KU Leuven/EnergyVille

Integrated energy system modelling:

Linking the electricity generation and demand side through heat-pump demand response

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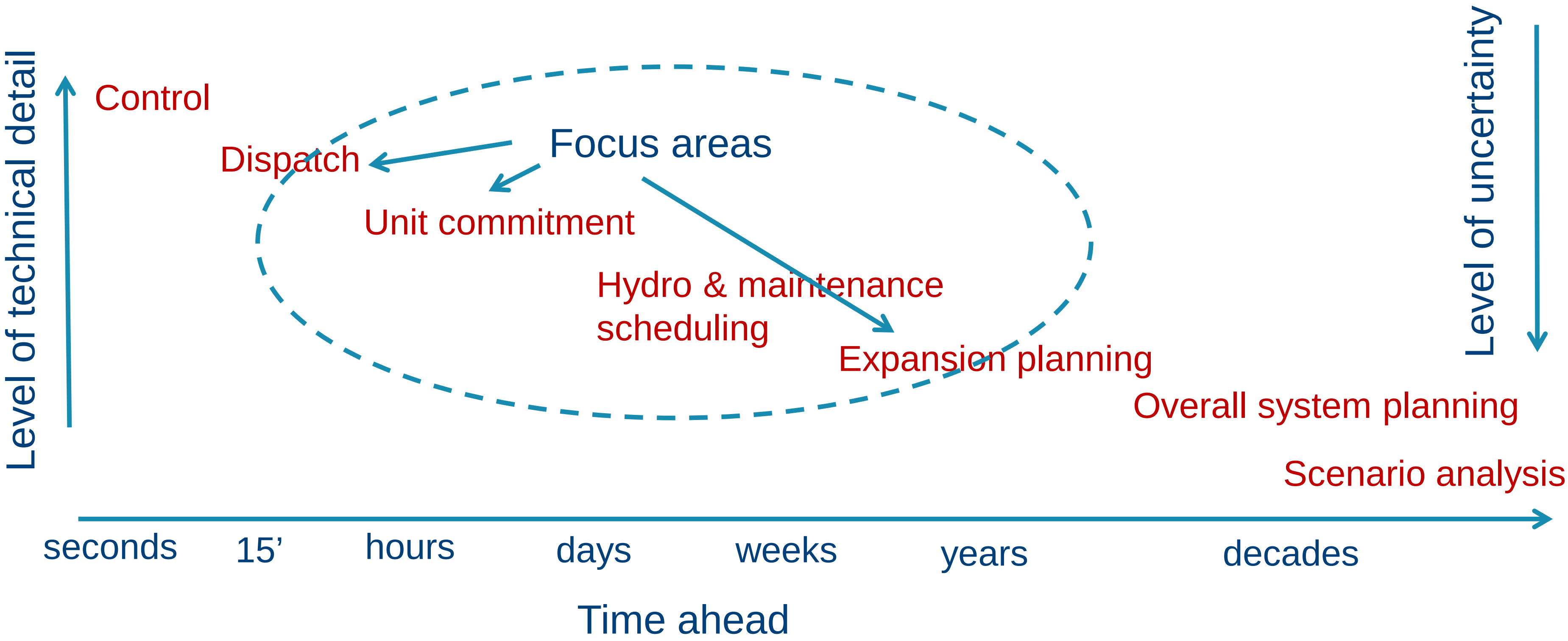
Electricity generation system operation and planning



Electricity generation system operation and planning

- LUSYM framework
  - Operational model
    - Mixed-integer programming for unit commitment
    - Unpredictability: forecast errors, reserve sizing/allocation/activation
    - New technologies: e.g., CCS, active grid elements, power-to-gas
  - Expansion planning models - TIMES framework
    - Improve operational representation and technical detail
    - Uncertainty and market elements
  - Energy policy and market applications

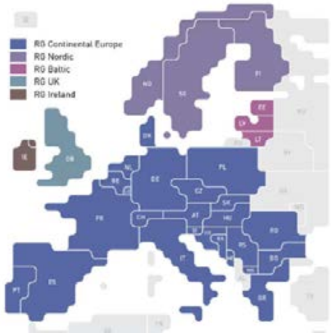
LUSYM: Set-up of the standard unit commitment model

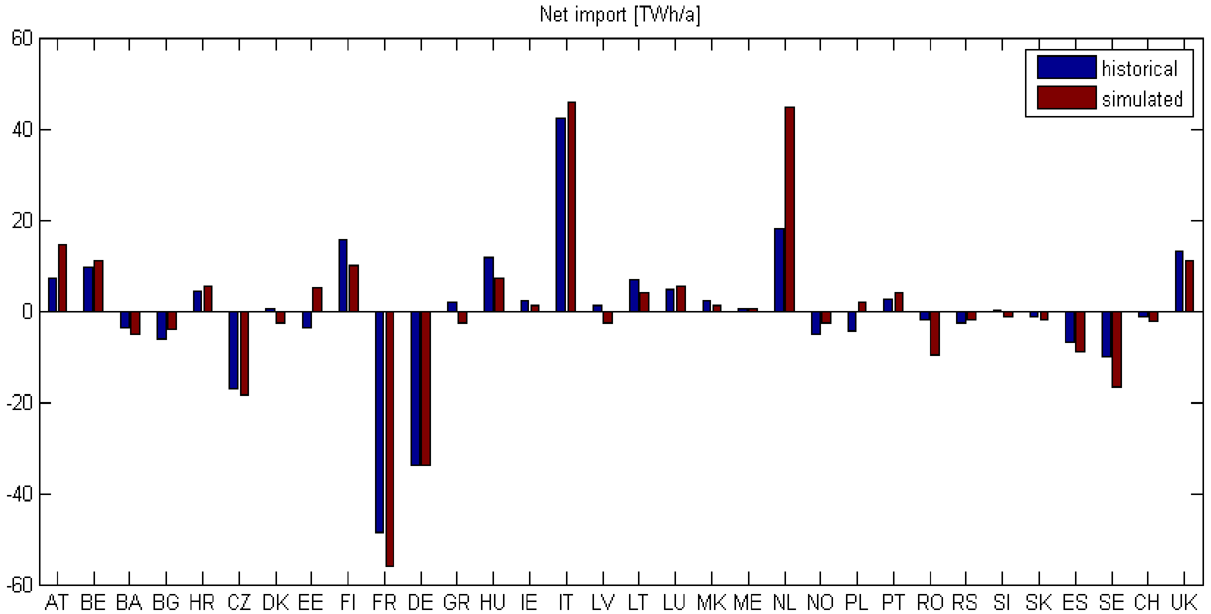
- Mixed Integer Linear Programming
  - Solve on HPC
  - Large-scale model set up
  - Tight and compact formulation
  - “Flexible” model

  - Computation time is important factor

LUSYM: Validation of the standard unit commitment model

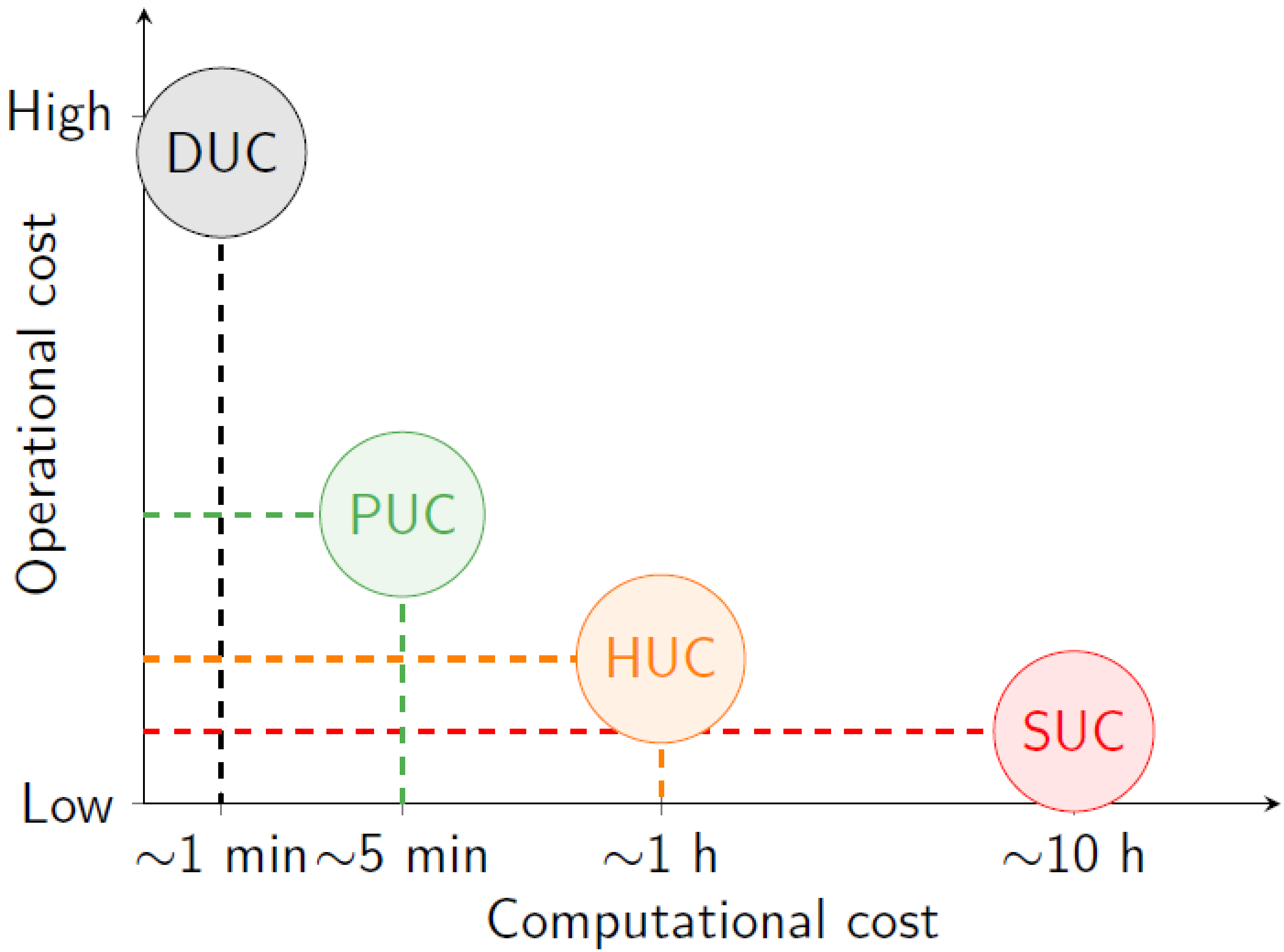
- Calibration on the European system (ENTSO-E area, 2013)





Net import

LUSYM: Uncertainty in the unit commitment model



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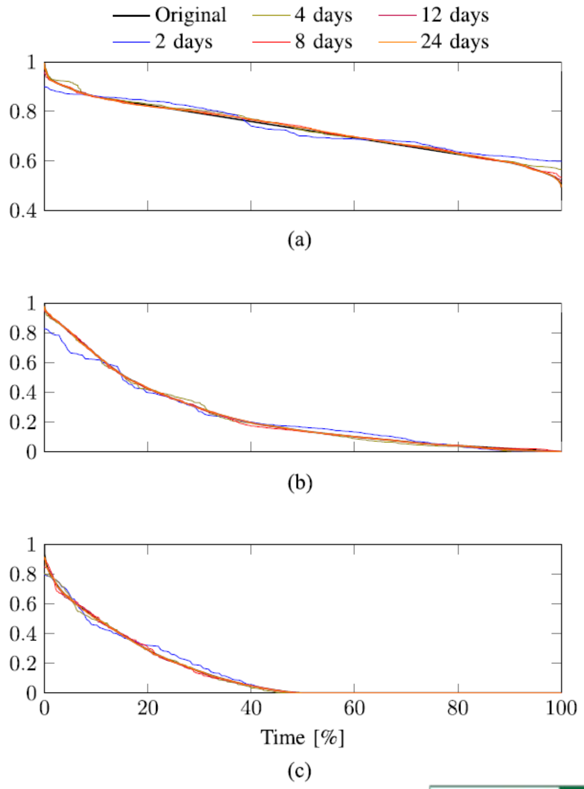
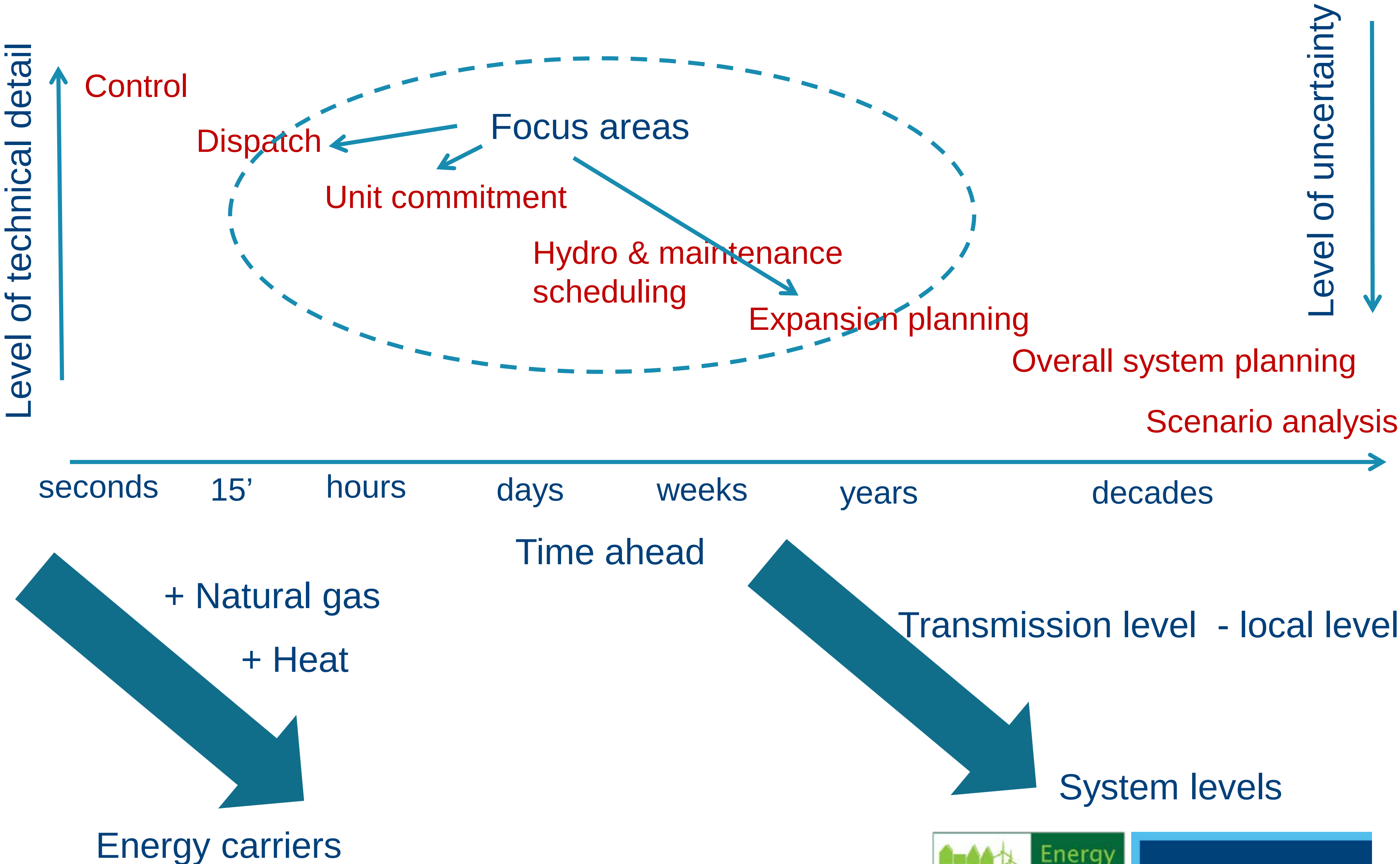
LUSYM: Expansion planning model

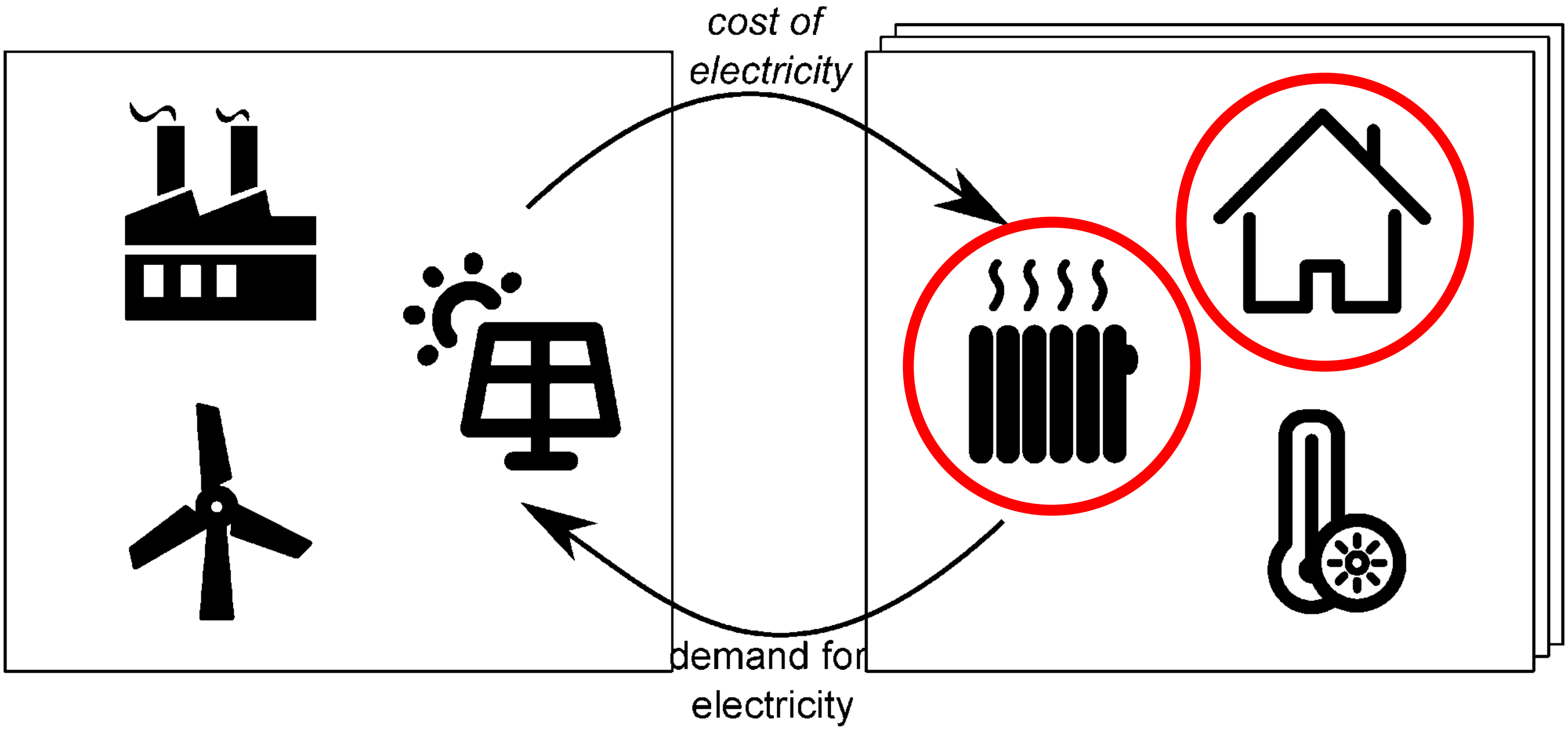
- Increasing the level of temporal detail
  - Optimization to select set of representative days
    - Duration curves
      - Load
      - RES series
      - Ramping
      - Correlations
      - …



Electricity generation system operation and planning



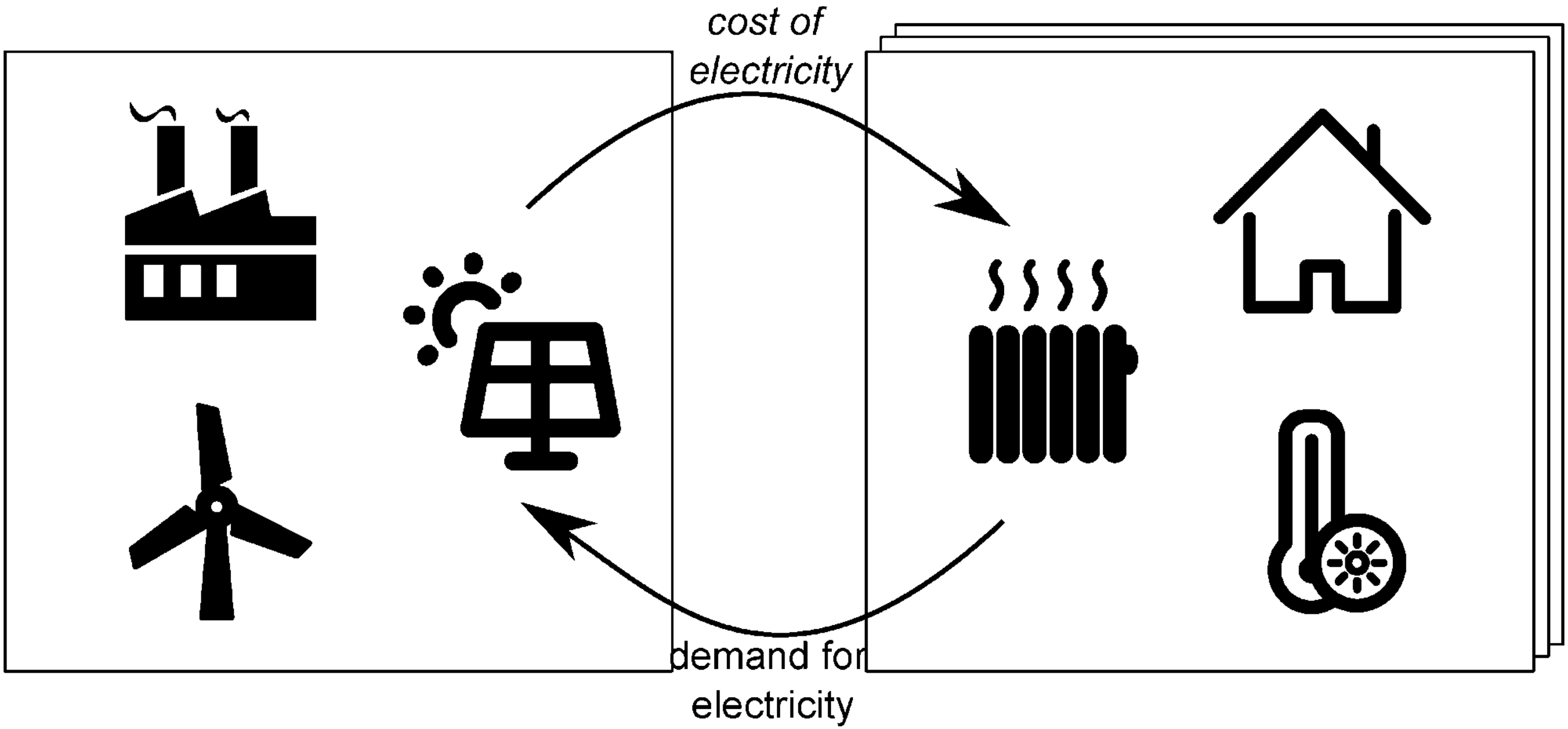
Scope & motivation



Conventional & stochastic RES-based electricity generation

Thermal inertia allows decoupling the electrical demand and the thermal demand without loss of comfort

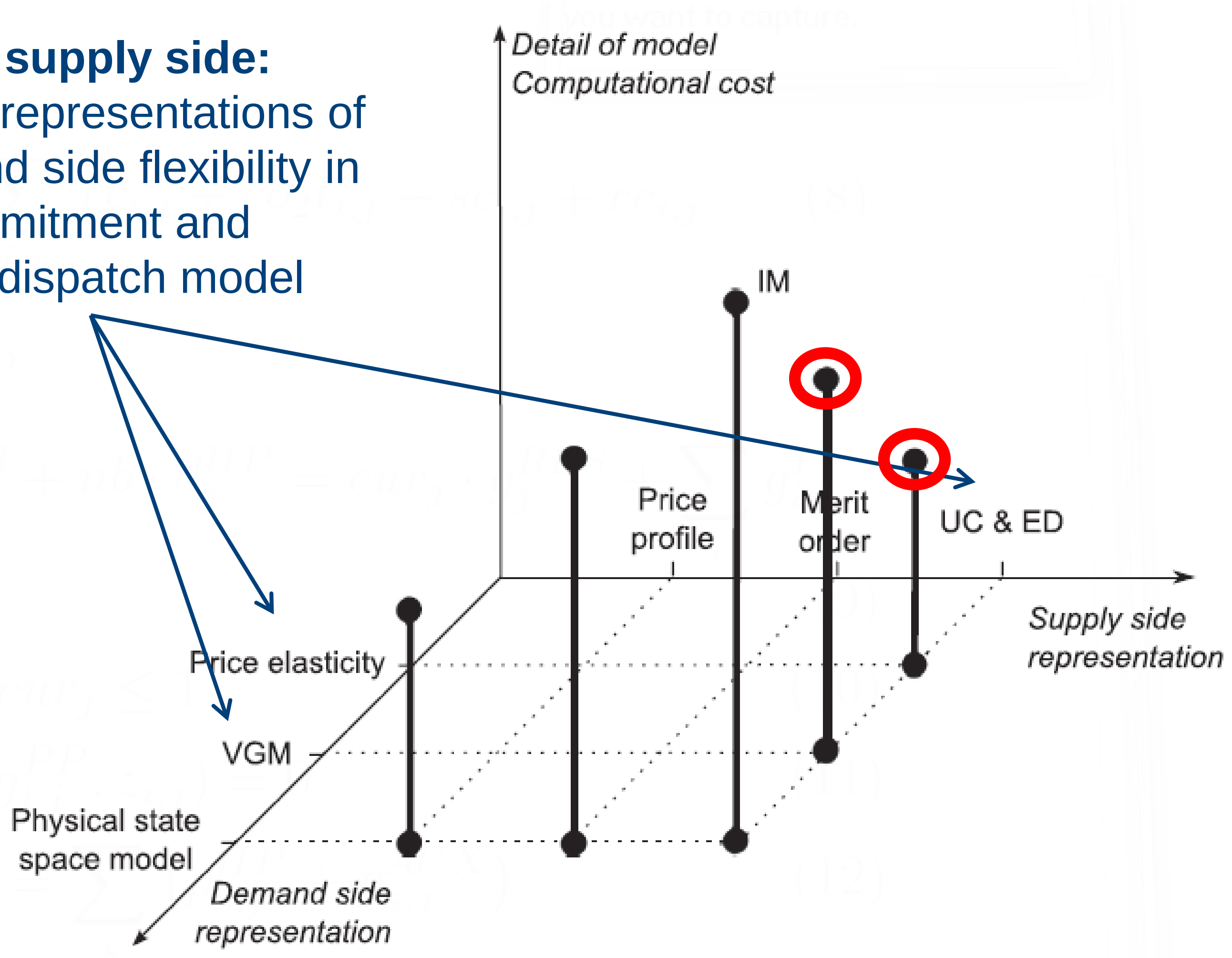
Modeling challenges & issues



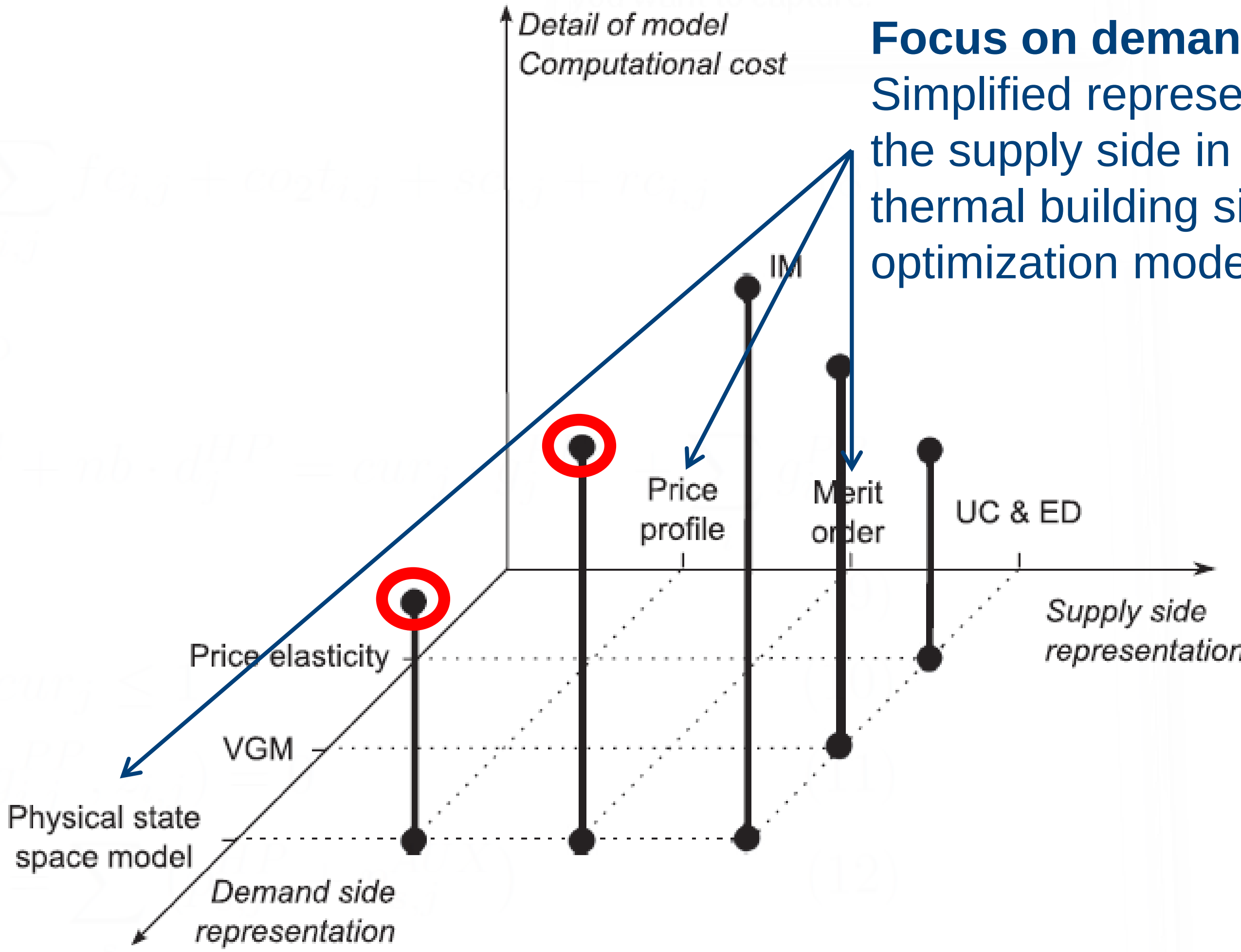
Complex interactions between demand and supply: how do you capture this in an operational model?

Modeling challenges & issues

Focus on supply side:
Simplified representations of the demand side flexibility in a unit commitment and economic dispatch model



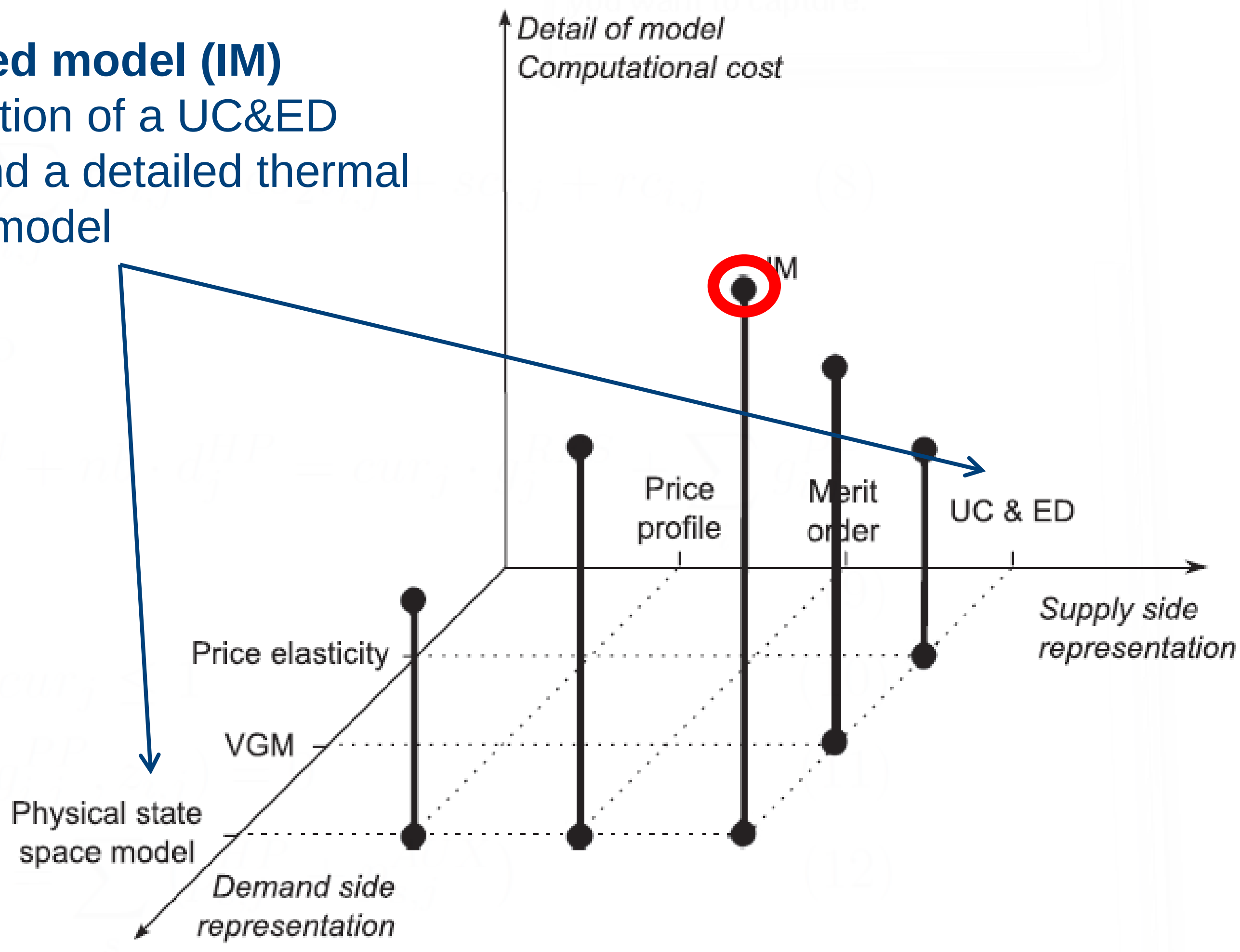
Modeling challenges & issues



Focus on demand side:
Simplified representations of the supply side in a detailed thermal building simulation or optimization model

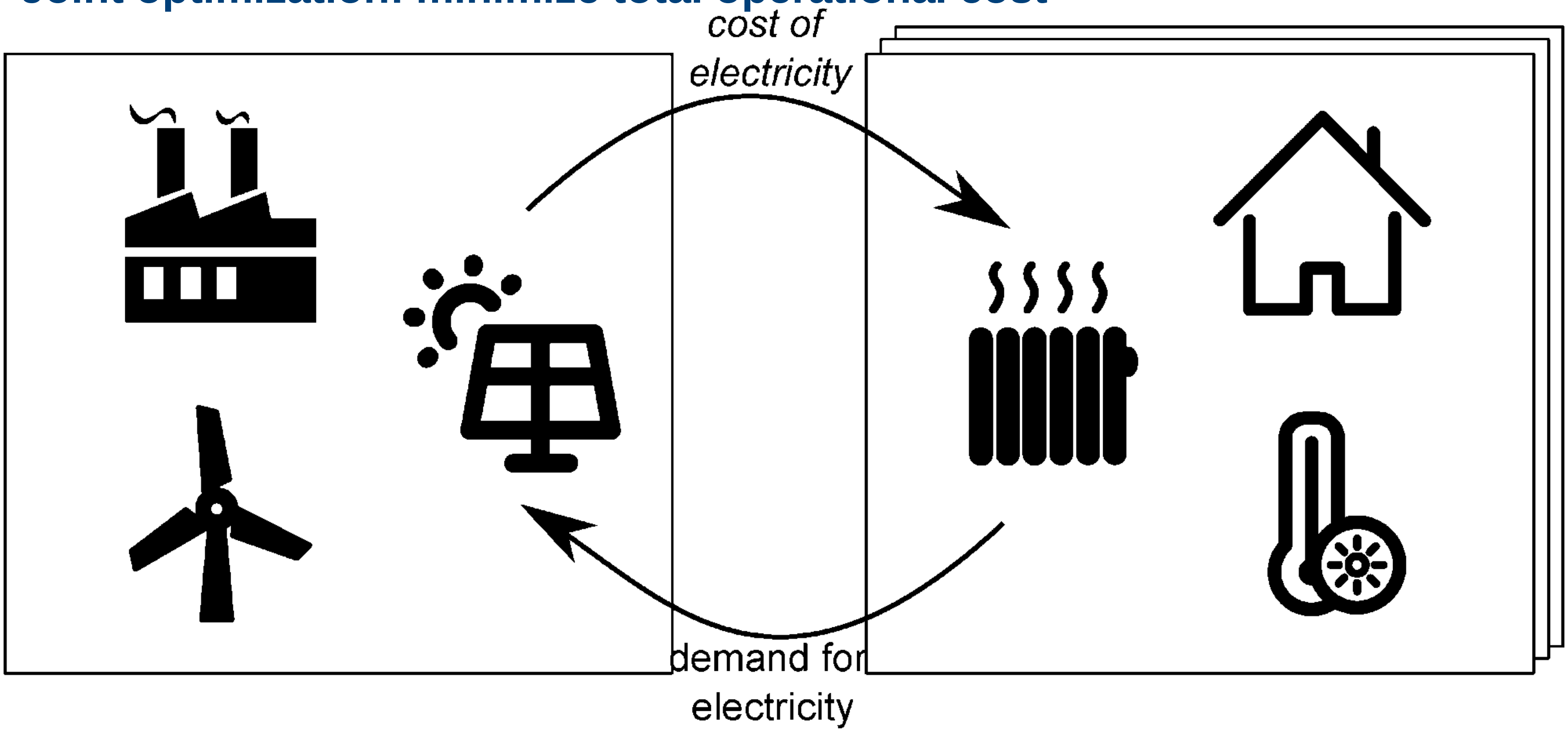
Modeling challenges & issues

Integrated model (IM)
Combination of a UC&ED model and a detailed thermal building model



An integrated model

Joint optimization: minimize total operational cost

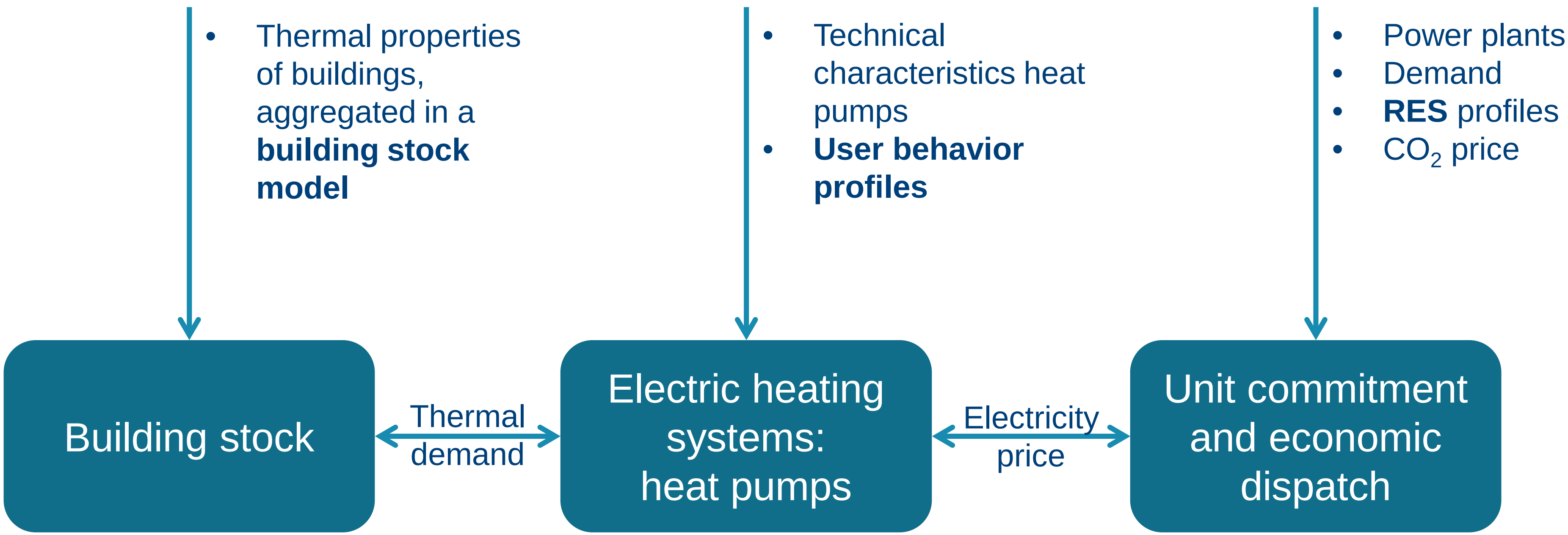


UC & ED model, considering set of power plants, RES-based generation and a fixed demand profile (MILP)

DR-adherent demand model: RC network (thermal dynamics building), linear heat pump model, user behavior & external gains (LP)

An integrated model

Joint optimization: minimize total operational cost



Linear state-space model

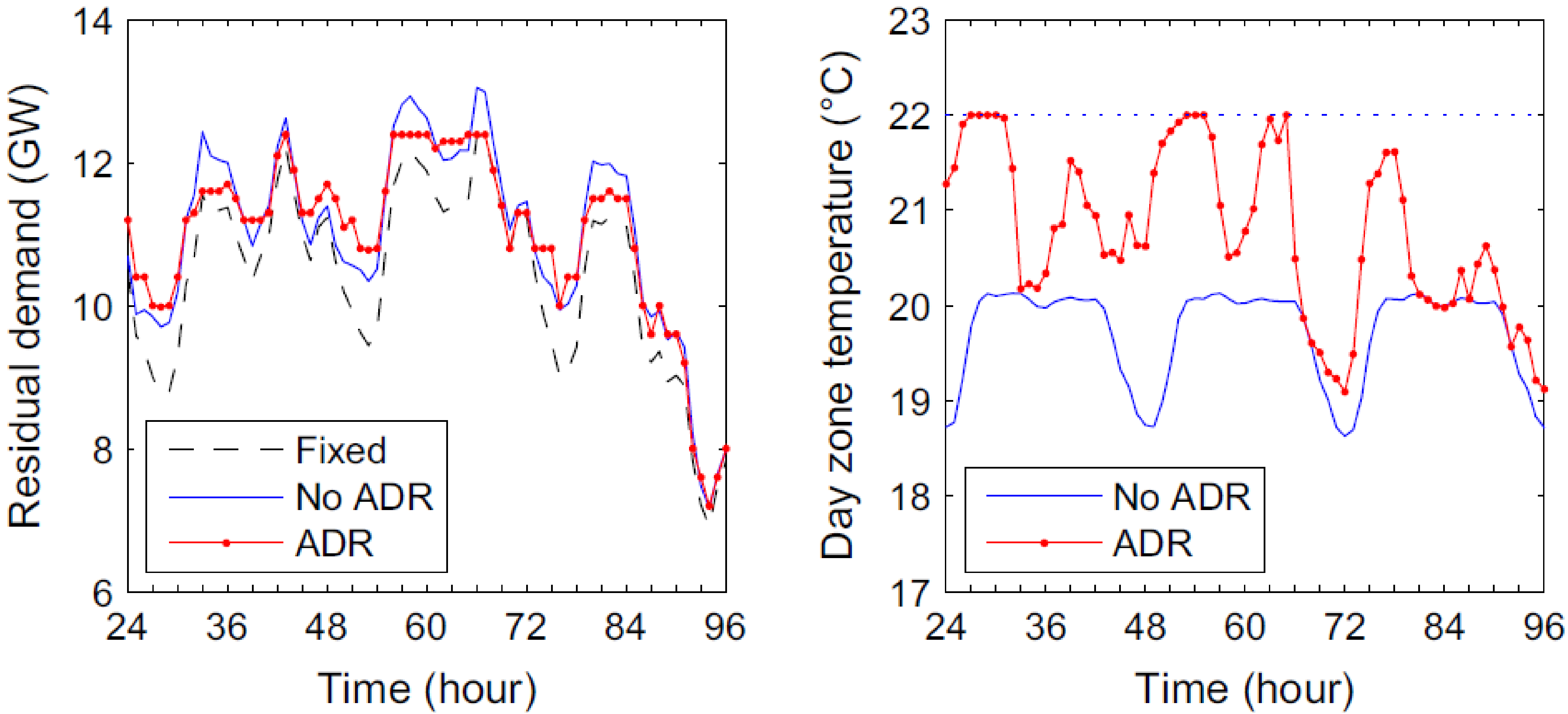
Different building types

Linear technical model

Different user behaviour types

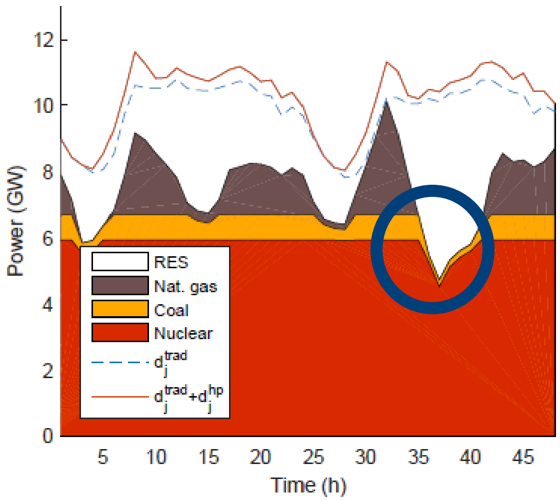
Mixed integer linear programming model

An integrated model: a first example

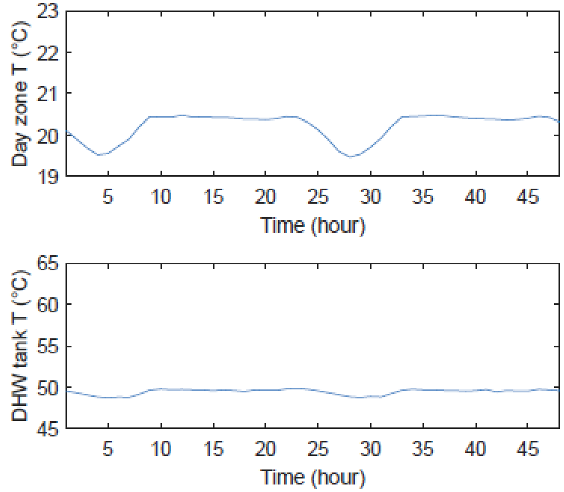


- Power system inspired on possible future setting of BE power system;
- 250,000 heat pumps;
- 52 user behavior profiles.

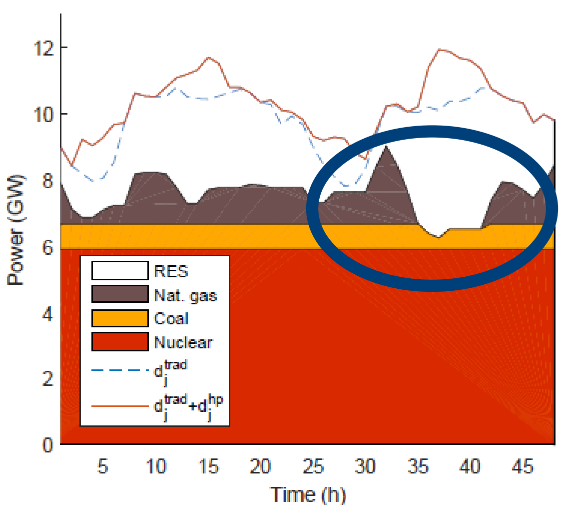
An integrated model: a second example



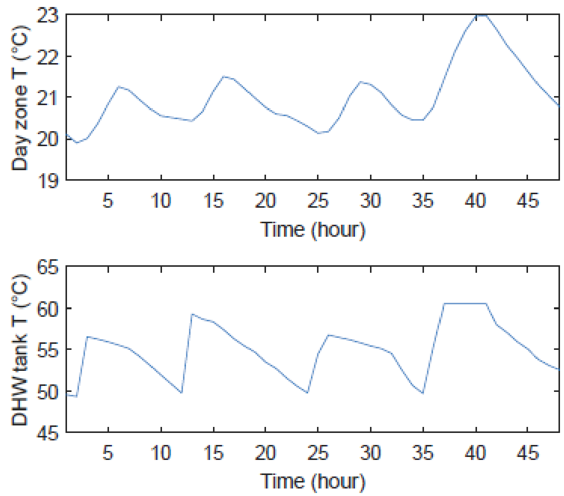
(a) Electricity generation, no DR



(b) Mean temperatures, no DR



(c) Electricity generation, with DR

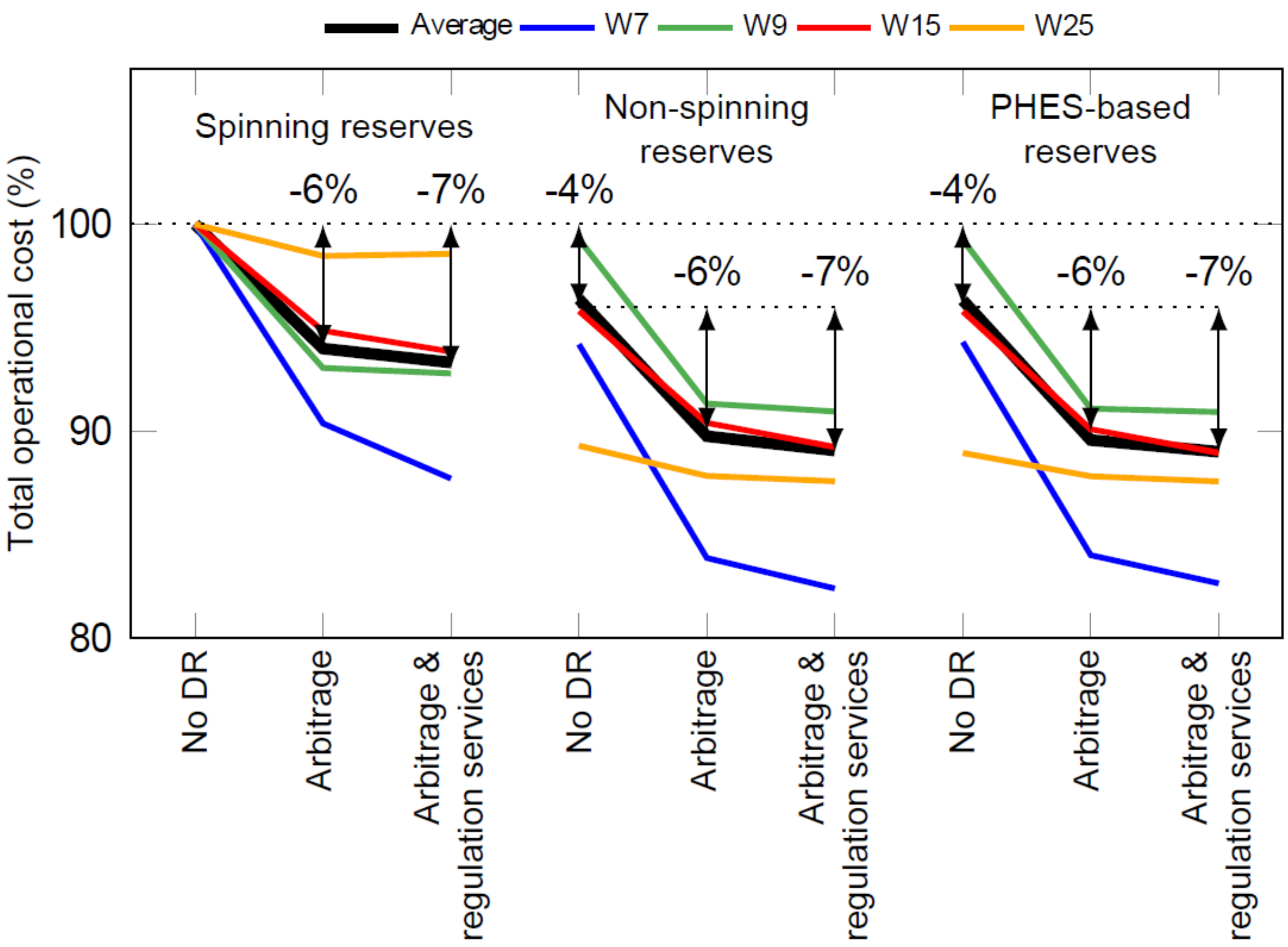


(d) Mean temperatures, with DR

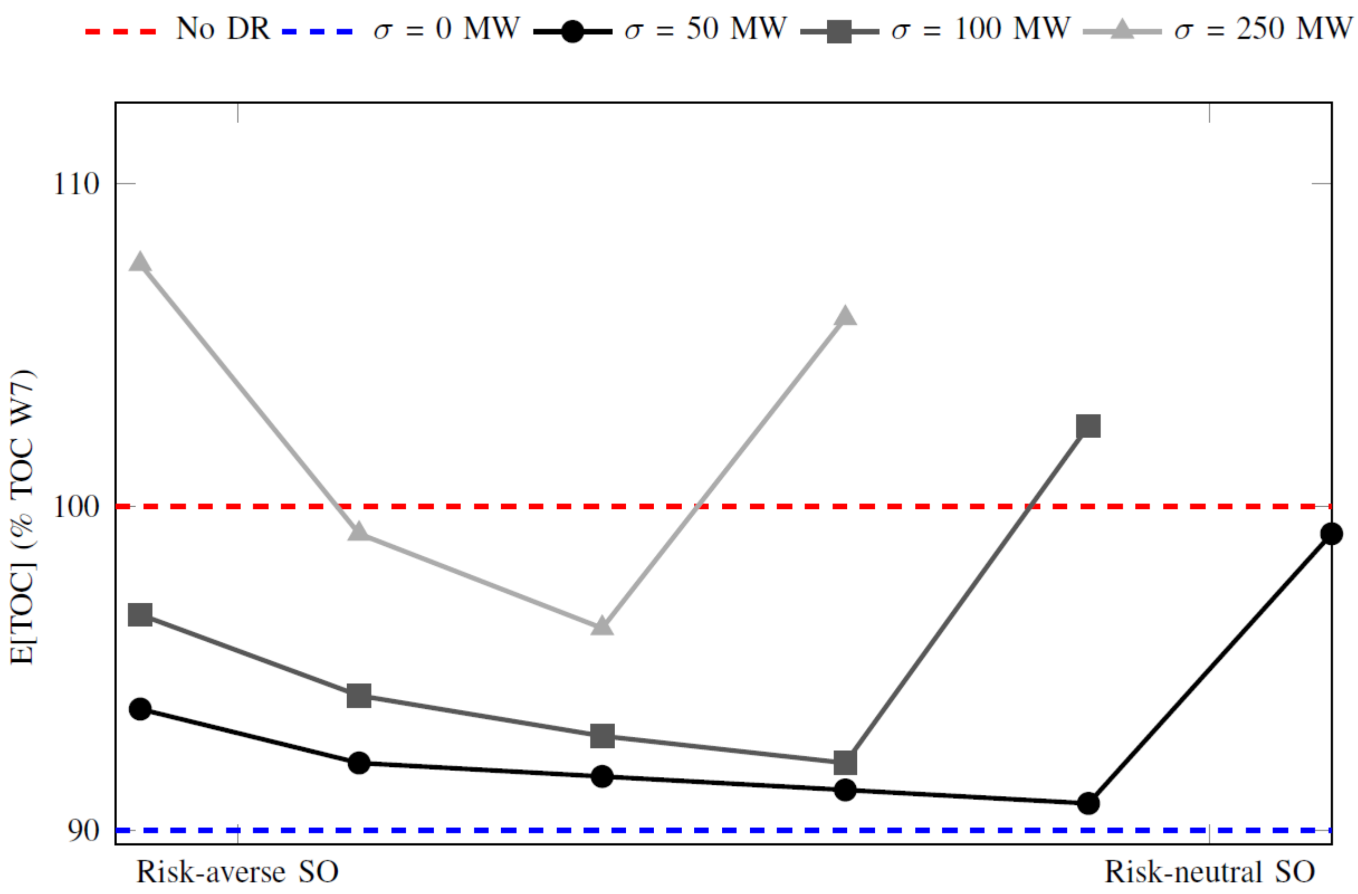
<u>Case study:</u>

- Power system inspired on possible future setting of BE power system;
- 250,000 heat pumps;
- Building properties represented via an ‘average’ building (detached dwelling);
- 52 user behavior profiles.

Value of DR-based arbitrage and regulation services



Impact of limited DR-controllability



From: Bruninx, K., Dvorkin, Y., Delarue, E., D'haeseleer, W., Kirschen, D. Valuing Demand Response Controllability via Chance Constrained Programming. IEEE Transactions on Sustainable Energy, 2017, in press.

Conclusion

1 **Integrated modelling framework**

- Operational demand and supply side model formulated using MILP
- More accurate representation w.r.t. other methods
  - Merit order model provides valuable results at much lower computational cost
- Myriad of applications possible

2 **Demand response with heat pumps**

- Could hold significant environmental and economical advantages: operational cost savings, (additional) peak demand reduction, cost-effective regulation services
- Current modeling provides upper bound
- Controllability needs being accounted for

3 **Future work**

- Impact on heating system design and life time
- Heterogeneity of DR-loads, user behavior, building types
- Conflicting objectives building owner – system operator
- Long term system adequacy

Further reading

[1] D. Patteeuw et al., *Integrated modeling of active demand response with electric heating systems coupled to thermal energy storage systems*, Applied Energy 151, pp. 306-319, 2015.

[2] D. Patteeuw et al., *CO2-abatement cost of residential heat pumps with Active Demand Response: demand-and supply-side effects*, Applied Energy 156, pp. 490-501, 2015.

[3] A. Arteconi et al., *Active demand response with electric heating systems: impact of market penetration*, Applied Energy 177, 636-648, 2016.

[4] K. Bruninx, E. Delarue (co-supervisor) and W. D'haeseleer (supervisor), *Improved modeling of unit commitment decisions under uncertainty*, PhD thesis, KU Leuven, May 2016.

[5] D. Patteeuw and L. Helsen (supervisor), *Demand response for residential heat pumps in interaction with the electricity generation system*, PhD thesis, KU Leuven, September 2016.

[6] K. Bruninx, et al., *Valuing Demand Response Controllability via Chance Constrained Programming.* Under Review at IEEE Transactions on Sustainable Energy, 2017.