RESIDENTIAL HEAT PUMPS AS FLEXIBLE LOADS FOR DIRECT CONTROL SERVICE WITH CONSTRAINED PAYBACK

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Introduction

- **Who?**

  Aggregator with direct control of heat pumps

- **What?**

  from the consumption of its portfolio, proposes a consistent modulation service

- **How?**
  - Optimize baseline to minimize energy cost for end-user
  - Maximize amount of modulation available for given payback

- **Why?**
  - Relieve congestions in distribution network
  - Solve an imbalance

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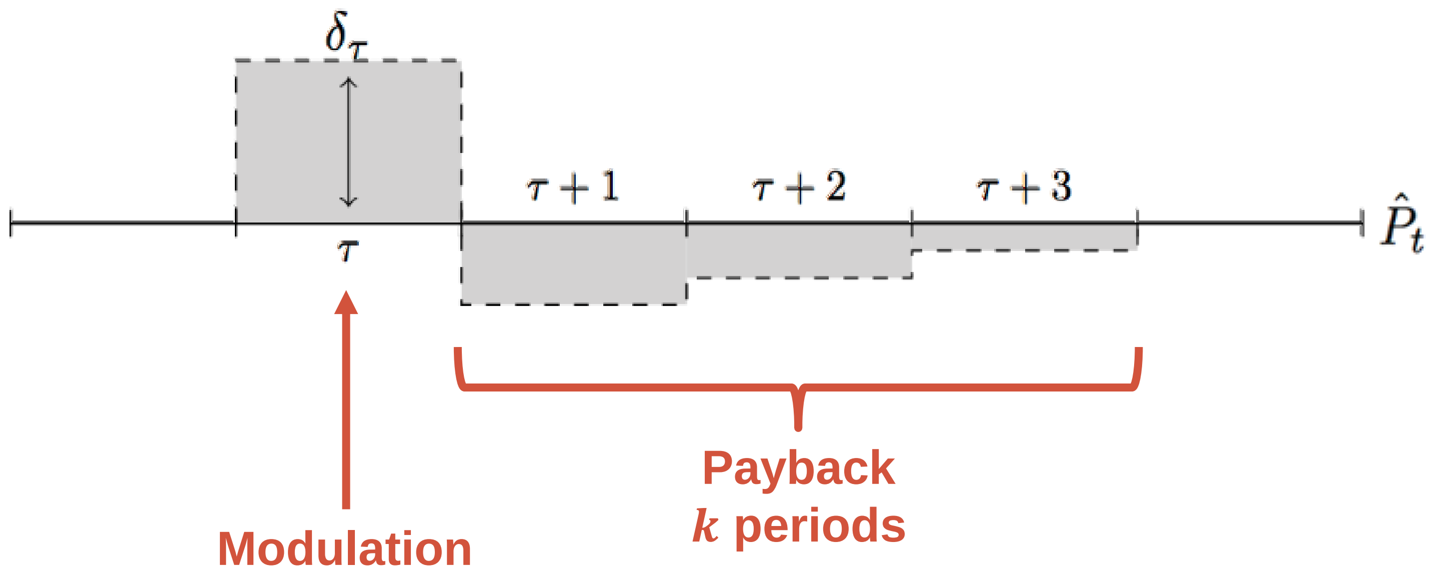
Flexibility service

- Flexibility service with a modulation in a given period τ and a payback in k following periods



Flexibility service

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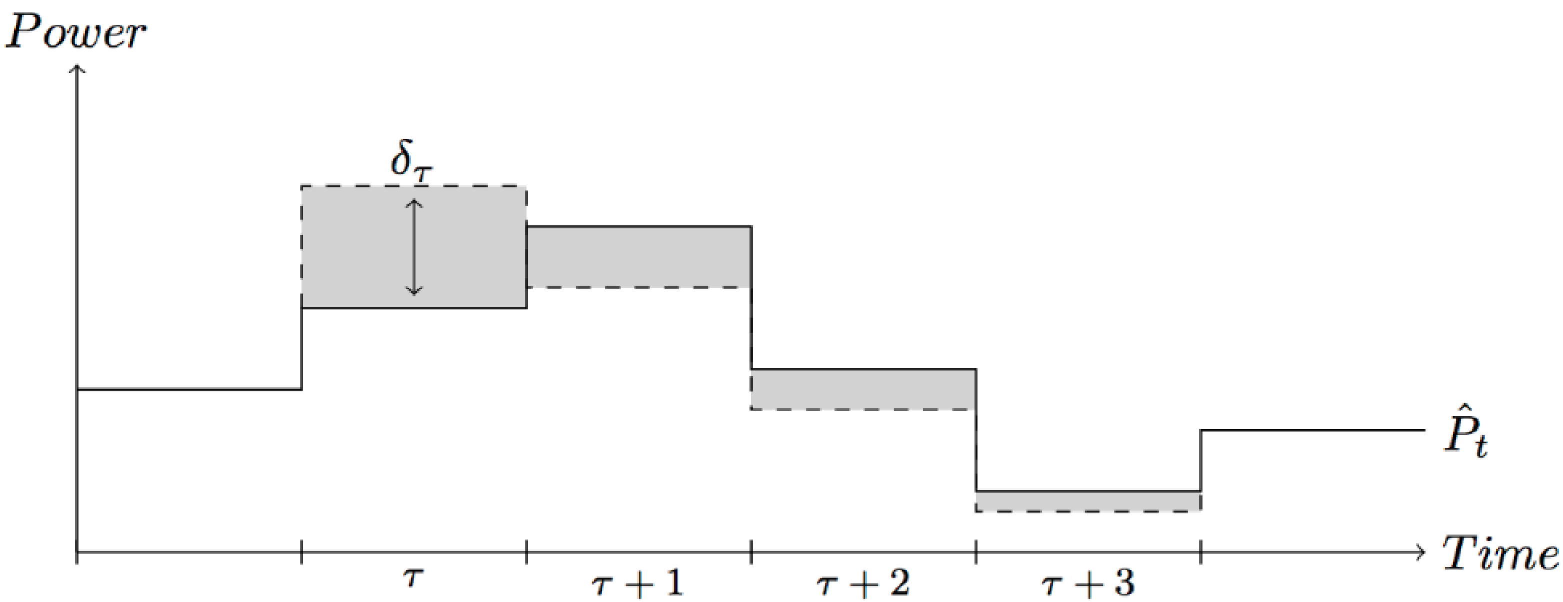


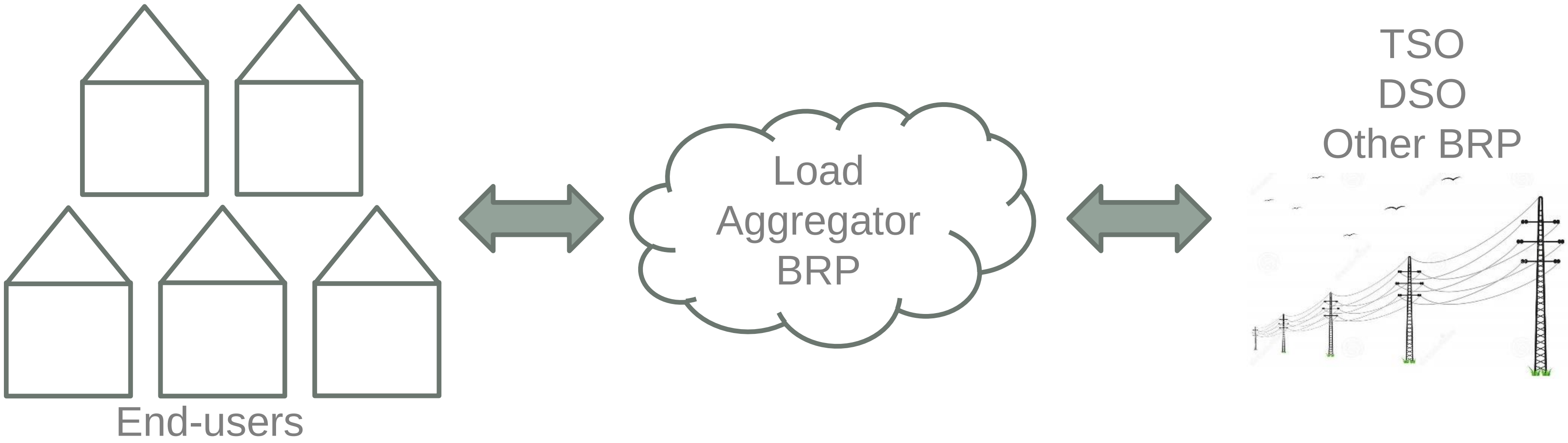
Deviations from baseline

$\Rightarrow$ Imbalance

$\Rightarrow$ Other congestions ?

Definition of a baseline

- Reference: baseline which minimizes the electricity cost for the consumer
  - the use of flexible heat pumps should benefit the end-user as an incentive to enroll in flexibility programs
  - if an aggregator is a BRP, then it has to state its positions to the TSO in the form of baselines



Thermal state transition model

- In the optimization problem, the thermal states transition model and the state constraints are summarized by

$$\boldsymbol{x}_{t+1} = f(\boldsymbol{x}_t, \boldsymbol{u}_t, \boldsymbol{W}_t)$$
$$x_{t,min} \leq x_t \leq x_{t,max}$$

and detailed in a few slides.

Where

- $\boldsymbol{x}_t$ state variables
- $\boldsymbol{u}_t$ model parameters
- $\boldsymbol{W}_t$ modulable variables

Optimization of the baseline

Solve

Min energy cost

Subject to

- thermal state transition model
- state constraints
- power limitations
- heat pump constraints

Optimization of the modulation

To obtain the maximum upward modulation in a period τ with a payback effect in the k following periods, solve

Max amount of modulation available in period τ

Subject to

- thermal state transition model
- state constraints
- power limitation
- heat pump constraints
- payback limited on k periods

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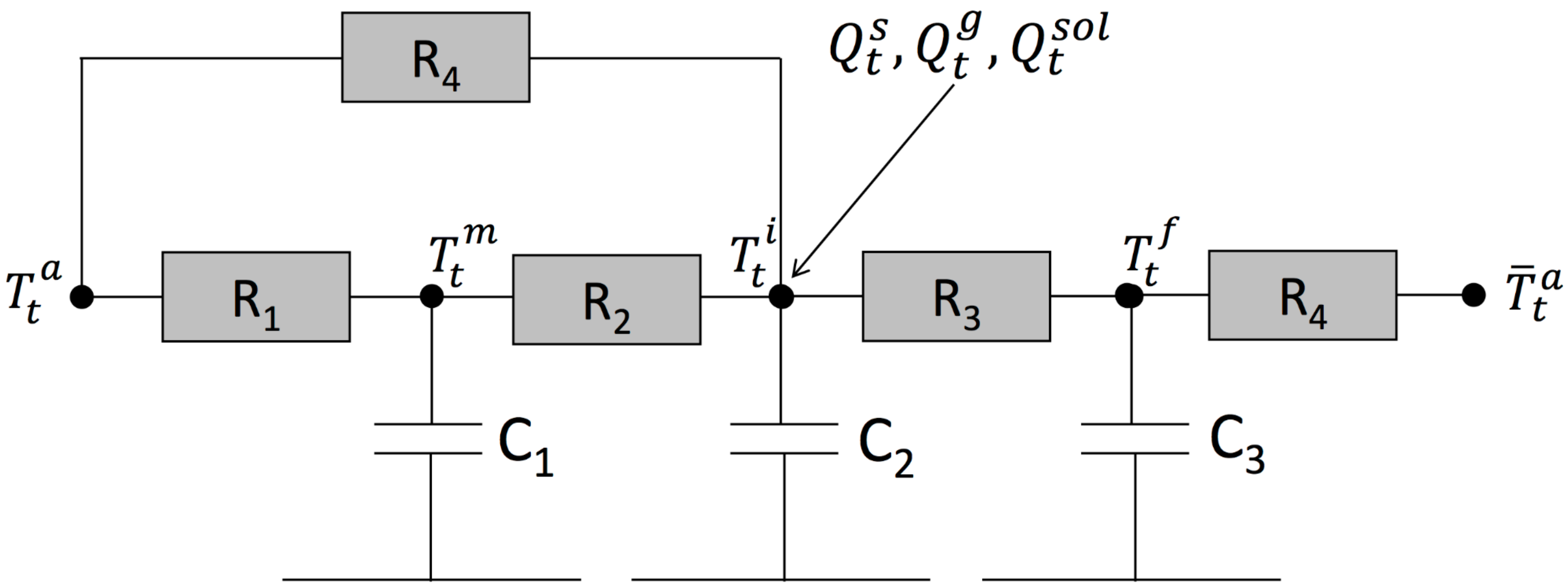
Thermal model: building

- Building thermal behavior modeled by an equivalent single zone 5R3C thermal network
- Parameters identified from detailed validated models
- Zone temperature constrained to remain within thermal comfort



Thermal model: heat pump

- Variable-speed air-to-water heat pumps used to cover domestic hot water and space heating needs

- Modeled using a linear empirical model with a coefficient of performance function of
  - the ambient temperature
  - full-load / part-load performance

- The heat pump can only supply either the domestic hot water tank or the direct space heating emitters

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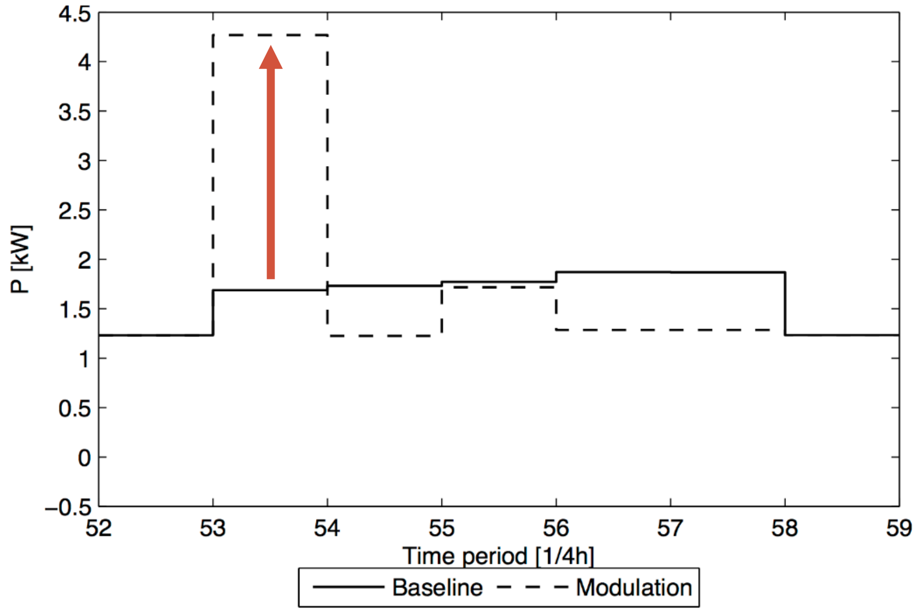
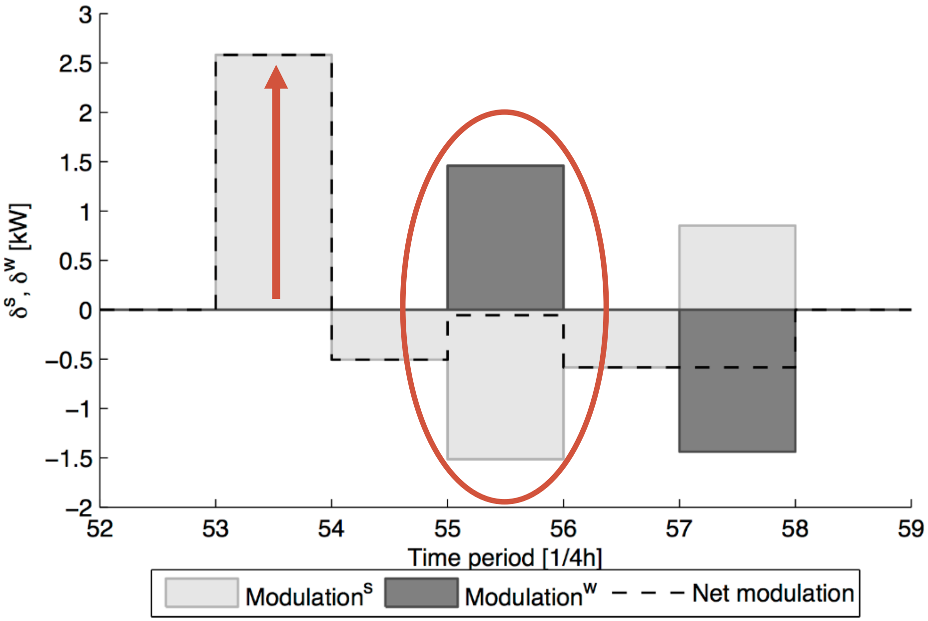
Results: single house

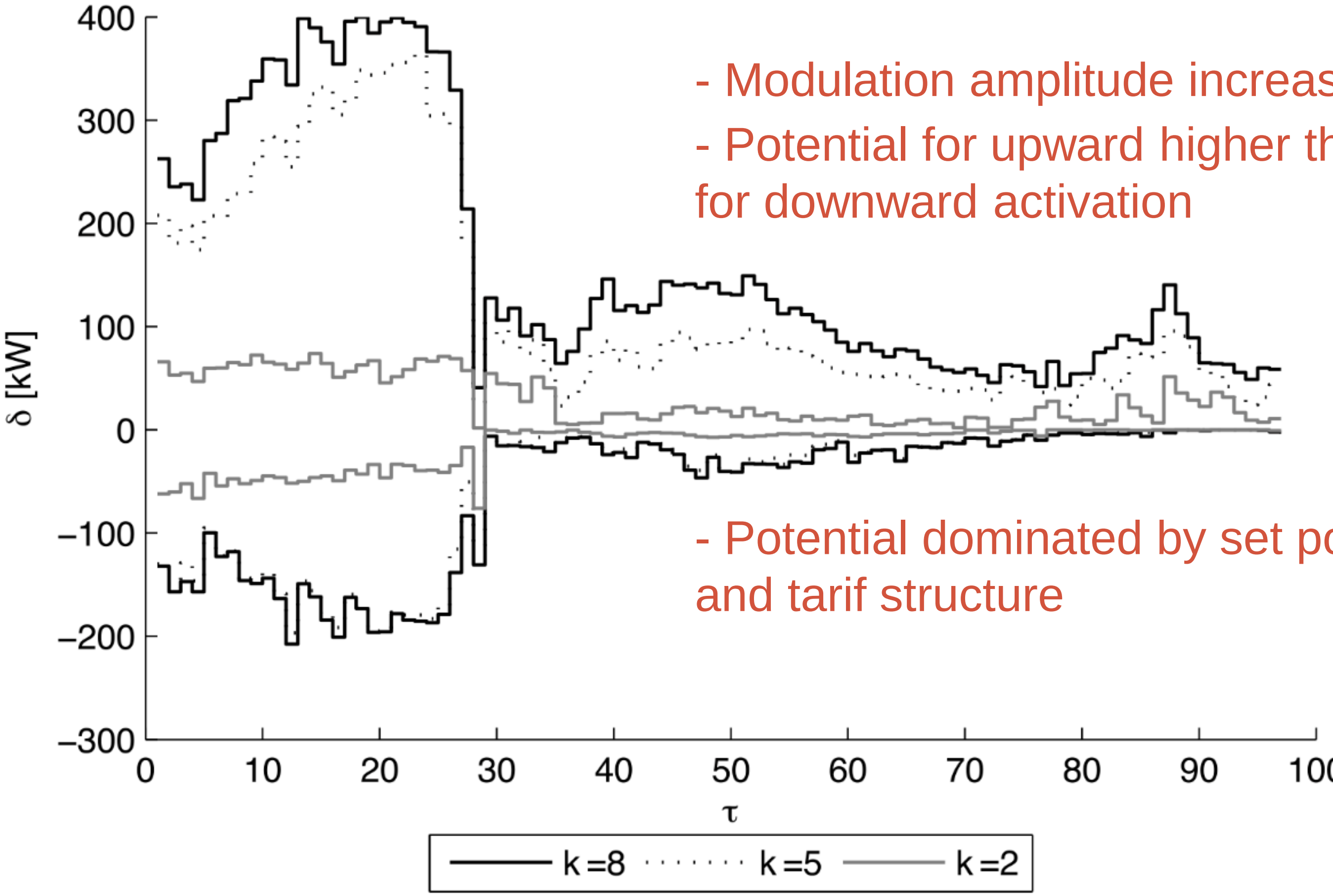
- Modulation in quarter 53 with a payback of 1 hour
  - 2.5 kW of modulation provided by space heating
  - Domestic hot water counterbalances space heating to limit deviations during payback





Results: 100 houses

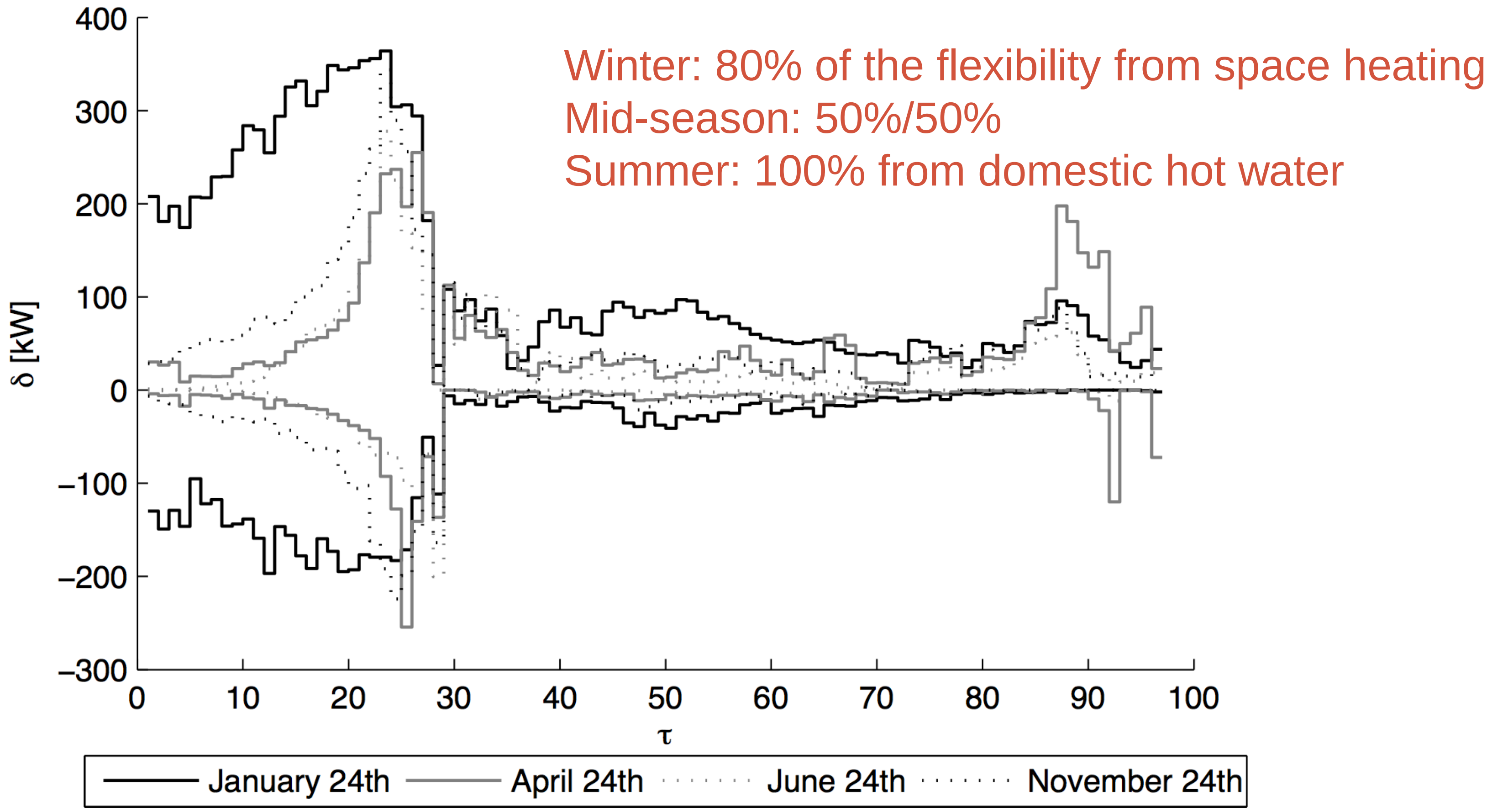
- Freestanding houses built > 1971
- Average nominal power: 4.3 kW (heat pump + resistance)



- Modulation amplitude increases with k
- Potential for upward higher than for downward activation
- Potential dominated by set point profiles and tarif structure

Results: 100 houses

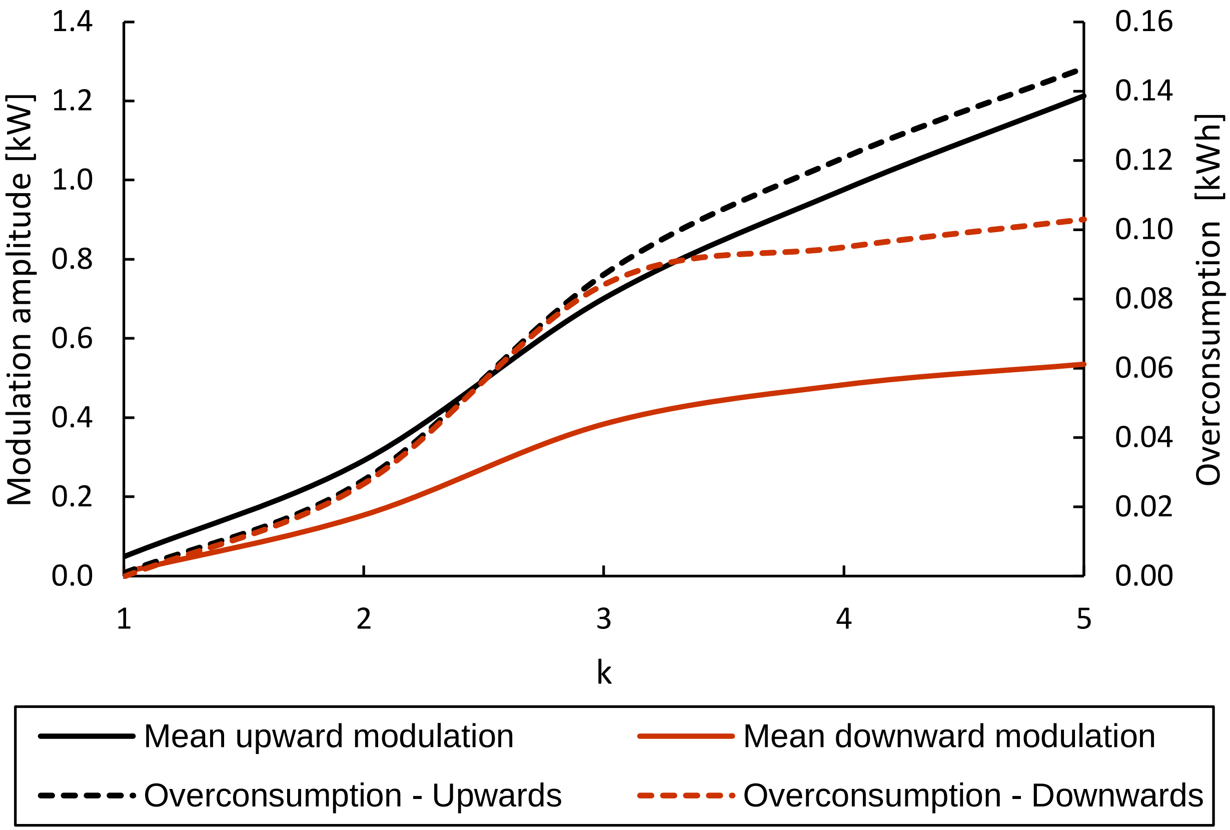
- Freestanding houses built > 1971
- Average nominal power: 4.3 kW (heat pump + resistance)



Results: 100 houses

- Average results per house depending on the payback
  - Overconsumption ~= ½ of energy of upward modulation

    ~= ¾ of energy of downward modulation



Conclusion

- Definition of a flexibility service provided by a load aggregator controlling domestic heat pumps
- Heat pumps used to supply domestic hot water production and space heating needs
- Consists in upward or downward activation of heat pumps at certain time-periods with a pay-back effect over a fixed number of periods
- Sequential optimization scheme to determine maximum modulation amplitude from an optimized baseline
- Application to a case-study with 100 houses:
  - Up to 1.2kW / 0.5kW for upward / downward modulation
  - Quantification of overconsumption and costs

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