Techno-Economic Analysis of Flexible Heat Pump Controls

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FCN | Future Energy Consumer Needs and Behaviour
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Outline: Techno-Economic Analysis of Flexible Heat Pump Controls

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   - Possibilities to Mitigate the Flexibility Gap
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Picture source: Viessmann

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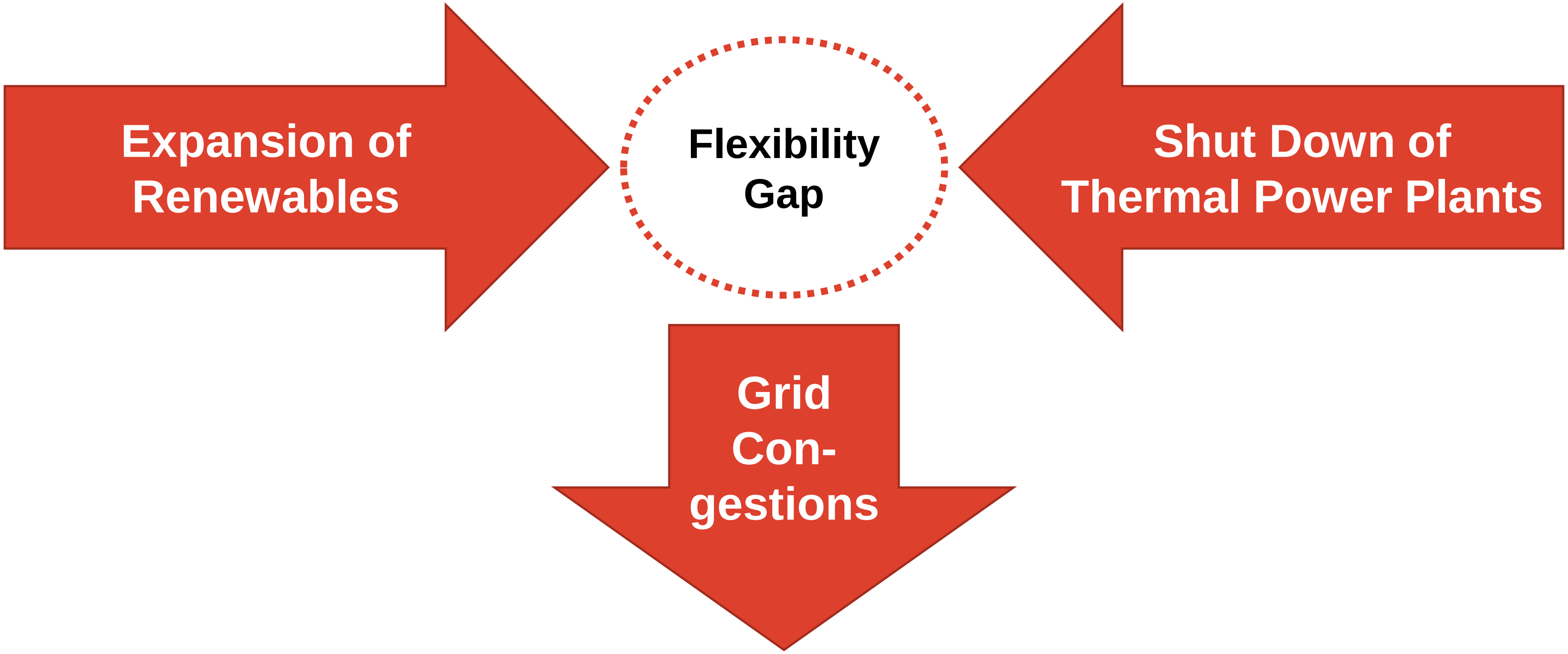
Need for Flexibility



→ Necessity of grid services causing costs of **~2 billion €** in 2015/16 (BNetzA, 2017)

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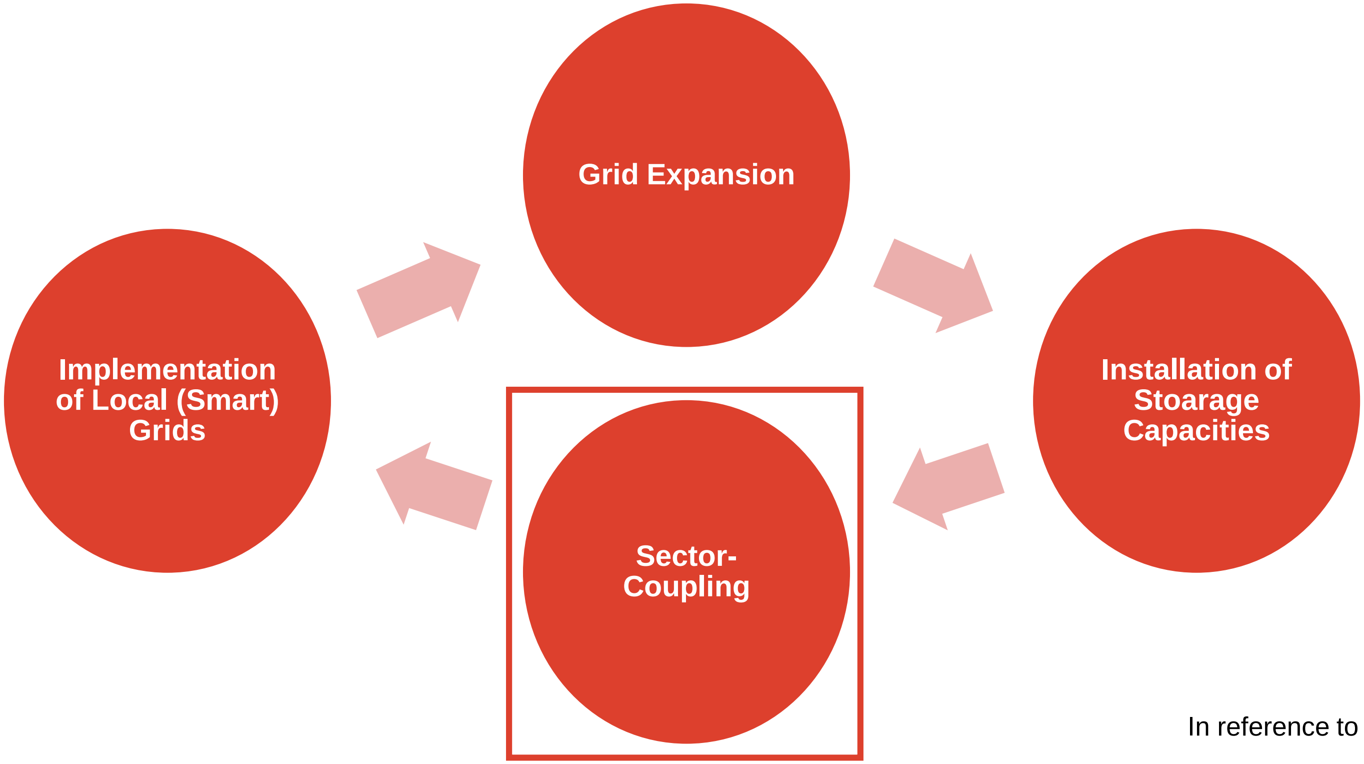
Possibilities to Mitigate the Flexibility Gap



In reference to Lund et al. (2015)

→ Space heating accounts for **30% of Germany's final energy consumption** (AGEB, 2017)
→ **Heat pumps** can be claimed a **very promising coupling-technology** (Fischer and Madini, 2017)

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Applied Control Methods:

- Model Predictive Control (MPC)
- Optimal Controls using MILP Formulations
- Maximization of Self-Consumption (On-Site PV/Wind)

Complex, only pilot trials

- **Rule-Based Algorithms**

Transferrable to large-scale applications

Comparison of Findings:

- Effects on Energy Efficiency:
  - Broad band of -75% to +15%
- Effects on Operating Costs:
  - Not always analysed, however possible cost savings of up to 35% are reported

→ Broad variety of findings, **need for techno-economic analysis** of easily applicable control methods

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Research Questions

*Are **currently applicable HP control methods** that provide flexibility **profitable** from an **efficiency** and **cost** perspective?*

*Further: Does the **ecological** and **economic profitability change** for a more advanced HP control method for flexibility provision **in the year 2030**?*

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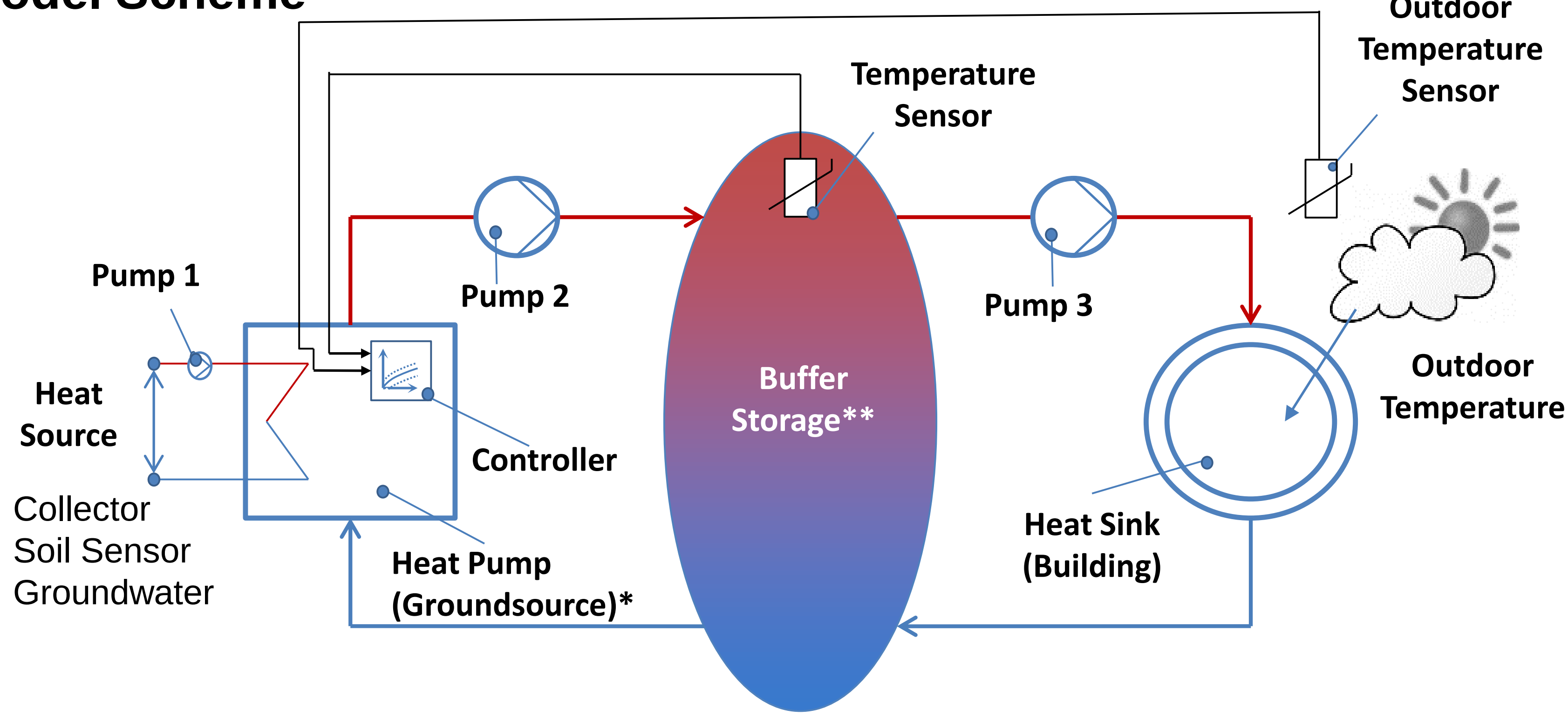
Model Scheme



- Collector
- Soil Sensor
- Groundwater

→ Flexibility can be provided by varying the buffer storage's set temperature

* A validated model of a *Viessmann Vitocal 350-G type BW 351.A07* was used. Necessary data was collected in field measurements of a real HP unit.

** A validated model of a *Viessmann Vitocell 100-E Typ SVW* was used.

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Analysed Controls for the Provision of Flexibility

1. Time of Use (TOU) Control

- Differentiation between high tariffs (HT) and low tariffs (LT)
- Preheating of buffer storage to 45°C before HT starts
- Usage of current market structures and tariffs (Neckermann Strom GmbH, 2016; FairEnergie GmbH, 2016)

2. Day-Ahead Price Based Control

- Variation of buffer storage's set temperature according to day-ahead prices
- Usage of spot market data for the heating season 2014/15 (EPEX Spot, 2016)
- Leveraging to domestic price level

3. Residual load based control

- Variation of buffer storage's set temperature according to residual load
- Analysis of six different scenarios for residual load curves in 2030 based on Trieb (2006)

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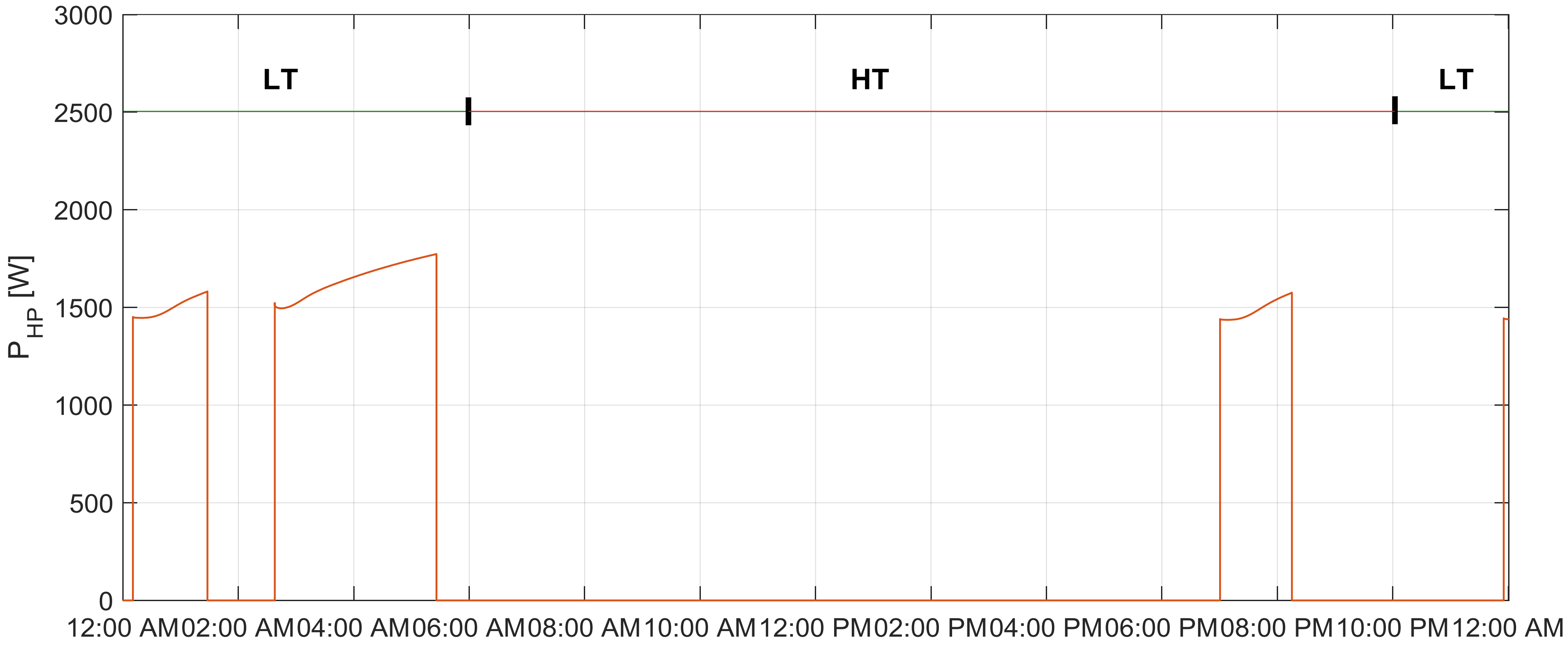
Time of Use Control



→ TOU based control is able to shift load to low tariff times

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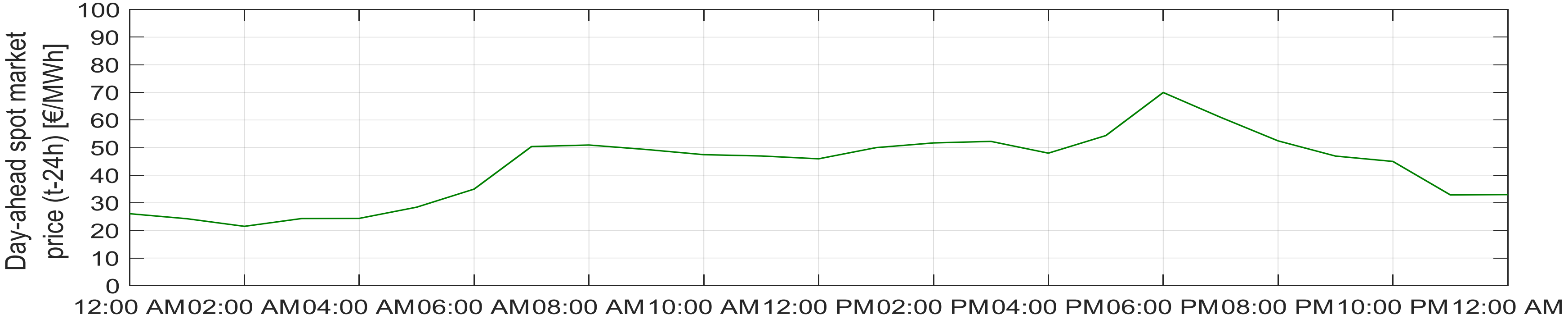
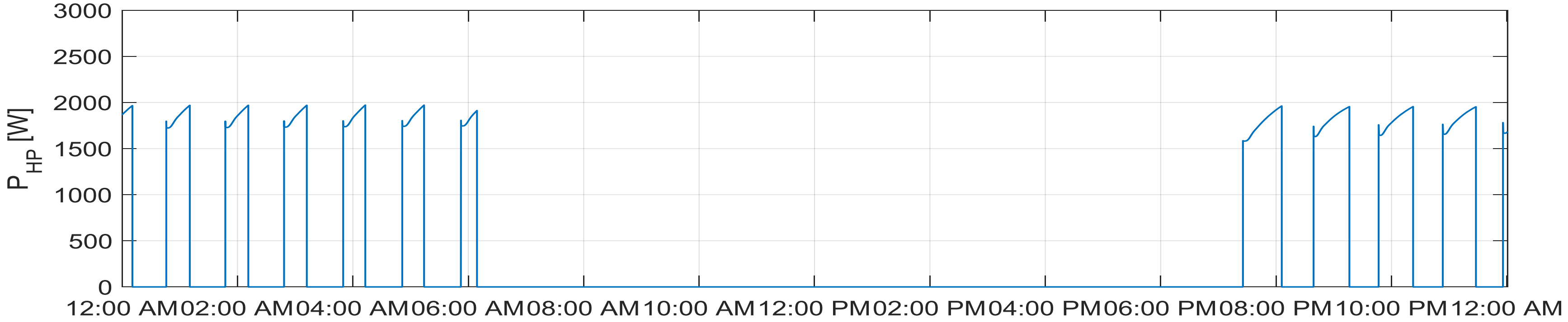
Day-Ahead Price Based Control





→ Day-ahead price based control is able to shift load to times with low prices

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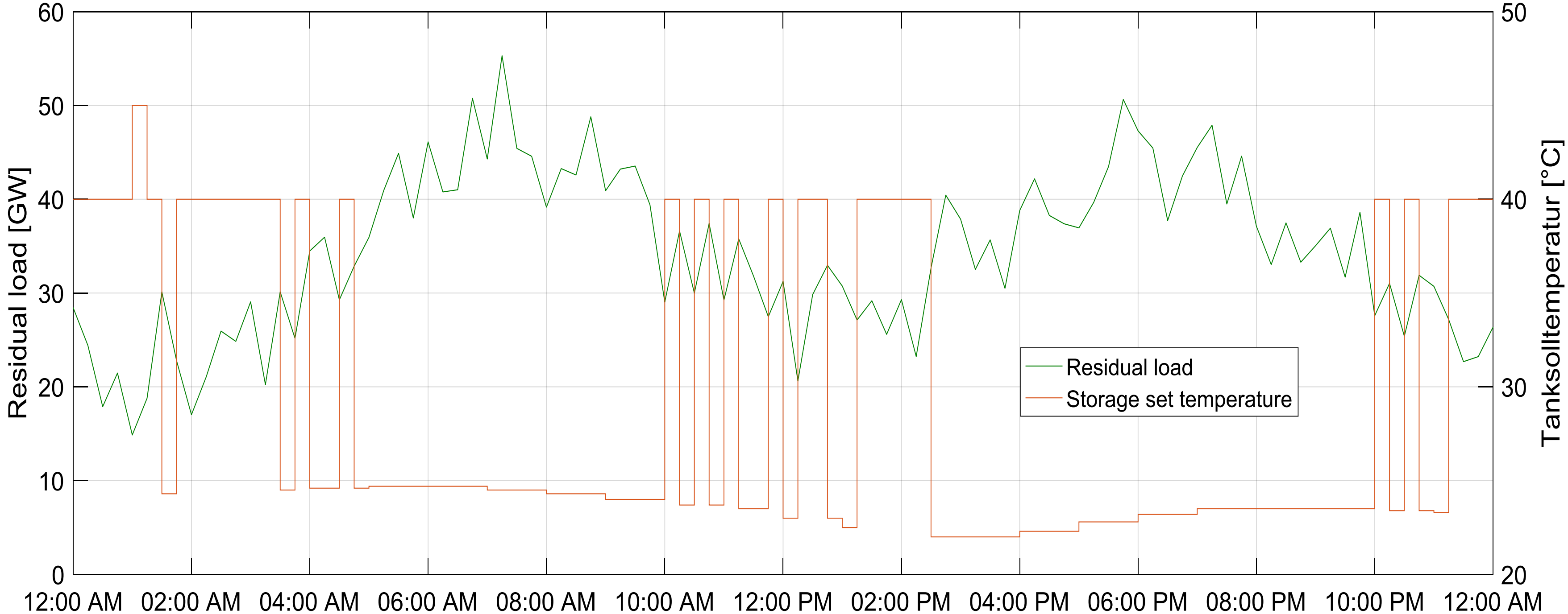
Residual Load Based Control



→ The residual load based control shifts the storage tank's set temperature

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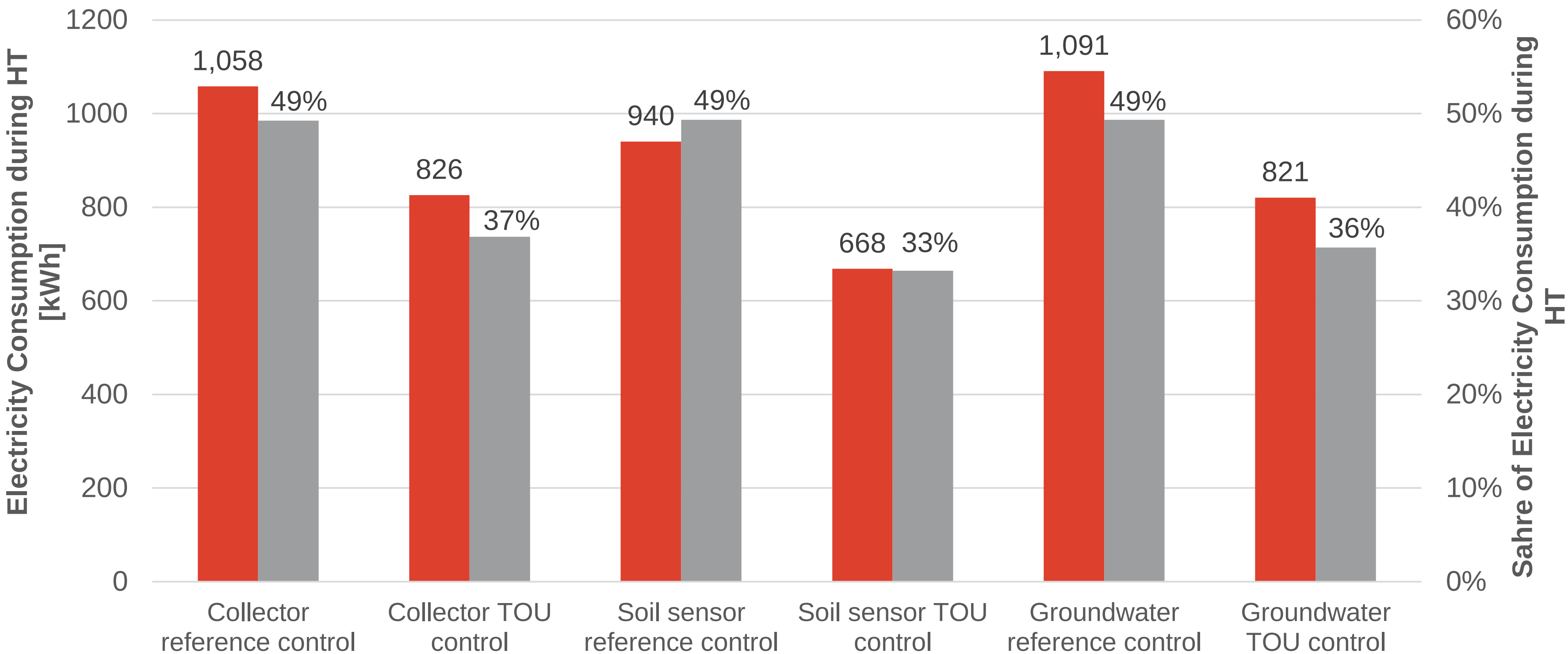
Time of Use Control



→ TOU based control is able to **reduce HT electricity consumption** by **up to 16%**

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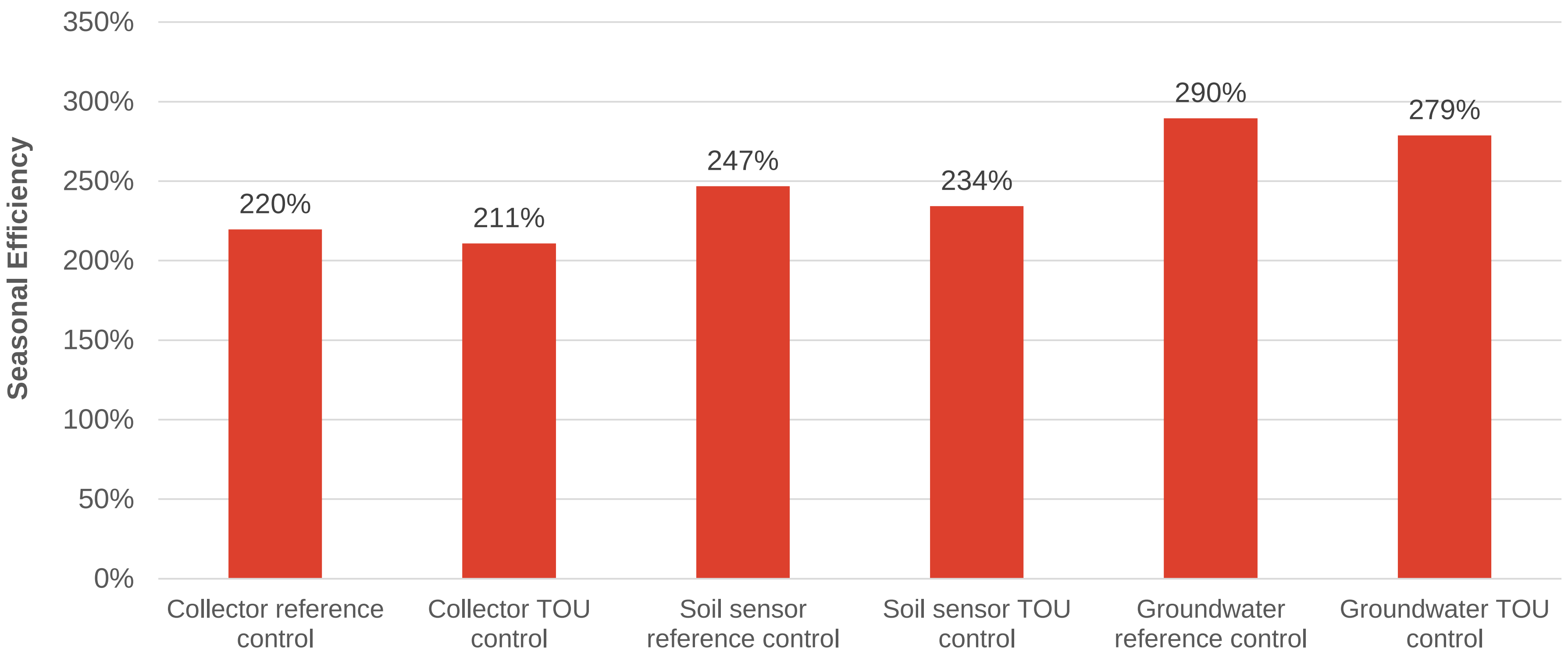
Main Results

Time of Use Control



→ However, **efficiency losses of up to 13%** are to be expected leading to **cost increases of 40 €** per heating season

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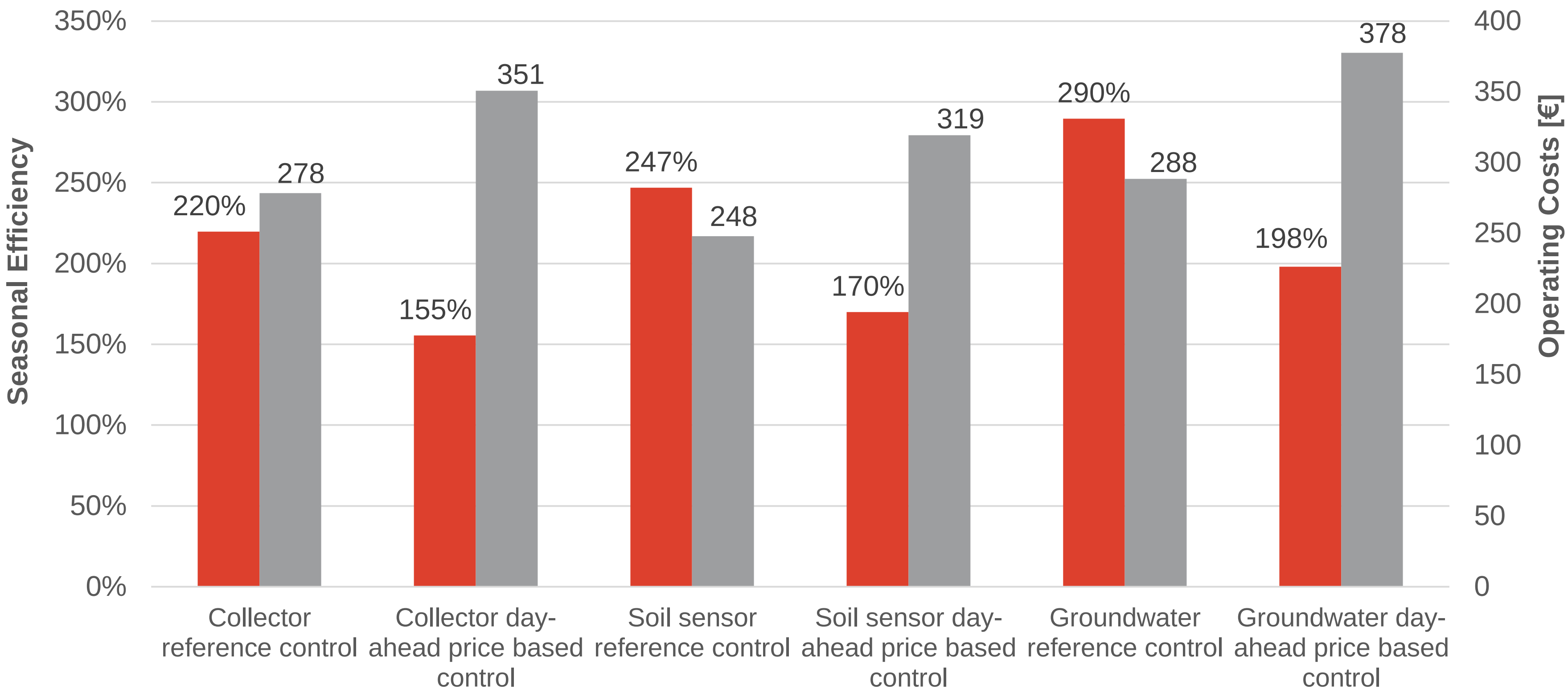
Day-Ahead Price Based Control



→ Even more drastic results for day-ahead price based control: **Efficiency losses of up to 92%** and **cost increases of up to 90 €** per heating season

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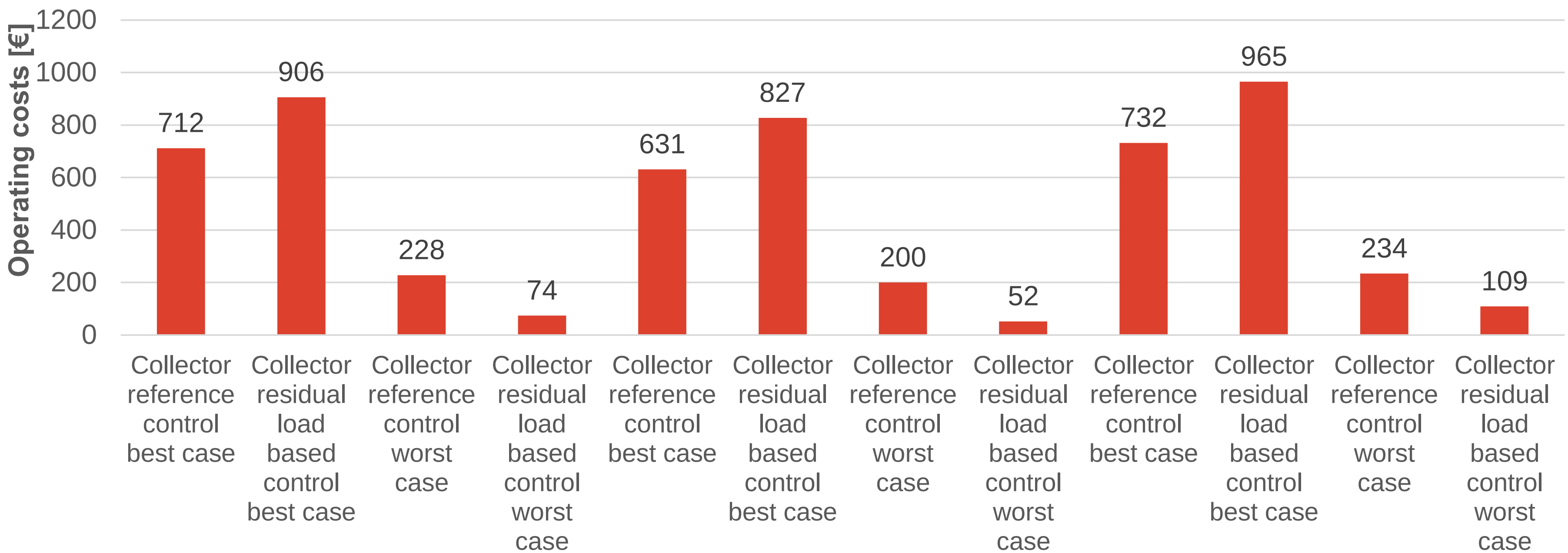
Residual Load Based Control



→ Definition of **energetic best** and **worst case scenarios**
→ Conflict between best case scenarios from an energy efficiency perspective and possible cost reductions

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Conclusion

1. Time of Use (TOU) Control

- Easily applicable control methods **can shift electricity consumption** and **provide flexibility**
- However**, efficiency losses** and **cost increases** occur

2. Day-Ahead Price Based Control

- Easily applicable, rule-based control methods can make **heat pumps follow price signals**
- However, **high efficiency losses prevent financial gains**

3. Residual load based control

- Easily applicable, rule-based control methods can make heat pumps **follow residual load signals**
- Very high efficiency **losses of up to 70 %** were revealed
- A **tension between ecological and economic** consequences arises, as scenarios with high efficiency losses go along with potential cost savings

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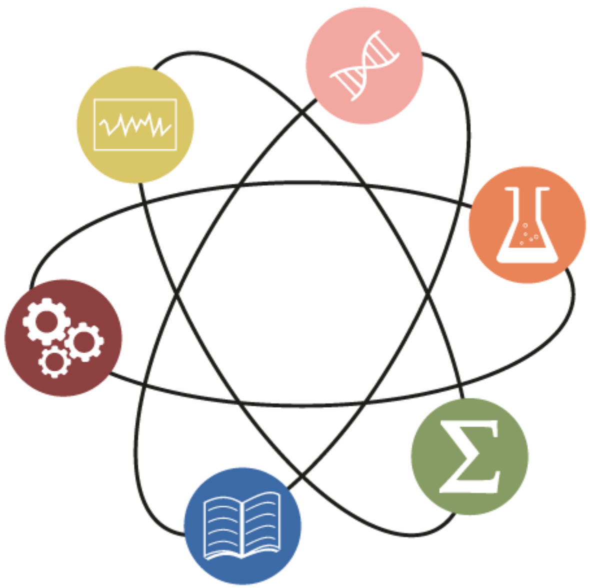
Outlook

- Comparison of efficiency gains on system level with losses on unit level
- Derivation of willingness to pay for flexibility
- Identification of business cases for heat pump owners that provide flexibility



Picture source: ndw-ka.de

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Regarding Publications

1. Heat Pump Controls

Lars Nolting, Aaron Praktiknjo, 2018. Techno-Economic Analysis of Flexible Heat Pump Controls. *Proceedings of the 41st IAEE International Conference at Groningen,* accepted paper.

2. Heat Pump Labels

Lars Nolting, Simone Steiger, Aaron Praktiknjo, 2018. Assessing the validity of European labels for energy efficiency of heat pumps. *Journal of Building Engineering,* in press, corrected proof. DOI: https://doi.org/10.1016/j.jobe.2018.02.013 (Open Access)

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Thank you for your attention!

Do you have any questions or comments?