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Facilitating Renewables Integration through Demand Response: A Modeling Approach

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Content

- Context and scope
- Some modeling examples
  - Including integrated modeling of demand and supply side
- Conclusions and reflections

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Demand response: concepts & issues

- Distinction between
  - Impact of (real-time) electricity price on demand Response to price
    - Possible overall decrease or increase of consumption
    - Change in behavior
    - Change in comfort/energy services demanded

  - Pure demand shifting
    - Peak shaving and valley filling
    - Same level of comfort/energy services demanded

How do you model Active Demand Response (ADR)?
Focus on electric heating & electric vehicles.

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Scope

- Modeling Active Demand Response
  - Operational perspective
  - Perfect information / anticipation
    - Deterministic setting

- Key questions:
  - What are different modeling approaches concerning demand response?
  - What are potential benefits in terms of system cost?

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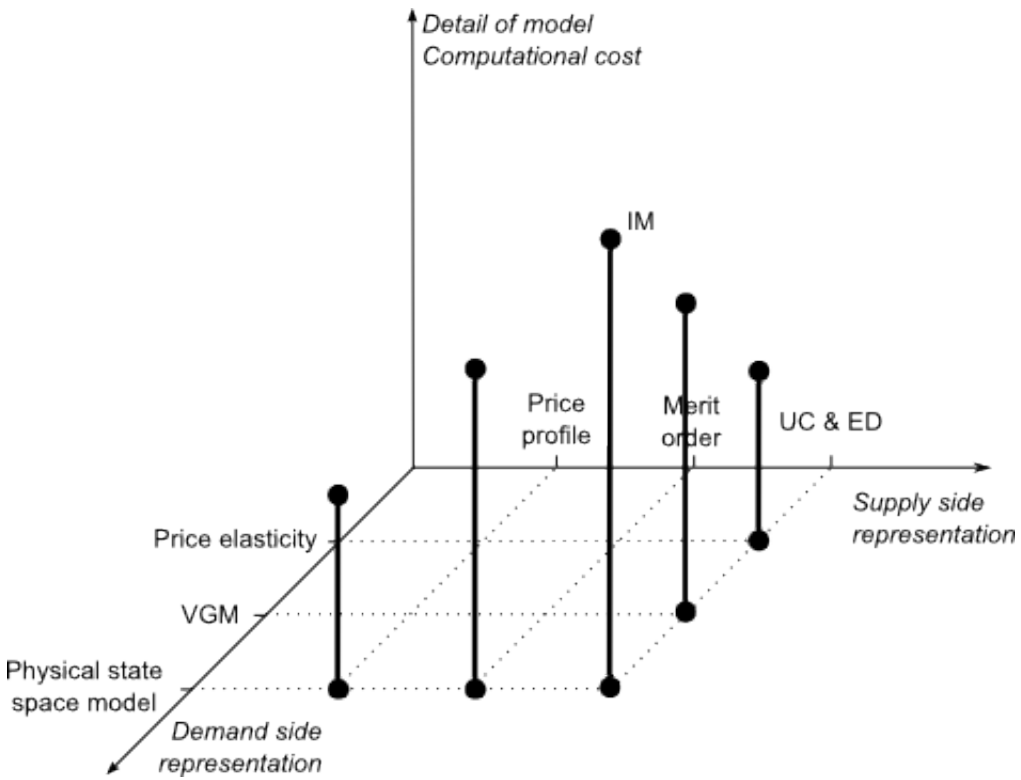
Different modeling perspectives



From **supply side** point of view

- E.g., Unit commitment (UC) models
  +
  Demand elasticities or Virtual generator models

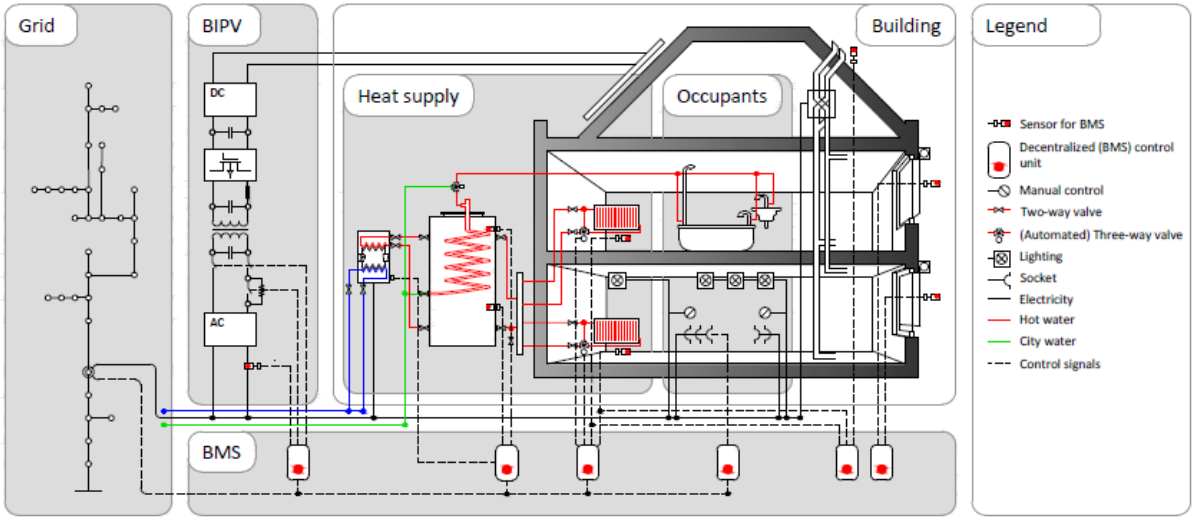
From **demand side** point of view

- E.g., detailed building models; detailed models for electric vehicles
  +
  Fixed electricity price profile

Both are insufficient to study the large scale integration of ADR: the need for **integrated models**, considering both supply and demand side in detail.

Demand side perspective

- Detailed models (simulation or optimization) employ an electricity price signal to control the behavior of flexible loads
- The feedback of this demand on the electricity price profile is often not included



Supply side perspective: price elasticity

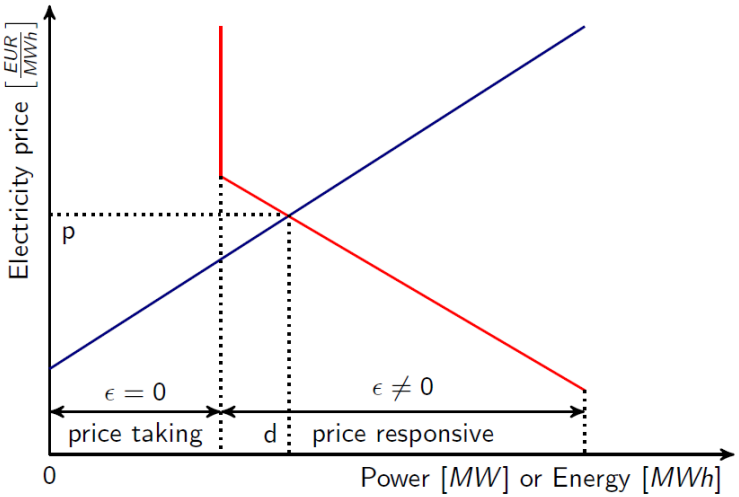
‘Elasticity matrix’:

- **Own price elasticities**
  - Relative change in demand for electricity in response to change in its price
  - Negative value

- **Cross-price elasticities**
  - Change in demand for electricity in hour a in response to a change in the price for electricity in hour b
  - Typically positive

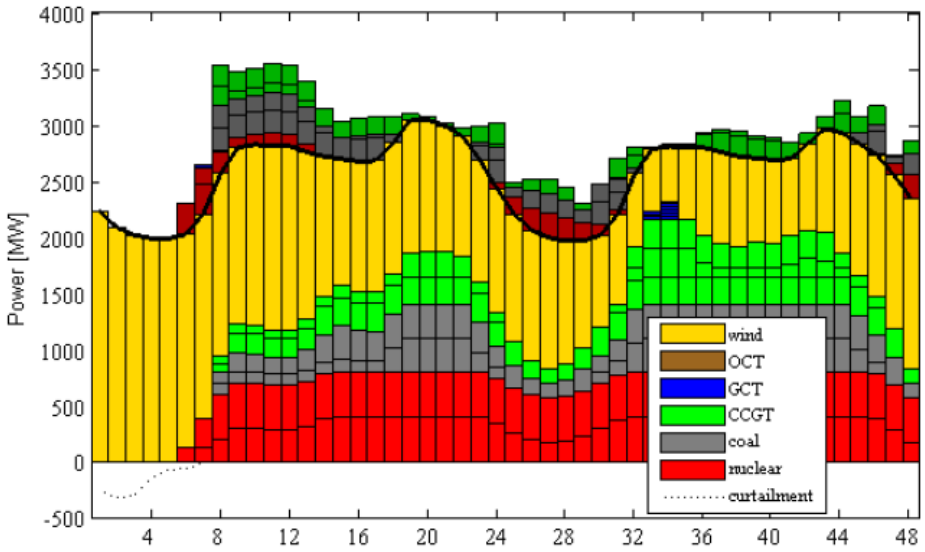
Supply side perspective: price elasticity

- Solve UC model with fixed demand (DEM_j)
  - Defines optimal commitment
  - Calculate price for every hour
    - As dual or shadow variable of energy balance
  - Calculate weighted average price
    - Assumed to be fixed single tariff P_0
  - (P_0,DEM_j) is reference point, for every hour specific

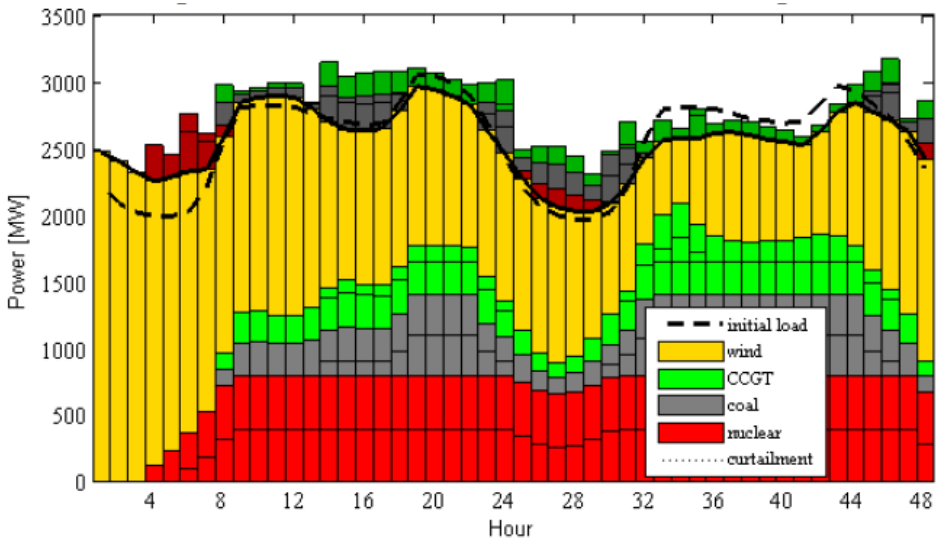


- UC model with elasticities
  - No longer linear
  - Moving from pure generation cost minimization (fixed demand) to welfare maximization

Supply side perspective: price elasticity



No elasticity – fixed demand



Own elasticity: -0.2 (all hours)

Source: De Jonghe, C., Delarue, E., D'haeseleer, W., Belmans, R. (2011). Integrating Real-Time Pricing into Unit Commitment Programming. Power Systems Computation Conference (PSCC). Stockholm (Sweden), 22-26 August 2011.

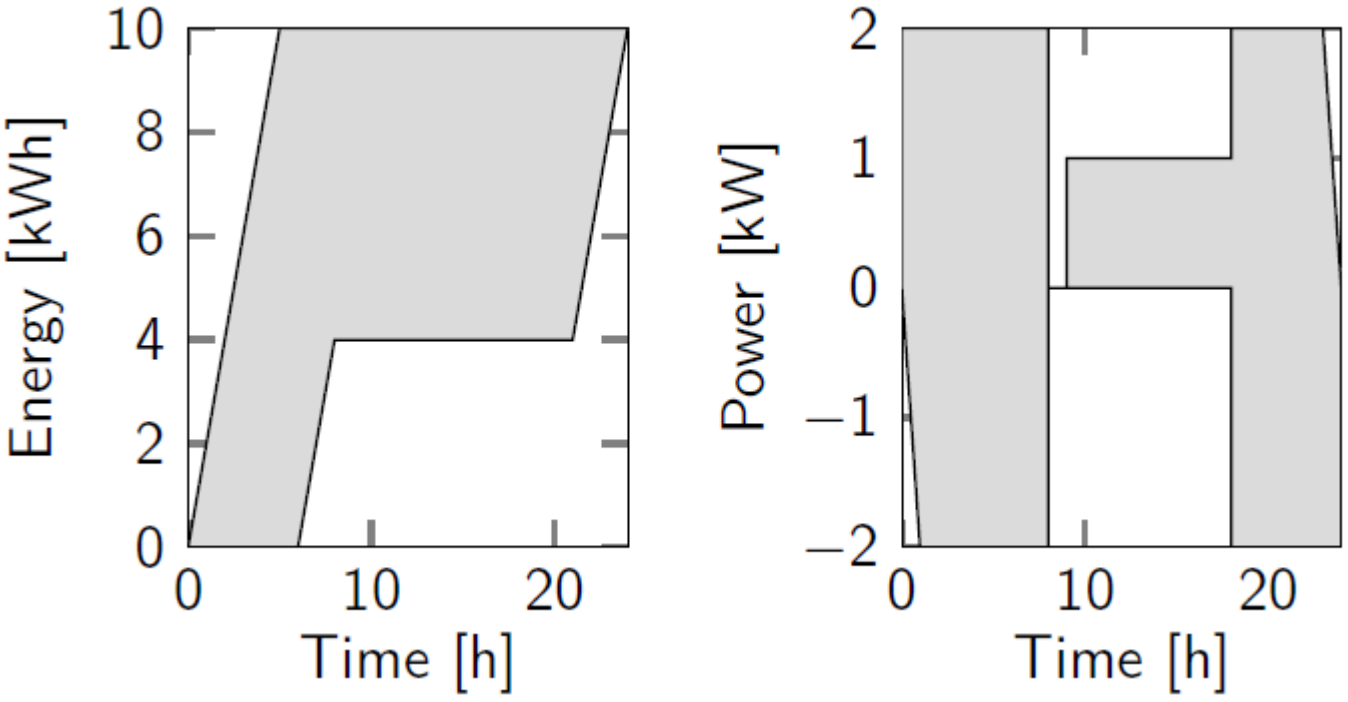
Supply side perspective: virtual generator models

- Flexible load characterized by
  - Energy constraints: minimum & maximum cumulative consumption
  - Power profile: minimum & maximum instantaneaous consumption
- Referred to as **“flex curves”**
- Additional load (power profile) to be added to demand in UC model
- Possibly also generation back into the grid: Negative power profile

Supply side perspective: virtual generator models

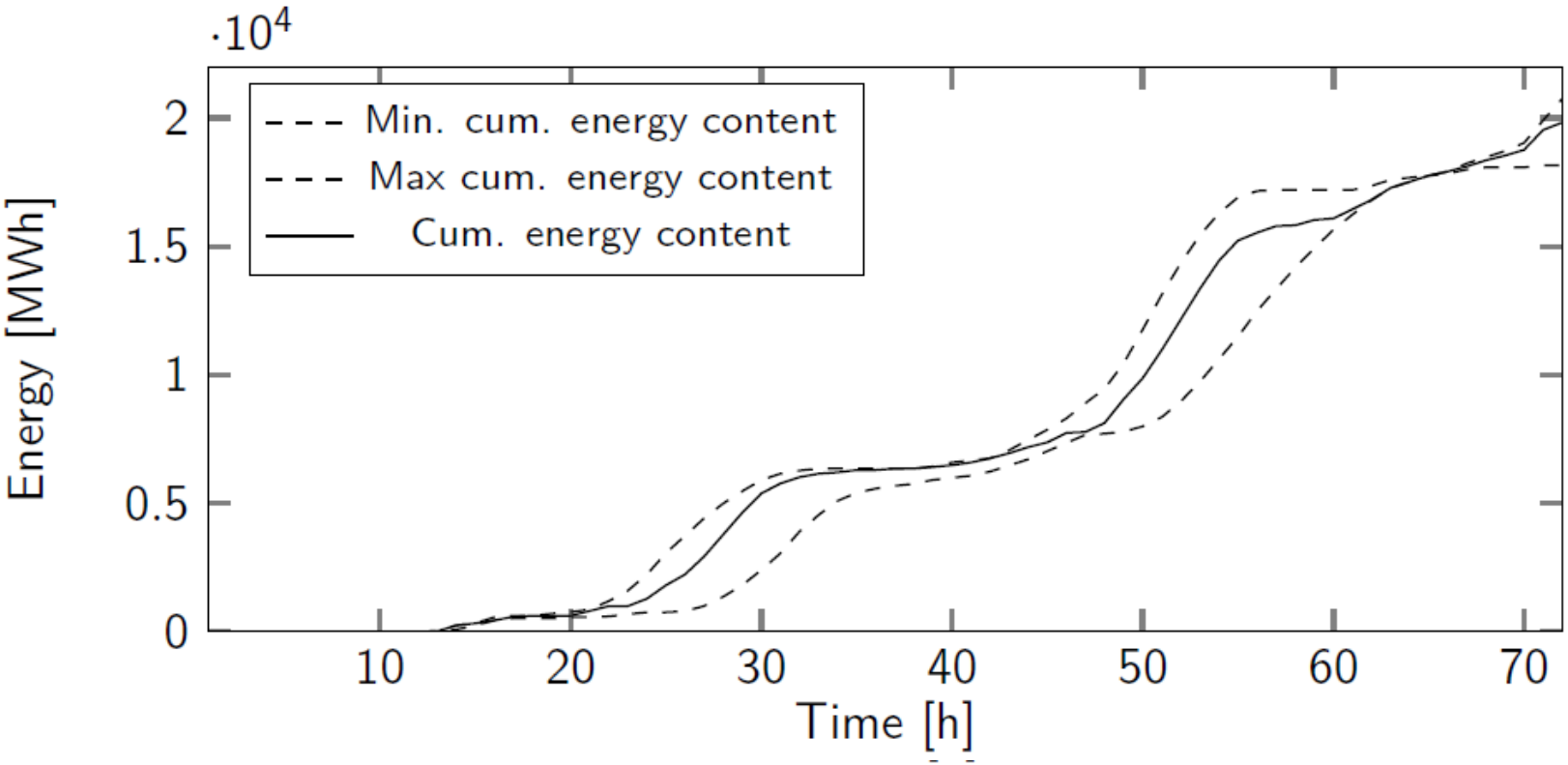
Example: EV, 24h, also V2G

- 2 kW charger, 10 kWh battery
- 4 kWh trip at 8 AM
- 1 kW limit in charging station, no V2G



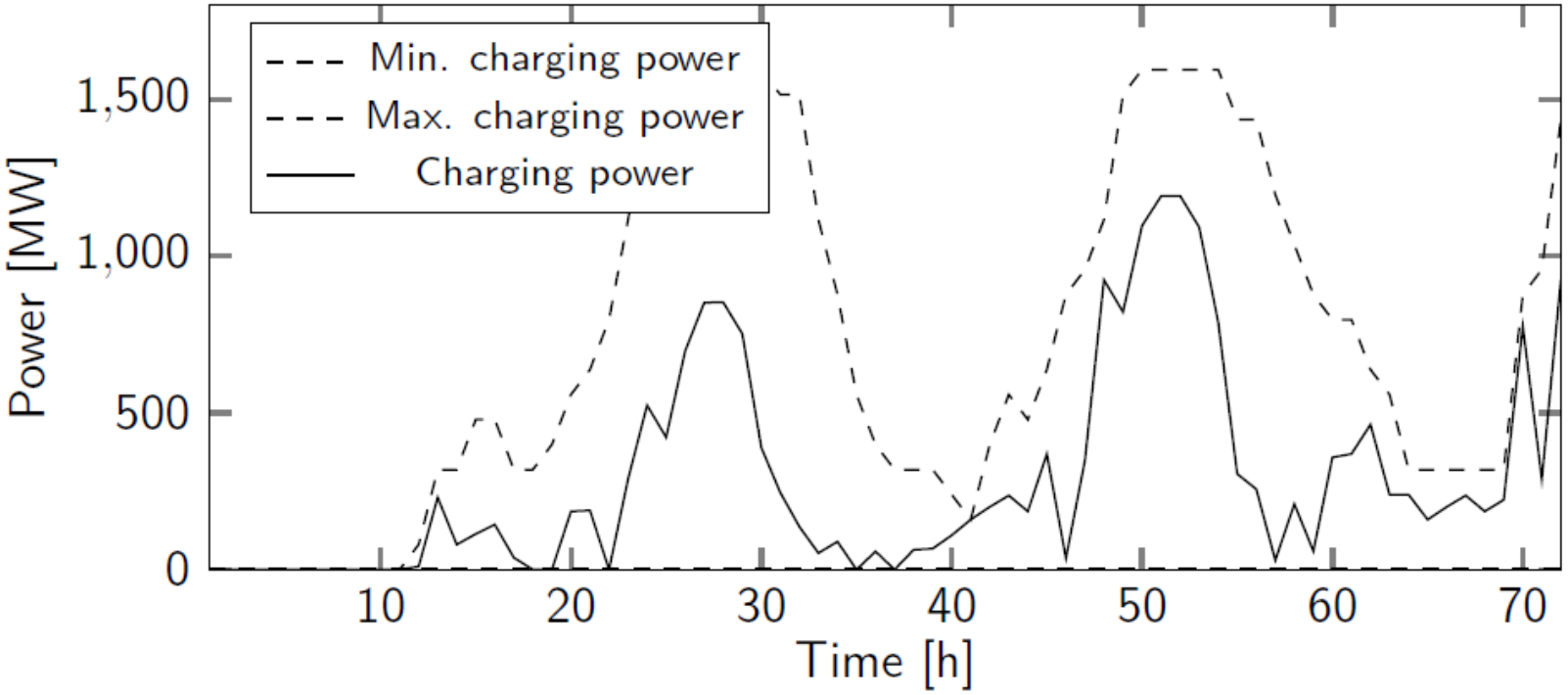
Supply side perspective: virtual generator models

Energy flex curves & energy supplied to the EVs



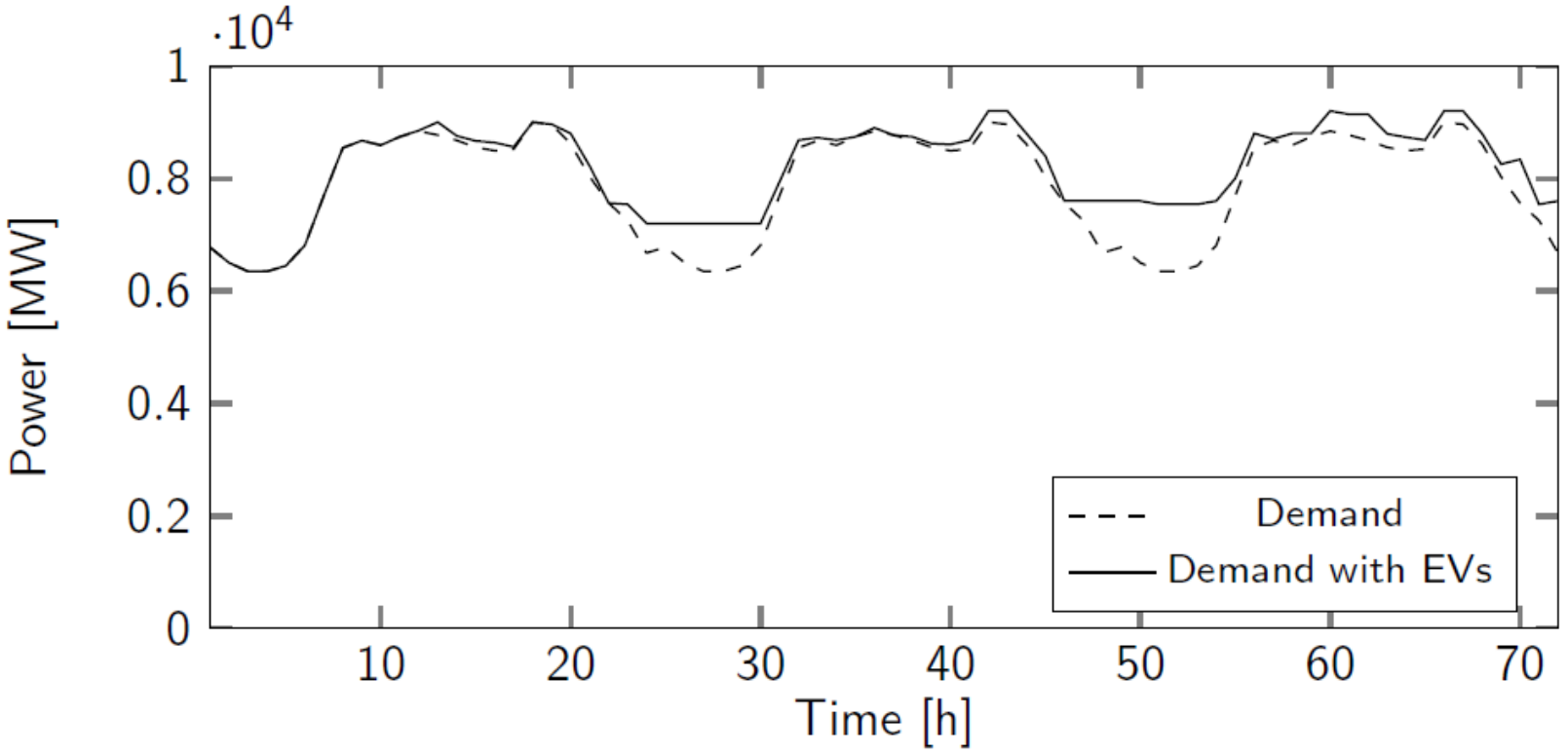
Supply side perspective: virtual generator models

Power flex curves & power supplied to the EVs



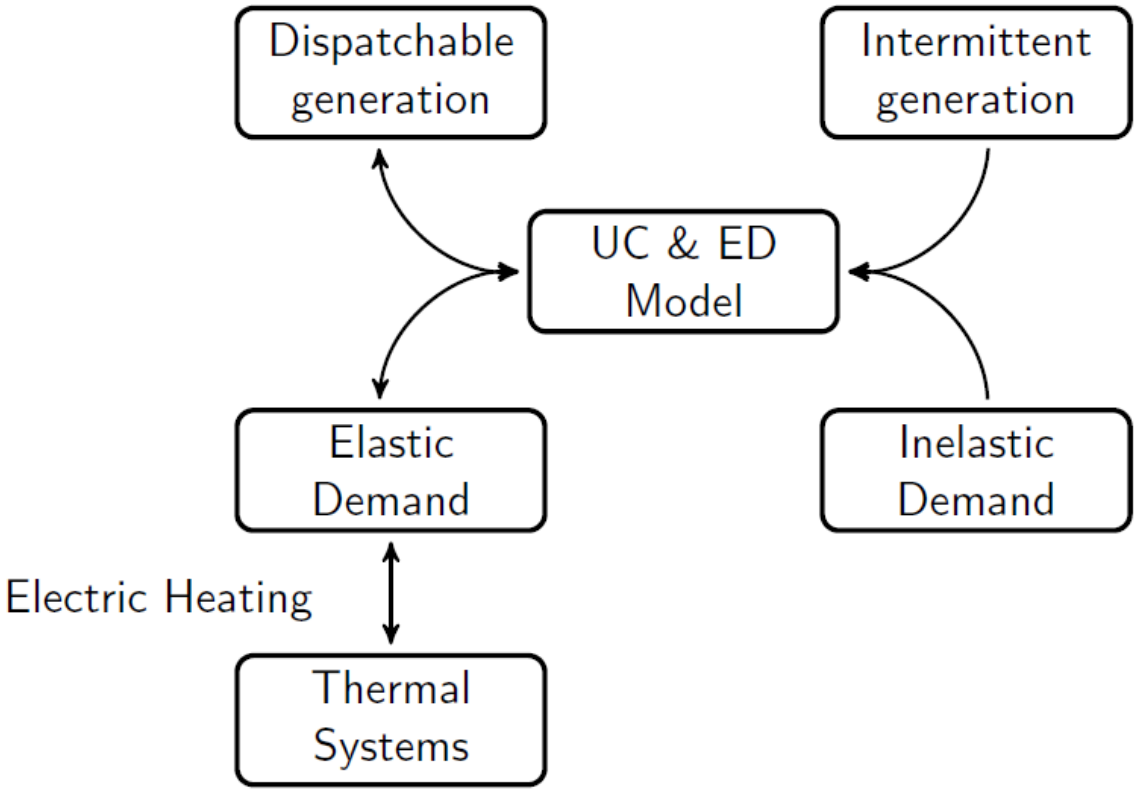
Supply side perspective: virtual generator models

Impact on load

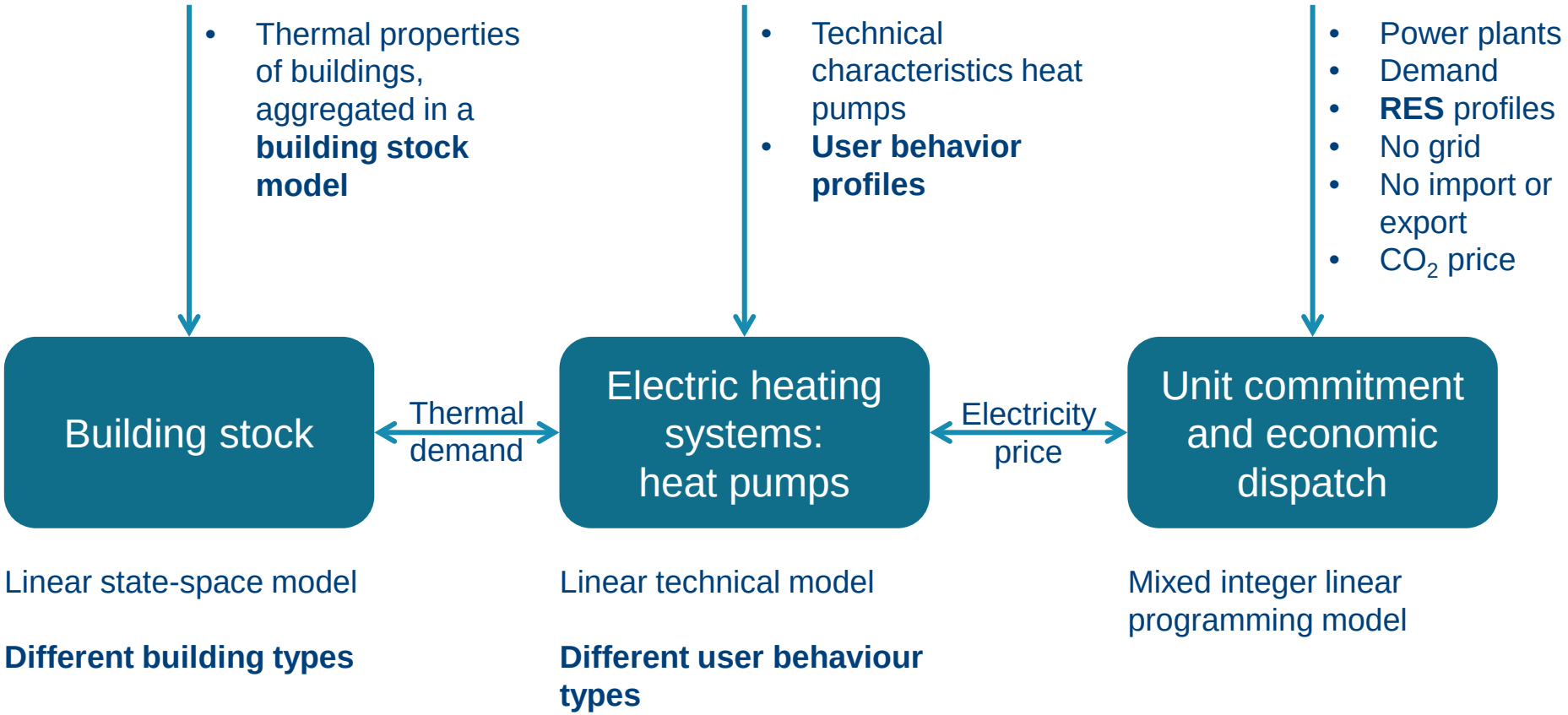


Integrated modeling

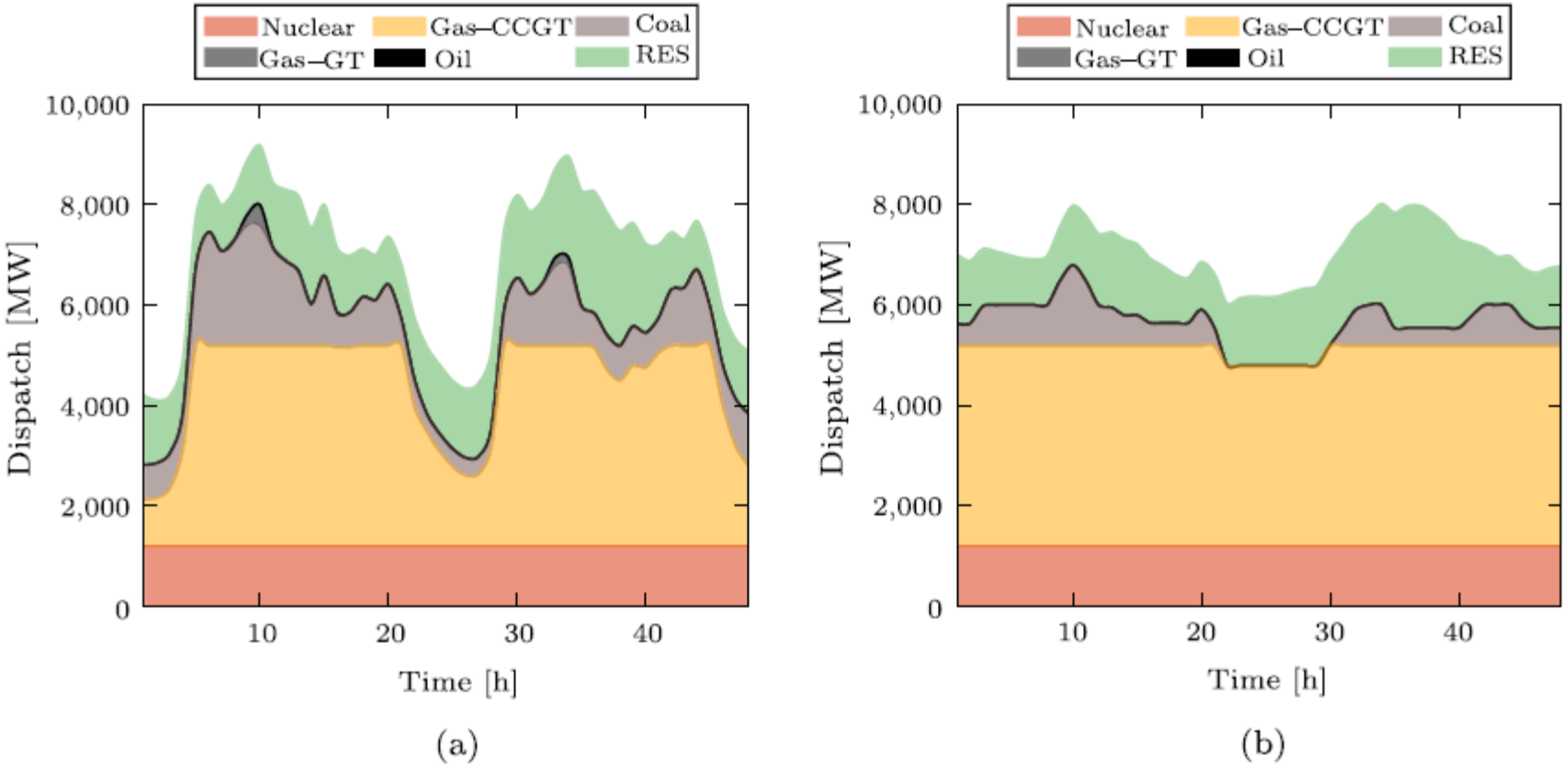
Example of integrated modeling: electric heating systems



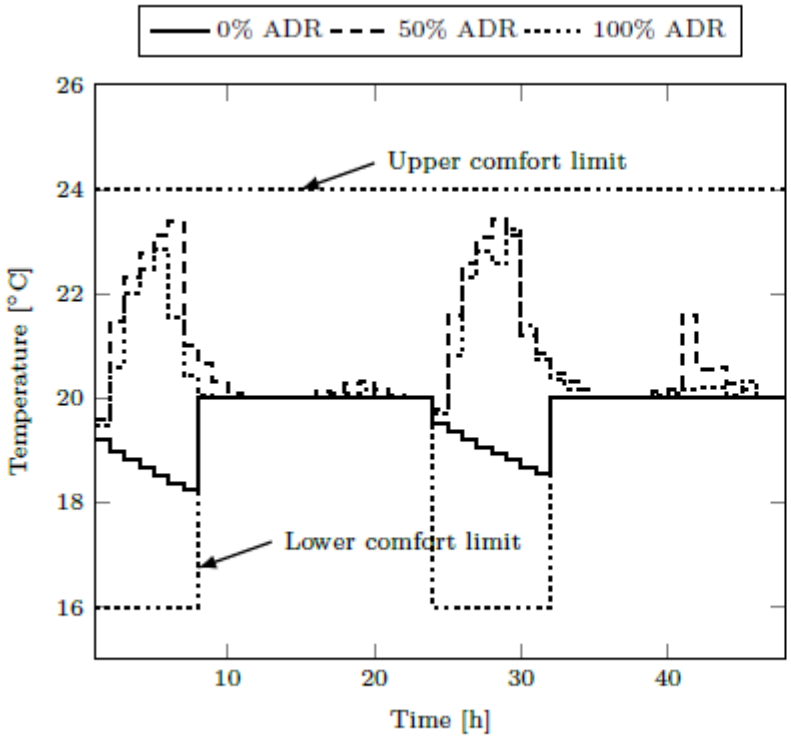
Integrated modeling



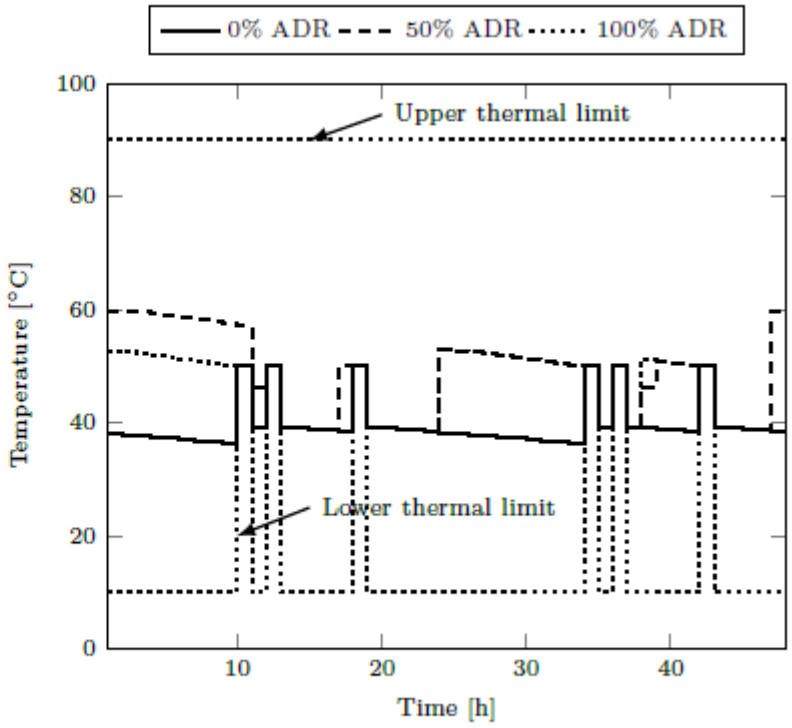
Integrated modeling: supply side perspective



Integrated modeling: demand side perspective



(a) Indoor air temperature



(b) Domestic hot water tank temperature

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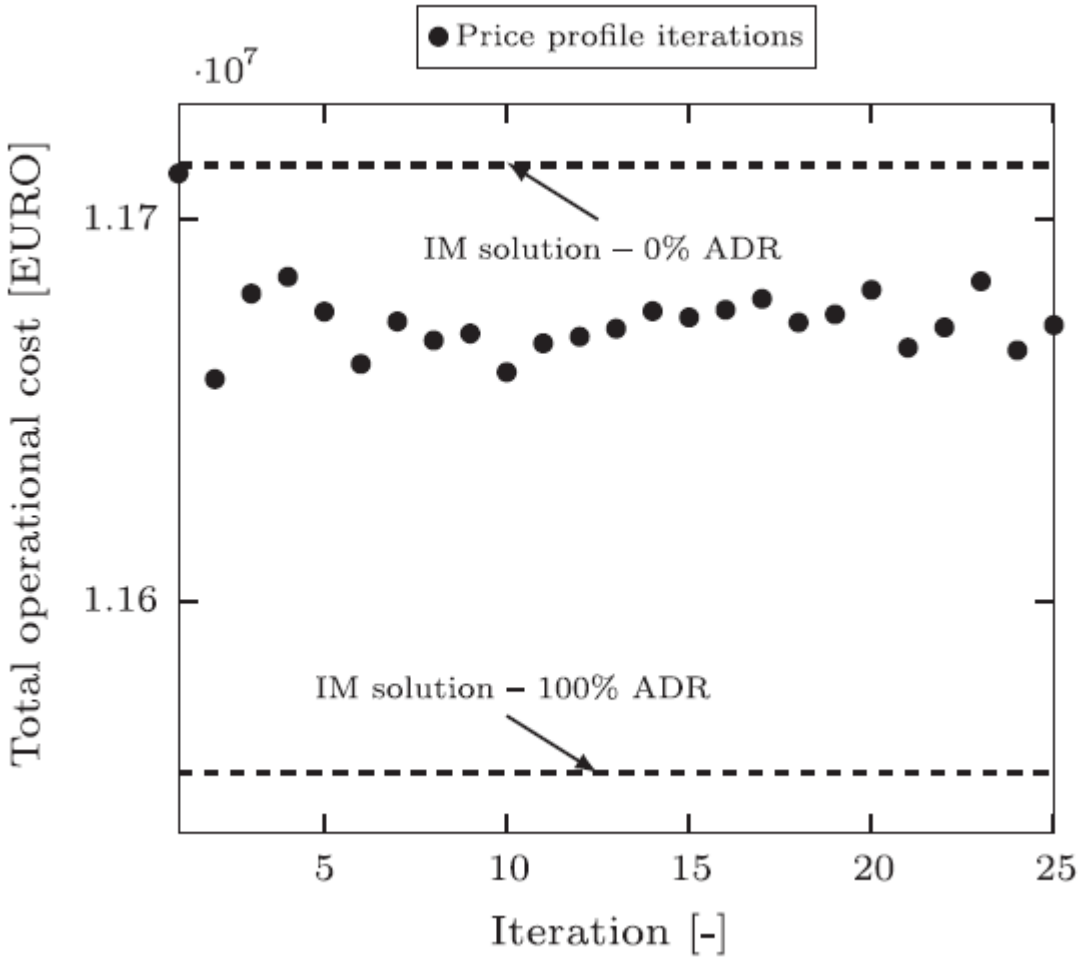
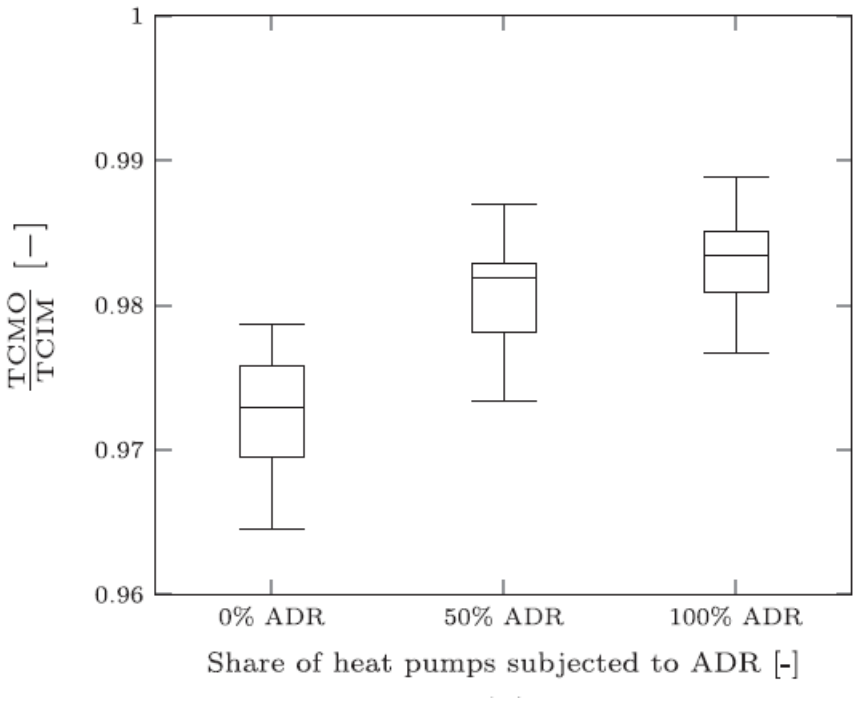
Integrated modeling: approximations

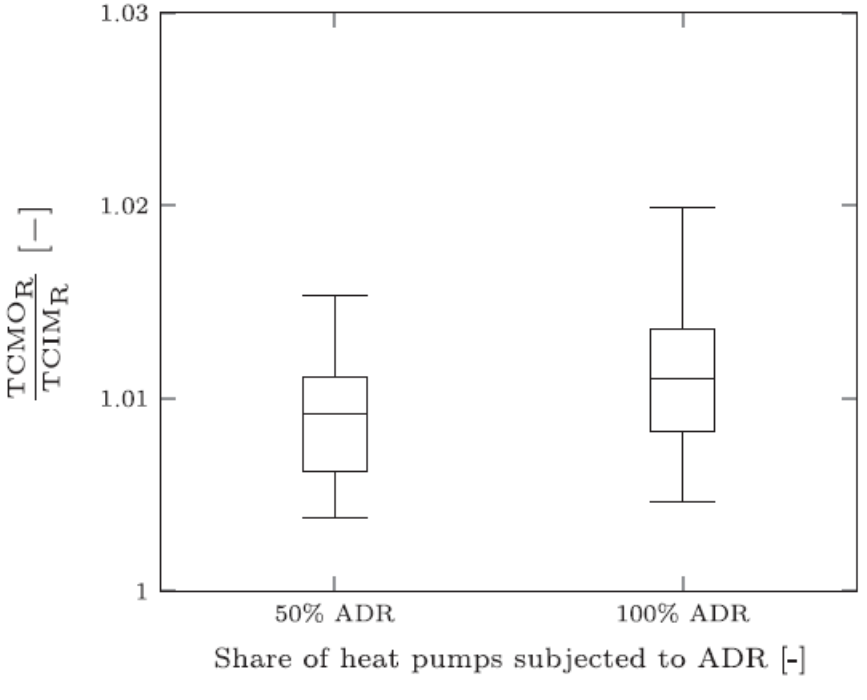
Iterative approach: electricity prices and demand profiles



Integrated modeling: approximations

Merit order model: simplifications





Conclusions and reflections

- Modeling
  - Different approaches
  - More complex types of ADR require advanced modeling
    - Potential simplifications, but require validation

- Quantification of ADR benefits on system level
  - Controlling heating systems
    - Complex strategies – full control
    - More basic strategies?
      - E.g., interrupting load of air conditioning

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Conclusions and reflections

- ADR in the European electricity market?
  - Activating the demand side, observing elastic demand and corresponding flexibility
    - Metering, communication, tarification schemes, new market actors
  - Benefits, with limitations
    - Trade off for consumer between benefits and “costs”
      - External control, predictability, privacy, etc.

Contacts

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Overview

- Different modeling approaches for Active Demand Response (ADR)
  - Demand elasticities
  - Virtual generator models
    - E.g., electric vehicles
  - Integrated modeling
    - E.g., electric heating systems
- Focus on system cost benefits