Data-Intelligent

District Heating Systems

Henrik Madsen + many others

DTU Compute (CITIES, HEAT4.0, SCA, IDASC, FED, TOP-UP)

https://smartcitiesaccelerator.eu/

http://www.smart-cities-centre.org

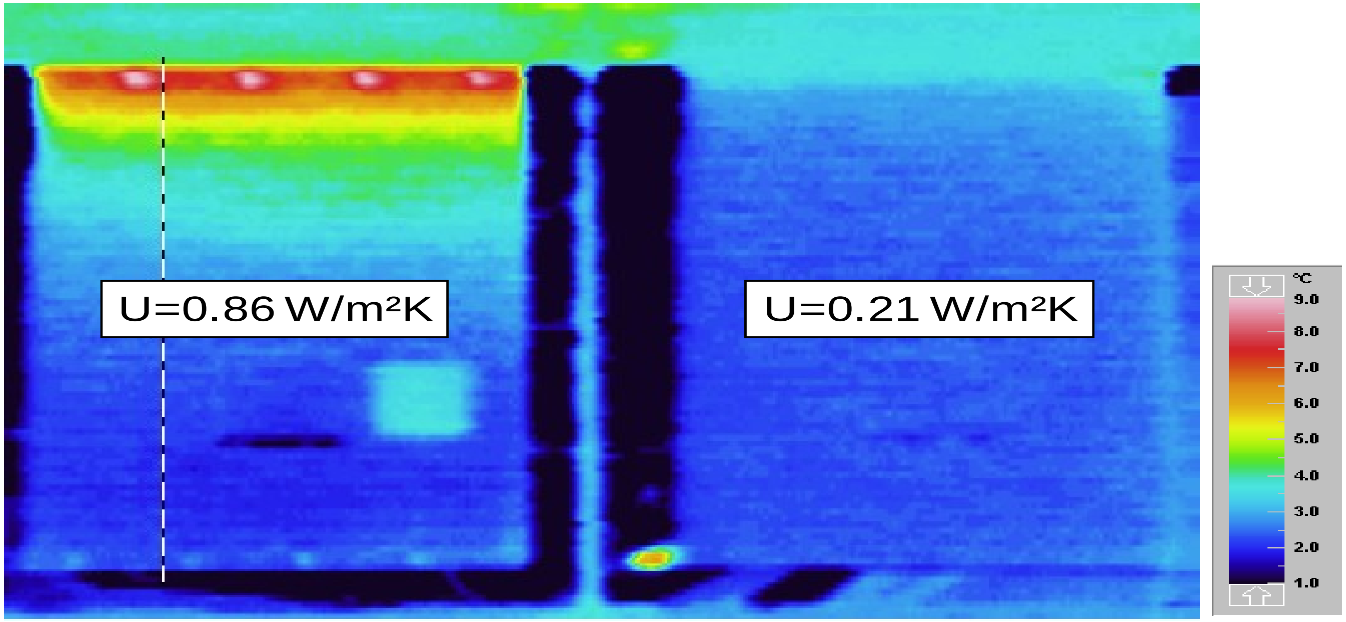
http://www.henrikmadsen.org

Case Study No. 1

Thermal Performance Characterization of Buildings

CITIES
Centre for IT Intelligent Energy Systems

Example



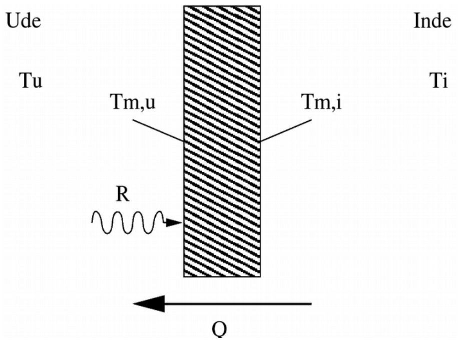
Consequence of good or bad workmanship (theoretical value is U=0.16W/m2K)

Case Study No. 2

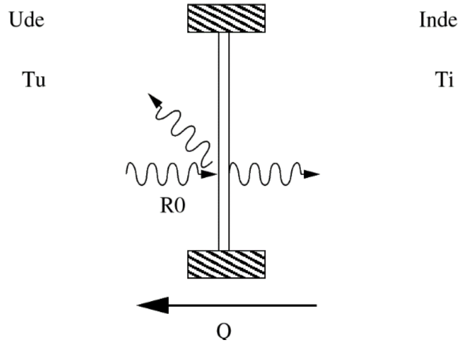
Load Forecasts Using MET Forecasts AND Local Weather Data

Model components in load forecasting

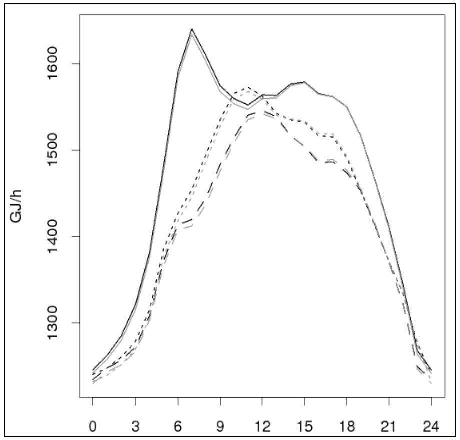
Wall: Slow reaction on climate



Windows + ventilation: Fast reaction



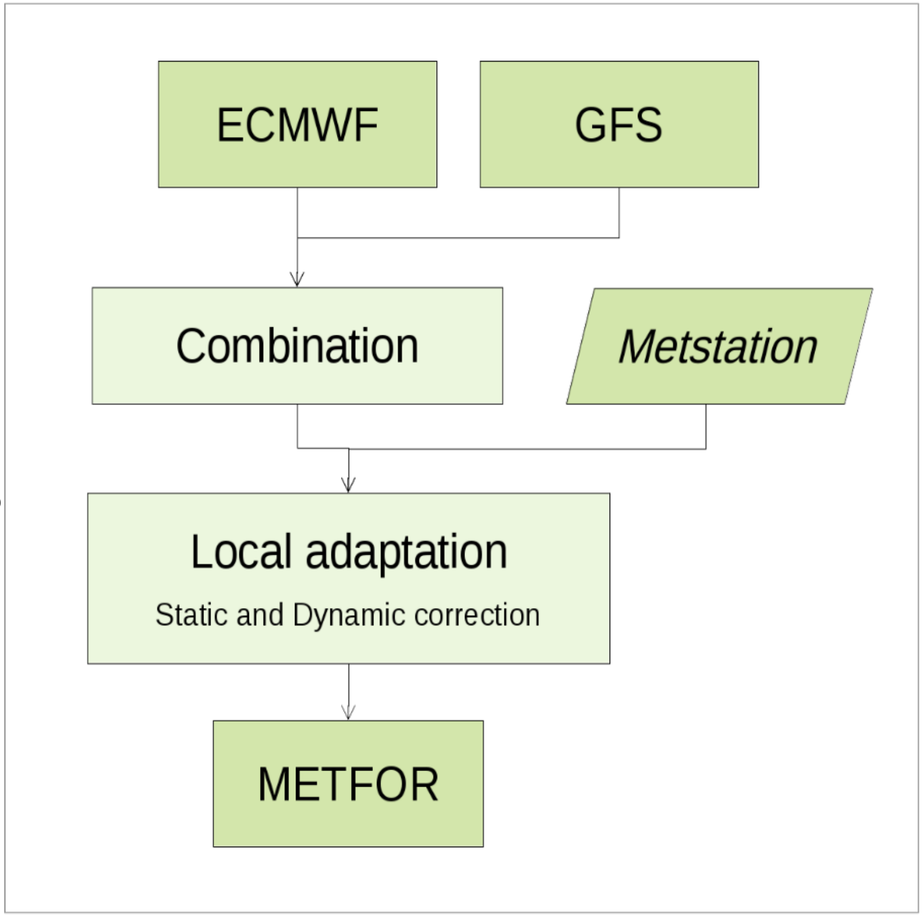
Occupant behavior



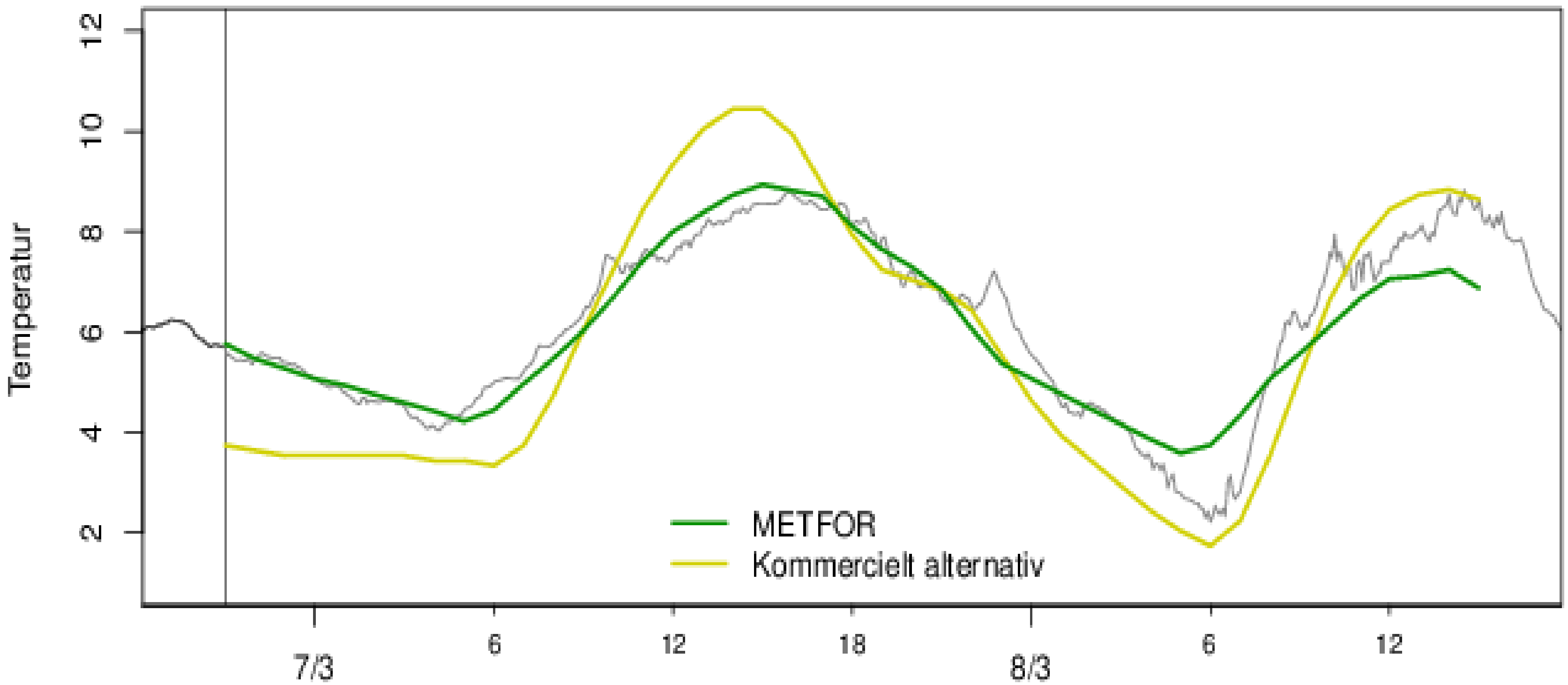
Weather data and forecasts

Optimize local weather forecast base on:

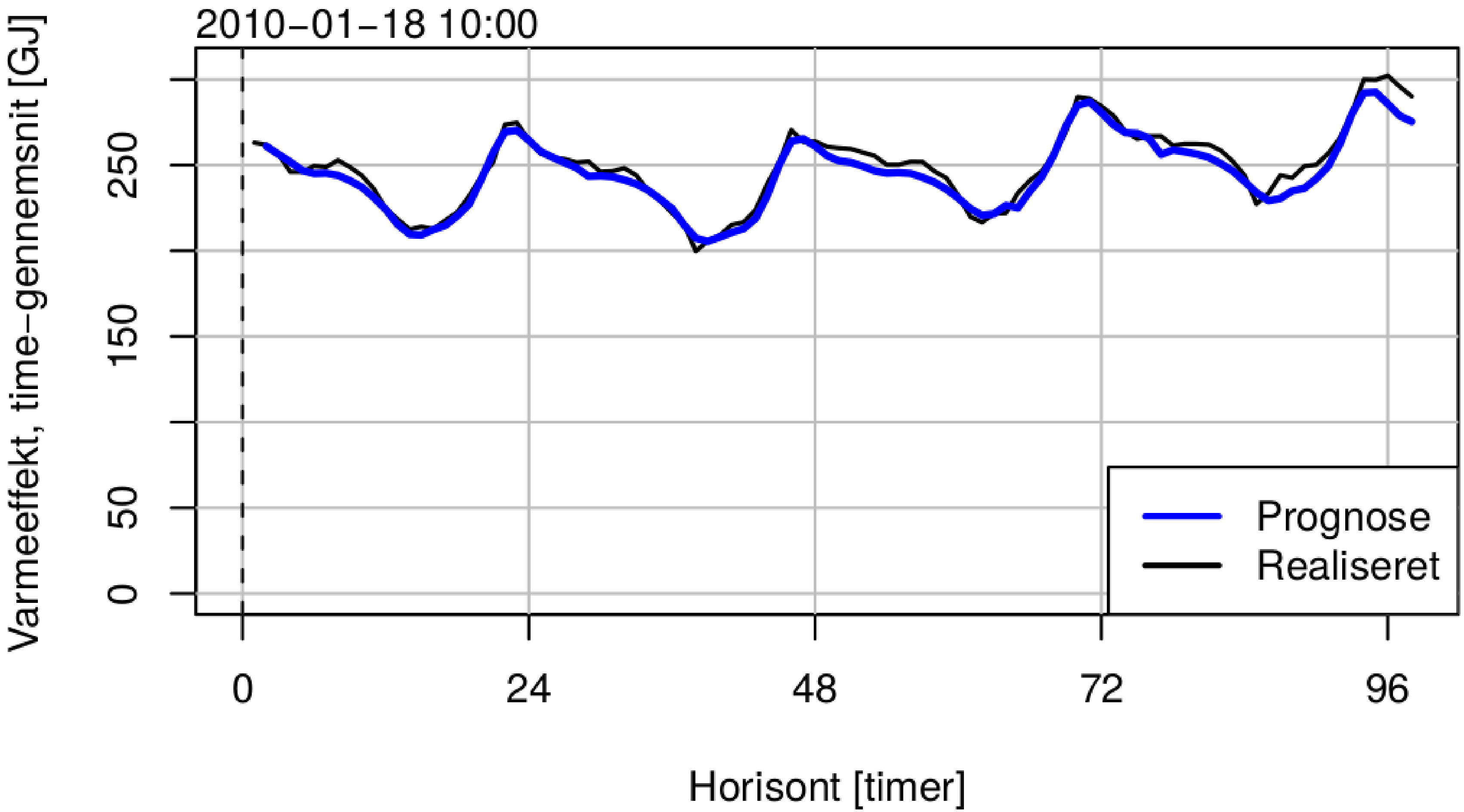
- Local climate data
- Several MET forecasts



METFOR forecast example



HEATFOR[†] Load Forecast (Example)



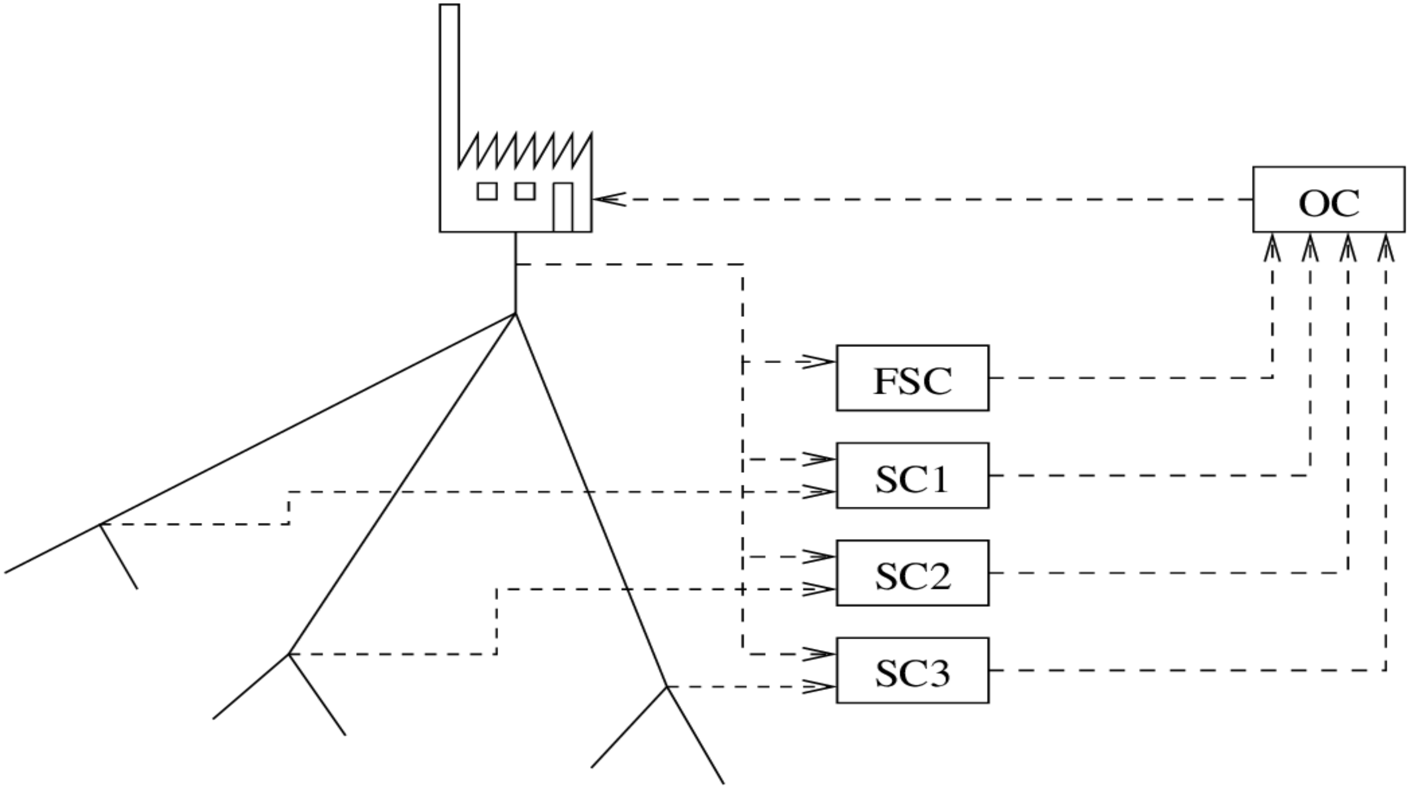
[†]ENFOR ~ https://enfor.dk/

Case Study No. 3

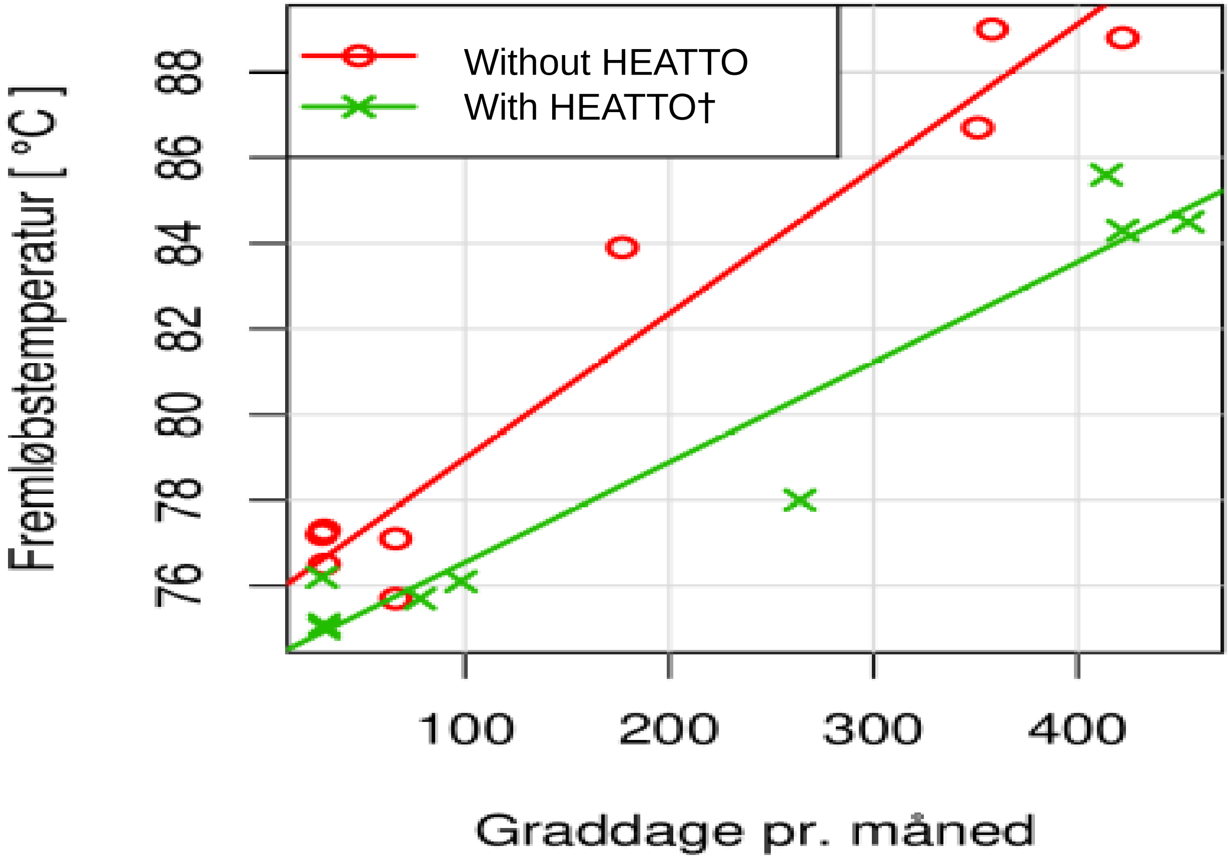
Data-Intelligent Temperature Optimization

Models and Controllers

(Highly simplified!)



Supply temperature with/without data intelligent control



†ENFOR ~ https://enfor.dk/

Savings
(Reduction of heat loss = 18.3 pct)

	Heat Supply		Electricity	
	GJ	1000 DKK	kWh	1000 DKK
Without HEATTO	653,000	30,750	499,000	648
With HEATTO†	615,000	28,990	648,000	842
Difference	37,400	1,760	-149,000	-194

Total savings (The 9 first months of normal year): 1,566,000kr

Savings for one normal year:

- 12/9 x 1,566,000kr = **2.1 millions**
- However, the period from Jan to Sept (75% of the year) is only ca. 65% degree days of the normal year
- 1.566.000/0.65 = **2.4 millions**

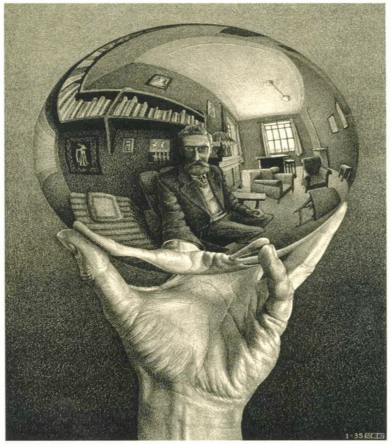
Savings

- A new report shows there is a potential of annual saving about 240-790 Million DKK in Denmark using data-driven temperature optimization*.
- Addition savings when implementing tools using the meter data. Only time will tell how much the additional savings based on the meter data
- Also, no need for critical points – Savings on maintenance.

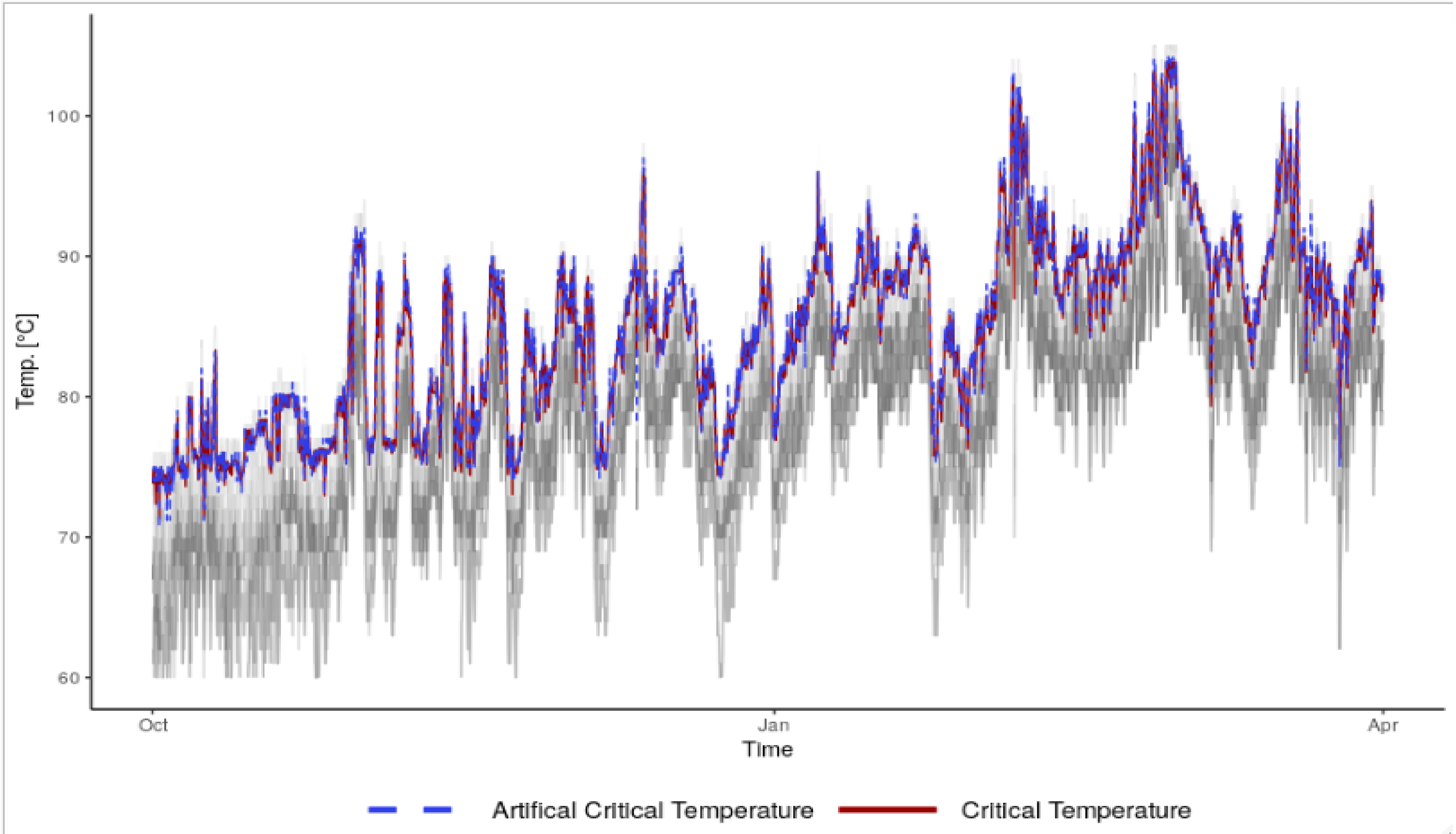
* Potentialet ved dynamisk datadrevet temperaturregulering i fjernvarmesektoren, DANVAD Analytics & Dansk Fjernvarme, 2019-02

Data Intelligent Temperature Optimization for DH Systems

- Able to take advantage of **information in data**
- **Self-calibrating** models for the DH network
- **Temperature zones** are easy to establish
- Shows where to **upgrade** the DH network
- **Fast** (real time) calculations
- Use DH net for **peak shaving** and **storage**
- Able to use **online MET forecasts** etc.



Artifical Critical Temperatures Using Meter Data (Kraftringen, Lund, Sweden)



HEAT4.0, FED, SCA, IDACS, TOP-UP:

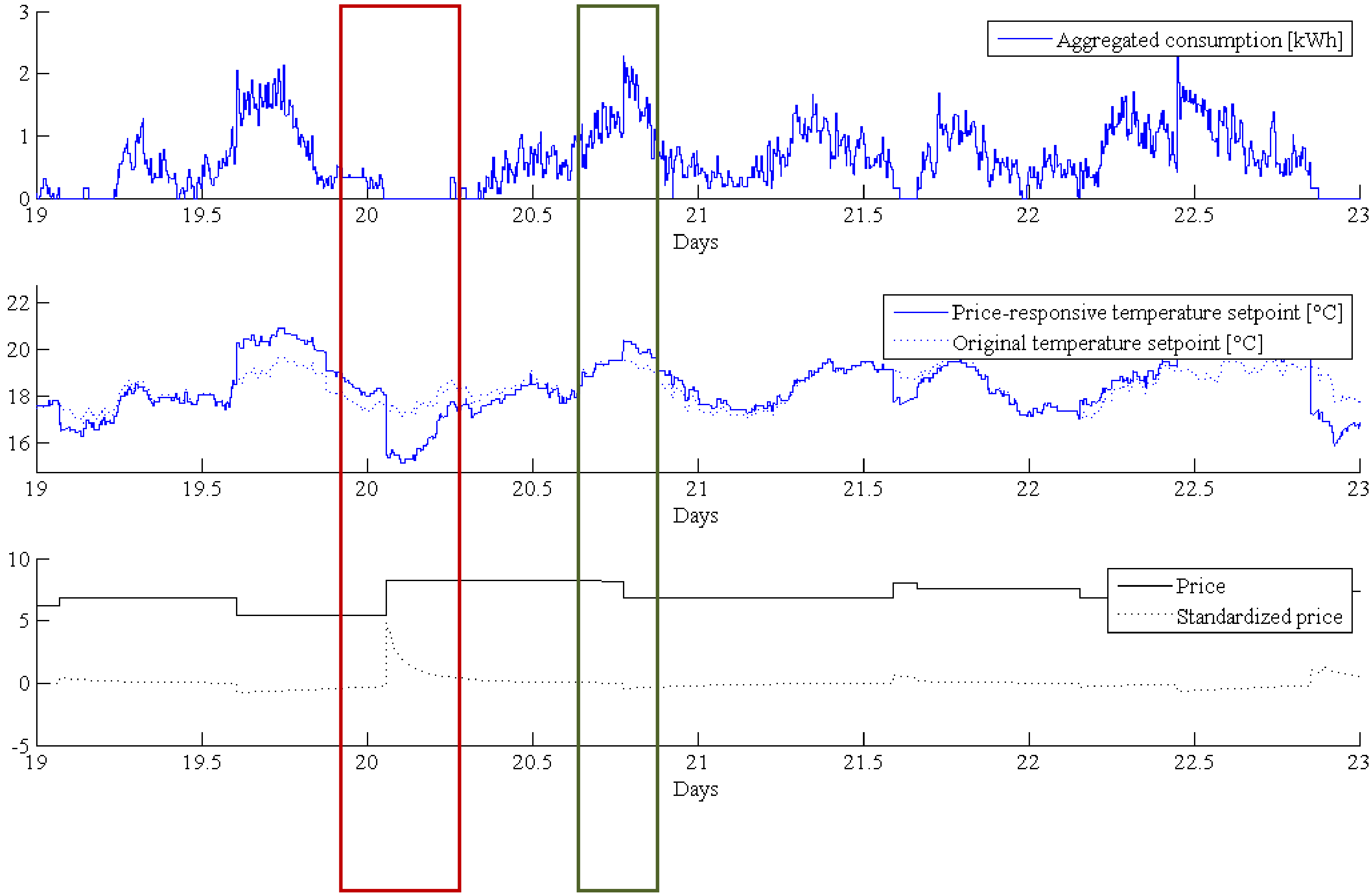
Data-Intelligence v. 4.0 (using also meter data)

- Eliminates or reduces the need for critical points in the DH net
- Filtering of #N smart meter readings -> available temperature
- Identify needs for upgrade of the local network
- Find users with a high flow
- Next generation of temperature zones
- Intell. Control – energy, emission, costs, peak,..
- Use user installations to store energy locally
- Time-varying prices – active use of end-users (see next demo..)
- Establish controllers for effect limitations at single users

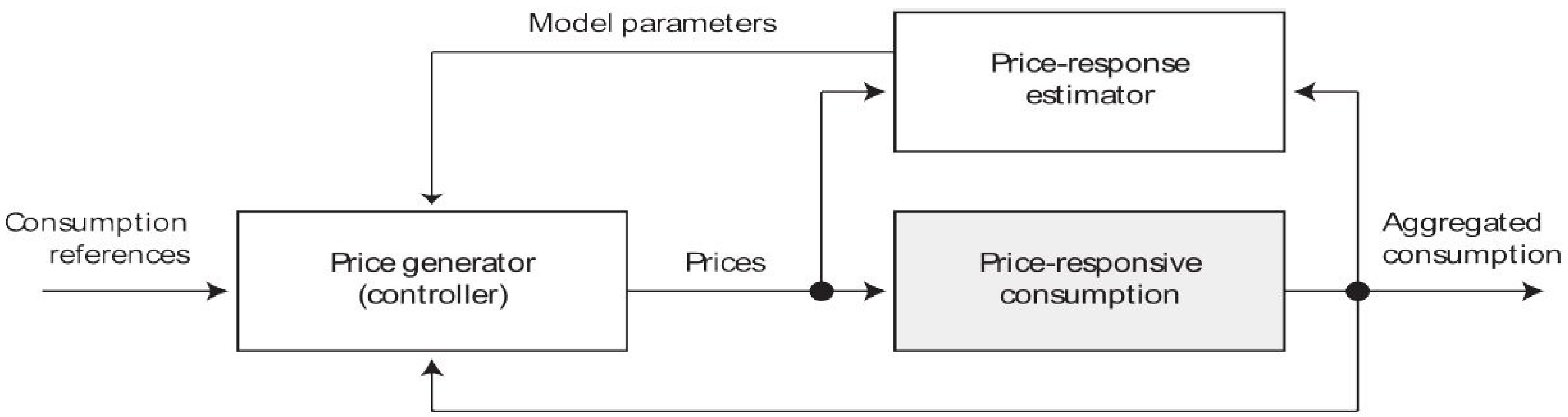
Case study No. 4

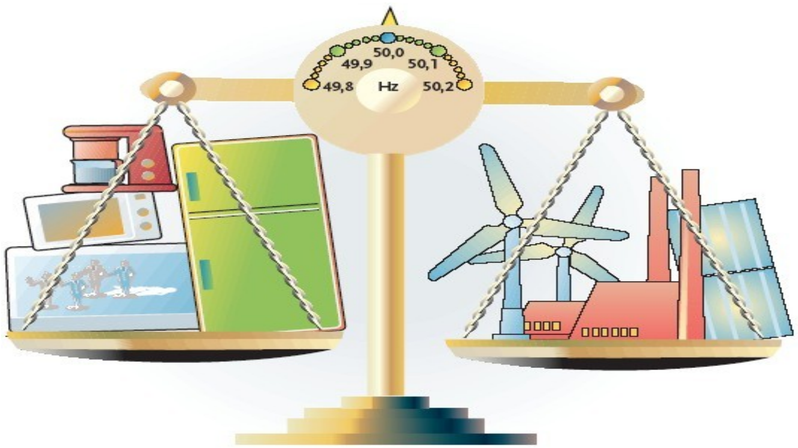
Control of Load
Using the Thermal Mass of Buildings
(Peak shaving)

Aggregation (over 20 houses)



Price based Control

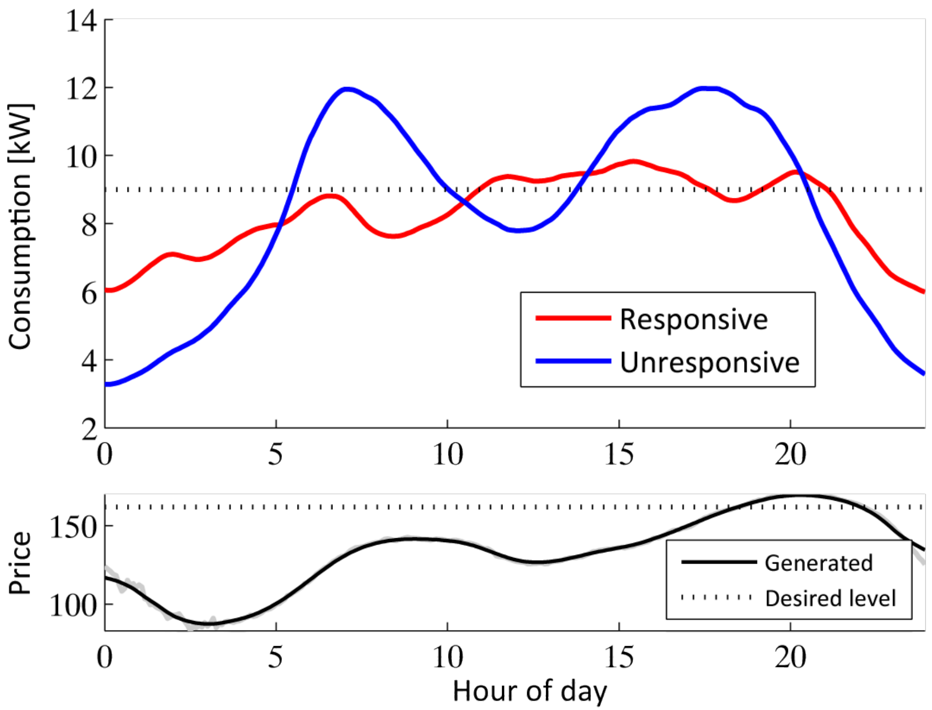




Control performance

Considerable **reduction in peak consumption**

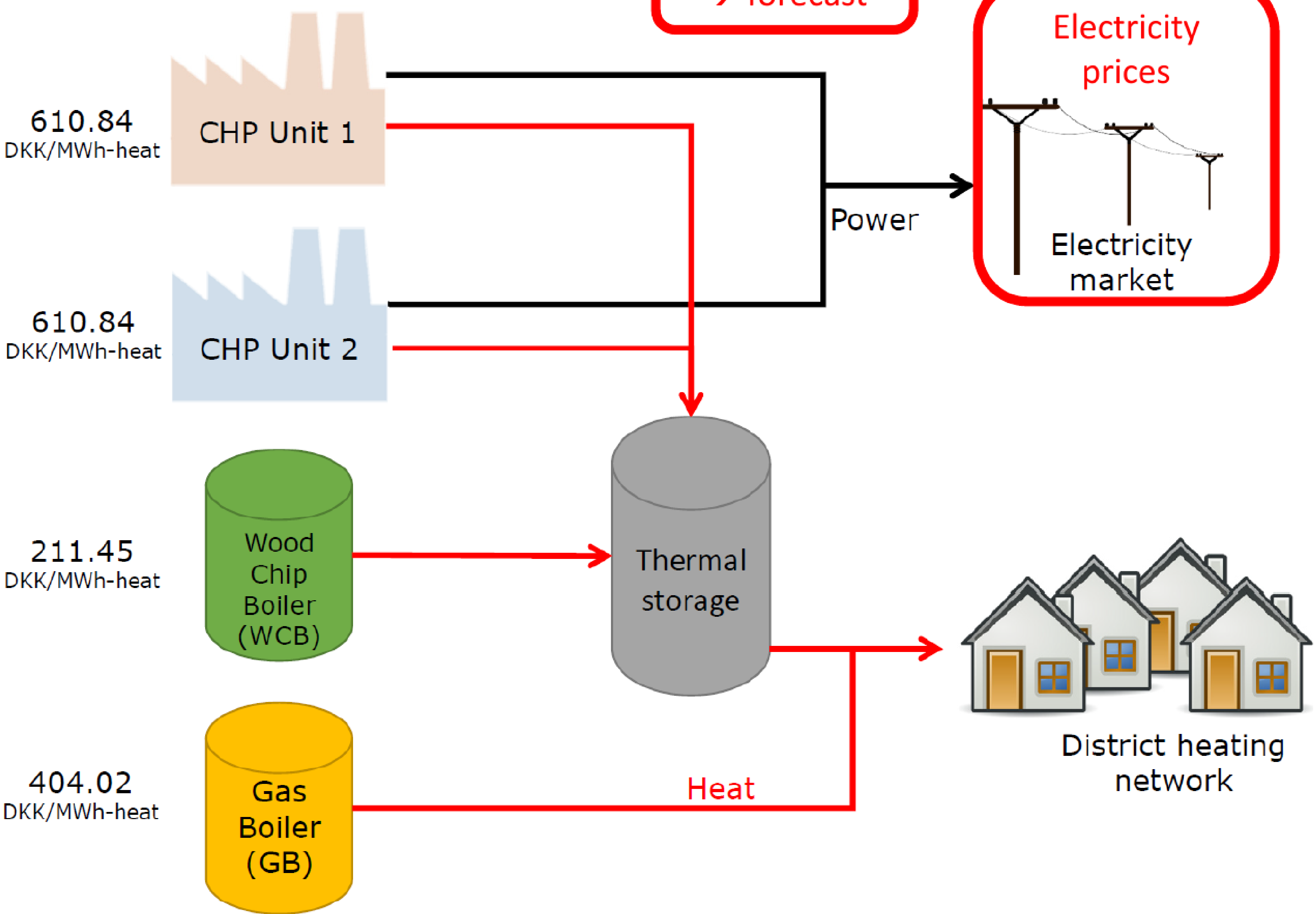
Mean daily consumption shift



Case study No. 5

Optimal Production and Bidding for DH Systems

Case study


Uncertainty
→ forecast
Electricity
prices
610.84
DKK/MWh-heat
CHP Unit 1
Power
Electricity
market
610.84
DKK/MWh-heat
CHP Unit 2
211.45
DKK/MWh-heat
Wood
Chip
Boiler
(WCB)
Thermal
storage
District heating
network
404.02
DKK/MWh-heat
Gas
Boiler
(GB)
Heat

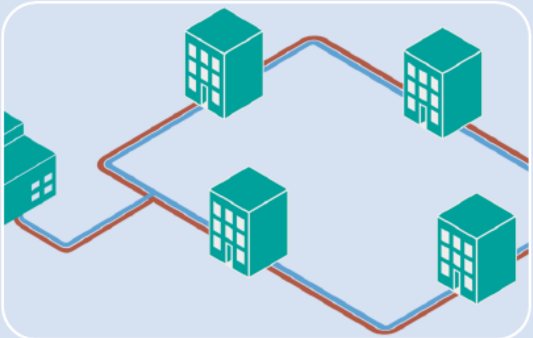
Results - Bids

Percentage of hours with bids and won bids in one month averaged over several samples

Method	Receding Horizon	CHP 1		CHP 2	
		Bids	Won	Bids	Won
HURB Worst	1	**98.91**	**41.95**	98.70	41.91
HURB Avg.	-	**99.79**	**42.19**	99.75	42.15
HURB Best	10	**99.89**	**42.28**	99.87	42.26
Conejo et al.	10	44.92	39.34	44.92	39.31
Rodriguez & Anders	5	82.52	35.85	82.40	35.82
Schulz et al.	12	45.02	18.54	45.01	18.53
Dimoulkas & Amelin	12	75.55	26.56	75.55	26.55
Ravn et al.	5	44.84	32.58	44.83	32.57

We can take advantage of the portfolio of heat production units and base the bidding amounts and prices on the heat production.

HEAT4.0 / HEATman
...... provides coupling and synergi



Production

Operational optimization for the integration with power system

Distribution

Temperature optimization of distribution system

Demand

Heating system optimization

Demand forecasting of buildings

Integration of MPC in building heating control systems

Long-term planning

Summary

- District Heating can efficiently provide the flexibility needed accelerating the green transition
- Real-time data (incl. use of meter data) can be used for:
  - Improved load forecasting
  - Data-intelligent temperature control (large CO2/DKK savings)
  - Virtual storage solutions (buildings, network, fuel-shift, ..)
  - Control of heat pumps in DH systems (> 15 pct CO2 reduction)
  - Identify where to upgrade the network
  - Optimal production planning and bidding
- We have demonstrated a large potential in Demand Response in DH systems. Automatic solutions are important
- HEAT4.0 / HEATman combines production, net and end-user solutions
- We see large problems with the tax and tariff structures in many countries (eg. Denmark; we are working on a new design of taxes and tariffs.

For more information ...

See for instance

www.smart-cities-centre.org

...or contact

– Henrik Madsen (DTU Compute)
  hmad@dtu.dk

Acknowledgement - DSF 1305-00027B