Pushing Computational Boundaries: Solving Integrated Investment Planning Problems for Large-scale Energy Systems with PIPS-IPM++

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Energy Systems Analysis

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Motivation

Motivation: Energy System Optimization Models

Purpose

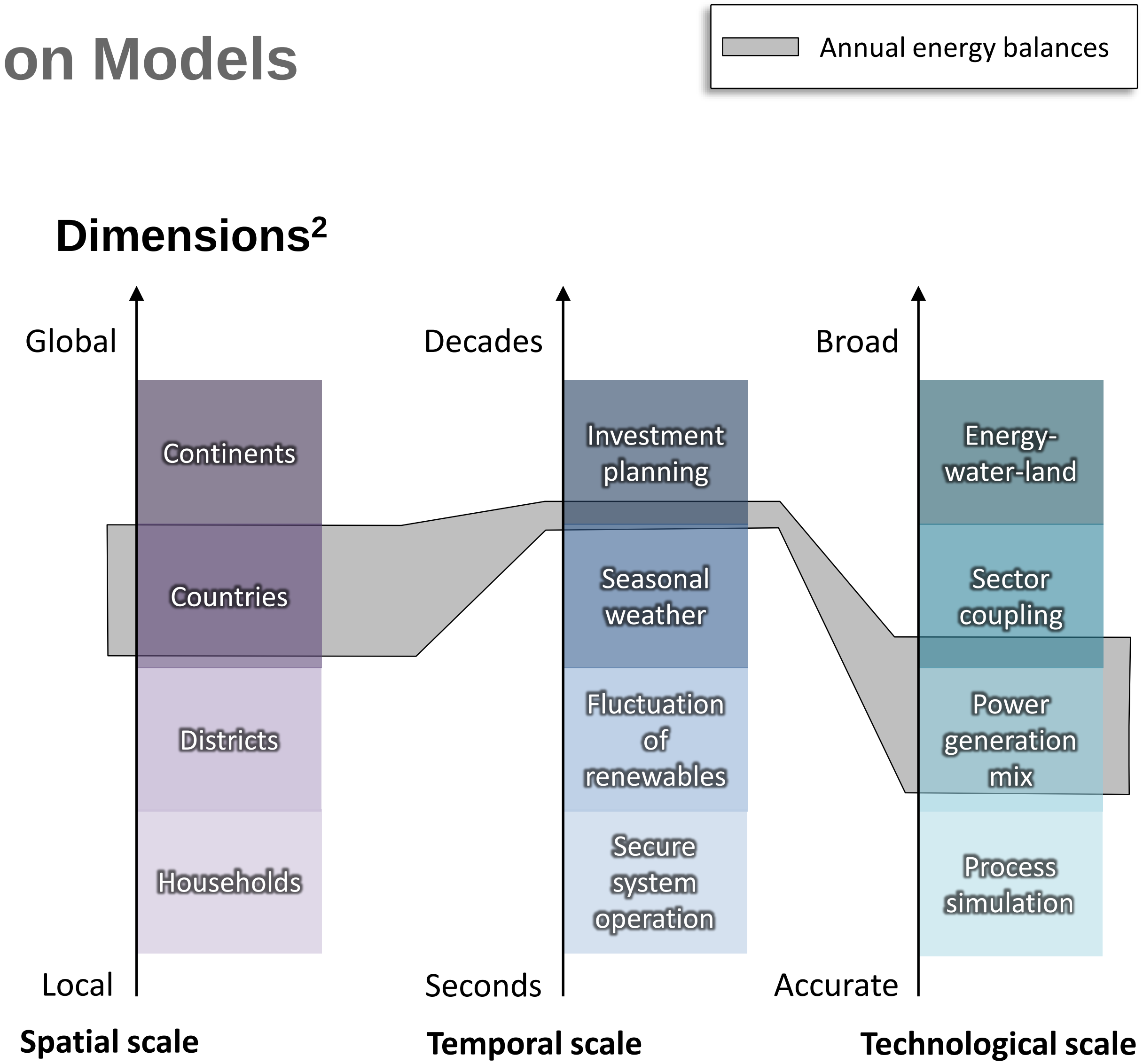
Future insights on

- supply and demand of energy
- infrastructure and investment needs
- feasibility

Trends[1]

- Addressing uncertainty and transparency
- Addressing the growing system complexity
- Increasing resolutions and scope

Dimensions[2]



1: According to: Pfenninger, S., Hawkes, A., & Keirstead, J. (2014). Energy systems modeling for twenty-first century energy challenges. Renewable and Sustainable Energy Reviews, 33, 74-86.
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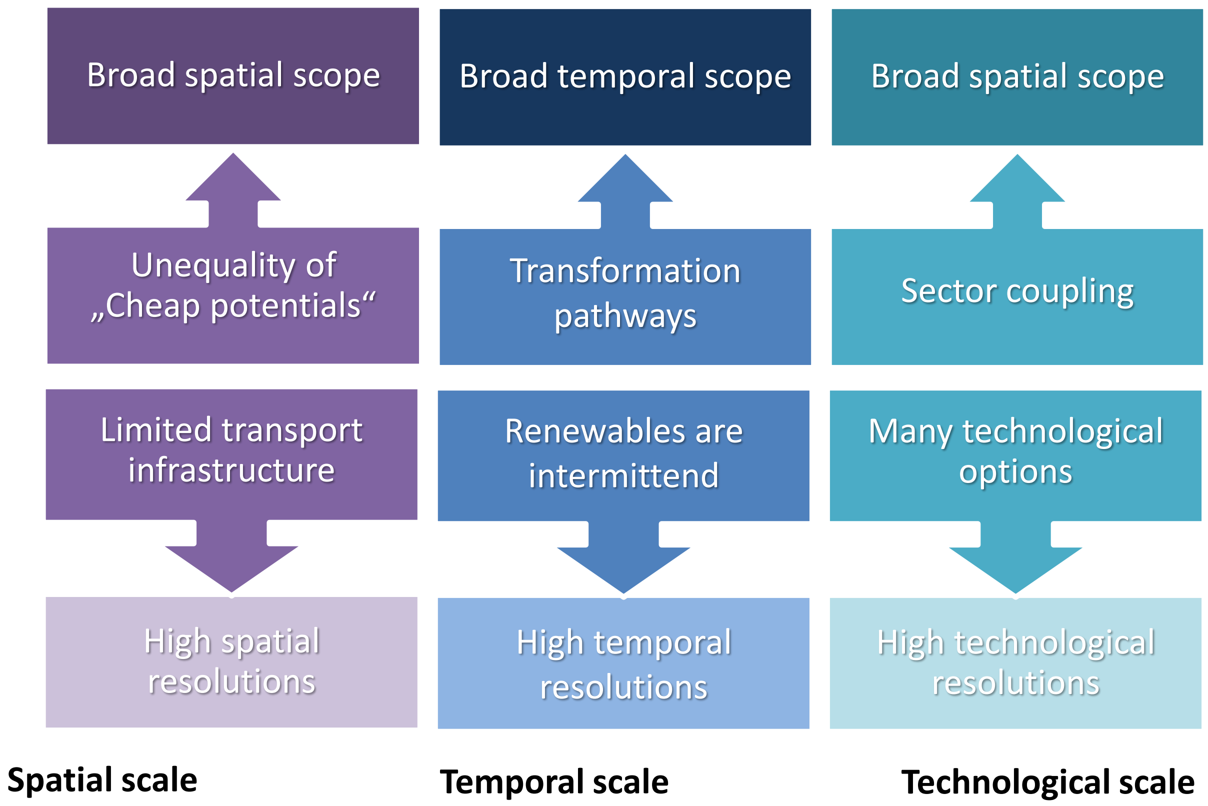

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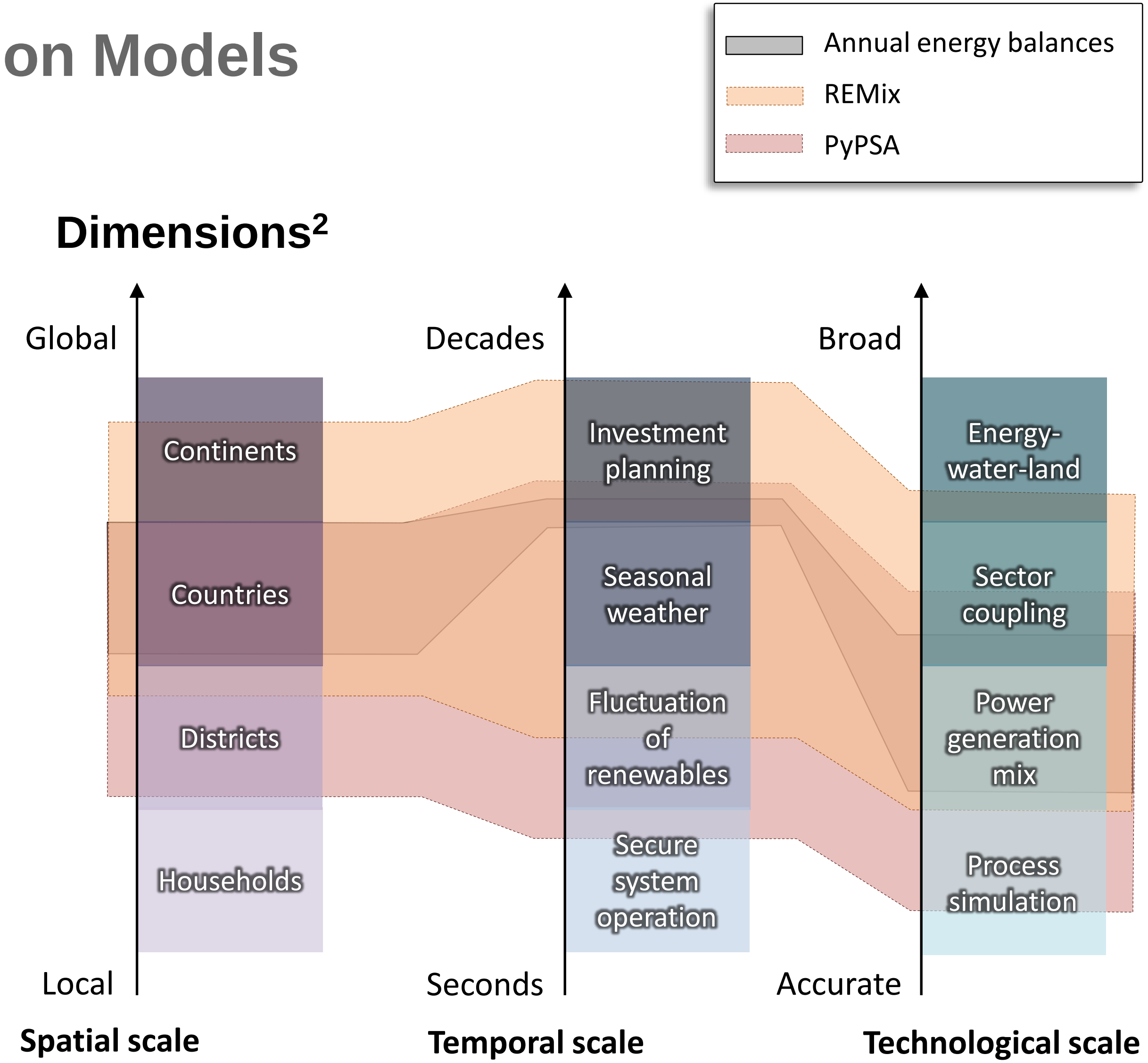

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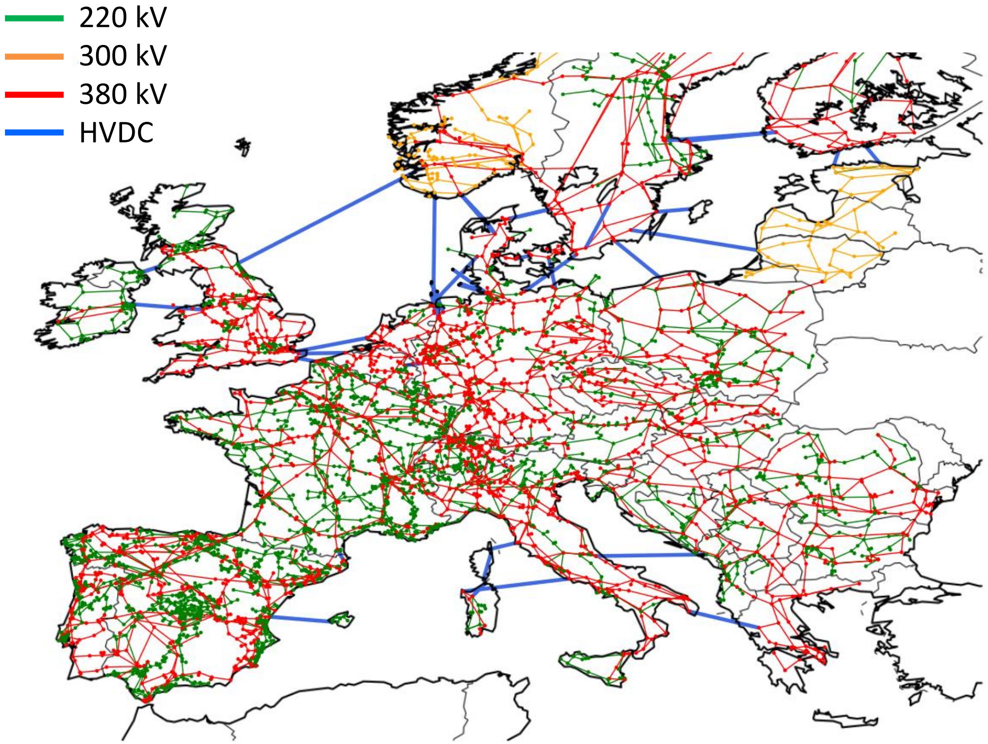
Modelling Large-scale Energy Systems

Example: Representation of PyPSA-Eur



Source: Hörsch, J., Hofmann, F., Schlachtberger, D., & Brown, T. (2018). PyPSA-Eur: An open optimisation model of the European transmission system. Energy Strategy Reviews, 22, 207-215.

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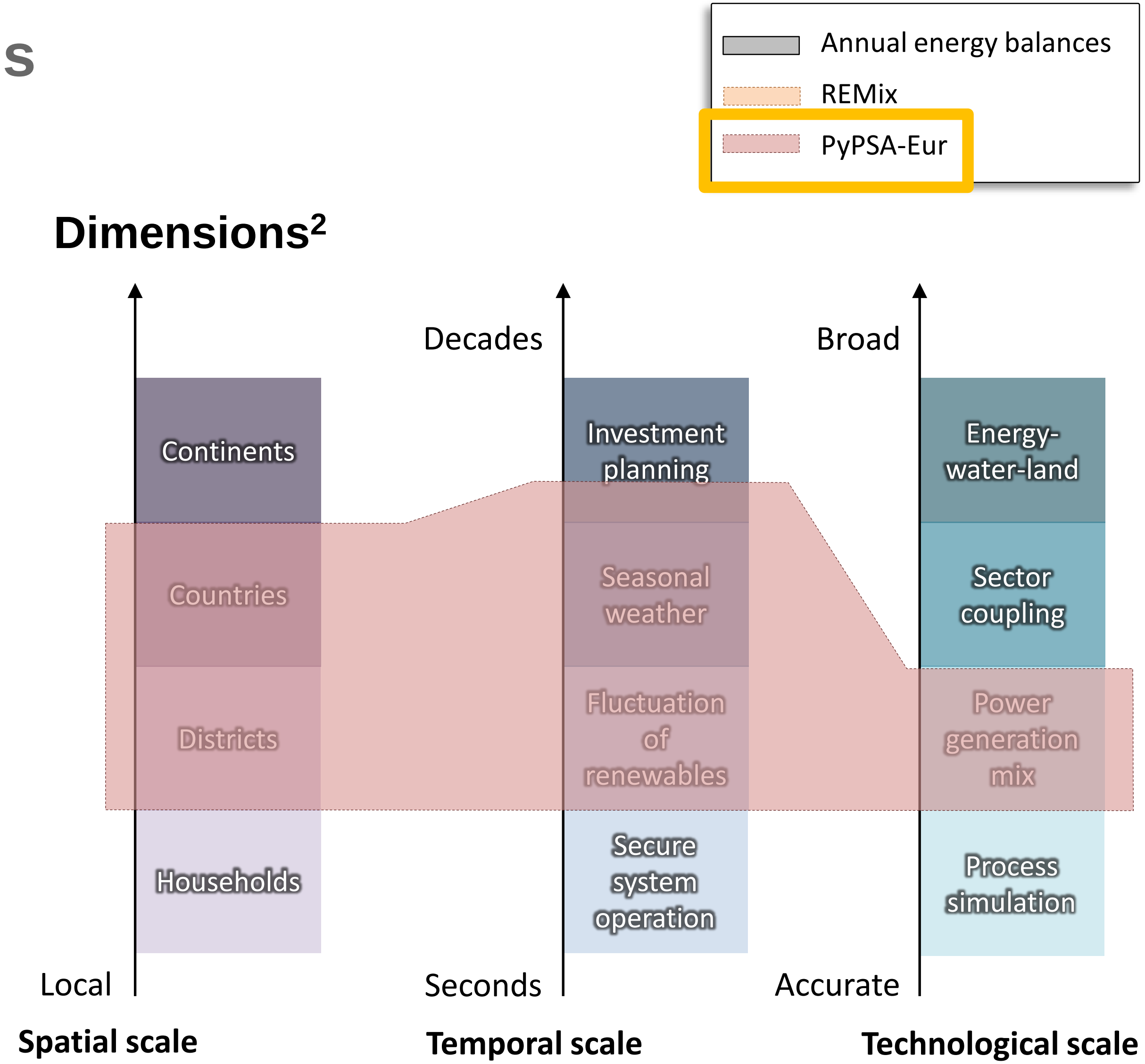
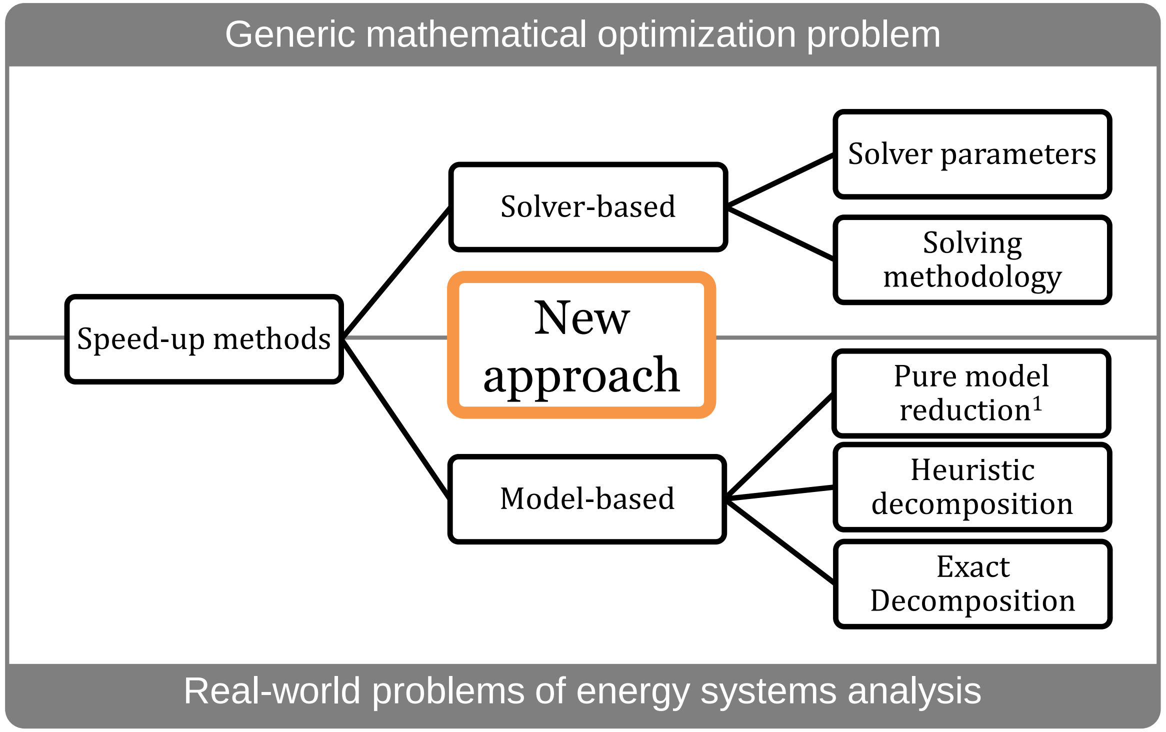


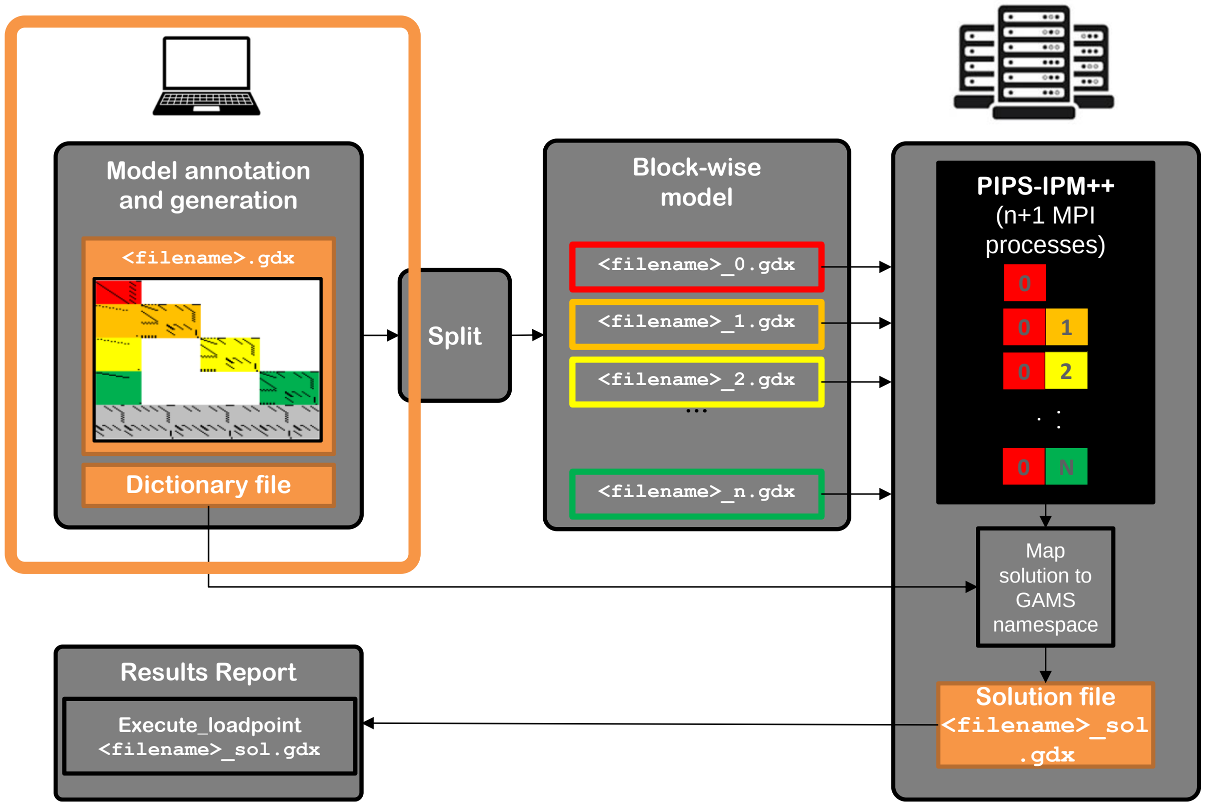
Methodology

Solving the Models

Methods on the Software-Side[3]

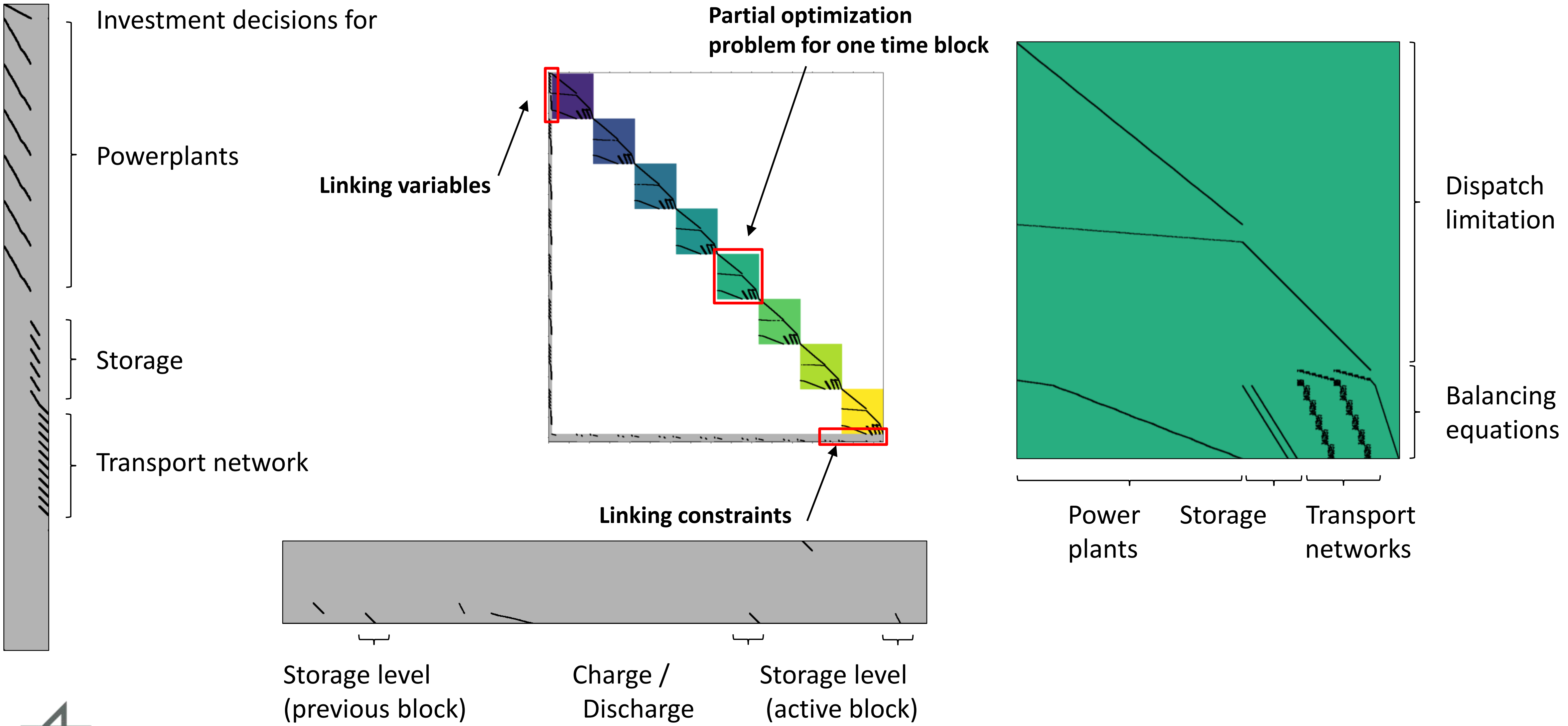


Modeller's Domain Knowledge + Supercomputing[2]



1: Investigated in: Raventós, O., & Bartels, J. (2020). Evaluation of temporal complexity reduction techniques applied to storage expansion planning in power system models. Energies, 13(4), 988.
2: Based on: Scholz, Y., Fuchs, B., Borggrefe, F., Cao, K. K., Wetzel, M., von Krbek, K., ... & Buchholz, S. (2020). Speeding up Energy System Models-a Best Practice Guide.
3: Based on: Cao, K. K., Von Krbek, K., Wetzel, M., Cebulla, F., & Schreck, S. (2019). Classification and evaluation of concepts for improving the performance of applied energy system optimization models. Energies, 12(24), 4656.

Understanding the Block Structure



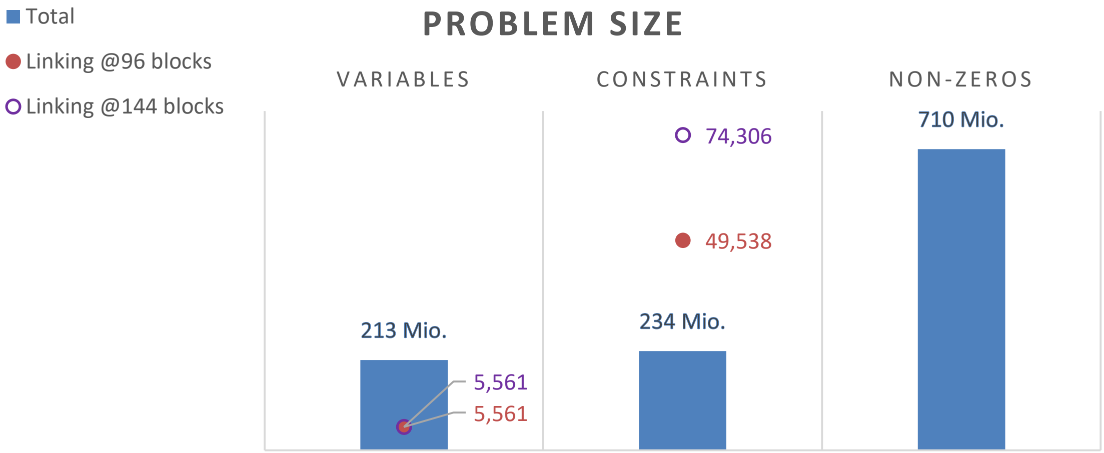
Results

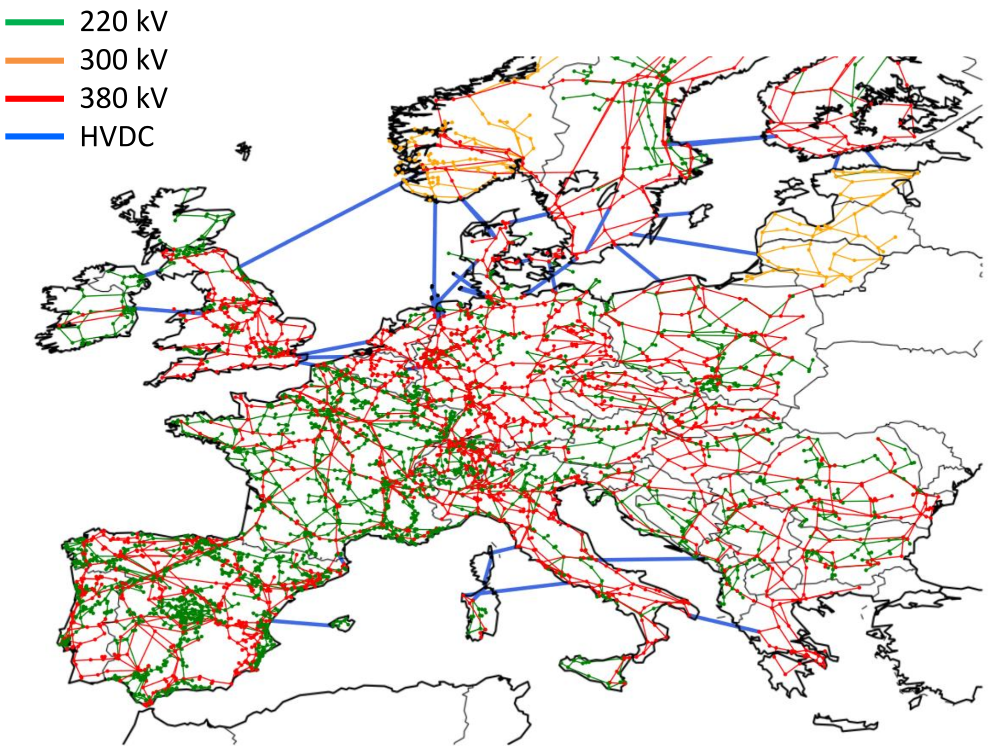
DLR

Solving PyPSA-Eur[1] with PIPS-IPM++

Annotation

No. regions	No. MPI-tasks (time blocks)
37	{96, 120, 144, 192, 768}
128	{…, 96, …, 192, …, 384, …, 1095}
512	{96, 144, 192, …, 528, 768, 792, 1056}
1024	{96, 144, 192}
3475	{96, 144}





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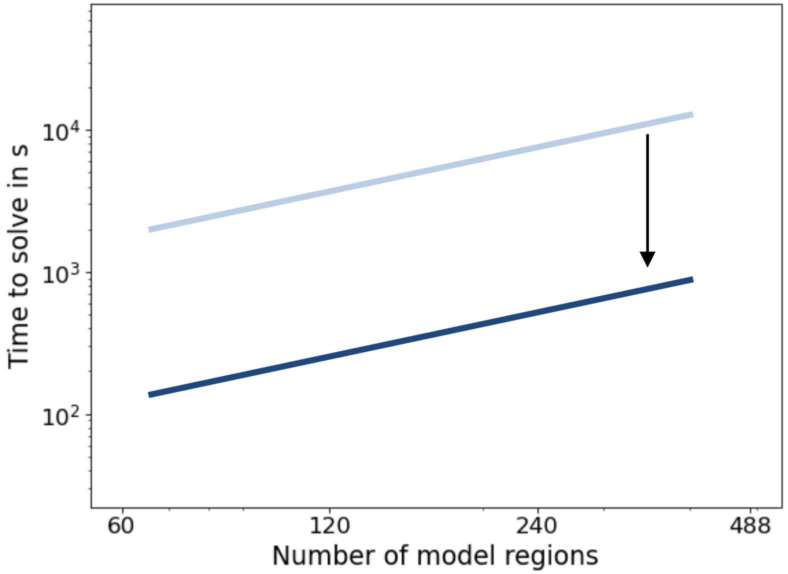
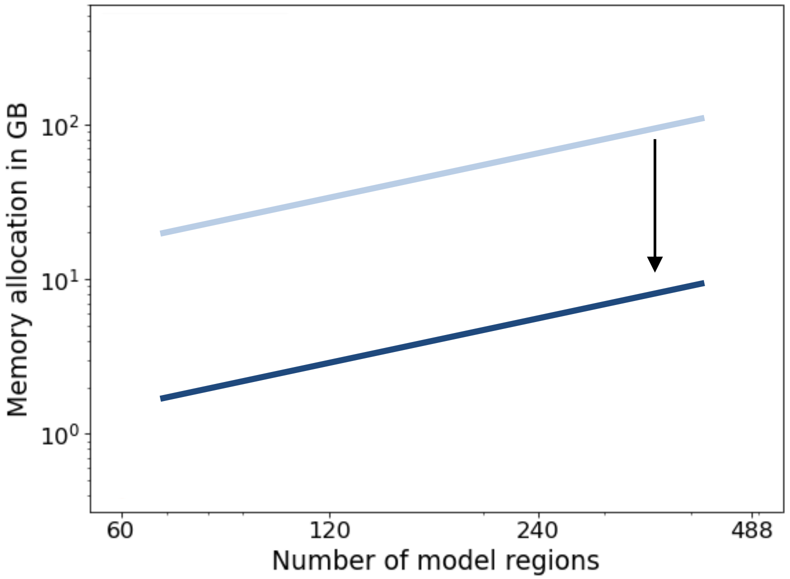
Measuring the Performance

Commercial solver on shared memory
PIPS-IPM++ on distributed memory

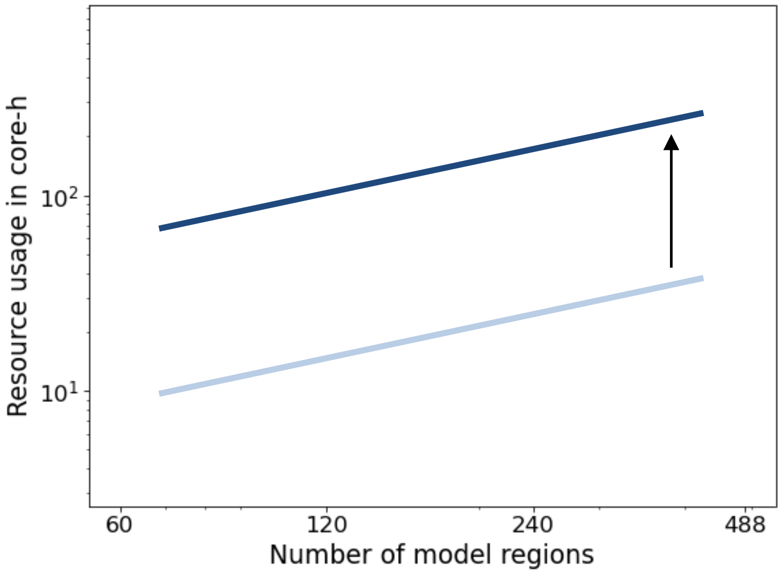
Speed-up



Max. memory savings



Resources

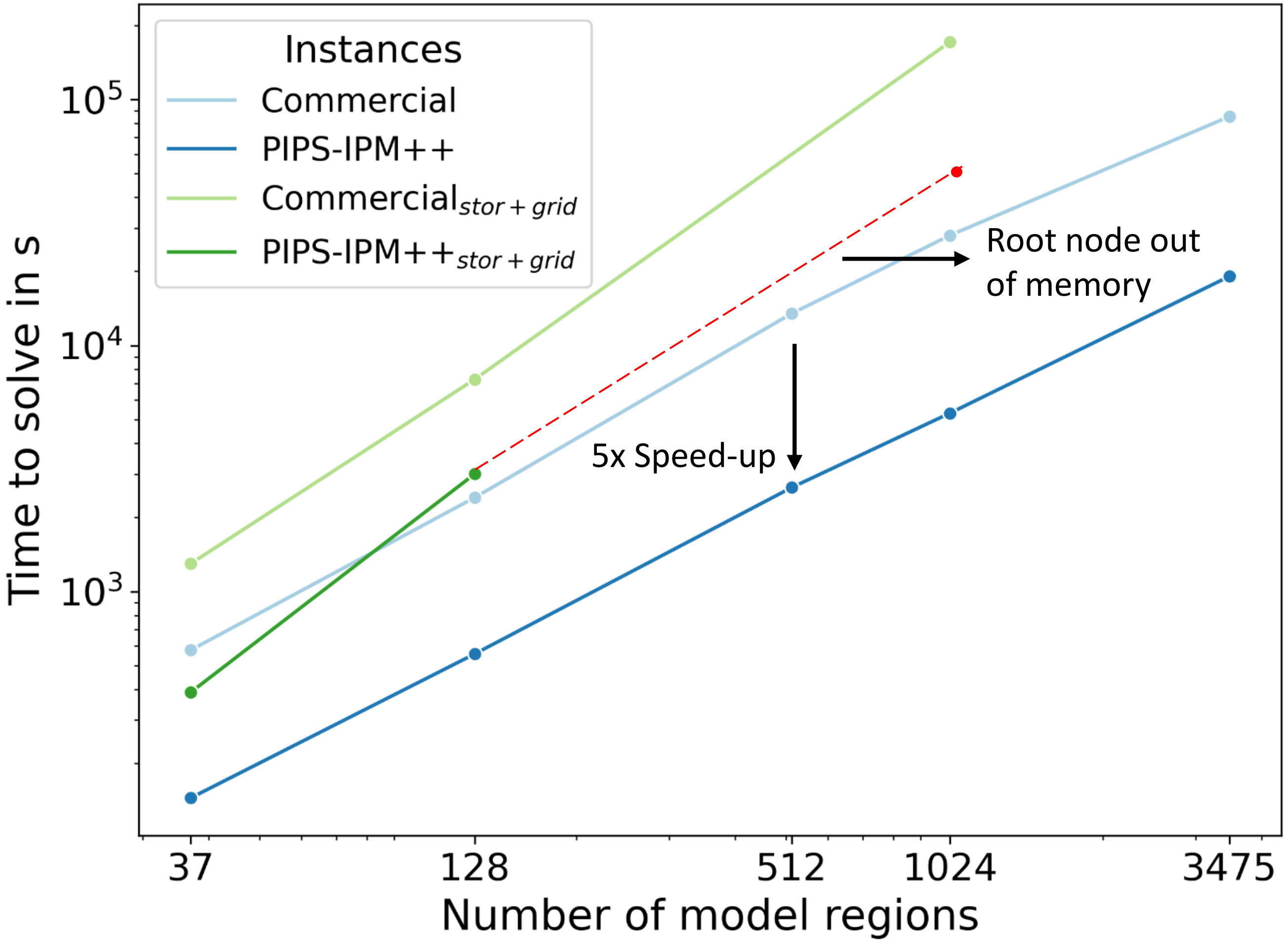


- Mitigation of both time and memory limits possible via compute node configuration on HPC systems
- Trade-off: Time to solve vs. resources consumption

Solving PyPSA-Eur with PIPS-IPM++

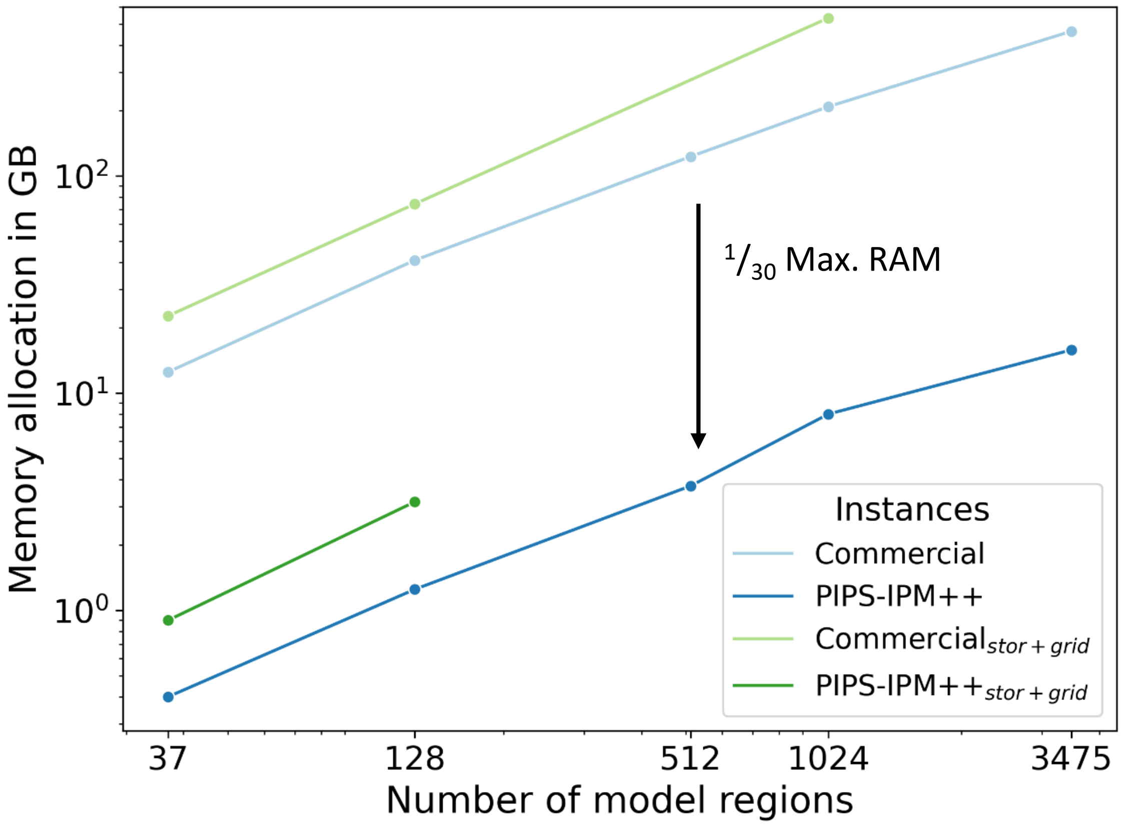
- Best-in-class:
  - Take best result for **Speed-up** across different annotations

- Operational and investment decisions
  - Investments into renewable energy generation
  - Additional investments into storage and power transmission capacities



Solving the PyPSA-Eur with PIPS-IPM++

Max. memory savings



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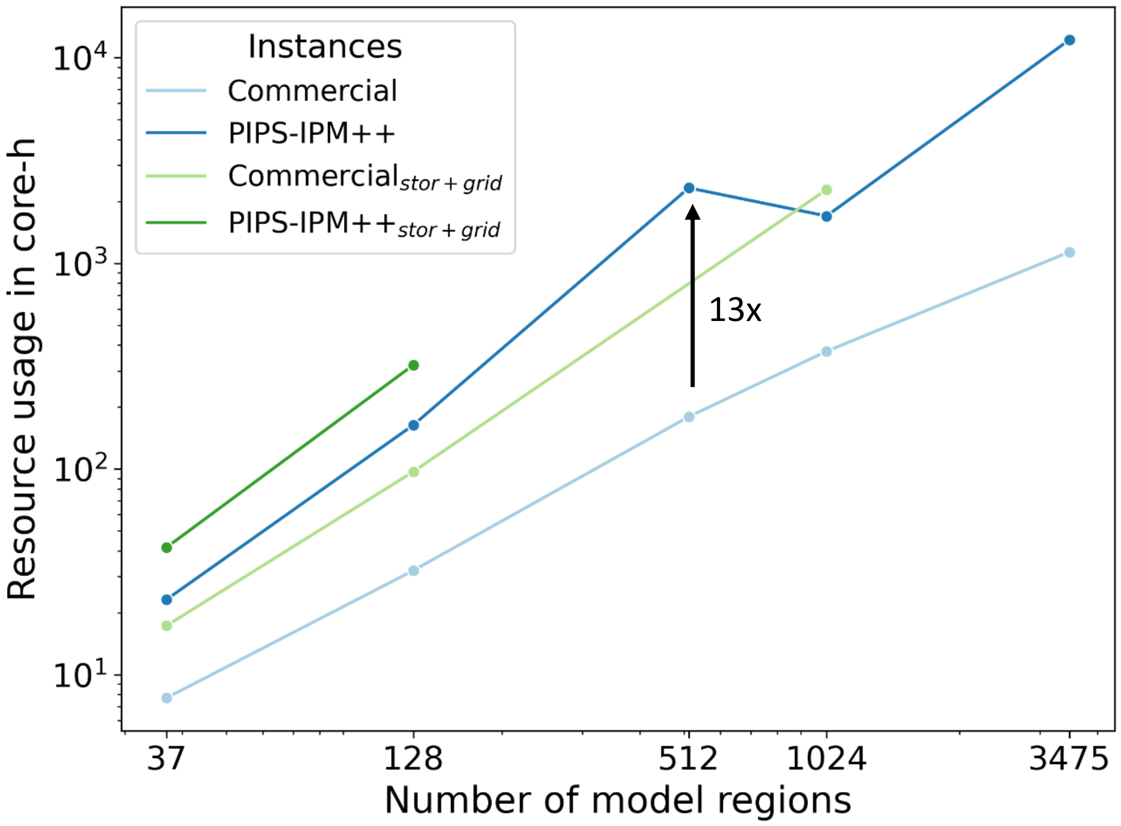

Conclusions

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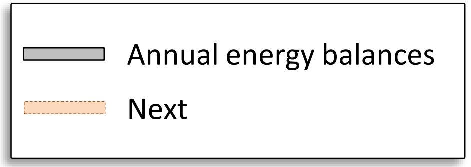
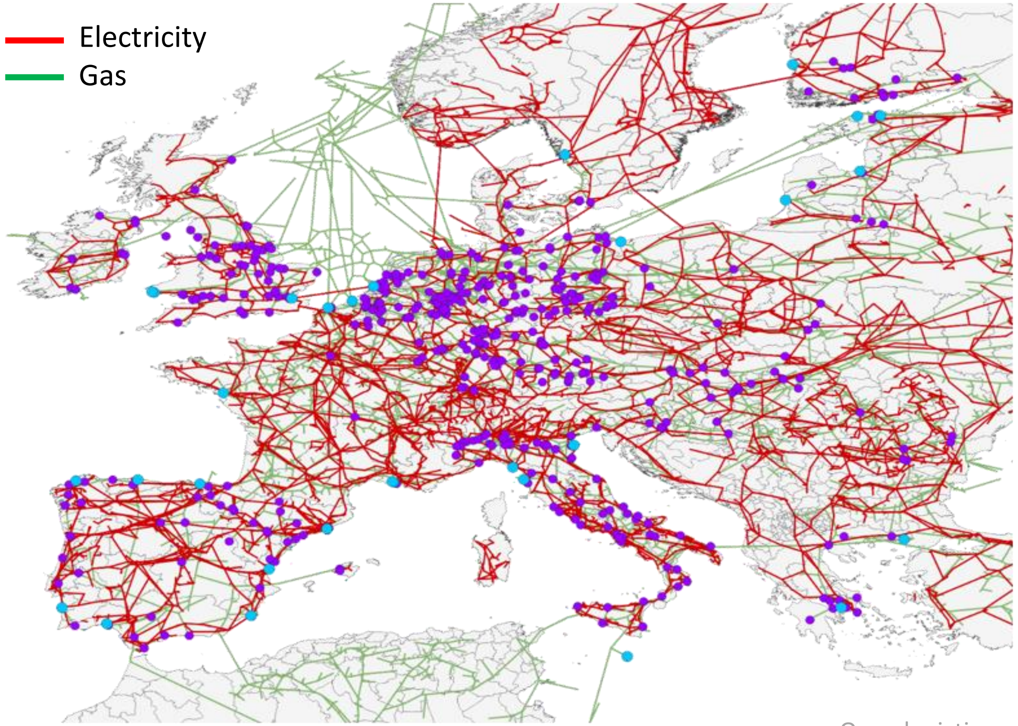
Trend	Large-scale energy system optimization models
	Higher resolutions and broader scopes
Challenges	Computing times
	Memory demand
Open parallel solver PIPS-IPM++[1]	Exact solutions
	Distributed memory hardware
	Speed-up vs. compute resources
Future	Parameter tuning
	Suitable use-cases

1: https://github.com/NCKempke/PIPS-IPMpp/

Outlook for Modelling Large-scale Energy Systems

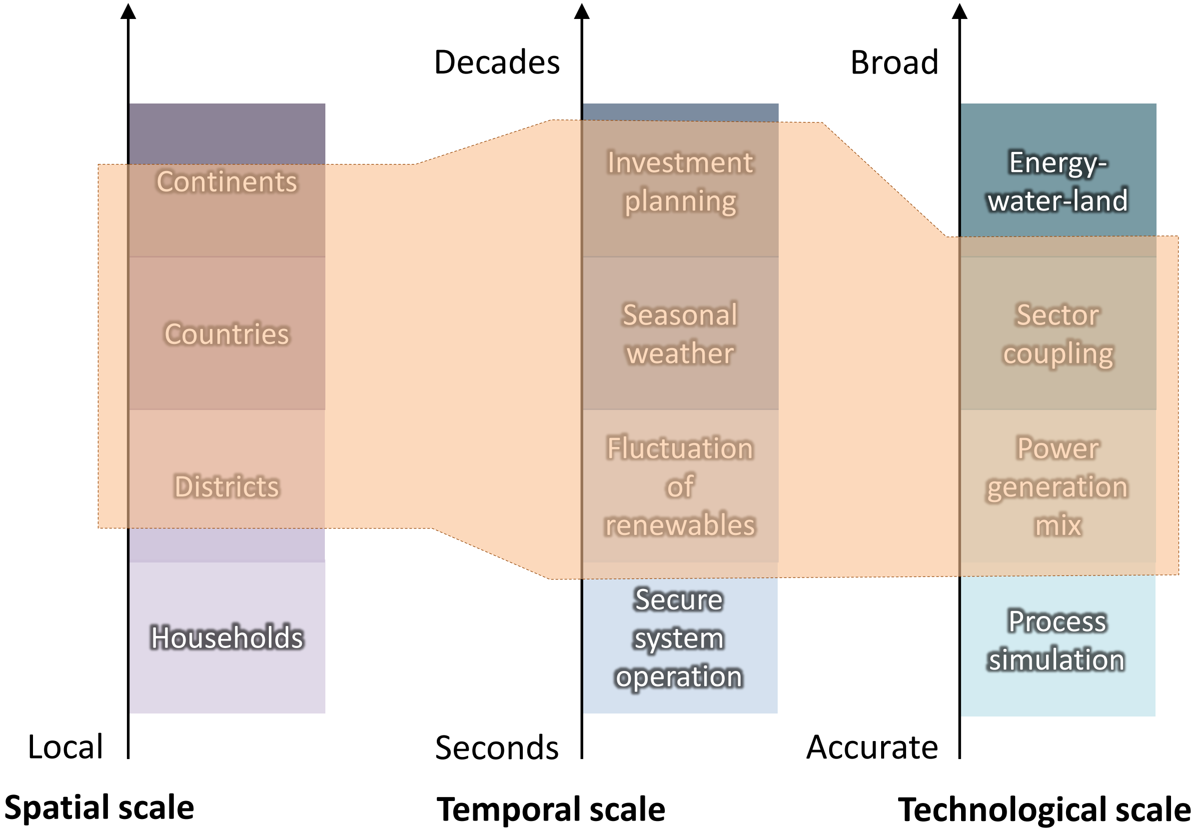


European Power and Gas Transmission Grid



Own depiction

Dimensions²



Thank you!

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