



PowerMatching City Phase-II: What is the value of flexibility?

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Where innovation starts

Today's content

Introduction PMC II	Evaluation PMC II: Results	Model to assess benefits	Results: value of flexibility
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PowerMatching City phase-II

Phase I launched 2010:

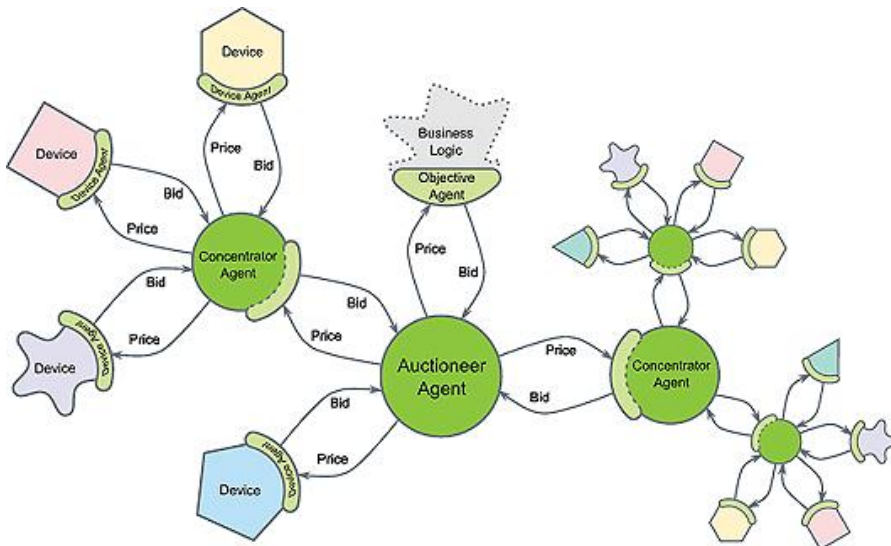
- 25 households in Hoogkerk, Groningen
- Multi-agent system, i.e. PowerMatcher technology

Phase II launched 2012, scaling up:

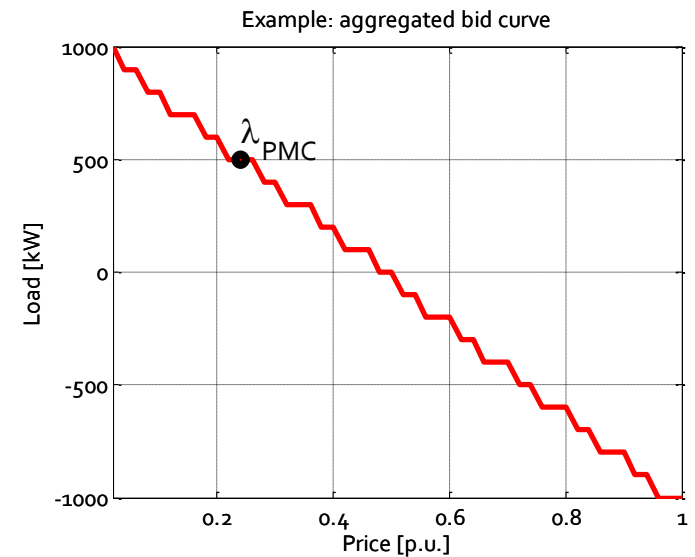
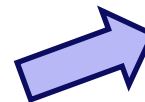
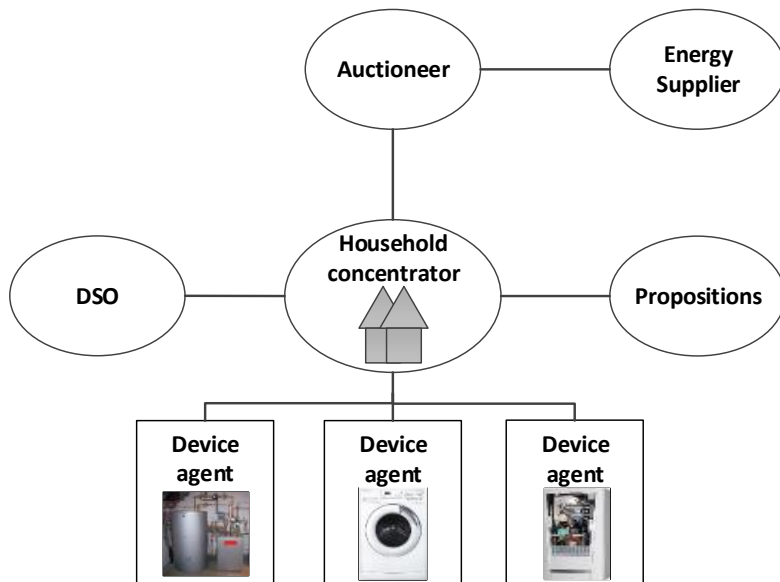
- 40 households: smart μ -CHPs and heat pumps
- Multi objective



PowerMatcher - PMC II architecture



$$\sum_{i=1}^N B_i(\lambda) = 0$$



PMC II architecture

Multi objective:

Device

- T limits

Consumer proposition

- *Sustainable- and cost savings cluster*

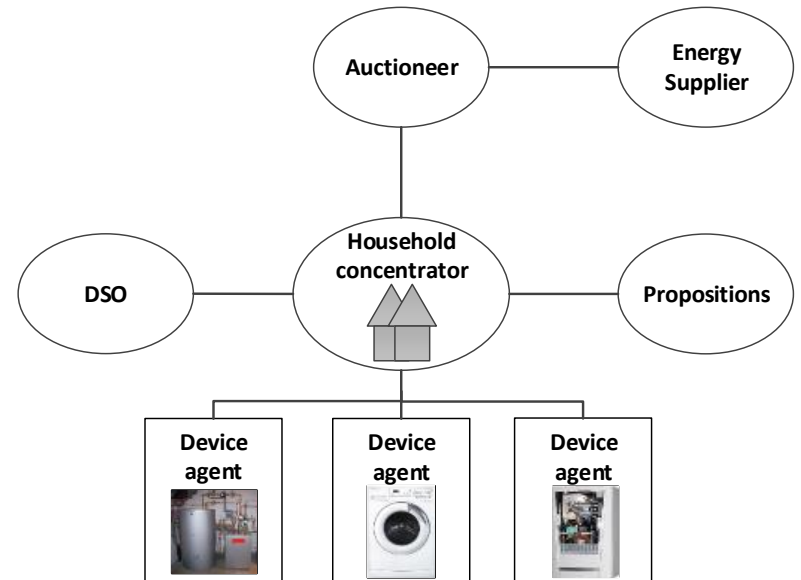
DSO

- Minimize peak loadings @ local transformer

Energy supplier

- Minimize cost on day-ahead and/or imbalance market

$$Price_{i,t} = f(\text{Devices}, \text{Propositions}, \text{DSO}, \text{Supplier})$$



Align PMC II output to model input

Step I: what is flexibility?

Step II: how to align PMC output to power system model input?

- Take into account model **AND** pilot limitations

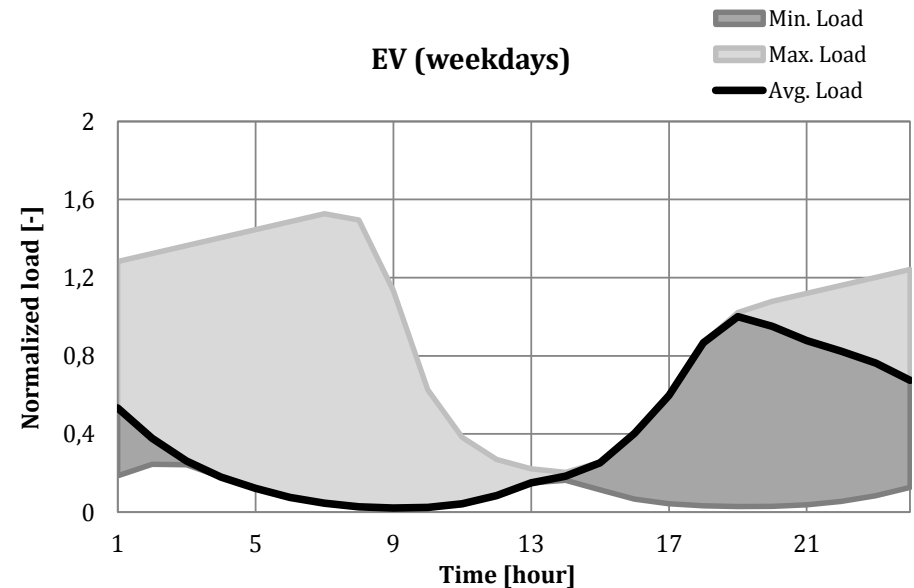
Flexibility profiles

Flexibility is the possibility to ramp up or down load/generation

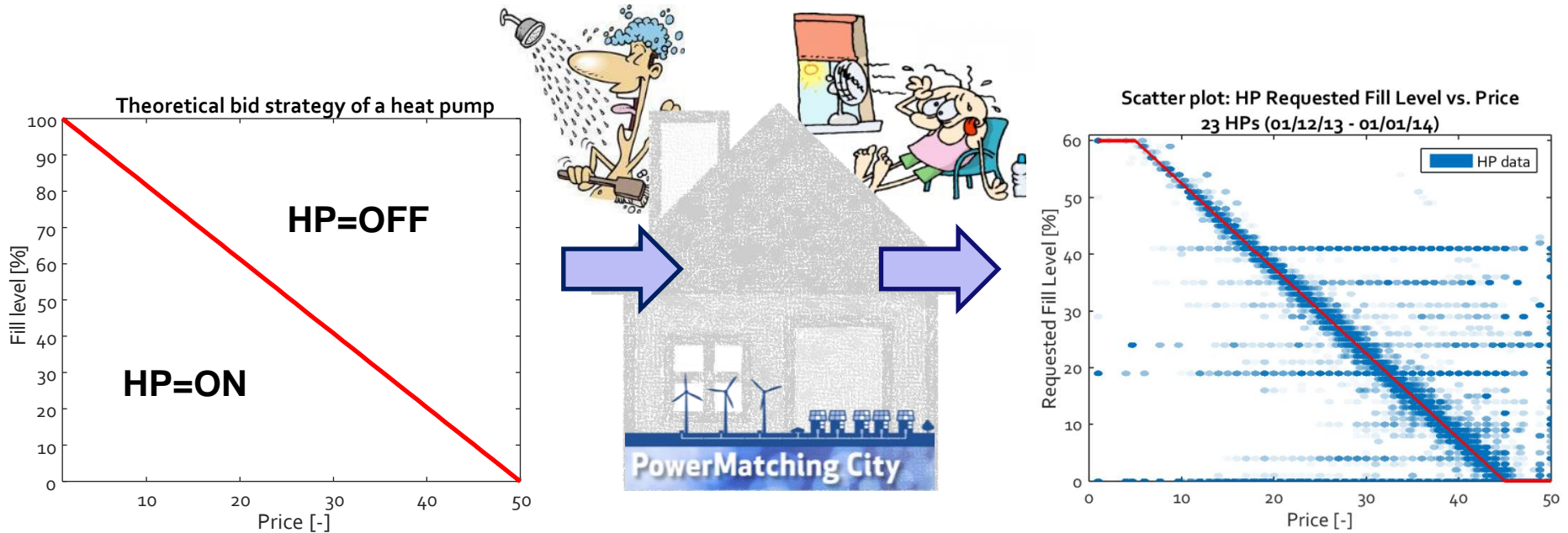
- Time dependent, due to consumer behavior
- Temperature dependent

Model limitations - requirements

- Hourly profiles for week- and weekend days
- Flexibility is assumed to have no 'memory effect', it is freely available during the day
- Daily load is constant



Evaluation of PMC: quantifying flexibility



Test results consider, amongst others:

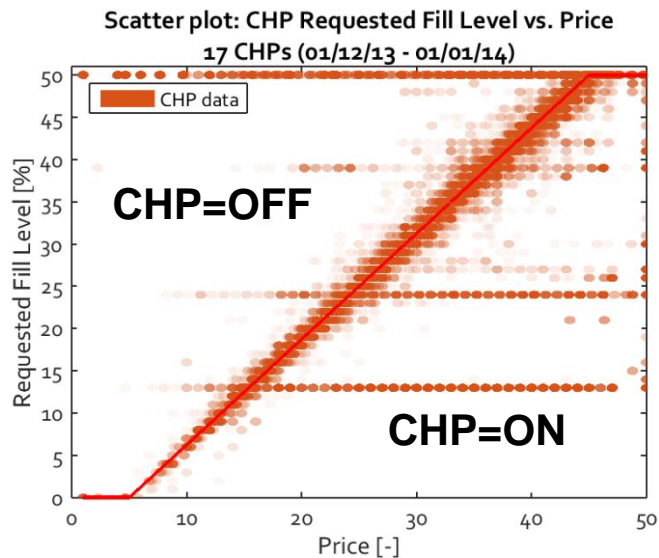
- Consumer behavior / acceptance
- 'Noise' due to technical issues

Flexibility

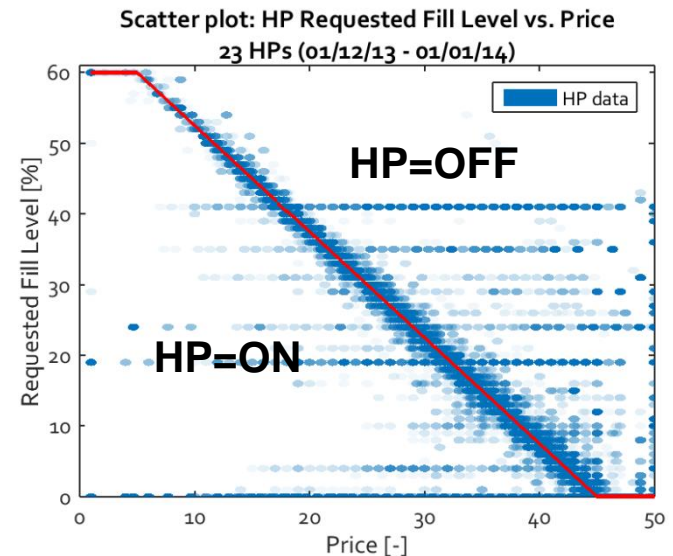
In line with the device's objective, flexibility is:

- The response of the load towards the price signal

$$\text{Max} \sum \lambda \cdot P_{CHP,t}$$



$$\text{Min} \sum \lambda \cdot P_{HP,t}$$



Flexibility

In PMC II load depends on:

- Consumer behavior:
 - Hour of the day (H)
 - Day of the week (Day)
- Outside temperature (TMP)
- Price (λ)

$$P_{i,t} = f(TMP, H, Day, \lambda)$$

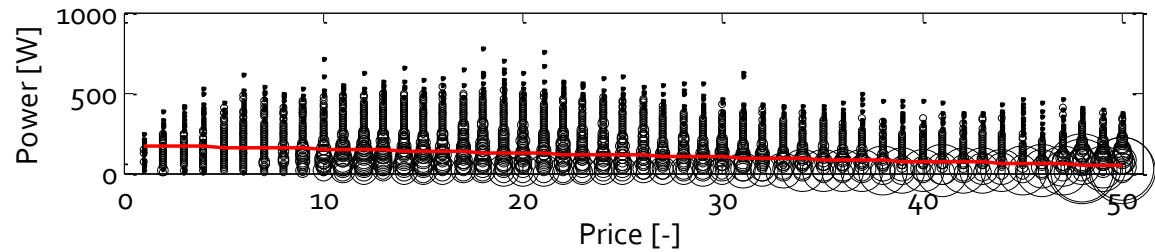
Average response to price

$$P_{i,t} = f(TMP, H, Day, \lambda)$$

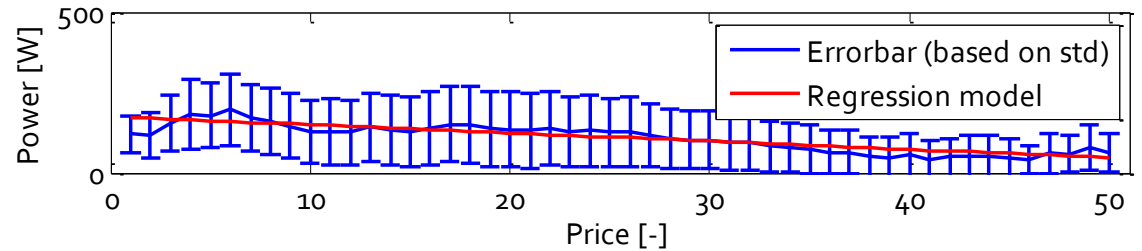
Avg. heatpump load per price, from: 30-Nov-2013 till: 01-Jul-2014

$$Y = 175.14 - 2.55 * Price$$

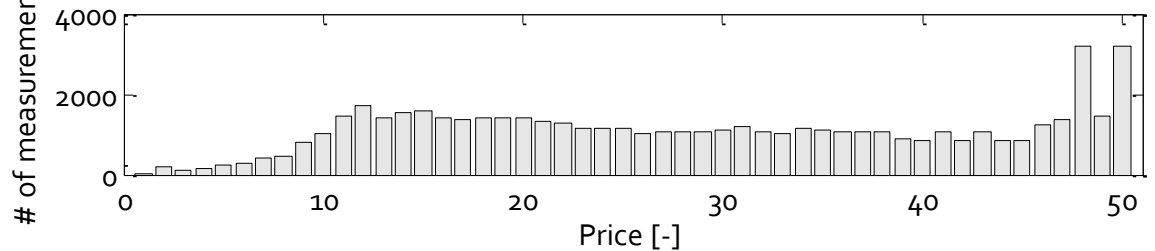
$$R^2 = 0.12, P = 0$$



Avg. load per price, incl. errorbar (based on std)

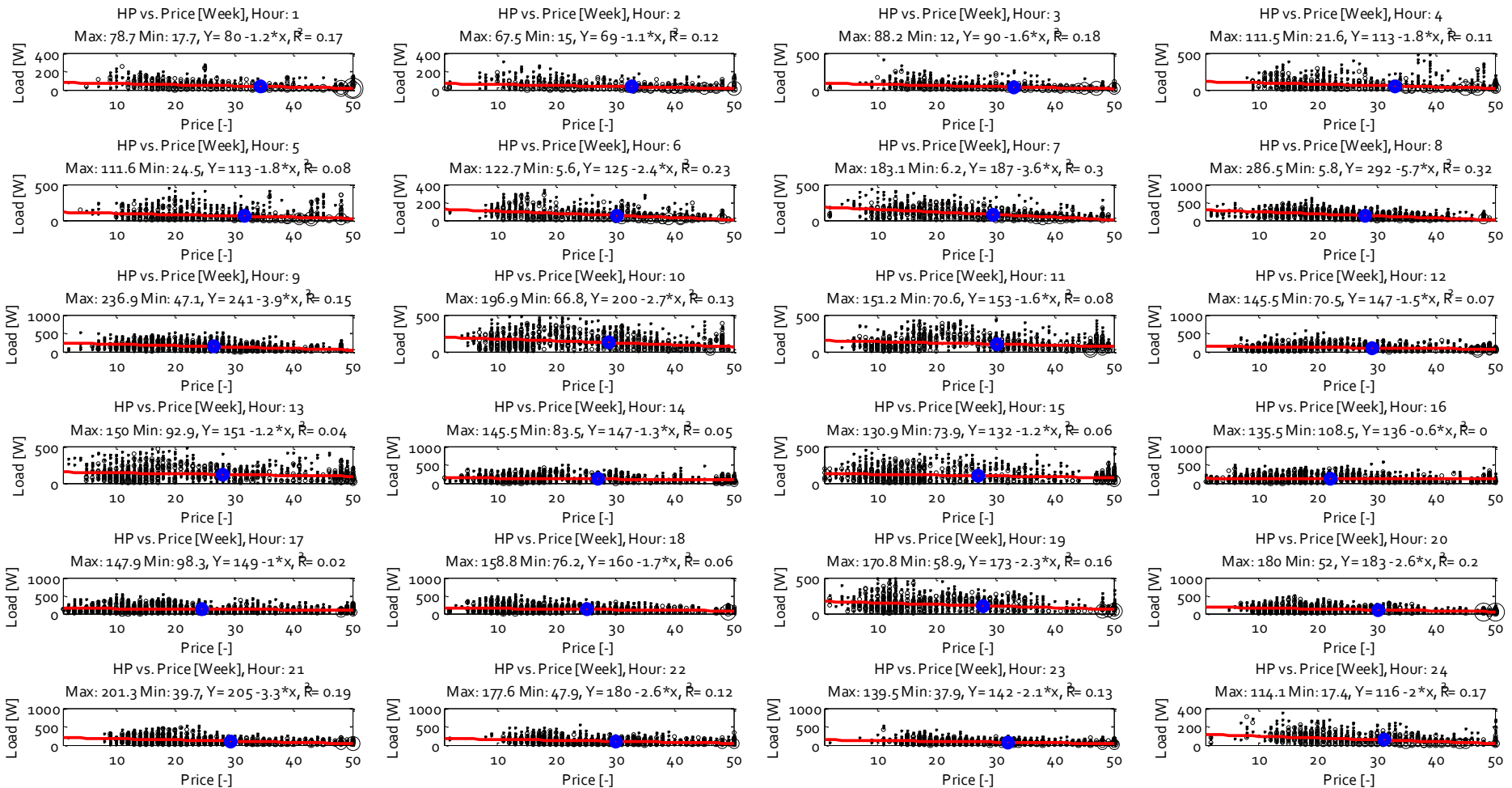


Number of measurements per price



Average response to price - per hour (weekdays)

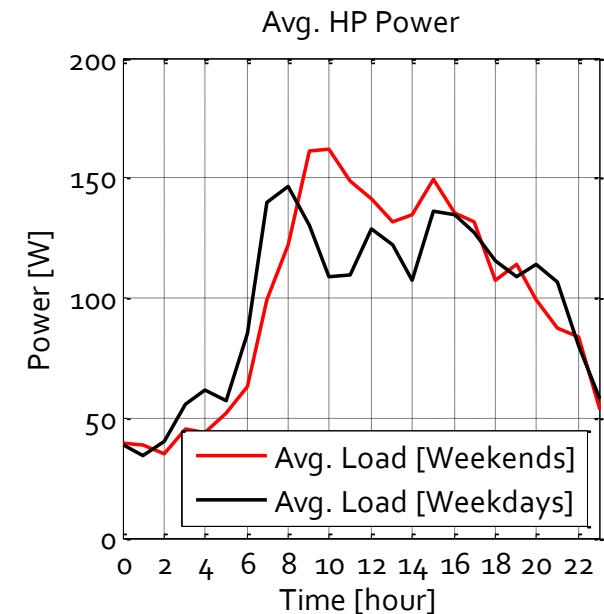
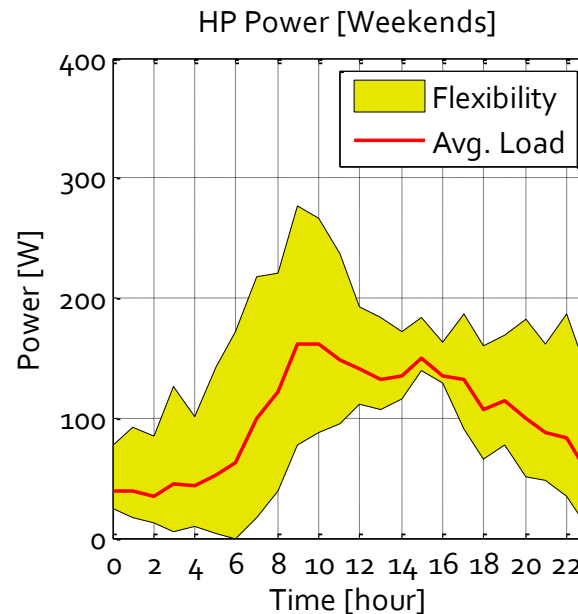
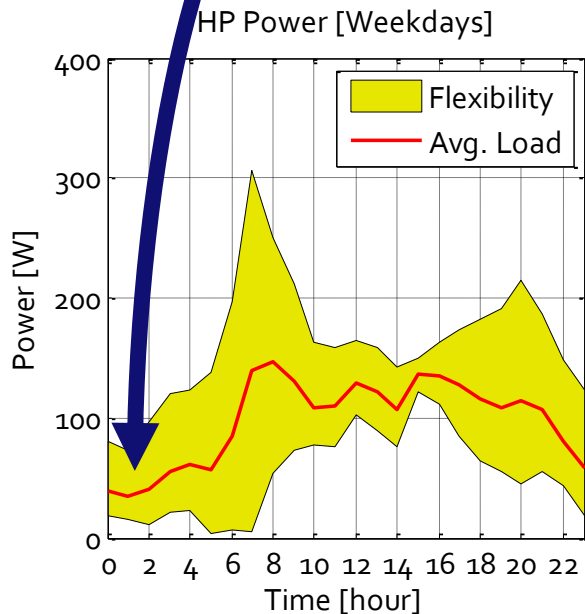
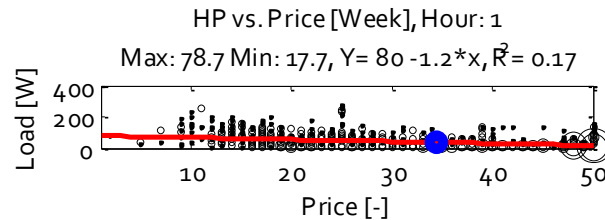
$$P_{i,t} = f(TMP, H, Day, \lambda)$$



Regression model

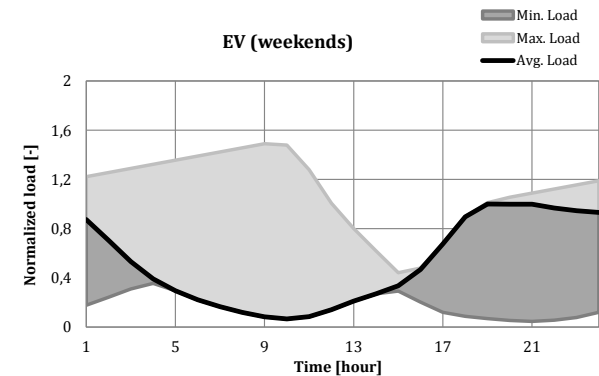
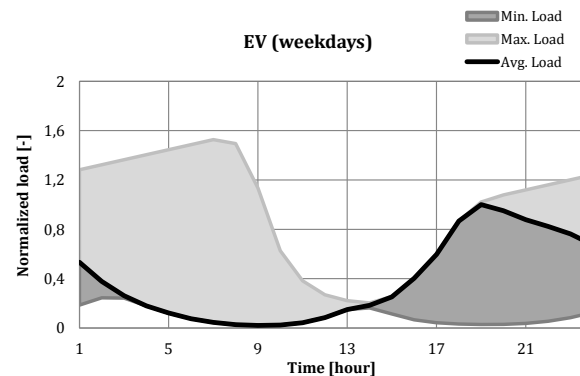
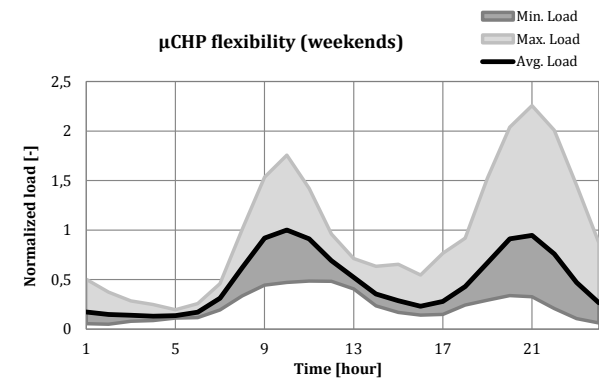
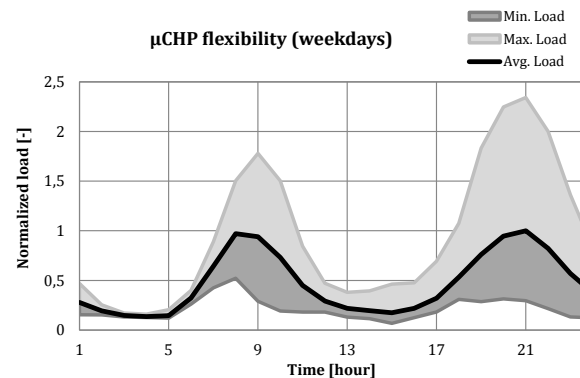
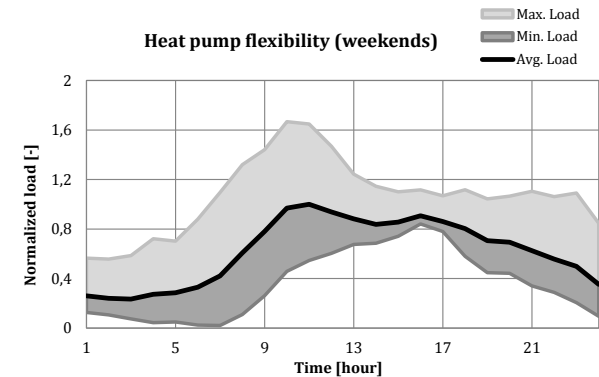
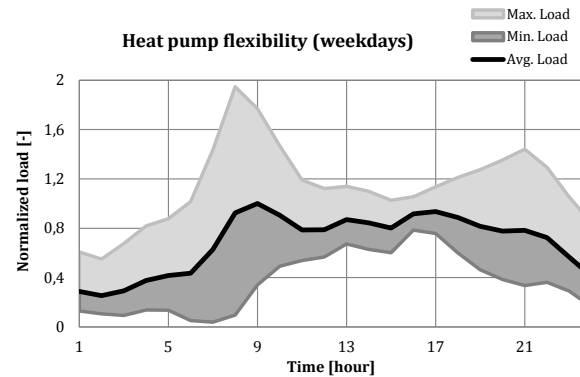
Regression model:
$$P_{i,t} = \beta_0 + \sum_{i=1}^{23} \beta_i H_i + \sum_{i=1}^{23} \beta_{d,i} H_i \text{ Day} + \sum_{i=1}^{23} \beta_{dt,i} H_i \lambda_i + \sum_{i=1}^{23} \beta_{T,i} H_i \text{ TMP} + \varepsilon$$

- *TMP* is assumed to be constant



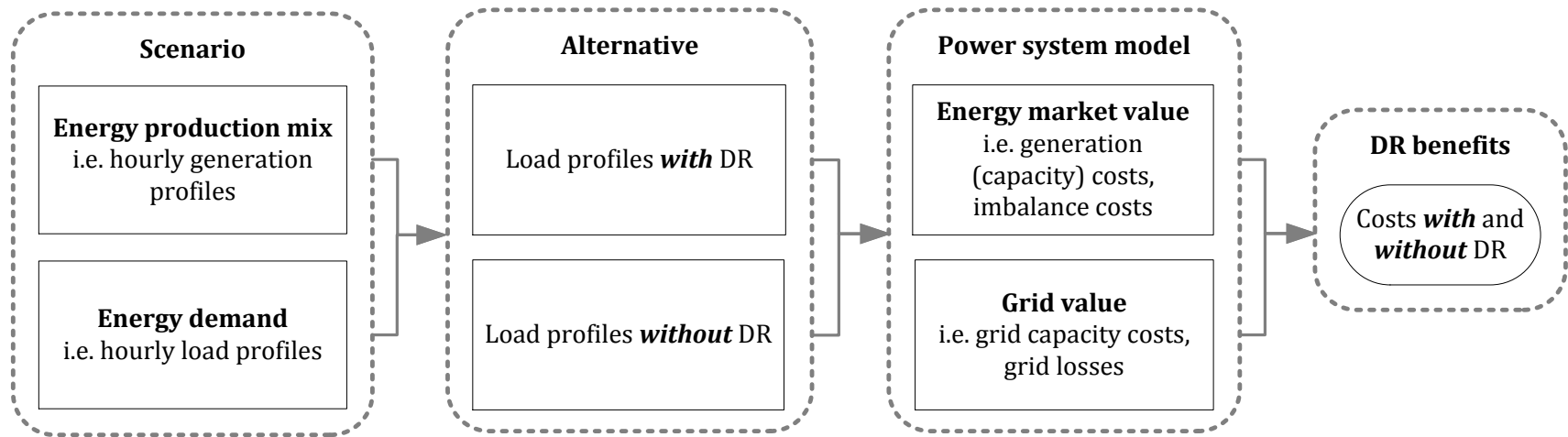
Flexibility profiles

- **Heat pump & μ -CHP** flexibility profiles based on measured data
- **Electric vehicle** flexibility profiles based on Dutch mobility and transport statistics [1]



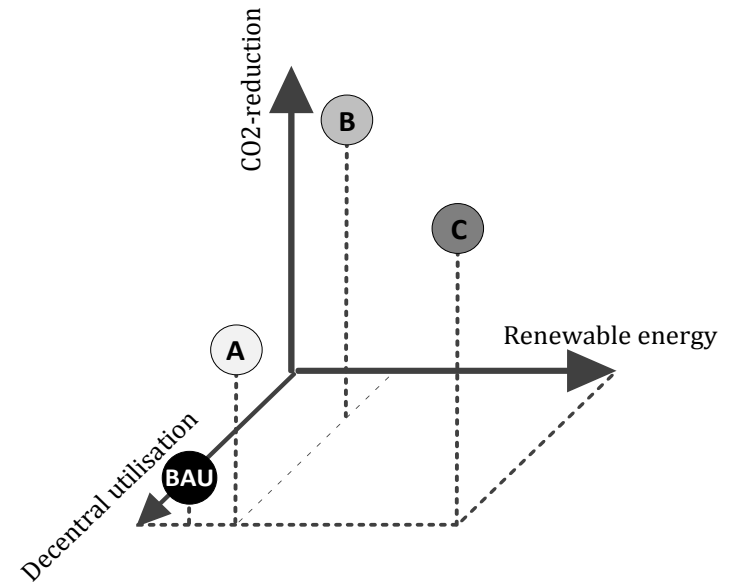
[1] CBS, "Onderzoek Verplaatsingen in Nederland (OVin) [in Dutch] (Mobility study in the Netherlands)," Den Haag, Centraal Bureau voor de Statistiek (CBS), 2011.

Framework to assess benefits



Scenario

- **6 different scenarios based on [2]**
 - *This presentation: 4 most extreme*
- **Analysis until 2050**

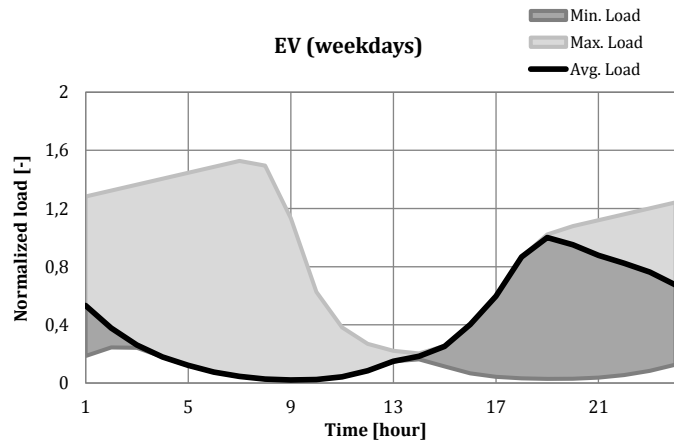


Scenario	BAU	A	B	C
CO ₂ -reduction [%]	24	55	100	100
Share of renewable energy sources [%]	18	25	25	100
Utilisation decentralised potential [%]	100	100	<25	100
Energy savings [%]	10	25	50	50
Dominant energy sources	Coal and gas	Gas	Gas and nuclear	Biomass, wind and solar
Decentralised storage capacity [MW]	870	870	0	28,000
Central storage capacity [MW]	0	0	0	11,100
H ₂ production [MW]	0	0	6,500	12,000
PV penetration* [%]	15	15	5	95
EV penetration* [%]	10	25	30	65
μCHP penetration* [%]	15	15	5	85
Heat pump penetration* [%]	5	15	30	15

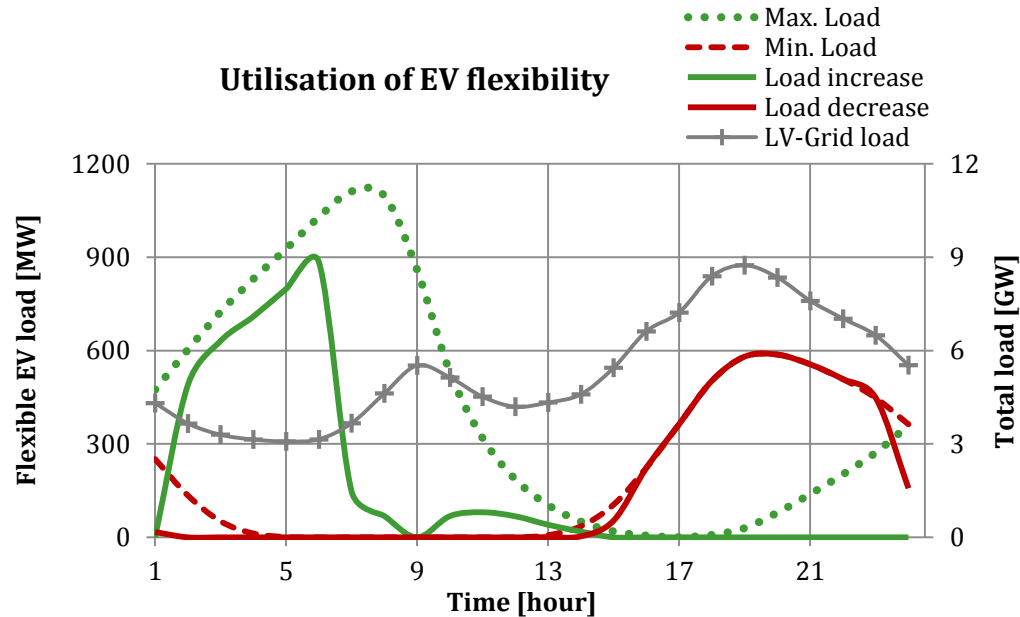
* Average penetration in residential (urban/rural) areas

[2] F. Rooijers, B. Schepers, R. van Gerwen, and W. Van der Veen, "Scenario-ontwikkeling energievoorziening 2030 [in Dutch] (Energy scenarios for 2030)," CE Delft and DNV GL, Report 14.3C93.34, <http://www.netbeheernederland.nl/publicaties/onderzoek/>, 2014.

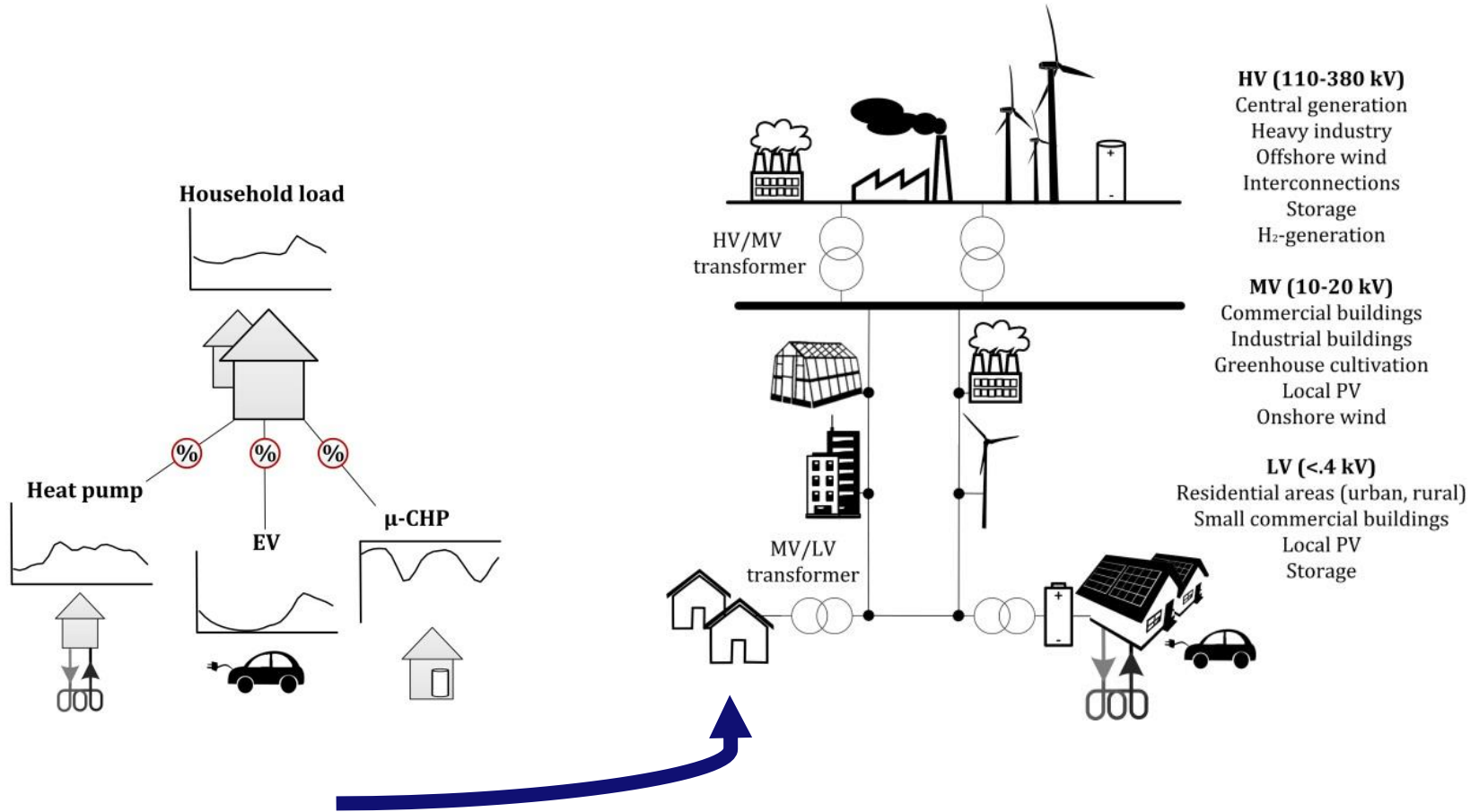
Alternative



Each day flexibility is used to minimize the peaks at the MV/LV-transformer

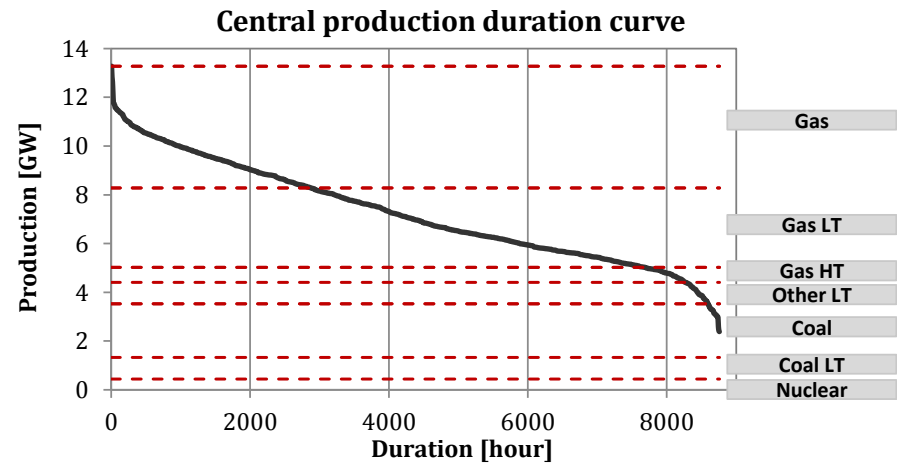
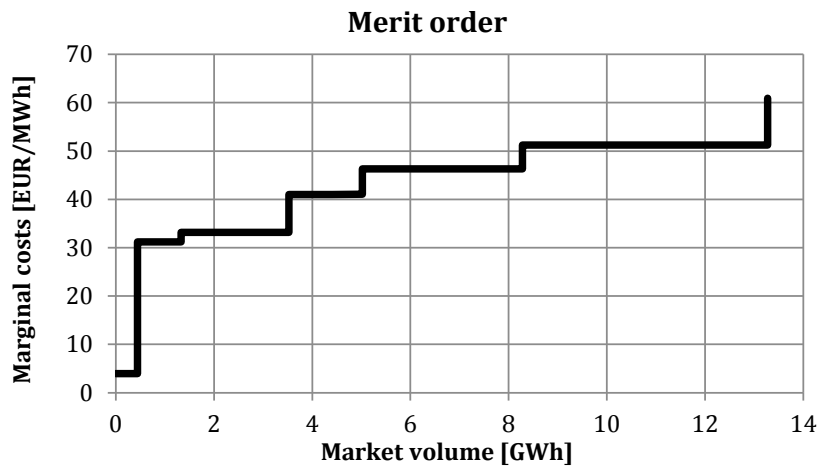


Power System Model - grid value



Power System Model - energy market value

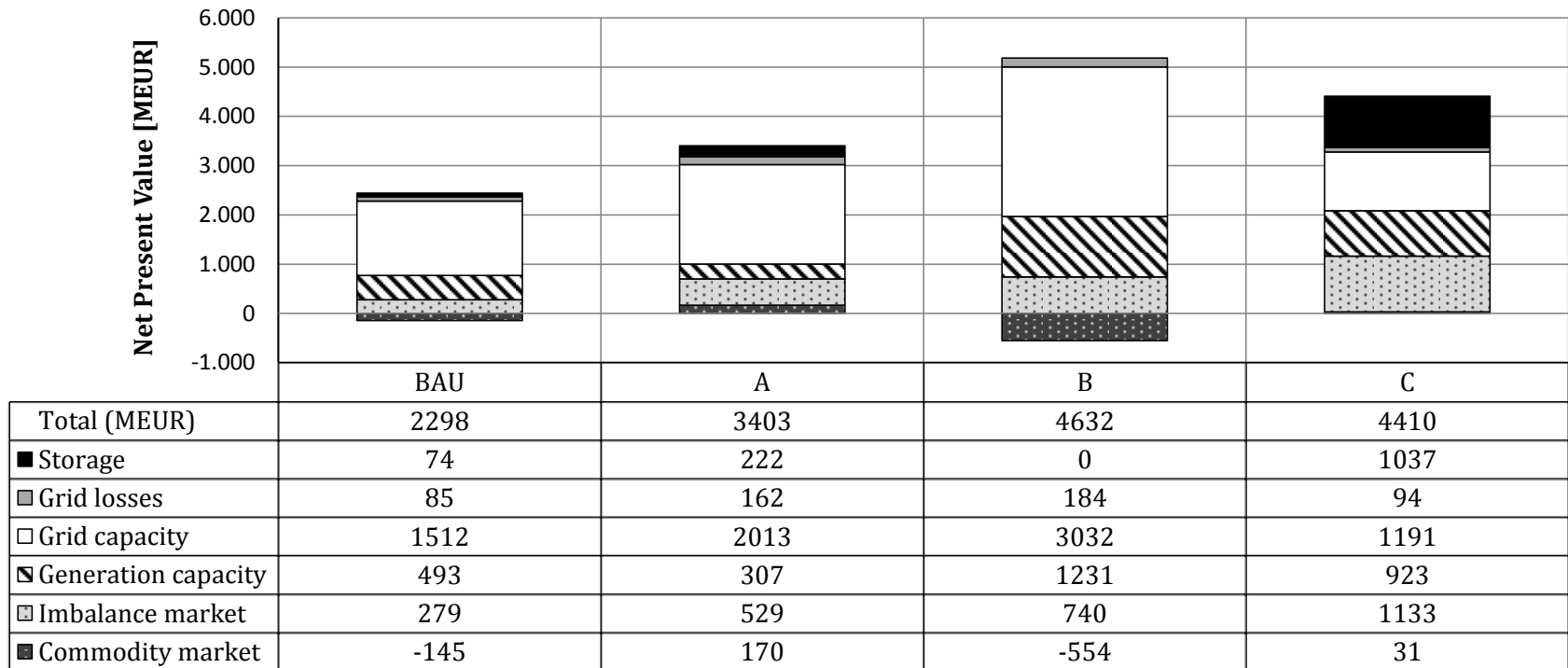
- Central generation mix (scenario dependent)



Benefits of PMC

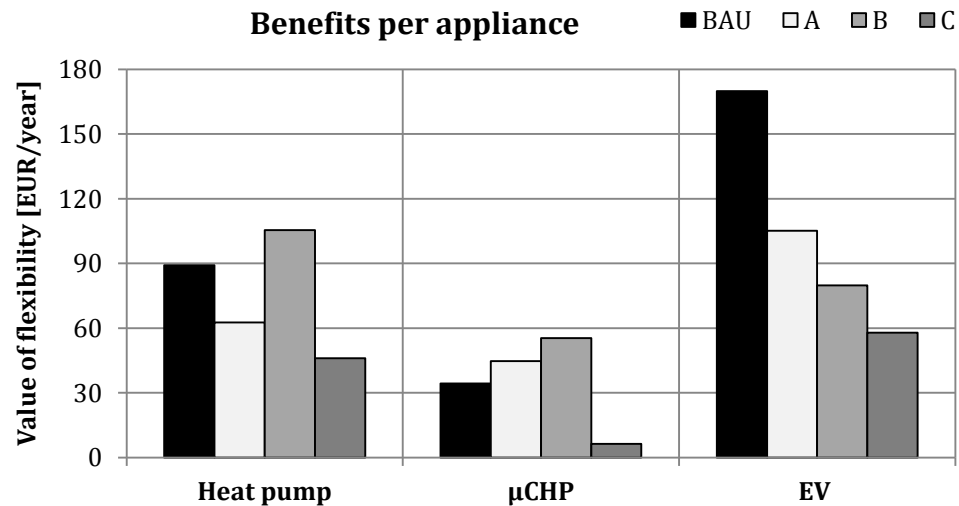
- Value for the Dutch power system until 2050
- Grid value dominates, however benefits become more significant and distributed if electrification or the percentage of renewables increases

Smart grid benefits per scenario



Benefits of PMC

- Benefits per appliance depend on appliances' penetration
- Avg. ~70 €/y



Wrap up

Introduction PMC II	Evaluation PMC II: Results	Model to assess benefits	Results: value of flexibility
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THANKS
FOR
LISTENING

