DataDrivenLM

A Data Driven Approach for Load Management of District Heating Networks

Philip Ohnewein, AEE INTEC
Florian Wenig, FH Burgenland

AEE - Institute for Sustainable Technologies (AEE INTEC)
8200 Gleisdorf, Feldgasse 19, AUSTRIA

Today
DataDrivenLM

1	*Context*	**District Heating. Load Management**
2	*Load Management*	**DataDrivenLM concept**
3	*Core*	**Modelling & Optimization**
4	*Deployment*	**Software. Test operation**

Energy: Heating & Cooling

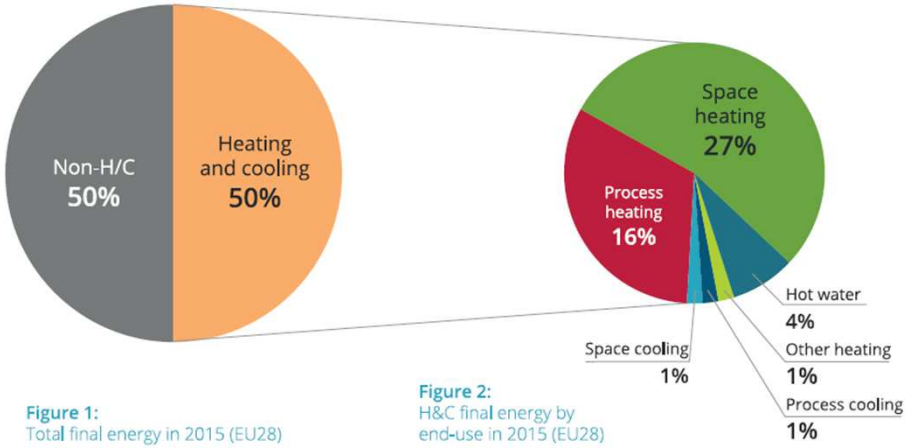
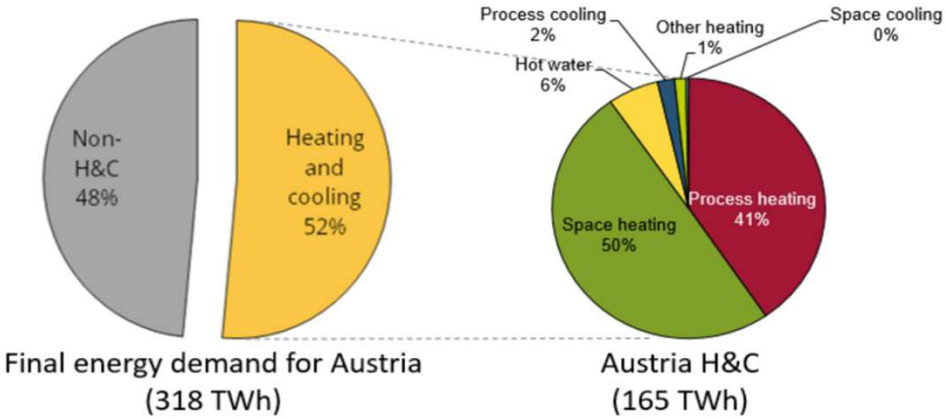


Figure 1:
Total final energy in 2015 (EU28)

Figure 2:
H&C final energy by end-use in 2015 (EU28)

Source: https://heatroadmap.eu



Source: Heat Roadmap Austria, Aalborg University 2018

Energy: Heating
District Heating

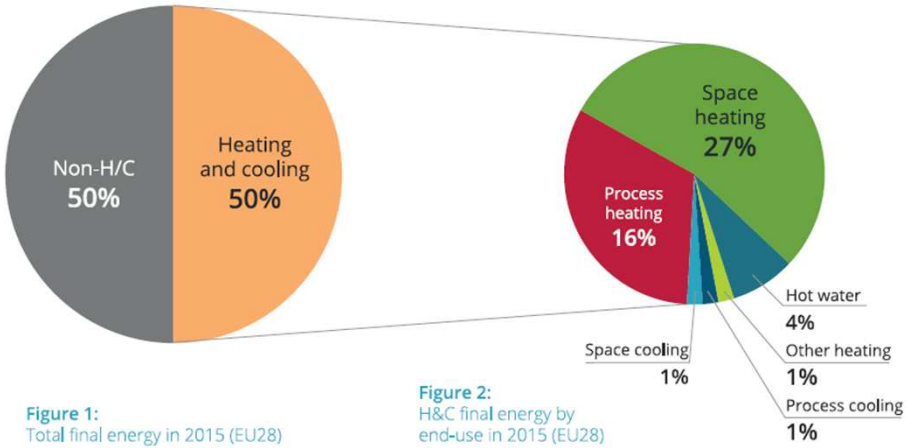
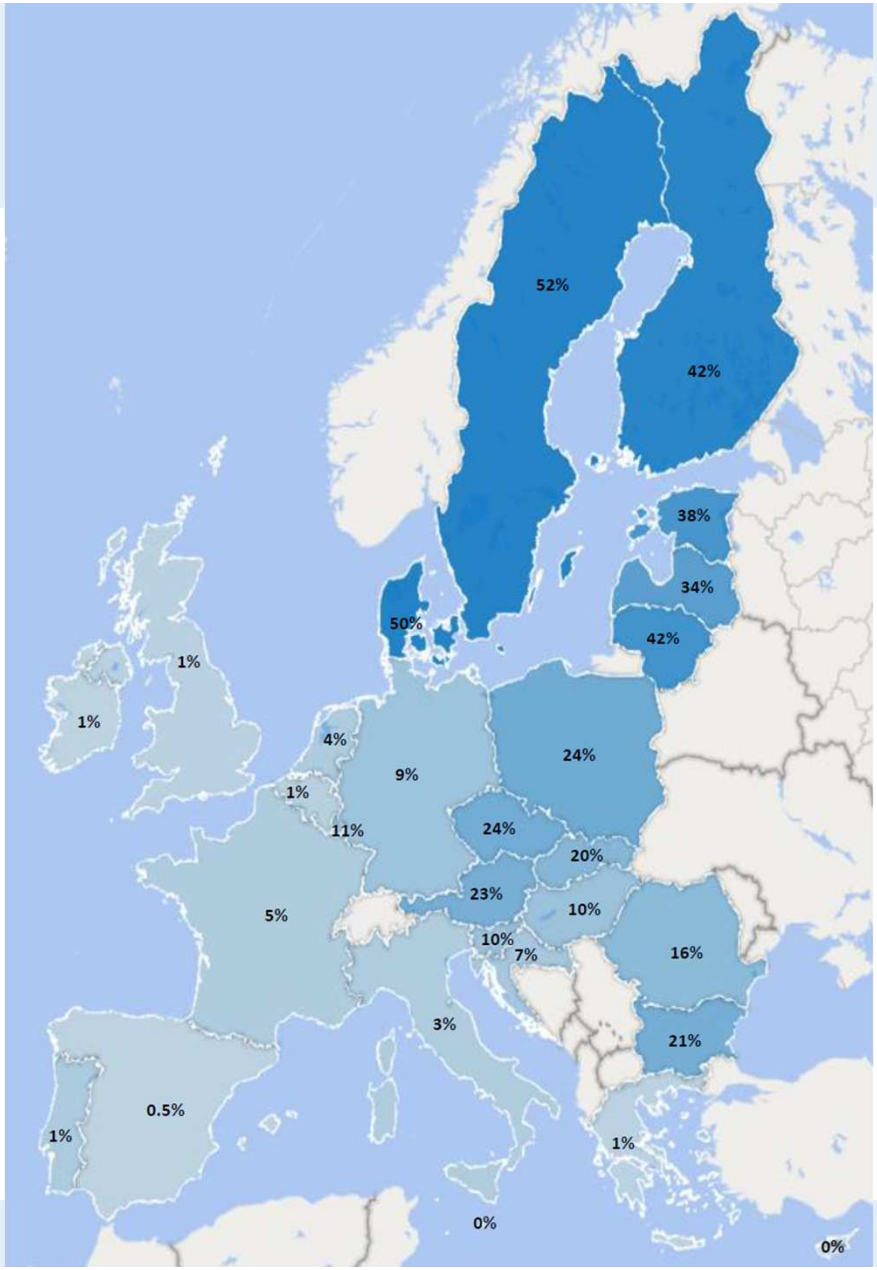


Figure 1:
Total final energy in 2015 (EU28)

Figure 2:
H&C final energy by end-use in 2015 (EU28)

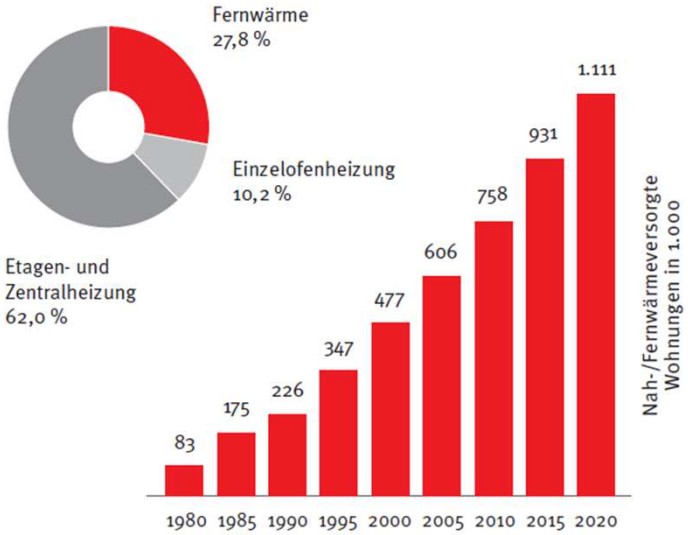
Source: https://heatroadmap.eu



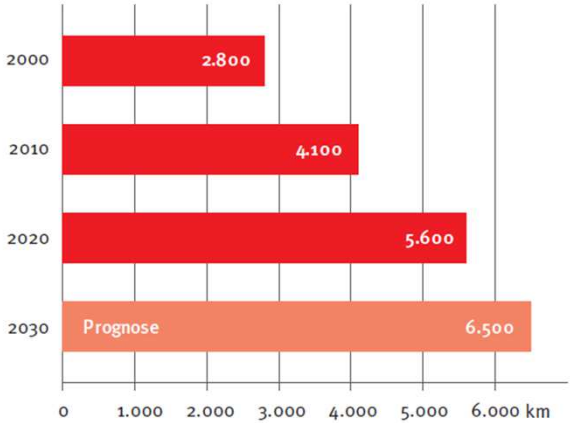
Source:Mathiesen et al., Towards a decarbonised heating and cooling sector in Europe, Aalborg 2019

District Heating
Austria

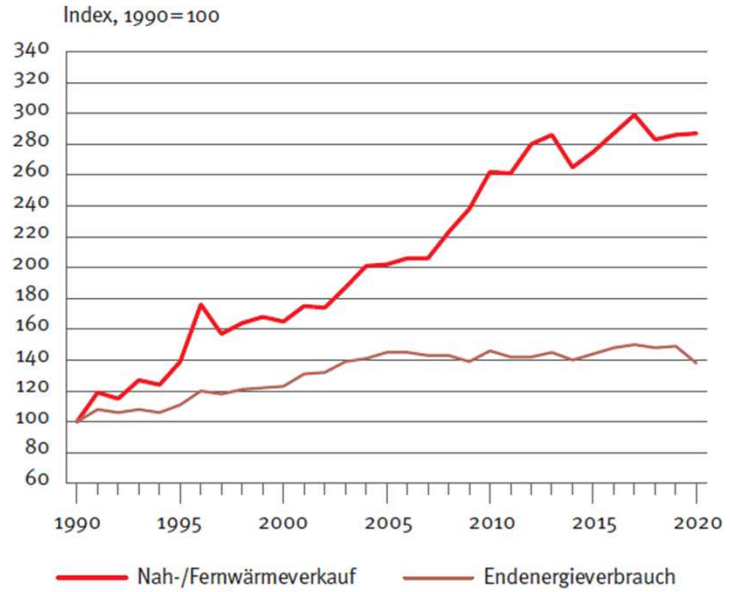
Customers



Network km

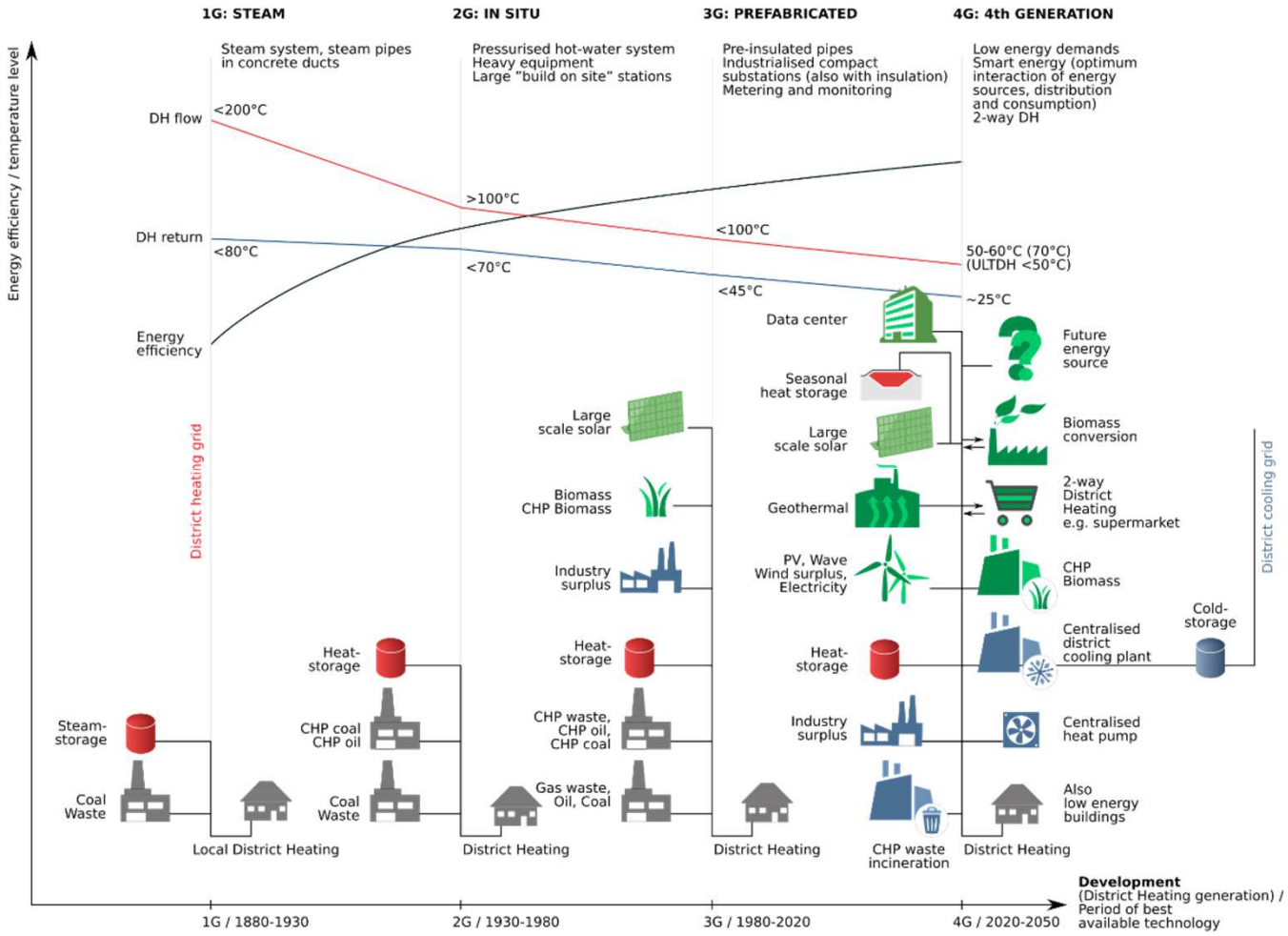


DH index



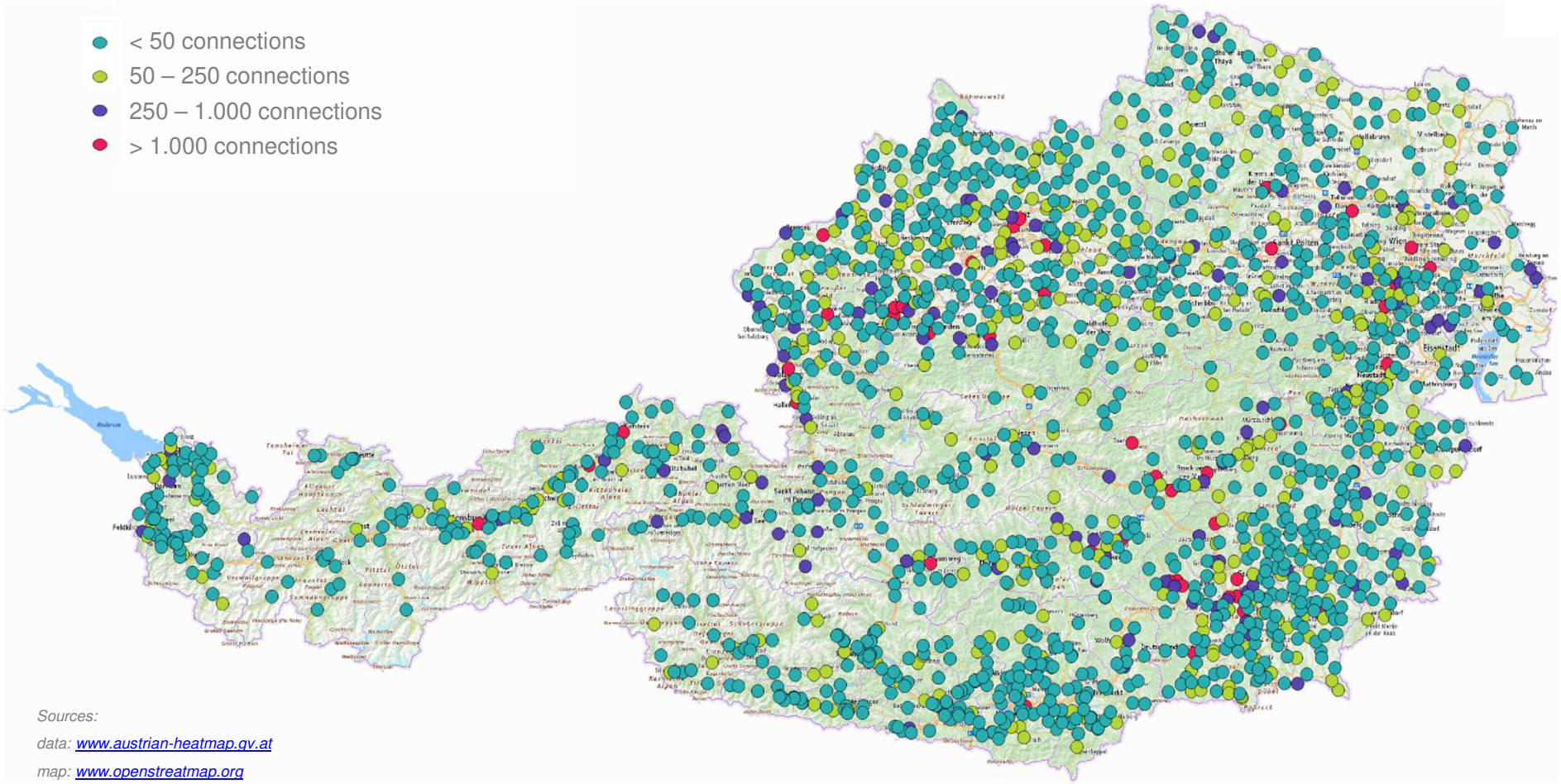
Source: Gas und Fernwärme in Österreich, Zahlenspiegel 2021
https://www.gaswaerme.at/service/publikationen/

District Heating
Generations



Source: Lund et al. 2014, doi:10.1016/j.energy.2014.02.089

District Heating
Austria



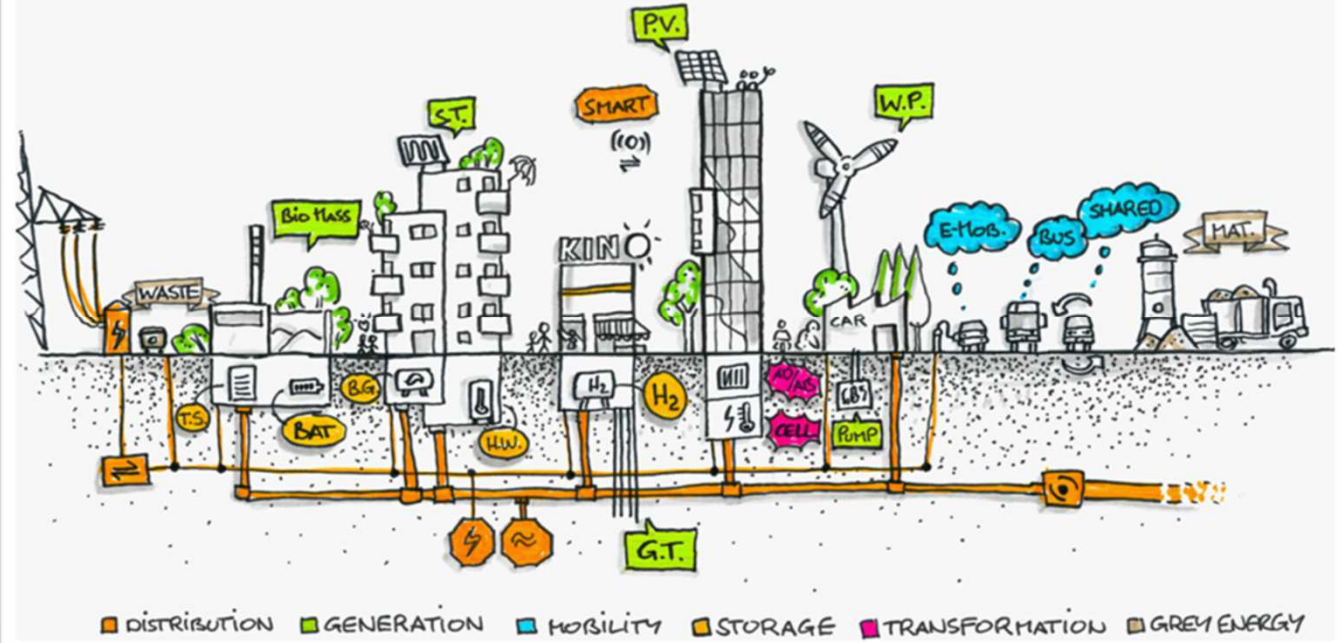
Sources:

data: www.austrian-heatmap.gv.at

map: www.openstreatmap.org

District Heating
Decarbonization

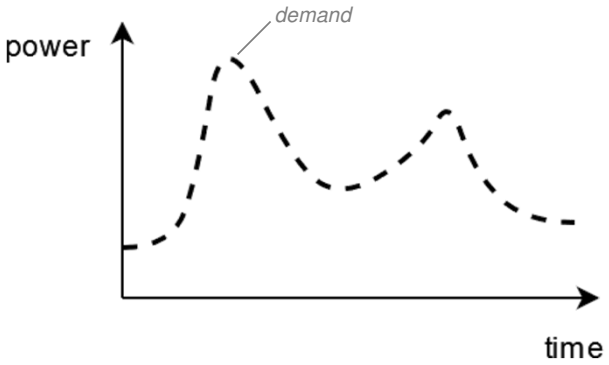
More Flexibility.
More Renewables.



Source: https://nachhaltigwirtschaften.at
Zeichnung Plusenergiequartier
(© Robert Six rb6)

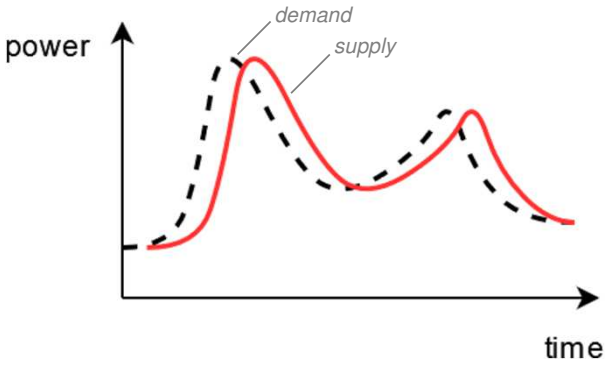
District Heating
Conventional Control

Supply follows demand



District Heating
Conventional Control

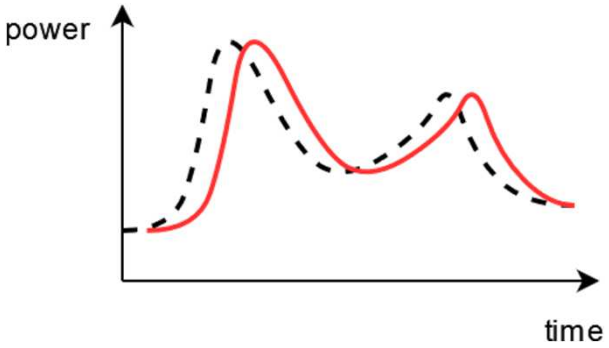
Supply follows demand

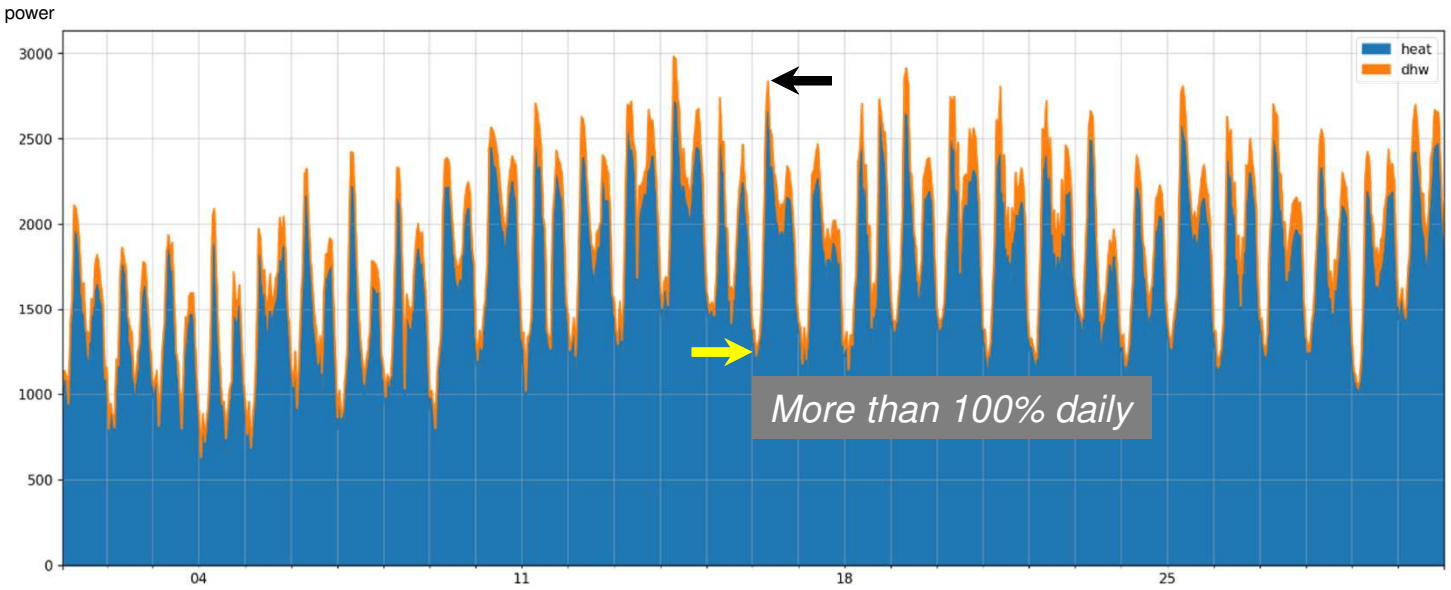


District Heating

Conventional Control: Challenges in practice

Supply follows demand





Source: AEE INTEC

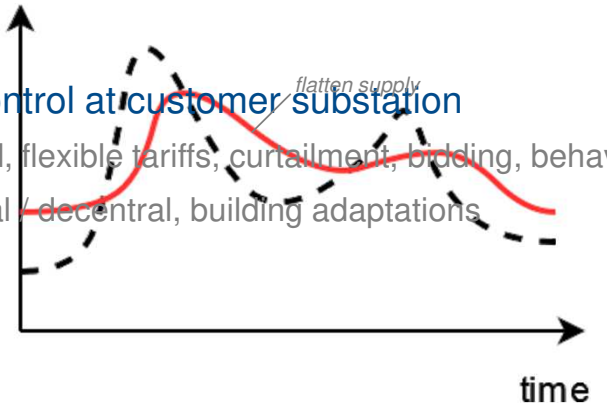
Demand Side Management

…is a set of techniques for *altering the timing and/or magnitude of energy demand* in a grid.

- **Goals:**
  - Increase match of supply and demand.
  - Reduce peaks, reduce variation.

- **Benefits:**
  - Reduce: fossil fuel, CO2, boiler starts
  - Connect more customers to same infrastructure
  - Minimize cost: operation, customers

- **How? Strategies**
  - ➢ Direct: Direct load control at customer substation
  - Indirect: Incentive-based, flexible tariffs, curtailment, bidding, behavioral approaches
  - Retrofit: Storages central / decentral, building adaptations

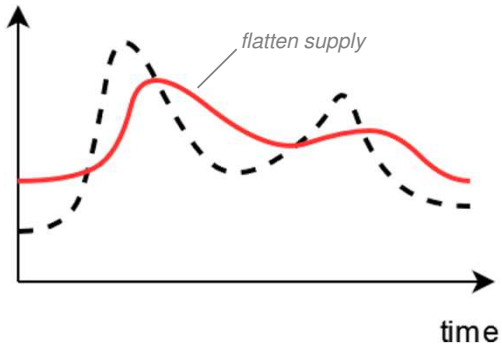


Demand Side Management

DataDrivenLM Concept

Supply follows demand

Decouple supply / demand



DataDrivenLM Concept:

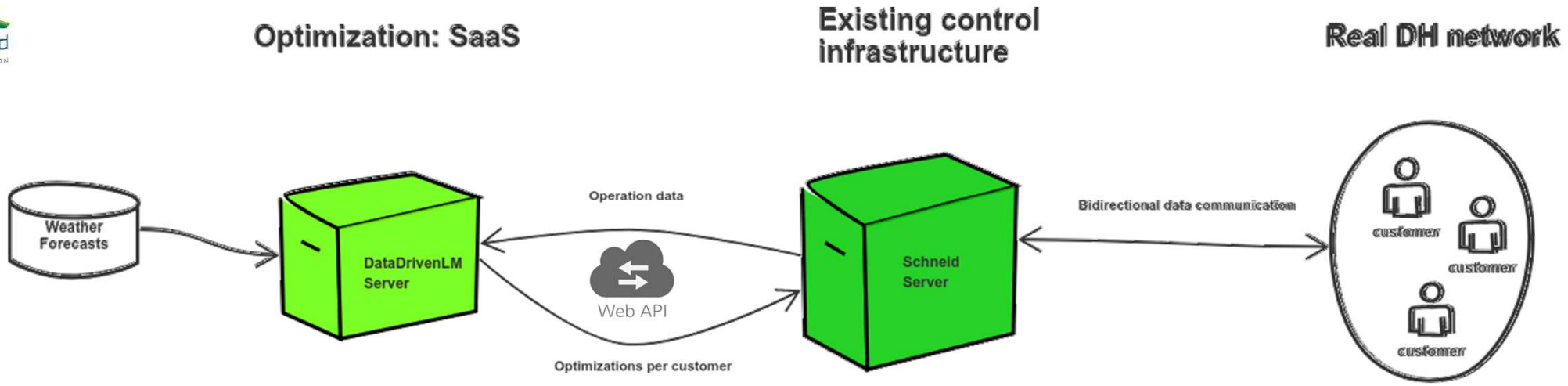
- Use buildings as thermal storages.
- Charge / discharge, without additional storages.
- MPC: forecast & optimization.

Two customer groups:

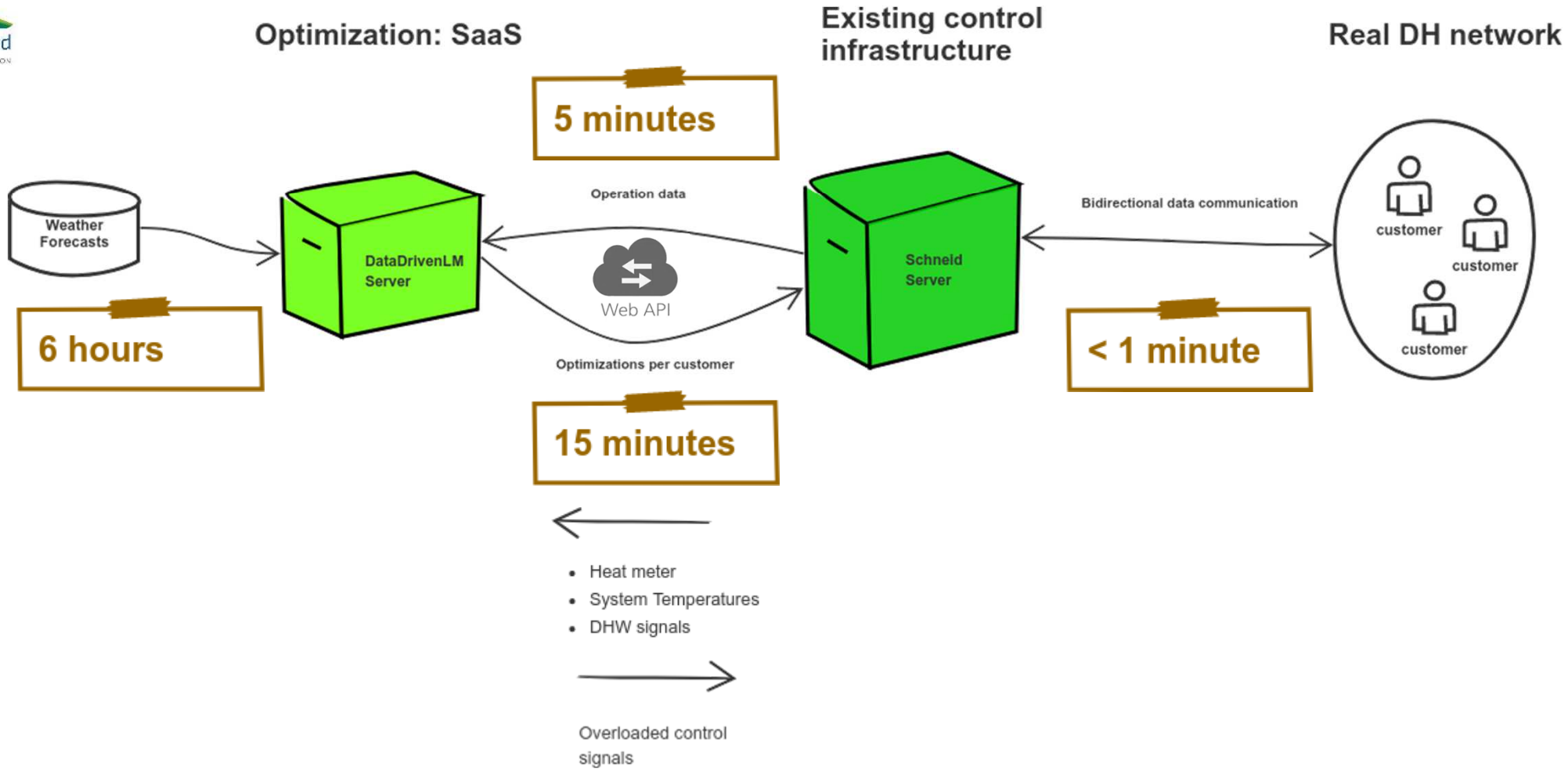
1) **Fixed customers → Unflexible Loads**
   - Certain industry processes
   - Waste heat profile
   - Limited thermal power, like geothermal
2) **Flexible customers → Flexible Loads**
   - E.g. dwellings, multi-family houses…

- Overall flatter load signal:
  - Flexible customers adapt to fixed customers.
  - Adaptation to ~arbitrary reference signals.
  - “Amount of flexibility” can be adjusted per customer.

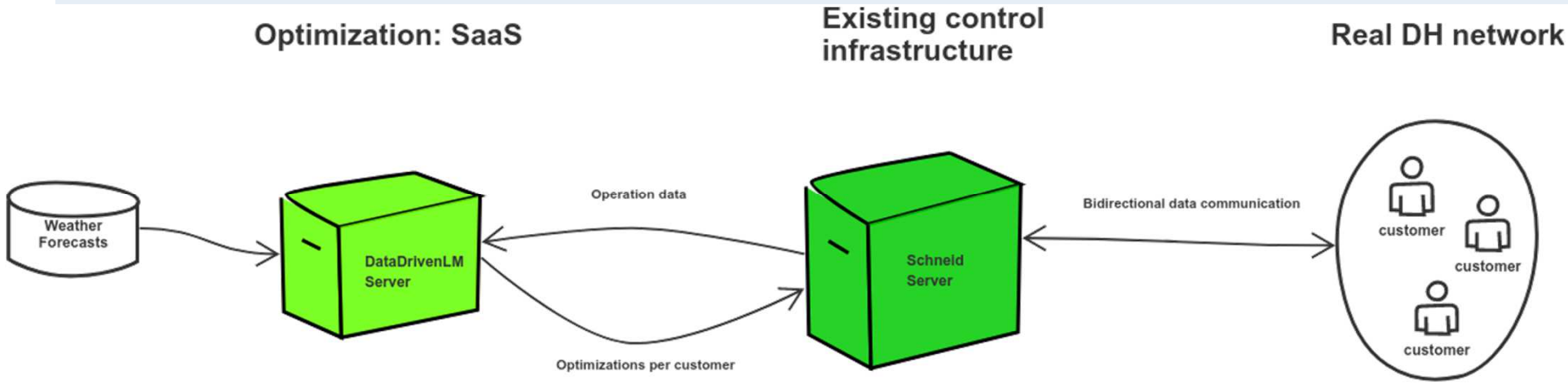
DataDrivenLM
Concept

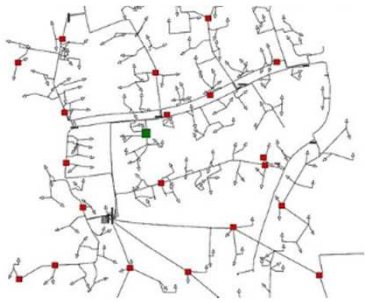


DataDrivenLM
Concept



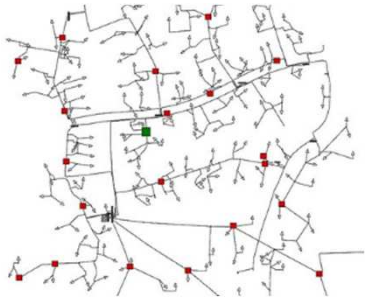
DataDrivenLM
Concept



Research & Innovation	Technology Development	Solution Delivery	End User
FORSCHUNG Burgenland RESEARCH & INNOVATION AEE INTEC Blue Sky Wetteranalysen	AEE INTEC SCHNEID GesmbH FORSCHUNG Burgenland RESEARCH & INNOVATION	SCHNEID GesmbH nahwaerme.at	 *Source: DOI: 10.3390/en14113290*

..

..

Research & Innovation	Technology Development	Solution Delivery	End User
FORSCHUNG Burgenland RESEARCH & INNOVATION	AEE INTEC	SCHNEID GesmbH	
AEE INTEC	SCHNEID GesmbH	nahwaerme.at	
Blue Sky Wetteranalysen	FORSCHUNG Burgenland RESEARCH & INNOVATION	AEE INTEC	

Modeling & Optimization
Basic Concept

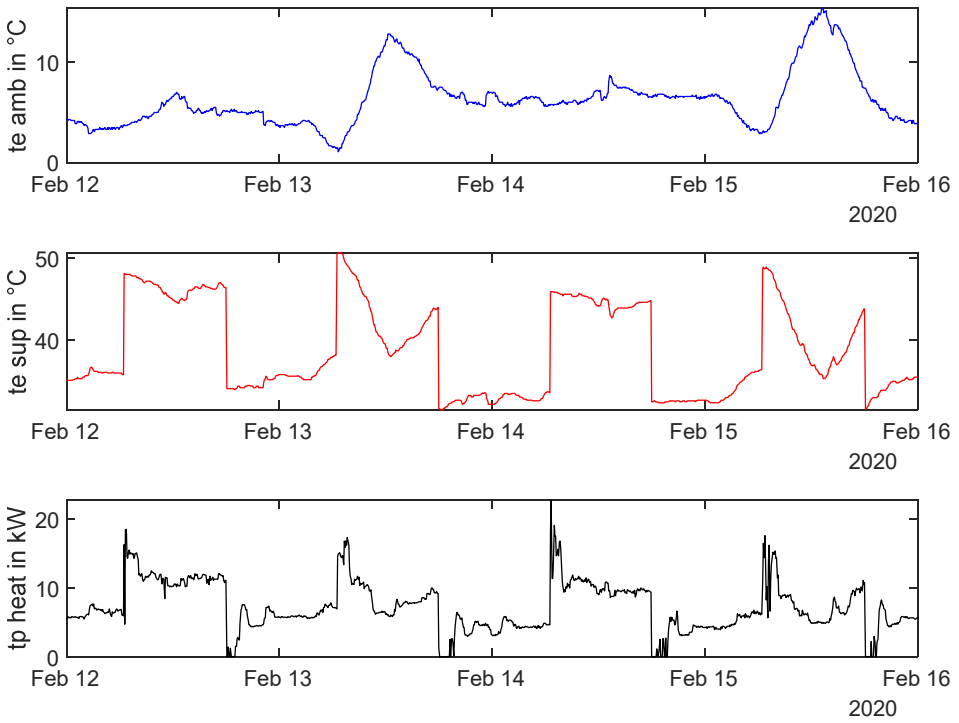
Data-driven, model-based, predictive optimization approach

- Data-driven … no/minimal manual interaction during setup and operation needed
  … adaptive behaviour, since decisions are based on LATEST historic data
- Model-based … thermal load requirements of single customers are represented by model
- Predictive … predicted future boundary conditions are available (weather forecast, user behaviour)
- Optimization … is used for decision making
  … multiple future operation strategies are calculated
  … best strategy is used for plant operation

Modelling & Optimization
Available data points

Available data points

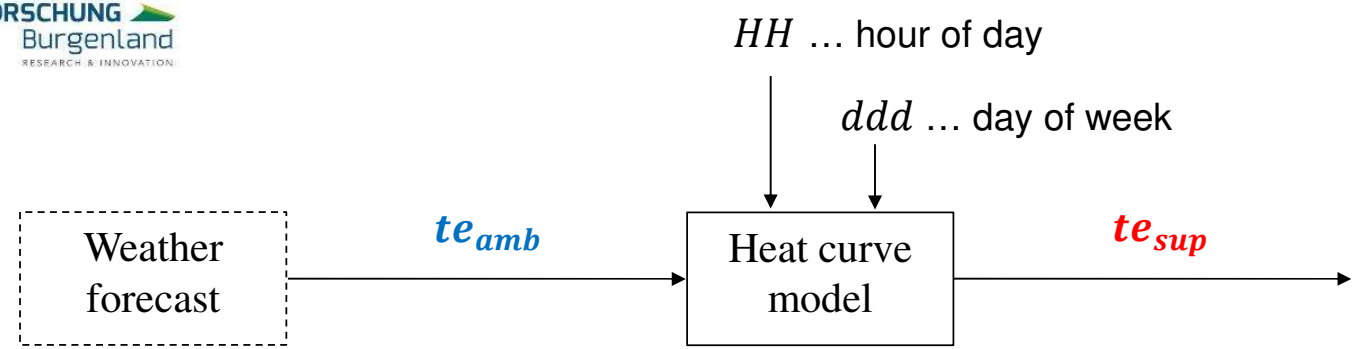
- **Local outdoor ambient temperature**
- **Customer supply temperature**
- **Thermal load**
  - Some operational data points
    - Domestic hot water pump, set points, etc.
  - No indoor/room temperature available!
    - Critical for thermal comfort assessment
  - No plant details available!
    - Radiators, floor heating, HVAC, industrial facilities, …

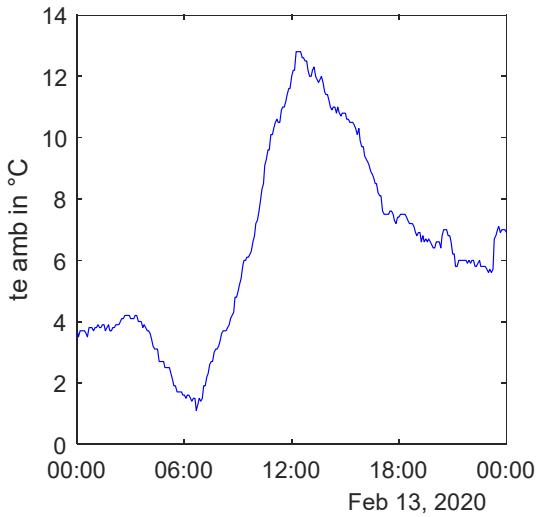


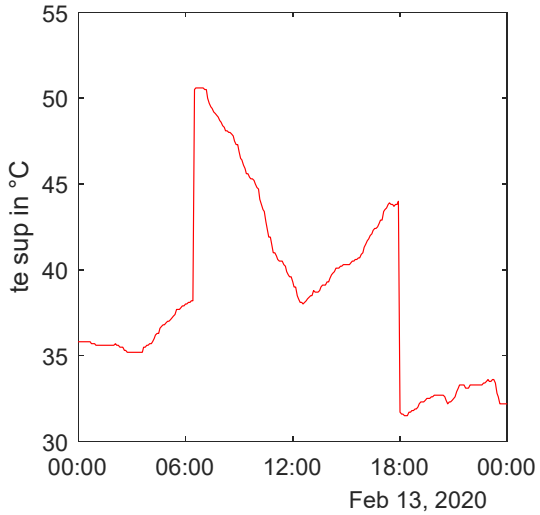
representative data of single customer

Modeling & Optimization

Modelling Concept



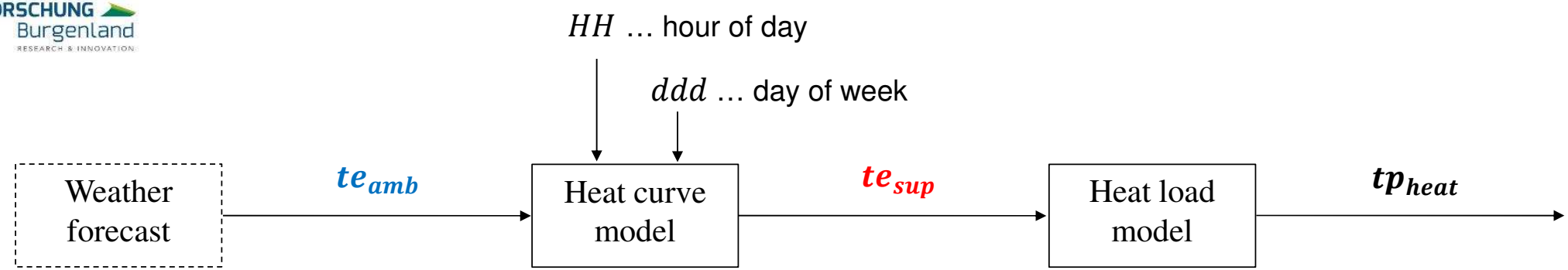


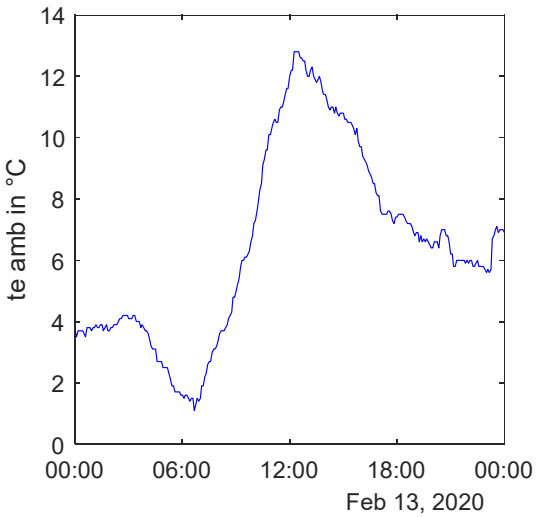


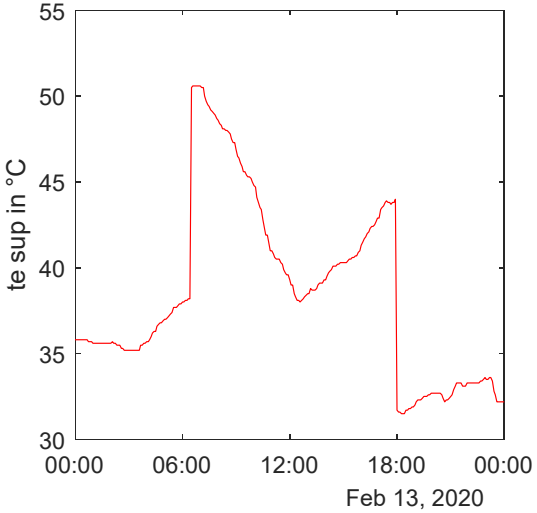
representative data of single customer

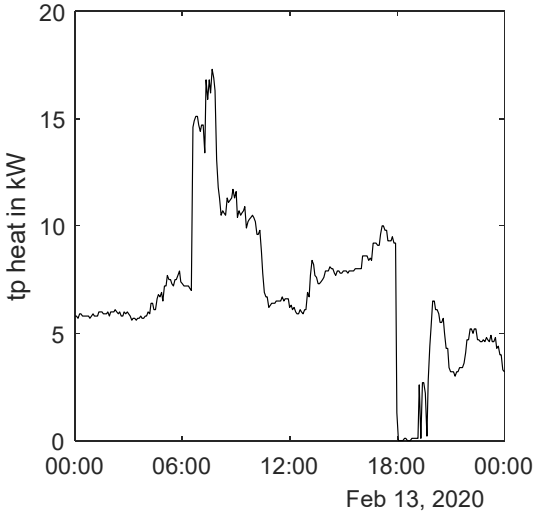
Modeling & Optimization

Modelling Concept





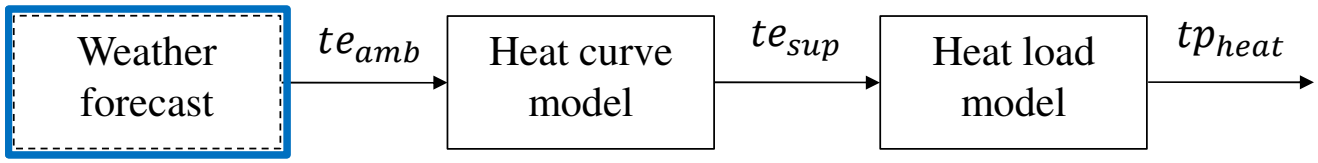




representative data of single customer

Modeling & Optimization

Heat curve model



Location and customer specific weather forecast required

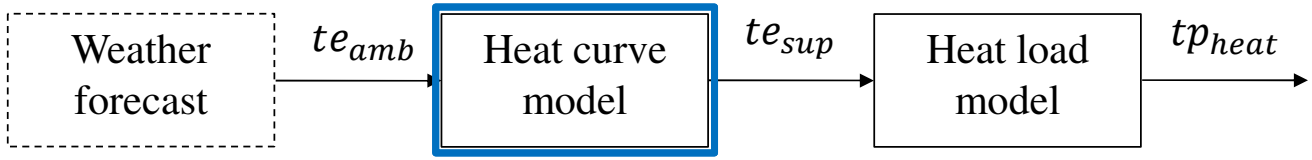
- Within DataDrivenLM provided by project partner: Blue Sky Wetteranalysen

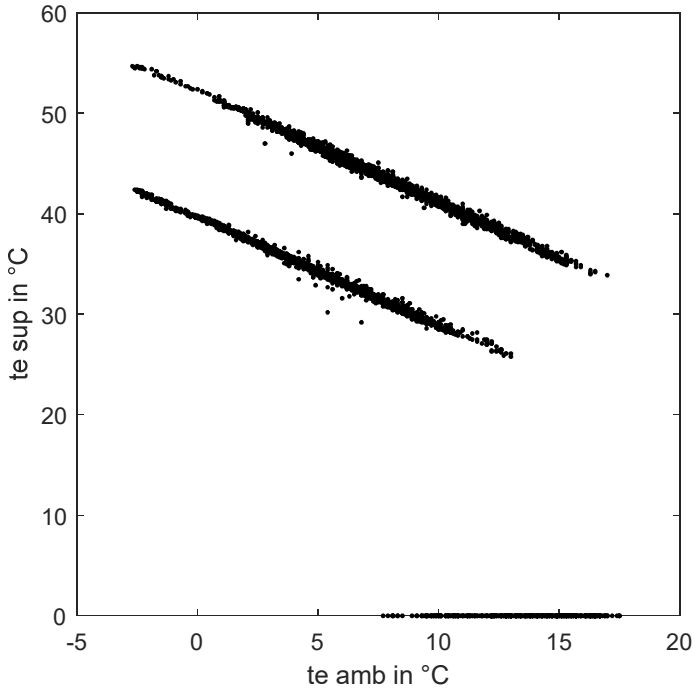
- Current local data -> used for high accuracy

- Historic local data -> used to include customer specific measurement errors (e.g. solar radiation effecting mounted sensor)

Modeling & Optimization

Heat curve model



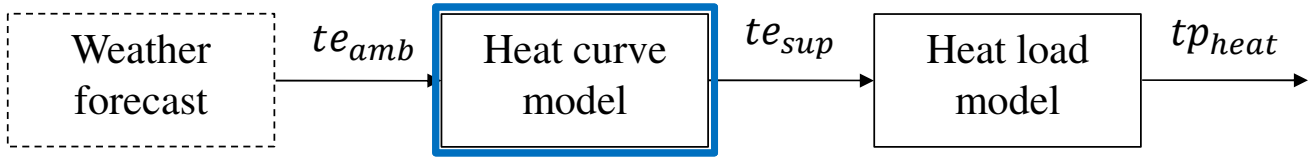


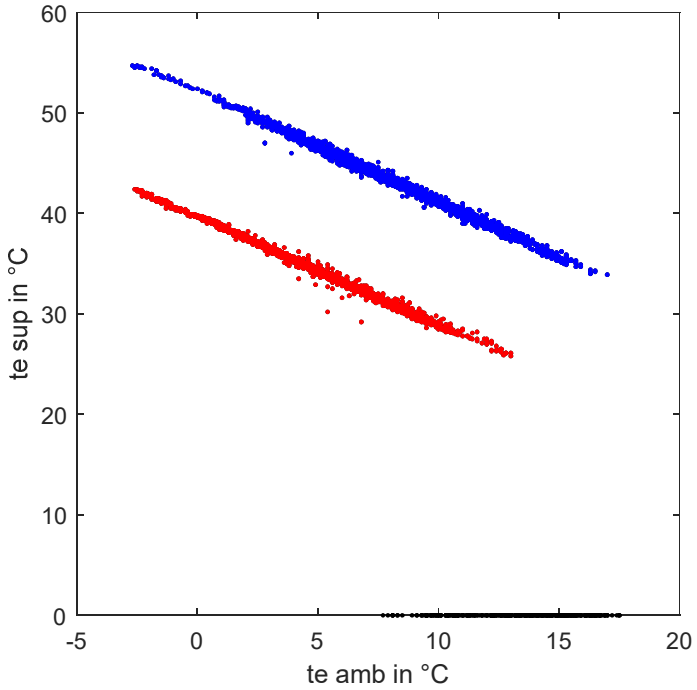
Steady state correlation from ambient to supply temperature

- Data pre-processing

Modeling & Optimization

Heat curve model



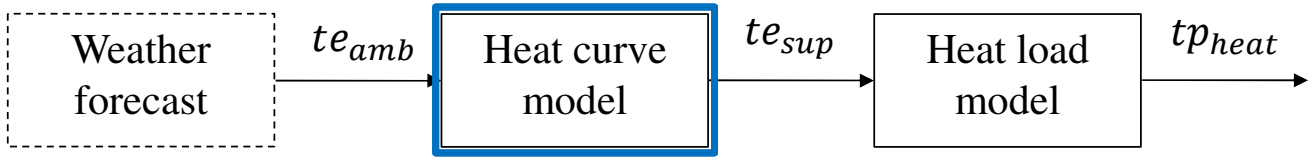


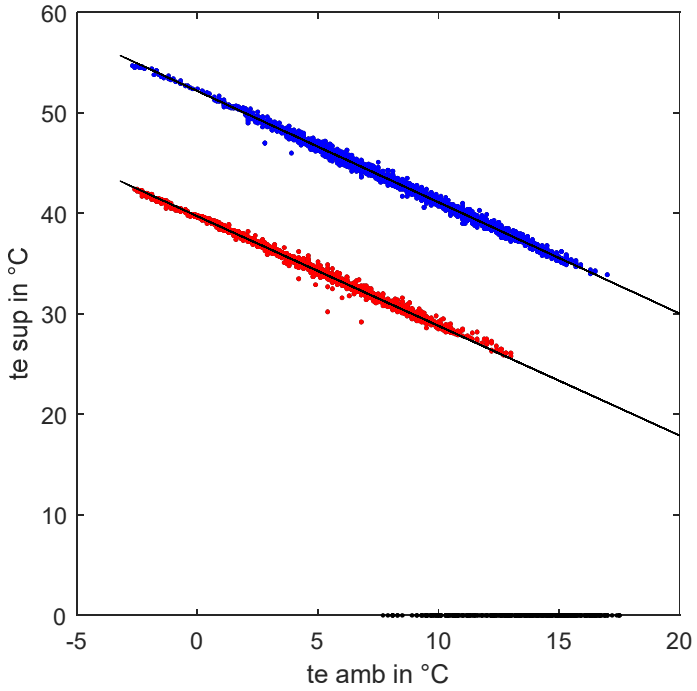
Steady state correlation from ambient to supply temperature

- Data pre-processing
- Allocation of **standard operation** (day) or **night setback** (ngh)
  - Density based clustering algorithm

Modeling & Optimization

Heat curve model



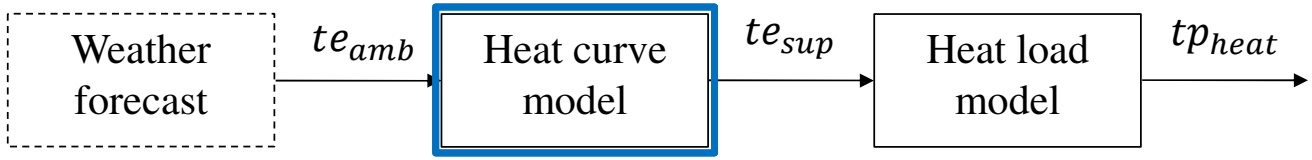


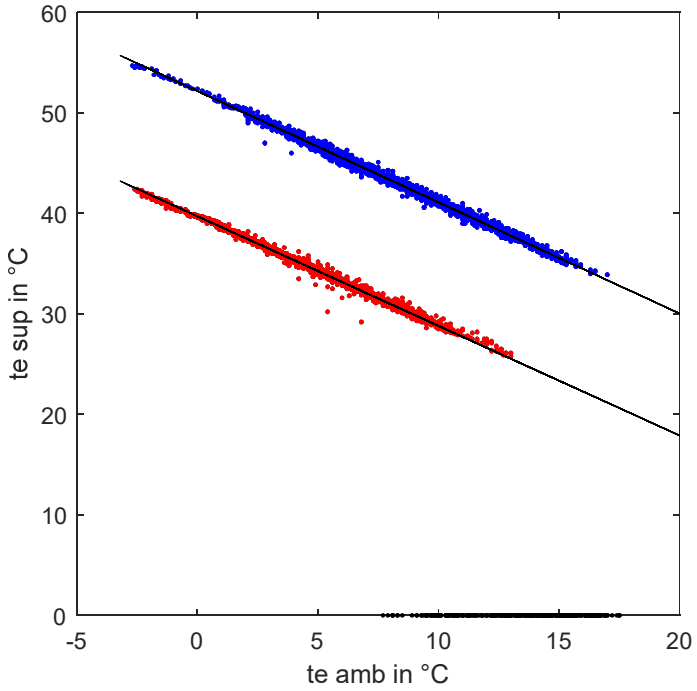
Steady state correlation from ambient to supply temperature

- Data pre-processing
- Allocation of **standard operation** (day) or **night setback** (ngh)
  - Density based clustering algorithm
- Linear (static) model fit per operating state (day/ngh)

Modeling & Optimization

Heat curve model



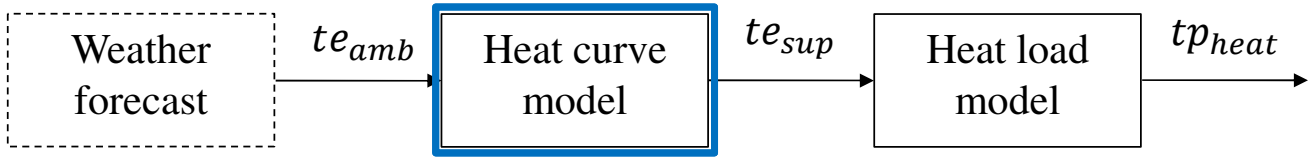


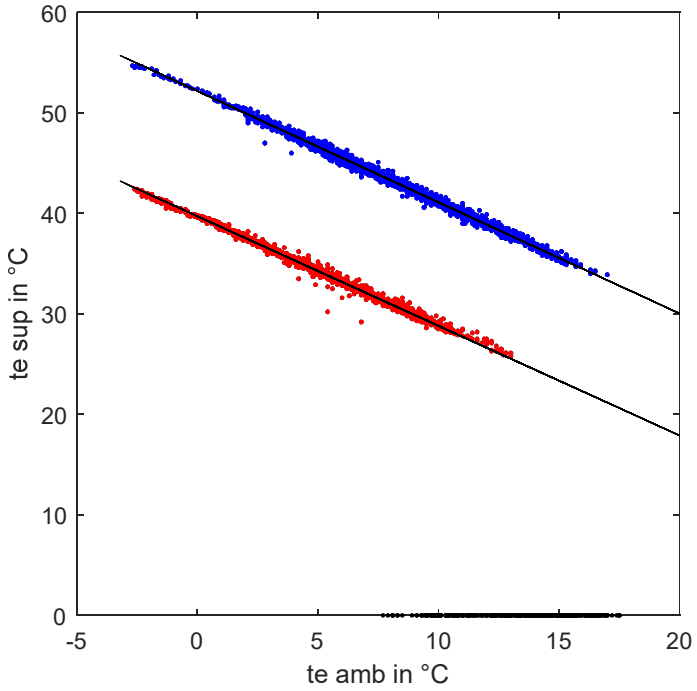
Steady state correlation from ambient to supply temperature

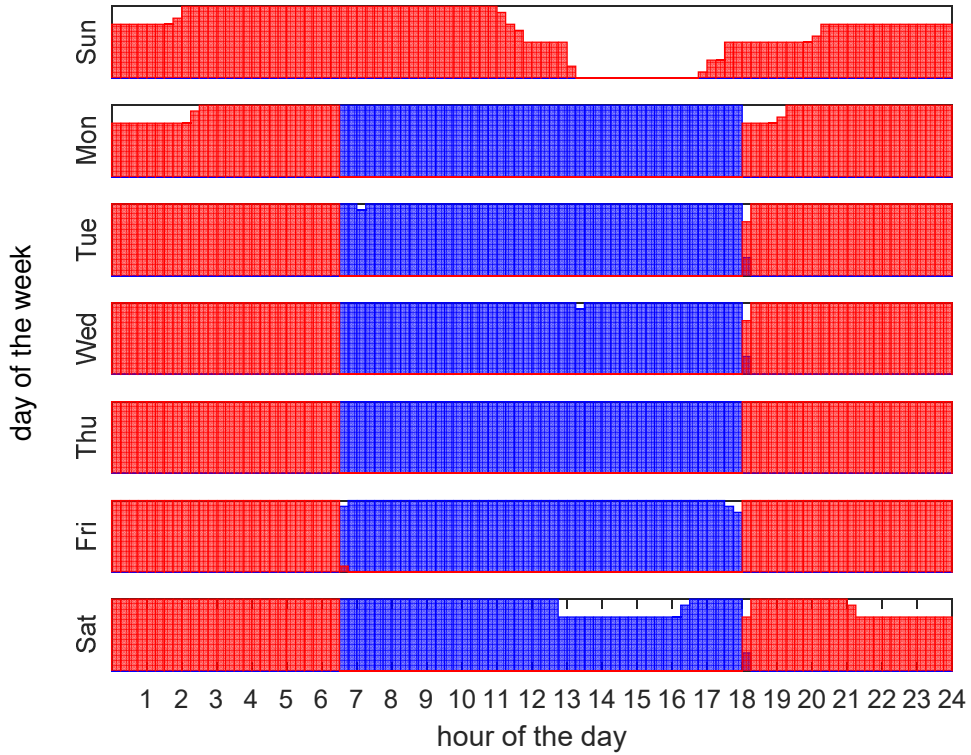
- Data pre-processing
- Allocation of **standard operation** (day) or **night setback** (ngh)
  - Density based clustering algorithm
- Linear (static) model fit per operating state (day/ngh)
- Building control settings are extracted from time series data
  - “Heat curve” function
  - Timetables for building operation

Modeling & Optimization

Heat curve model

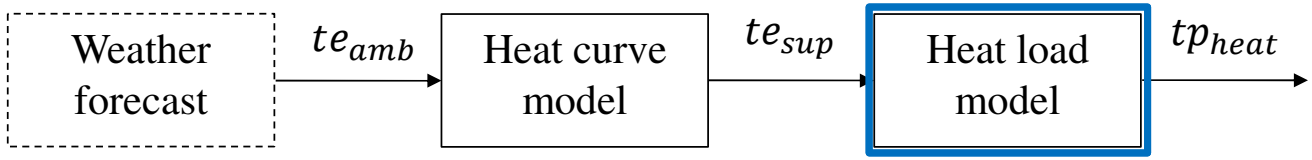


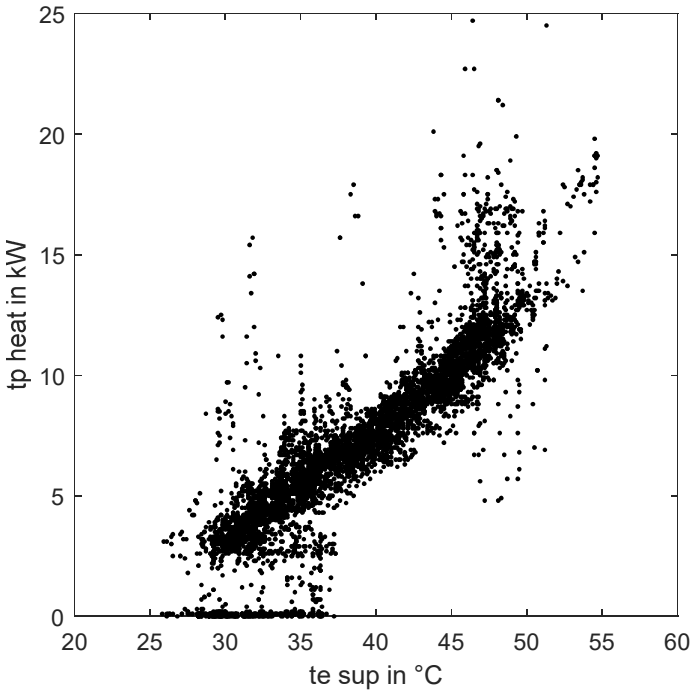




Modeling & Optimization

Heat load model



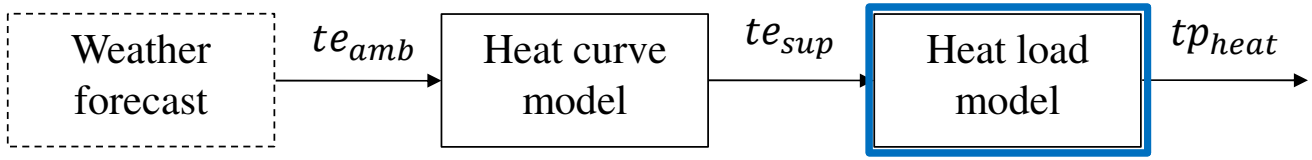


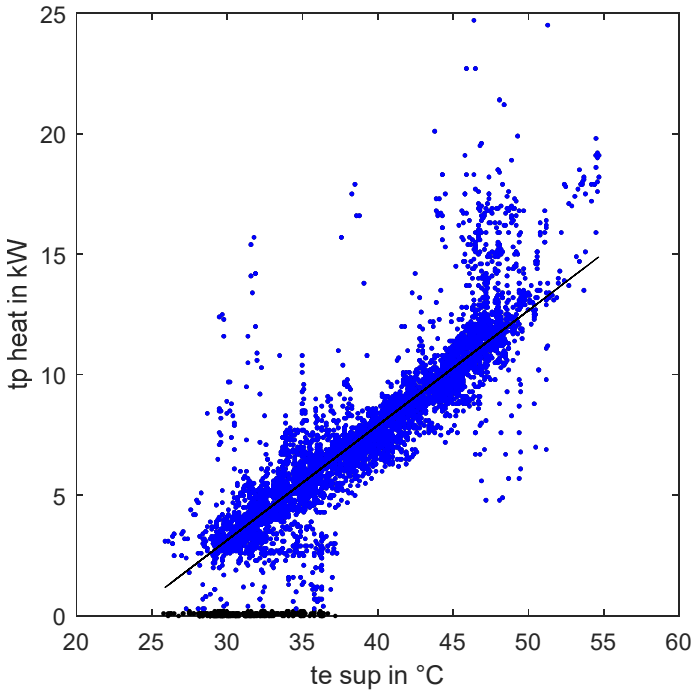
Steady state/dynamic model from supply temperature to thermal load

- Data pre-processing (clear domestic hot water load, etc.)

Modeling & Optimization

Heat load model



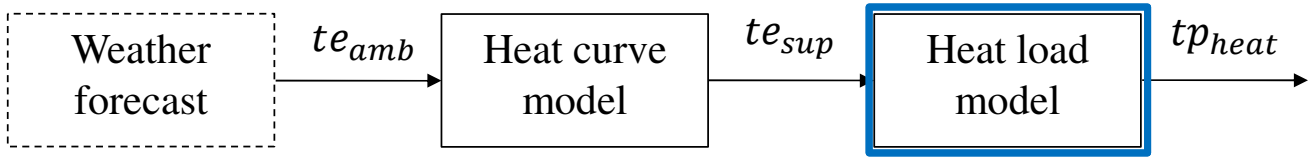


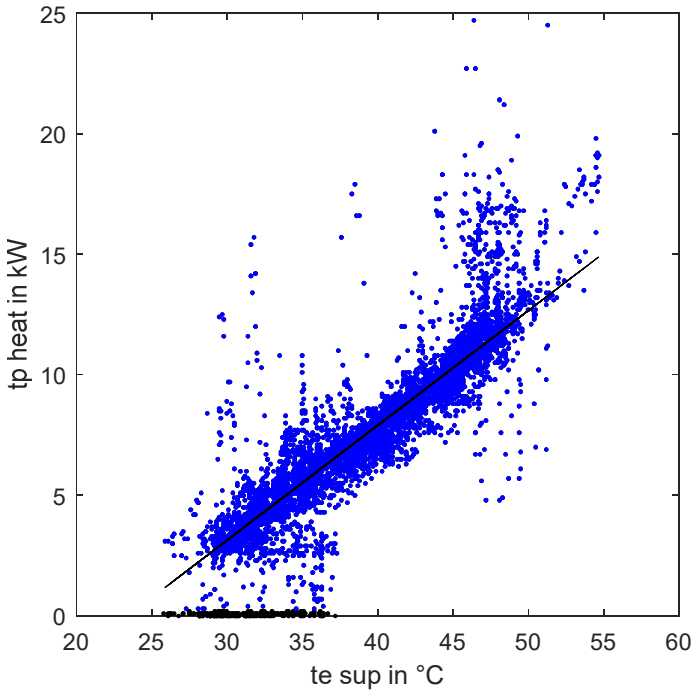
Steady state/dynamic model from supply temperature to thermal load

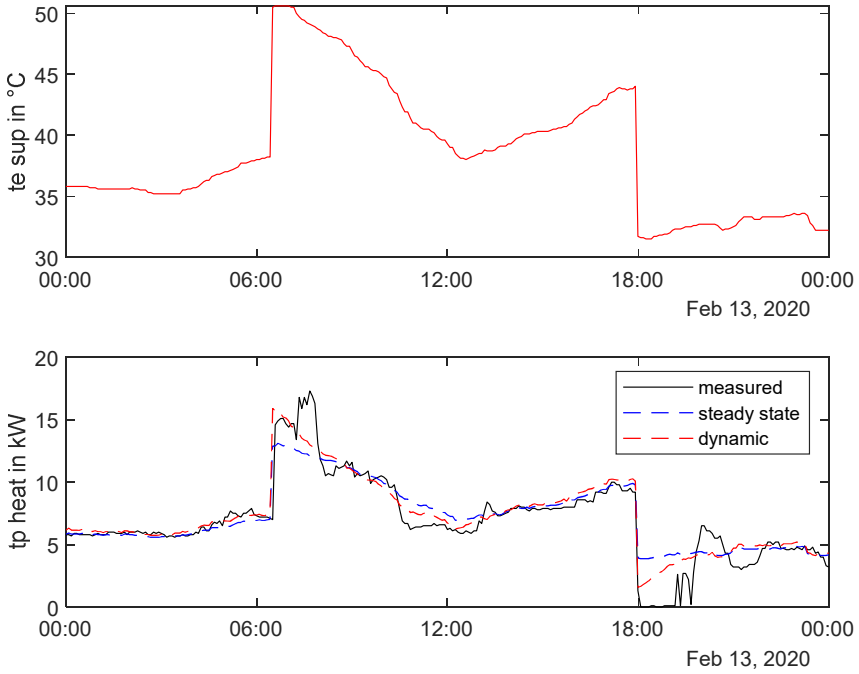
- Data pre-processing (clear domestic hot water load, etc.)
- Steady state approach
  - Linear model fit
- Dynamic approach
  - Transfer function

Modeling & Optimization

Heat load model

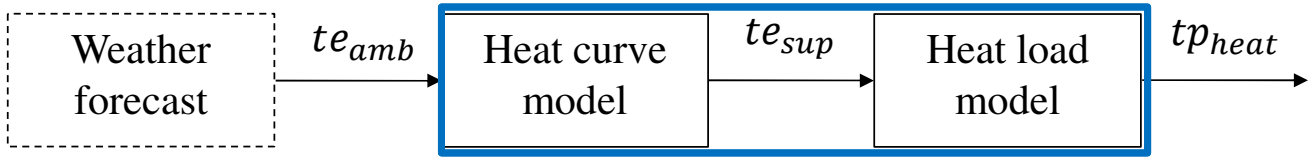


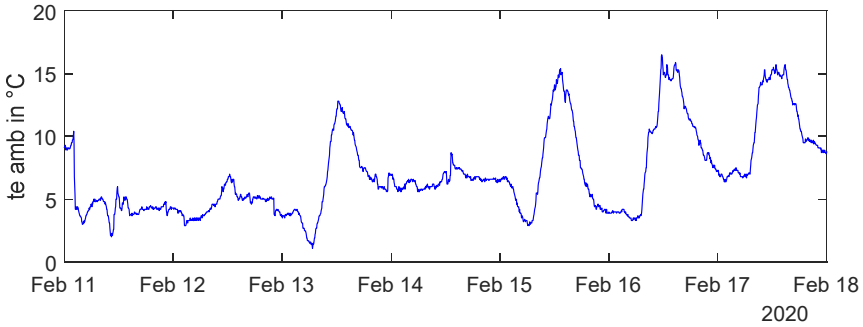


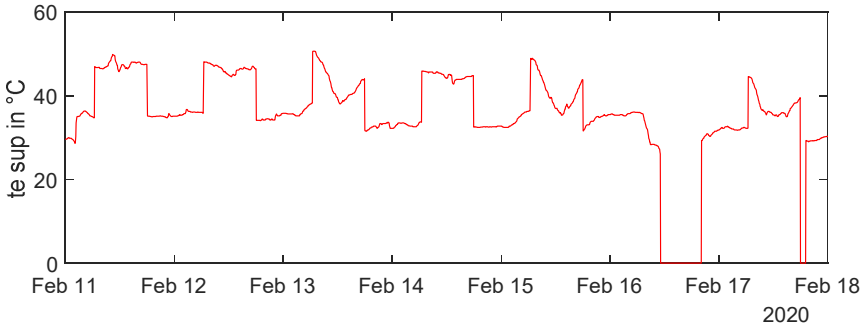


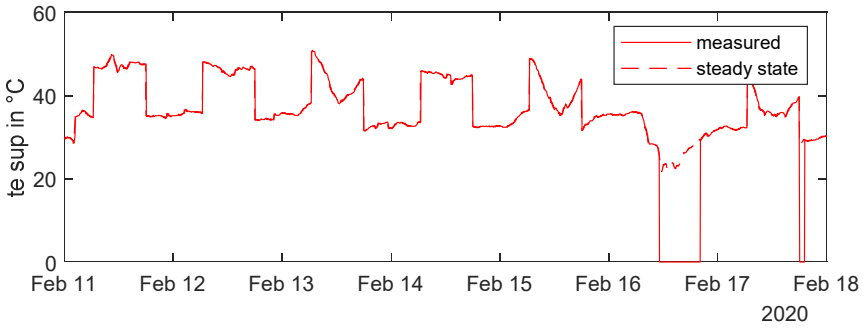
Modeling & Optimization

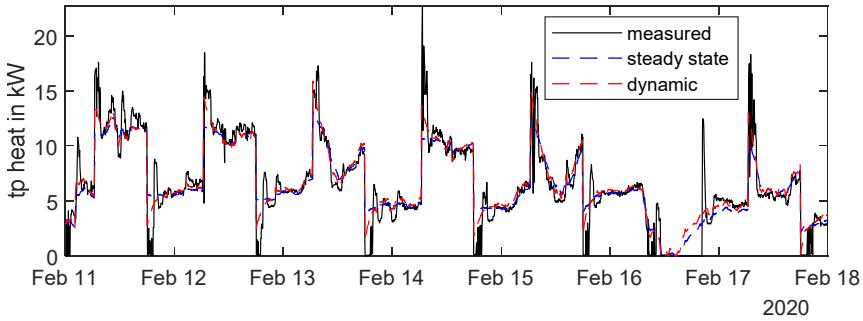
Combined models





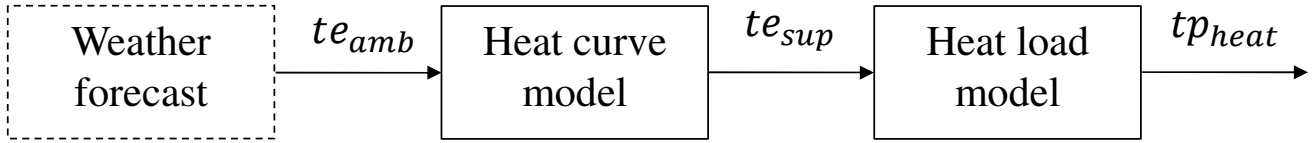




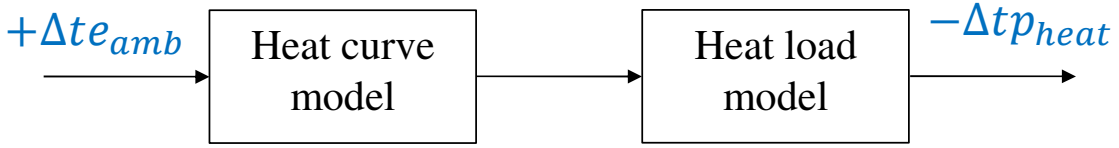


Modeling & Optimization

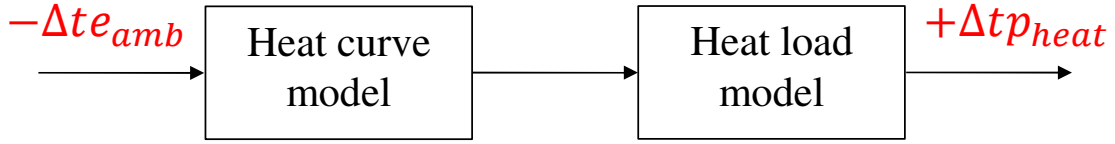
Customer influence



Decrese of thermal load:



Increase of thermal load:



Modeling & Optimization
Optimization

Basic optimization procedure

- Classic concept:
  Manipulate the thermal comfort within a accepted range to exploit the thermal storage of the buildings
  - FAILS, since the thermal comfort is unknown

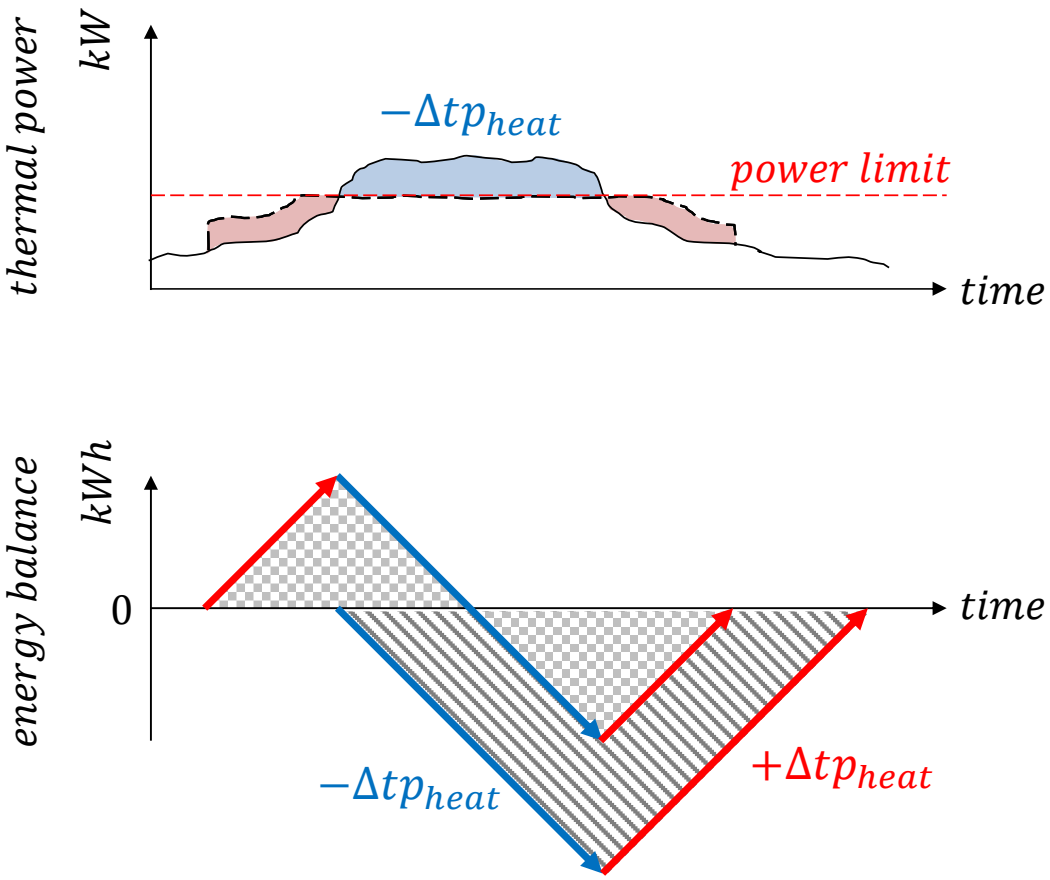
- Alternative concept:
  assuming an uninfluenced building matches the thermal comfort requirements
  every external thermal load change has an impact on the thermal comfort
  translated to mismatches in the energy balance,
  compared to the uninfluenced building operation

  - CONSTRAINT the total and individual thermal power requirements to carefully defined limits

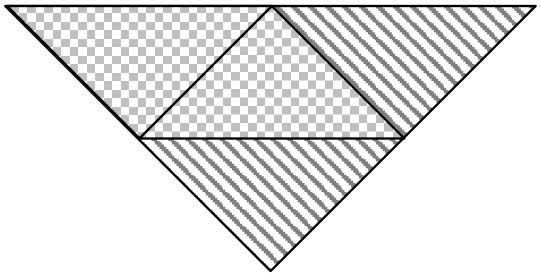
  - OBJECTIVE: find the least possible influence on the building energy balance to stay within constraints

Modeling & Optimization

Objective function

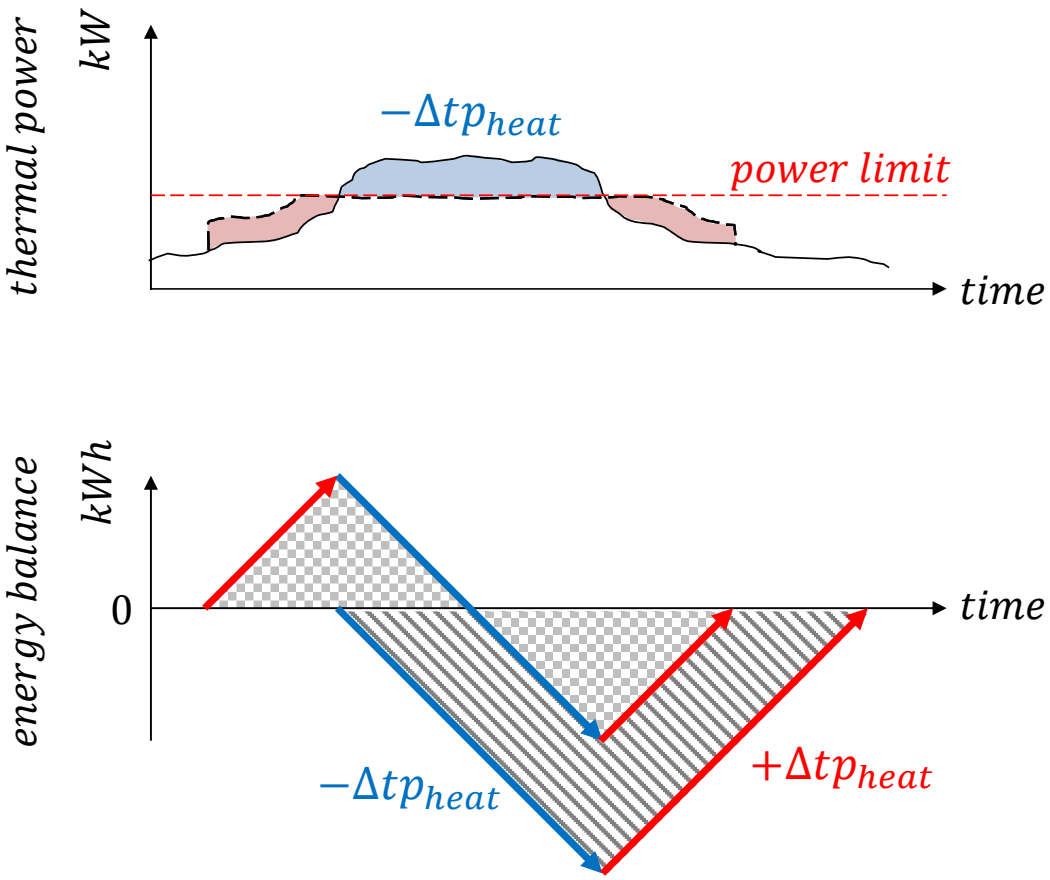


OBJECTIV in math. formulation:
Minimize the area
energy balance · time

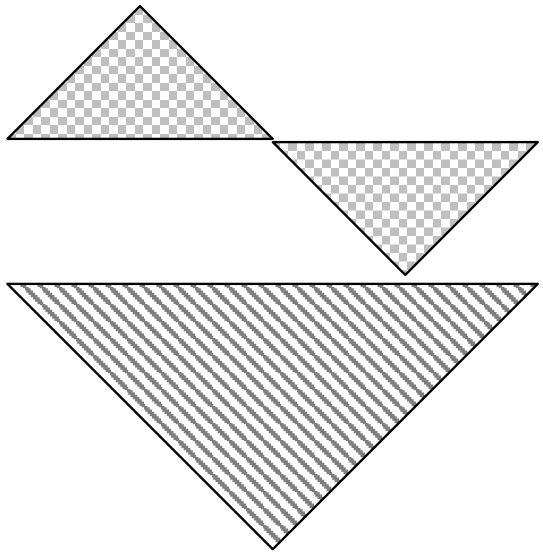


Modeling & Optimization

Objective function

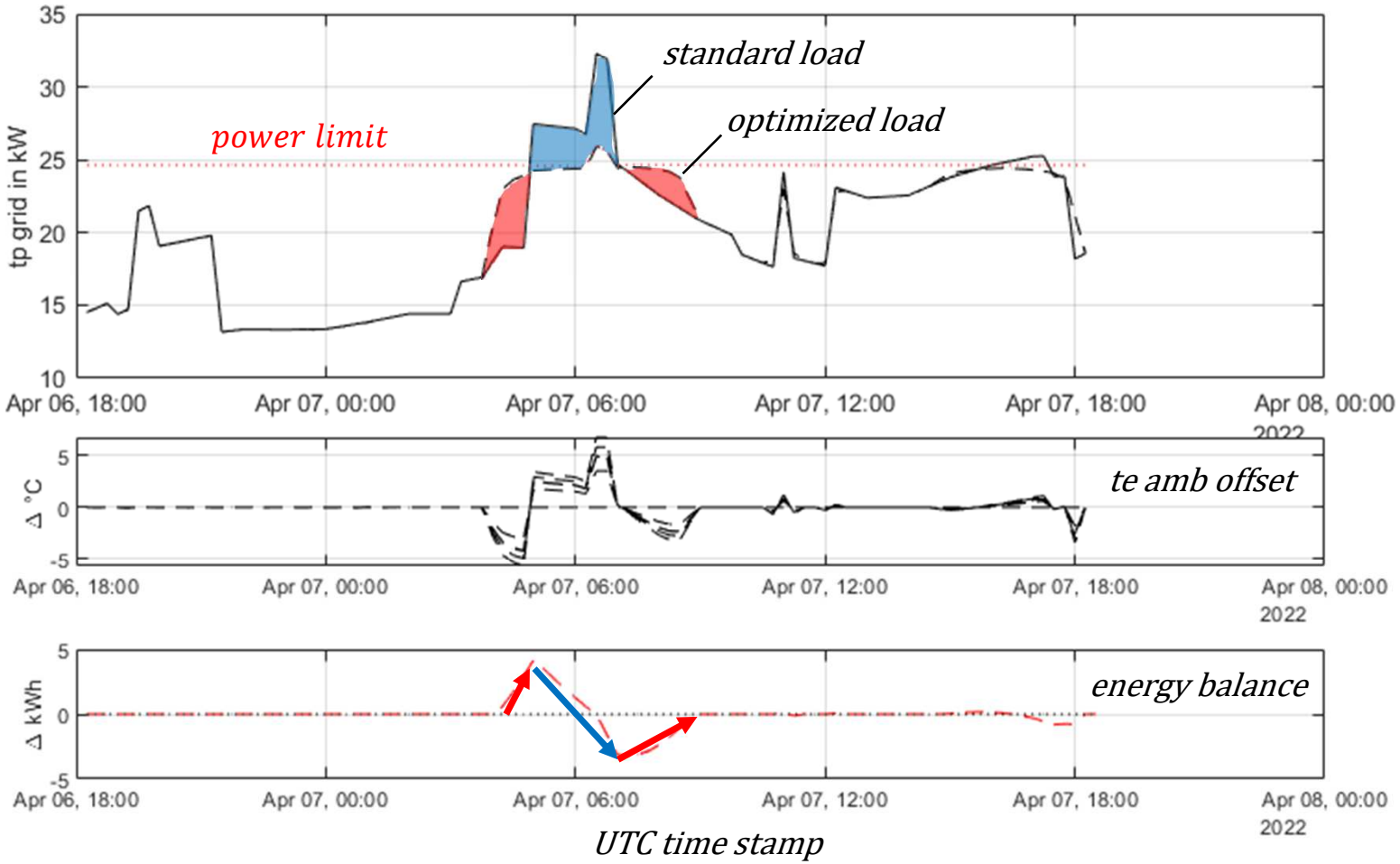


OBJECTIVE in math. formulation:
Minimize the area
energy balance · time



Test Operation
First results

- Test run at District Heating Network in Austria currently in operation
- 6 selected customers in artificial mini grid influenced by load management
- Optimization result from yesterday evening



Outcomes
DataDrivenLM

Current Status:

- Demand-Side Management method by automated modeling & central optimization.
- Status: Prototype in demonstration / test operation.

Benefit: Practical implementation

1) Uses available infrastructure: Suitable for current DH infrastructure in Austria.
2) Digital solution: easier to deploy → “Fast Transition” for DH
3) No retrofit / installation necessary (e.g. storages, devices).

Additional data that would make most sense:

- Room temperatures, controllable thermostats

Regulation Aspects → Business models to leverage technical benefits.

- Flexible heat delivery contracts
- EWG / Renewable Heating Law

Project DataDrivenLM

FFG Energieforschung, 5. Ausschreibung: Projekt 871697 „Verbesserung der Systemeffizienz von thermischen Netzen durch intelligente, datengetriebene Lastmanagementmethoden“:

Dieses Projekt wird aus Mitteln des Klima- und Energiefonds gefördert und im Rahmen des Energieforschungsprogramms 2018 durchgeführt.

AEE INTEC

FORSCHUNG Burgenland
RESEARCH & INNOVATION

IDEA TO ACTION

Los geht’s!