to 3% deviation of objective value
  - Intermediate-sized model (reference computing times <24h)
  - Memory may become also a bottleneck

Conclusion & Outlook

- Energy Systeme Optimization: more complex and thus computational heavy
- 2 approaches exploiting parallelization
- Observed speed-up: 10
- More stable versions of PIPS-IPM++
  - Large models: >48 h reference computing time
  - + Neural Networks → Mixed Integer Programs

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THANK YOU!