Data Intelligent Operation of DH Systems

(incl. Temp. Opt. v.4.0)

Henrik Madsen

Dept. Appl. Mathematics and Computer Science, DTU

http://www.citiesinnovation.org

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

http://www.henrikmadsen.org

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Software solutions

Software for combined physical and statistical modelling

Continuous Time Stochastic Modelling (CTSM) is a software package for modelling and simulation of combined physical and statistical models. You find a technical description and the software at CTSM.info.

Software for Model Predictive Control

HPMPC is a toolbox for High-Performance implementation of solvers for Model Predictive Control (MPC). It contains routines for fast solution of MPC and MHE (Moving Horizon Estimation) problems on embedded hardware. The software is available on GitHub.

MPCR is a toolbox for building Model Predictive Controllers written in R, the free statistical software. It contains several examples for different MPC problems and interfaces to opensource solvers in R . The software is available on GitHub.

Search ...

Latest news

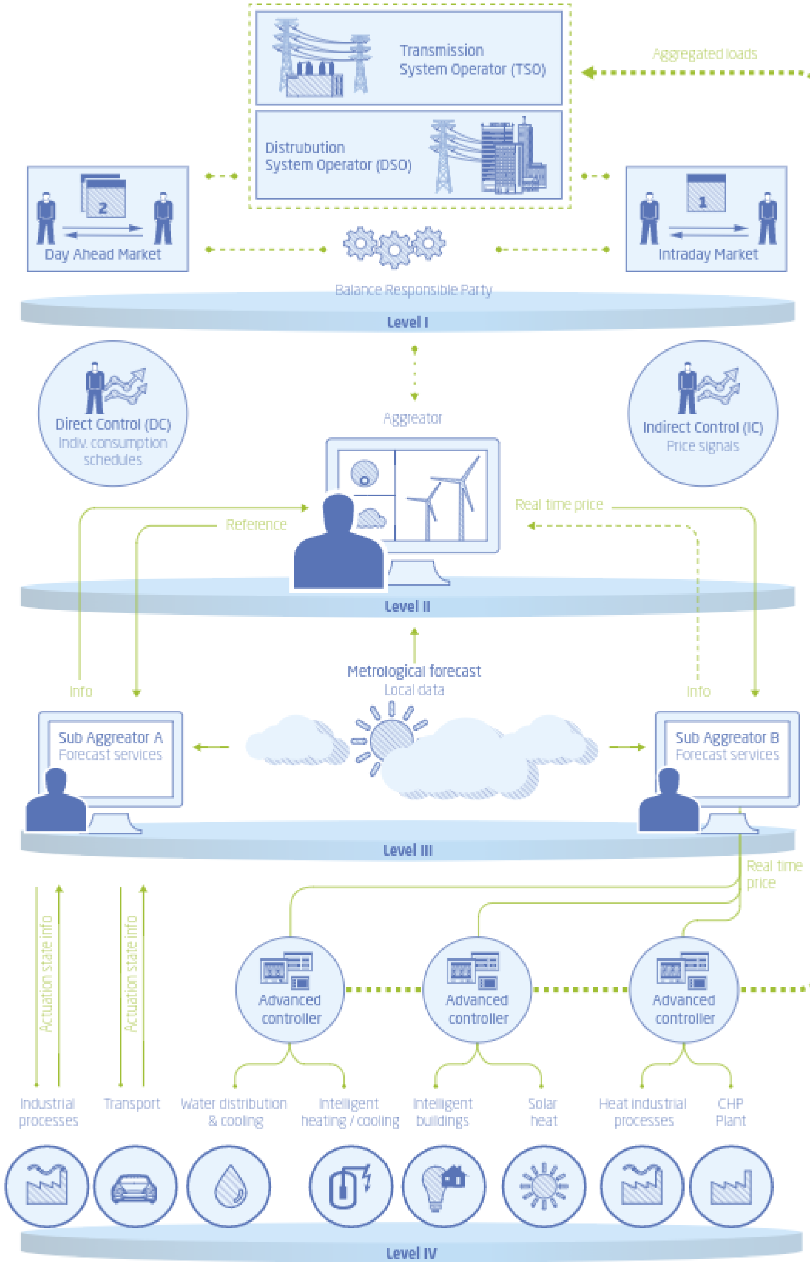
Summer School at DTU, Lyngby, Denmark – July 4th-8th 2016

Summer School – Granada, Spain, June 19th-24th 2016

Third general consortium meeting – DTU, May 24th-25th 2016

Smart City Challenge in Copenhagen – April 20th 2016

Guest lecture by Pierluigi Mancarella at DTU, April 6th



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Level I

This level contains a market clearing where the producers are selected based on bids. The connections between the actors in the market are represented with dashed lines because different markets have a different layout. The description is inspired by the Nordic layout with a day-ahed spot market, Elspot, and an intraday market or balancing market. Lines with circles indicate that these parts of the system are connected. Lines with arrows indicate information flow.

Level II

The Aggregator estimates its available flexibility and submits bids to the regulating power market directly or though the Balance Responsible Party (BRP). After clearing of the spot market, the Direct Control Aggregator (DC) will dispatch individual consumption schedules, while the iIndirect Control Aggregator (IC) will broadcast price signals.

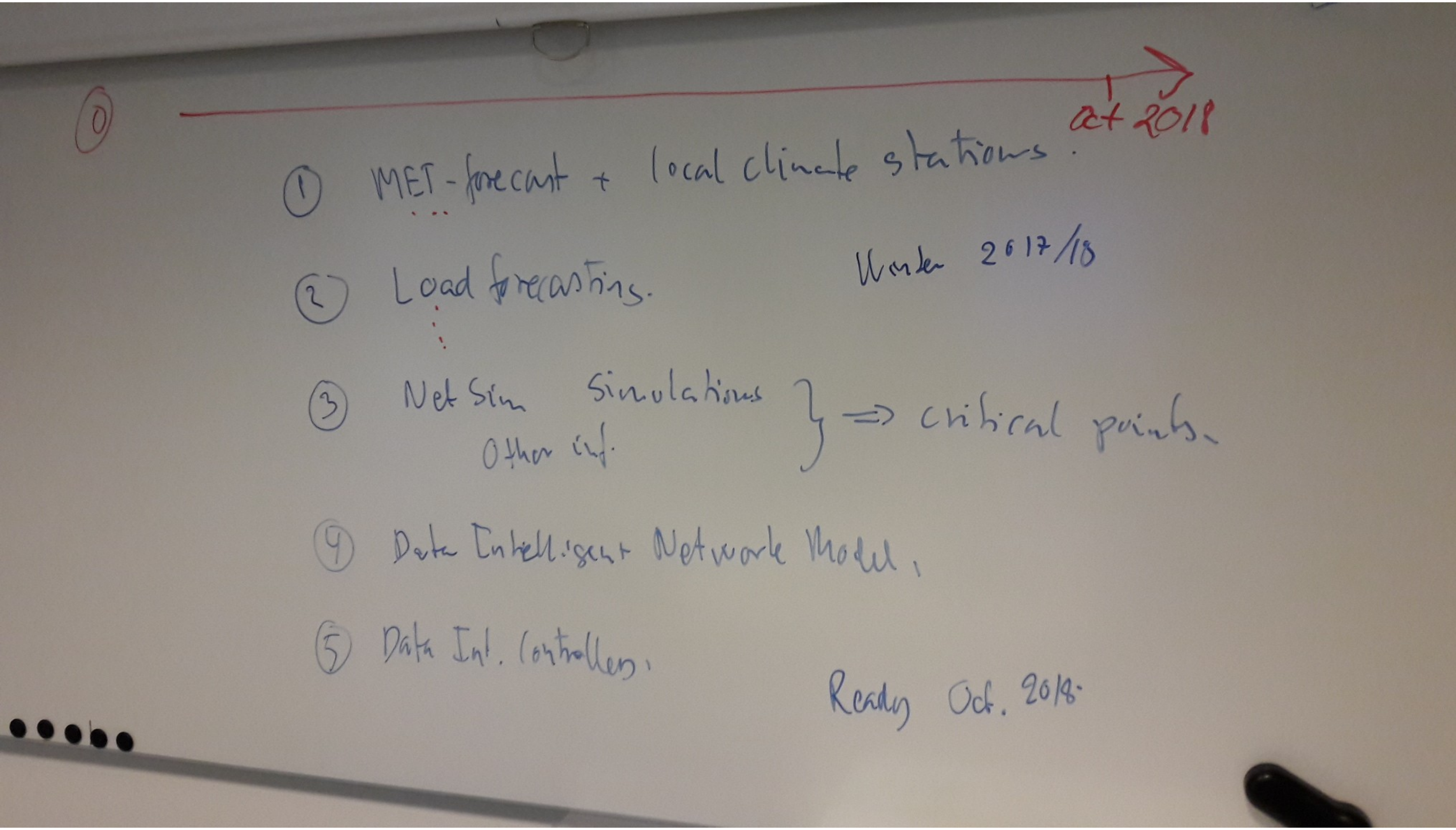
Level III

For the DC part, an important role of the Sub-Aggregator is to estimate the states of the DERs and compare the states with contractual values. In the case of IC the role of the Sub-Aggregator is to determine and communicate a signal in real-time to which the DERs respond by adjusting their operation according to the Aggregators needs. Another role of the Sub-Aggregators is to provide reliable probalistic forecasts for loads, prices, and weather conditions depending on the control strategy implemented.

Level IV

In the DC part the Sub-Aggregator A communicates the actuation signal based on the state information recieved from the DERs, and hence a two-way communication is needed. In the IC part, advanced controllers regulate the DERs (industrial processes, transport, water distribution & treatment, intelligent heating/cooling, etc.) based on real-time price signal transmitted from the Sub-Aggregator B, and this control scheme only requires a one-way signal. The price signal from the Sub-Aggregator is a delta-price, which is added to the market price in order to obtain the needed control objective.

Different hierarchies are displayed vertically with roman numbers (from I to IV), moving from the markets to the consumers. Direct control (DC) on the left where the power is altered directly by the aggregator, and indirect control (IC) on the right where the aggregator sends out a price signal to incentivize changes in power consumption [6.1].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Oct 2018
1 MET-forecast + local climate stations.
2 Load forecasting.
Winter 2017/18
3 Net Sim Simulations
Other inf.
⇒ critical points.
4 Data Intelligent Network Model.
5 Data Int. Controllers.
Ready Oct. 2018.

Modelling of Thermal Performance of Buildings using Smart Meter Data

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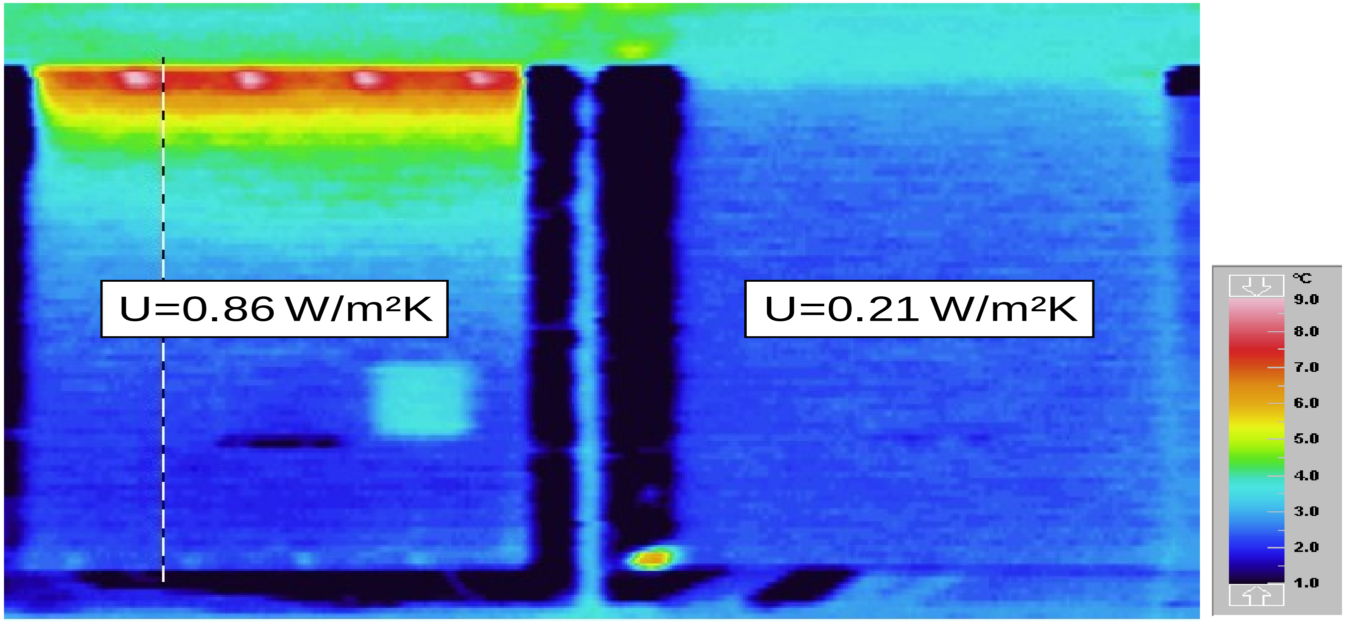
Example



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

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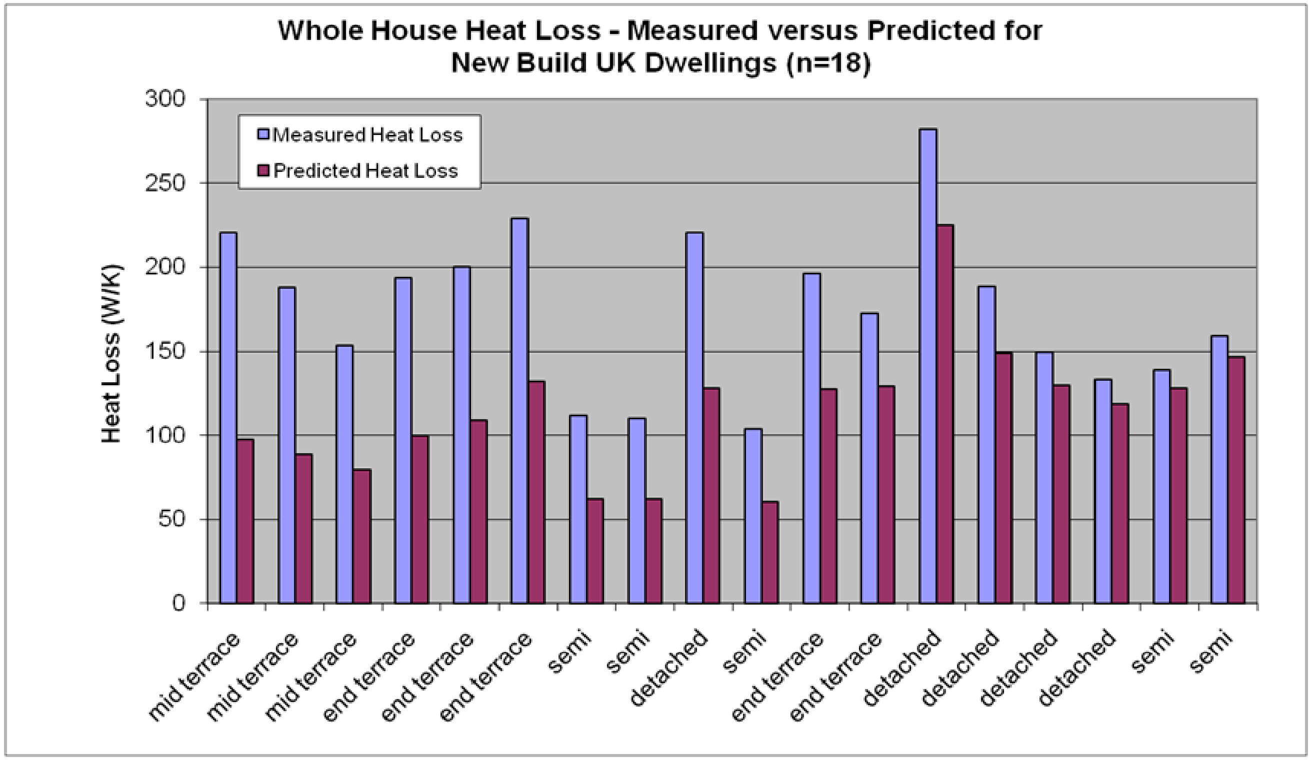
Examples (2)

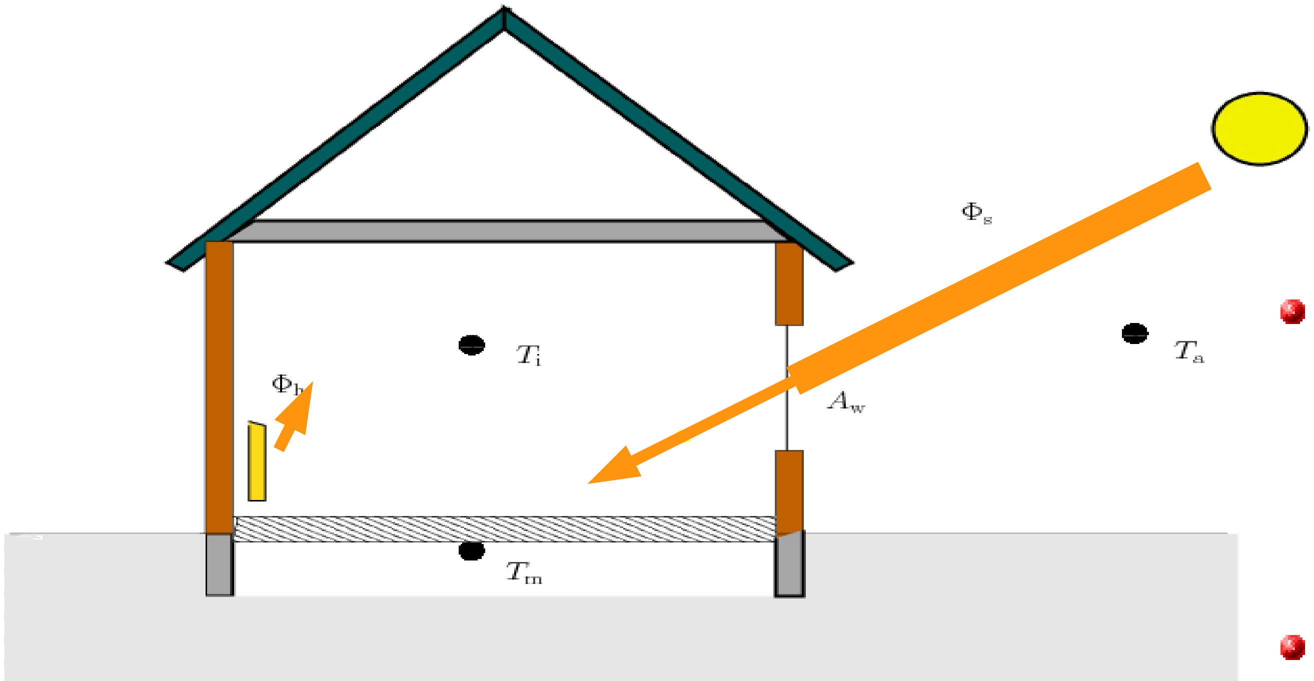


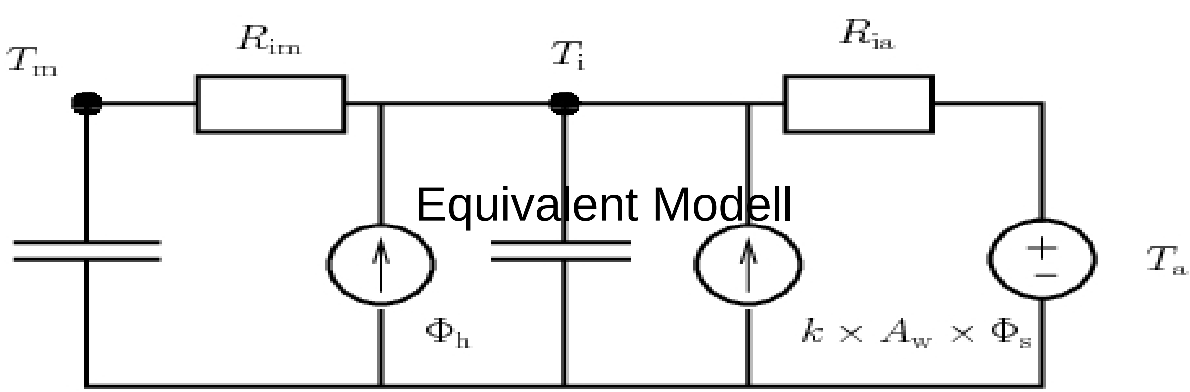
Measured versus predicted energy consumption for different dwellings

Results

	UA $W/^\circ C$	σ_{UA}	gA^{max} W	wA_E^{max} $W/^\circ C$	wA_S^{max} $W/^\circ C$	wA_W^{max} $W/^\circ C$	T_i $^\circ C$	σ_{T_i}
4218598	211.8	10.4	597.0	11.0	3.3	8.9	23.6	1.1
4381449	228.2	12.6	1012.3	29.8	42.8	39.7	19.4	1.0
4711160	155.4	6.3	518.8	14.5	4.4	9.1	22.5	0.9
4836681	155.3	8.1	591.0	39.5	28.0	21.4	23.5	1.1
4836722	236.0	17.7	1578.3	4.3	3.3	18.9	23.5	1.6
4986050	159.6	10.7	715.7	10.2	7.5	7.2	20.8	1.4
5069878	144.8	10.4	87.6	3.7	1.6	17.3	21.8	1.5
5069913	207.8	9.0	962.5	3.7	8.6	10.6	22.6	0.9
5107720	189.4	15.4	657.7	41.4	29.4	16.5	21.0	1.6
.	.	.	.	.	.	.	.	.

Model for the heat dynamics





- Measurements:
  - Indoor air temp
  - Radiator heat sup.
  - Ambient air temp
  - Solar radiations
- Hidden states are:
  - Heat accumulated in the building
  - *k*: Fraction of solar radiation entering the interior

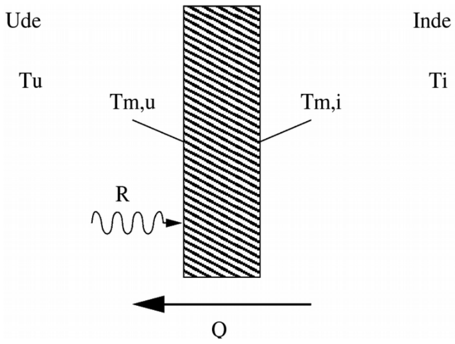
Perspectives (2)

"Skat, jeg kan se på k-værdierne, at vinduerne skal pudses"

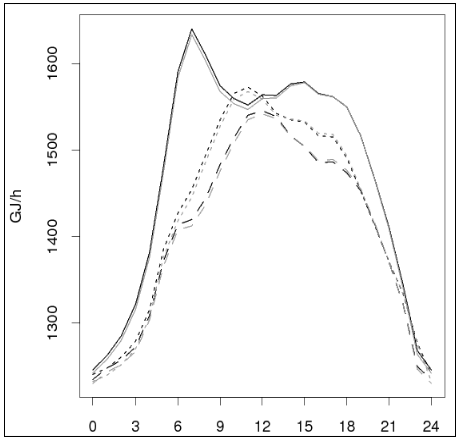
Data Intelligent Load Forecasting for DH Systems

Model components in load forecasting

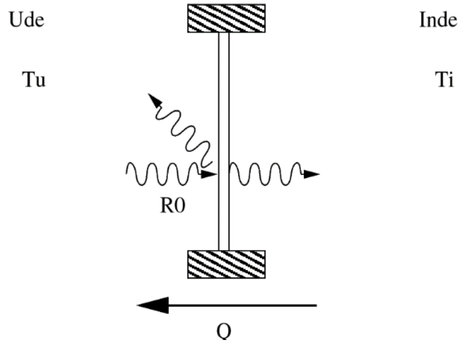
Wall: Slow reaction on climate



Occupant behaviorl



Windows + ventilation: Fast reaction



PRESS Load Forecast
(Model principles)

Load forecast for time t+k, Pp(t+k), is written:

Pp(t+k) = Fmur(Vejr(t+k)) + Fvv(Vejr(t+k) +

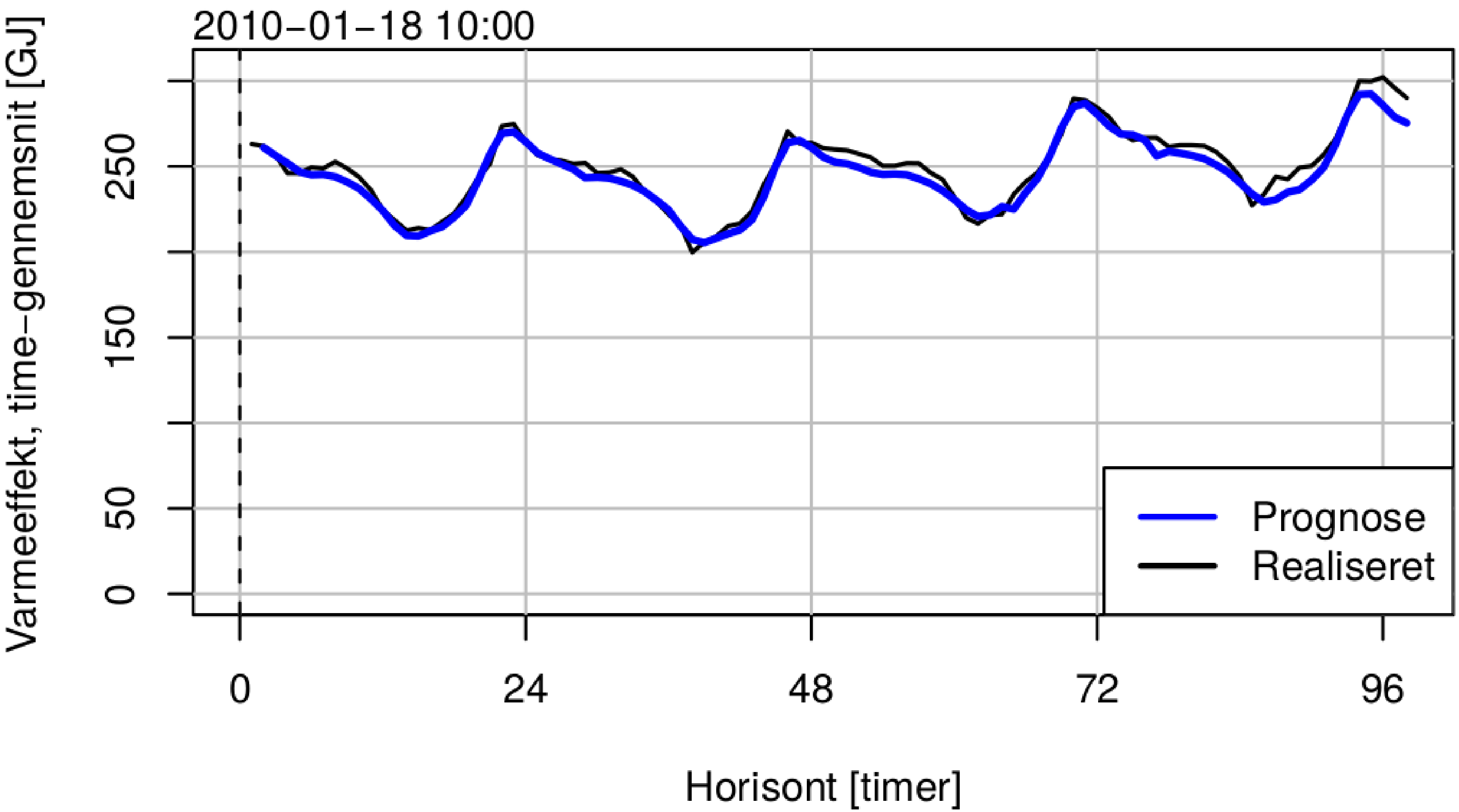
Far(Pp(t) - P(t)) + DP(t+k)

where

- Fmur, Fvv, Far and DP are semi-parametric functions (estimated by PRESS)
- Vejr(t+k) is weather input (measured + forecasts) for time t+k.
- P(t) is measured heat load for time t.

PRESS Load Forecast

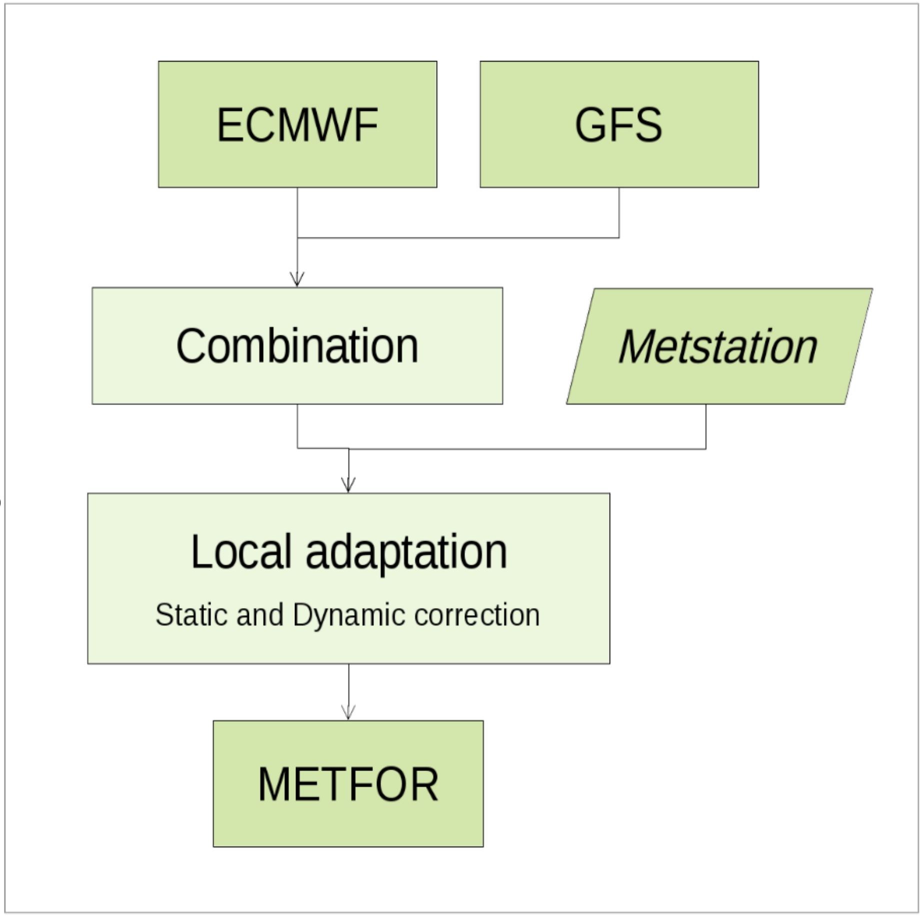
(Example)



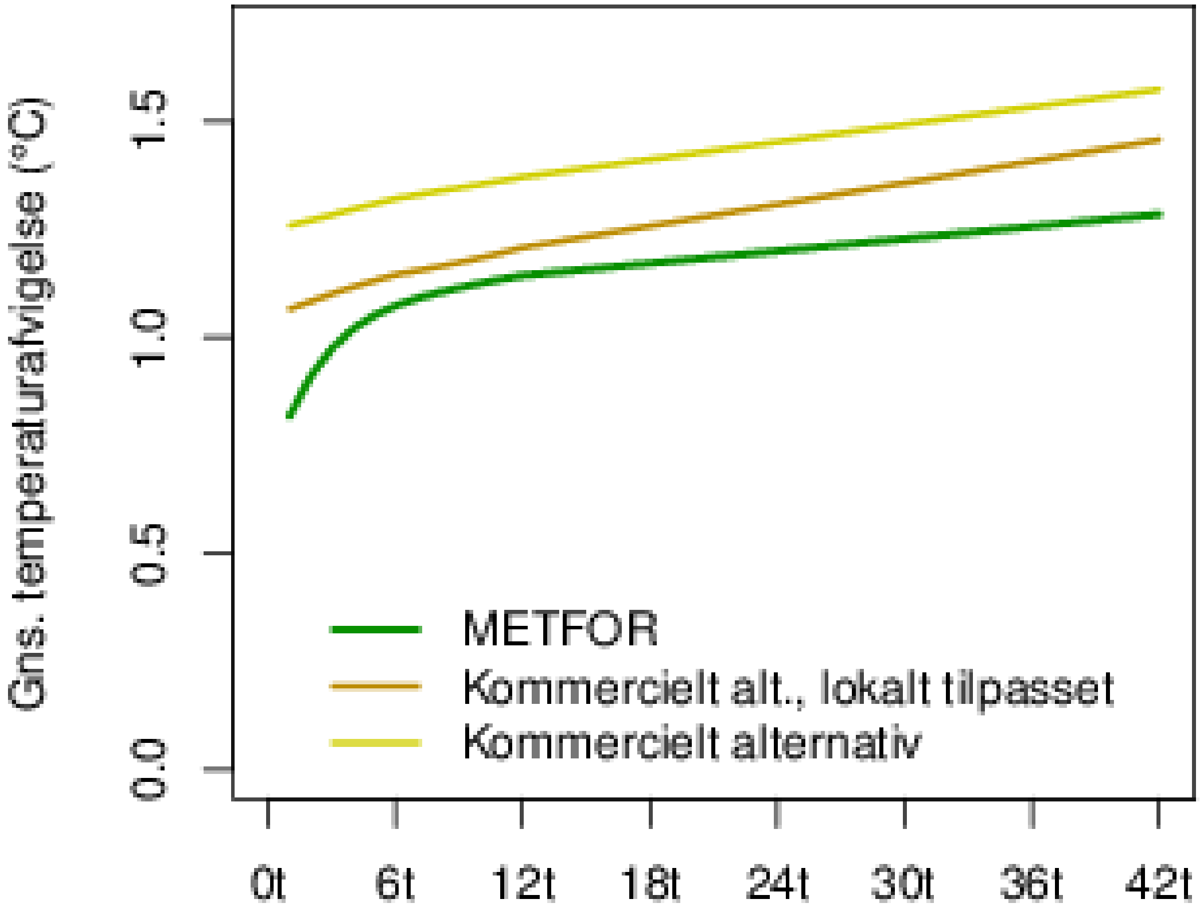
Weather data and forecasts

Optimize local weather forecast base on:

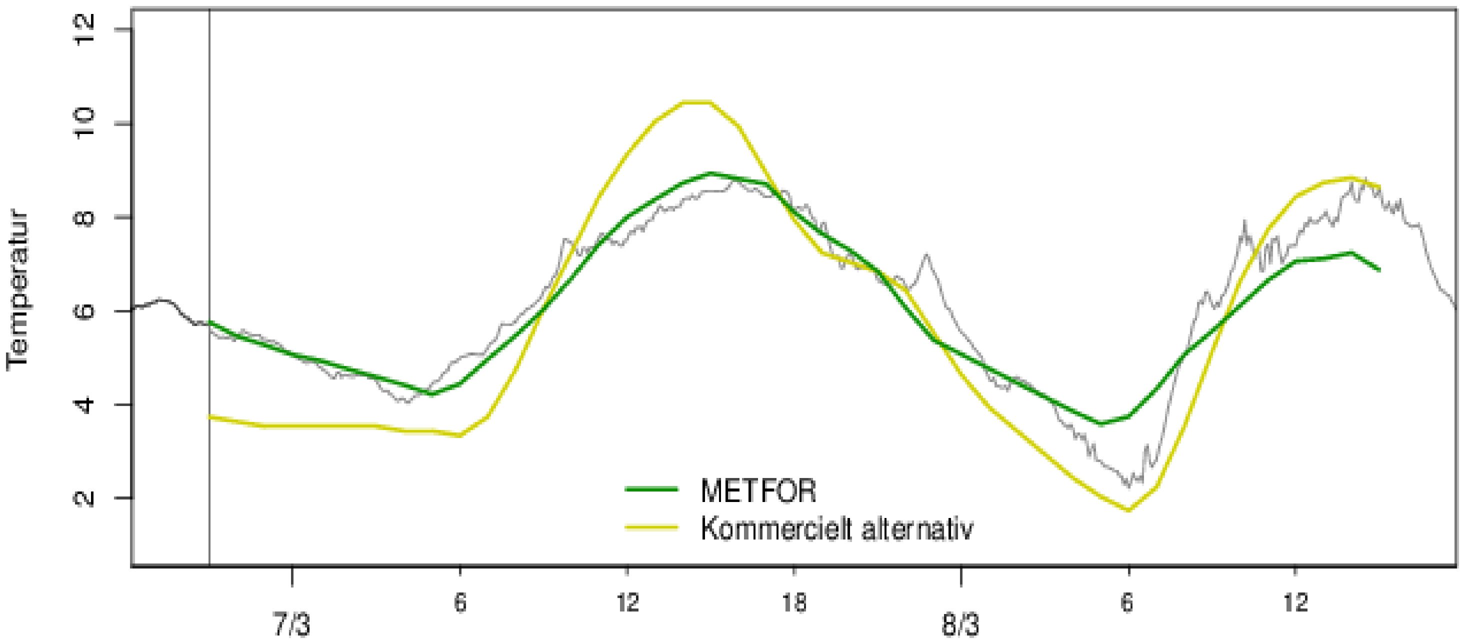
- Local climate data
- Several MET forecasts



MetFor performance



MetFor forecast example



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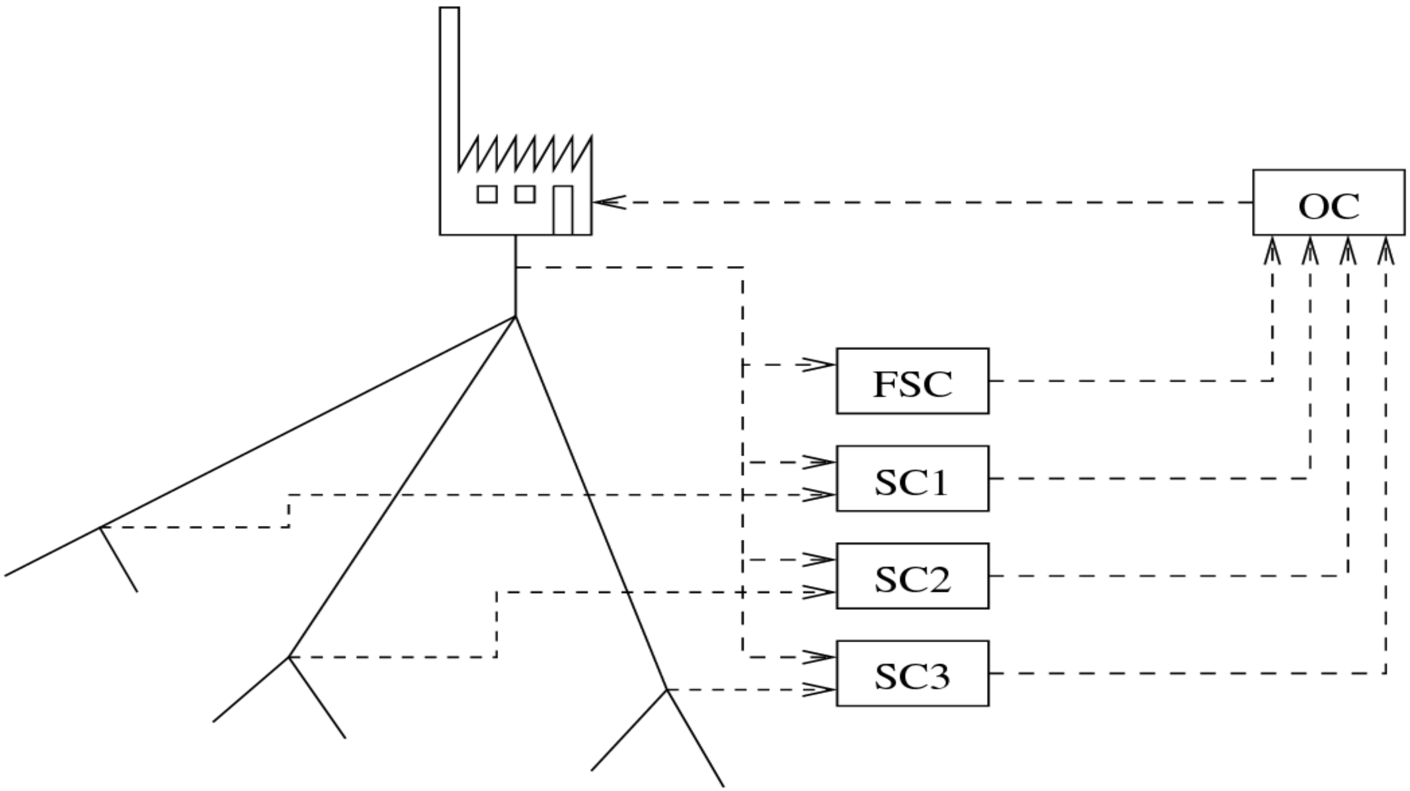
Data Intelligent Temperature Optimization

Models and Controllers

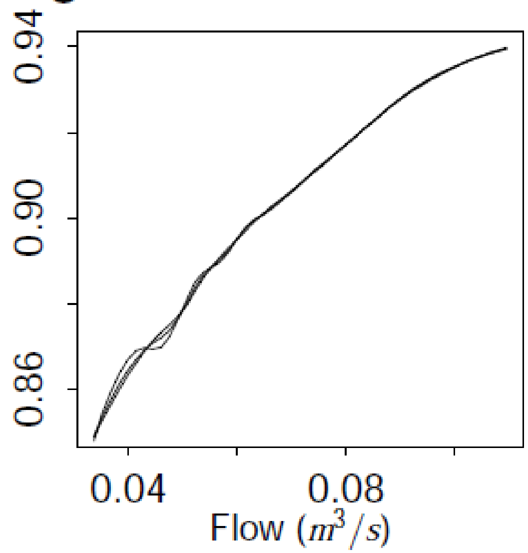
(Highly simplified!)



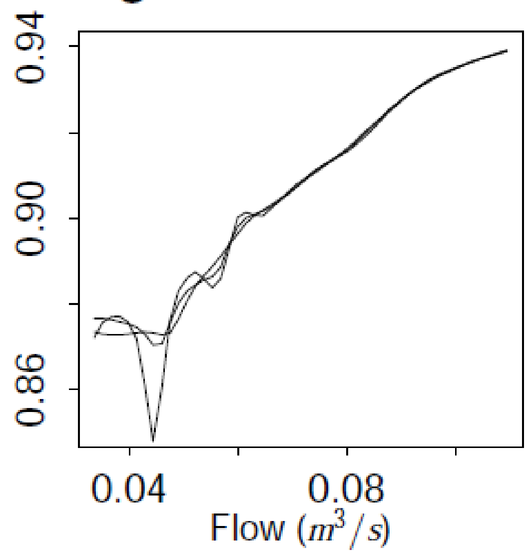
Characteristics

30%, 40%, 50%

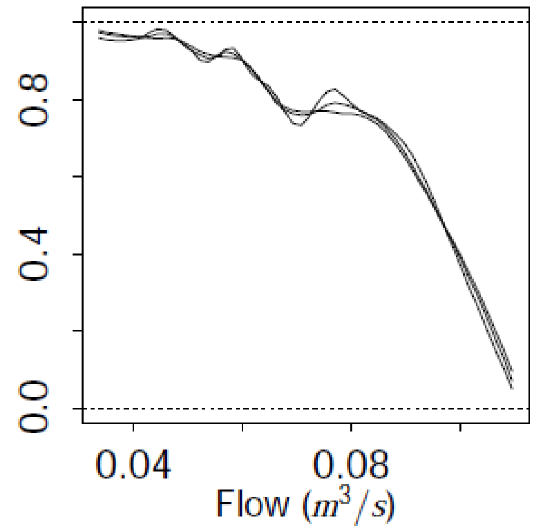
Stationary gain of FIR



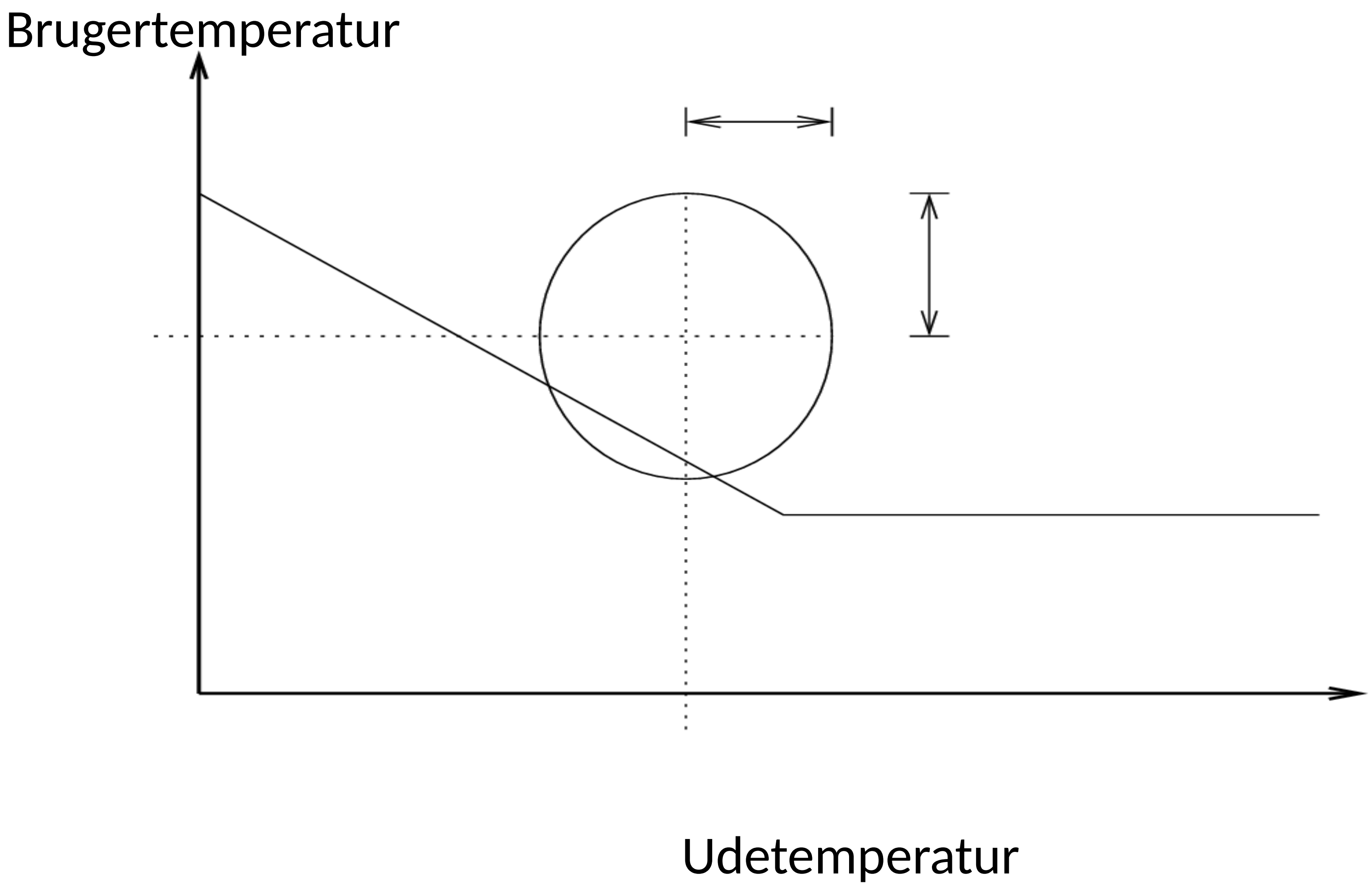
Stationary gain of ARX

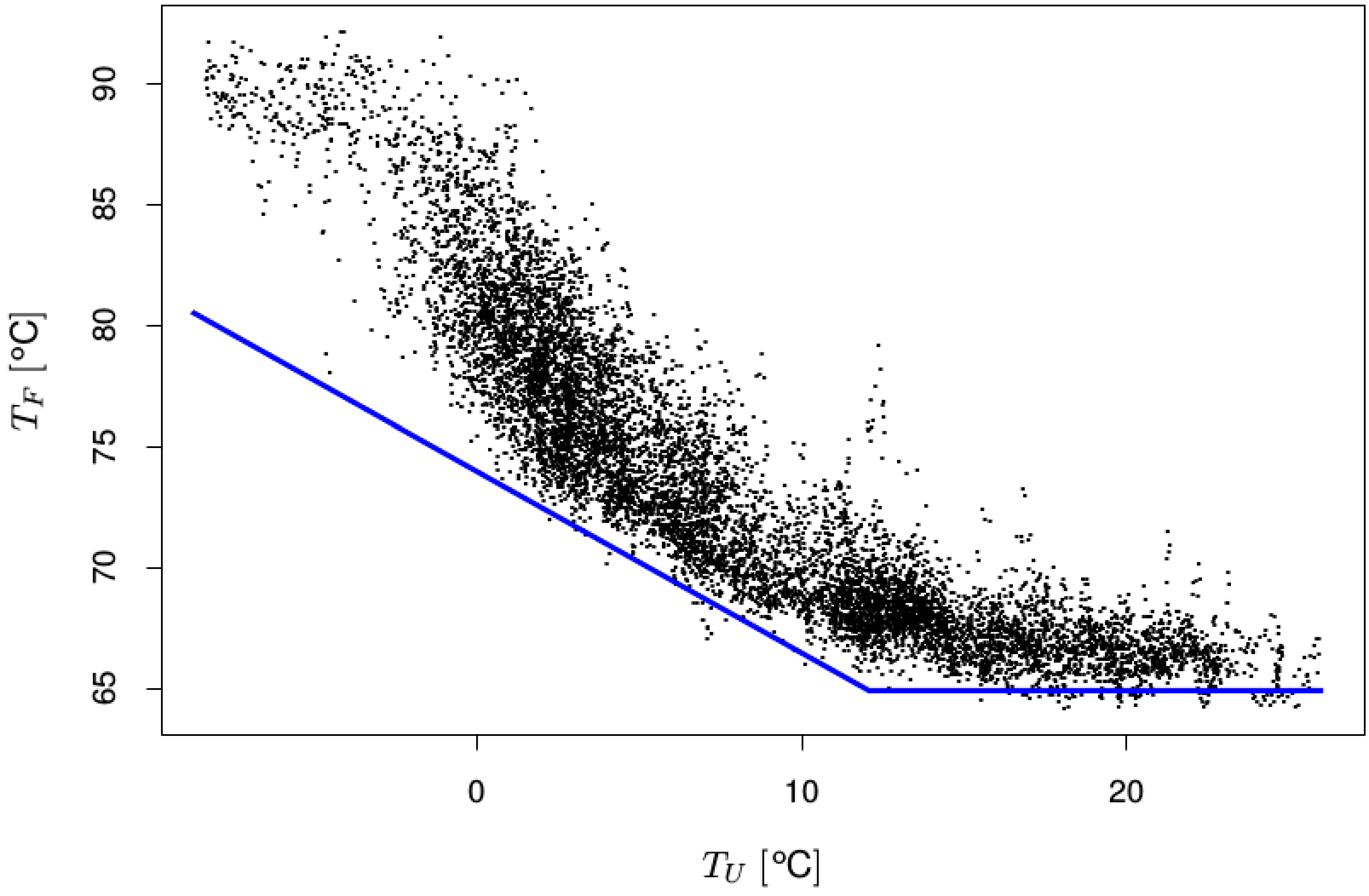


Pole of ARX



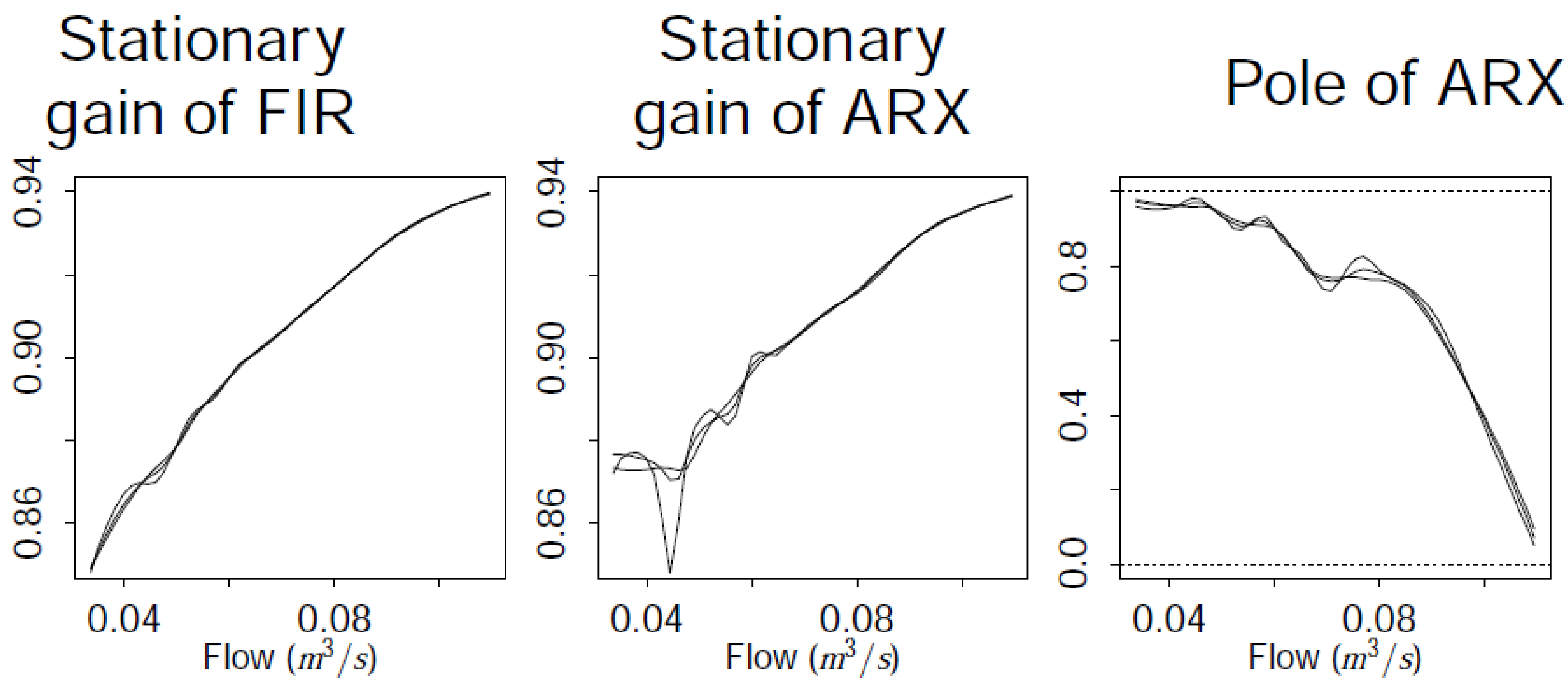
Optimal set-point taking uncertainty into account



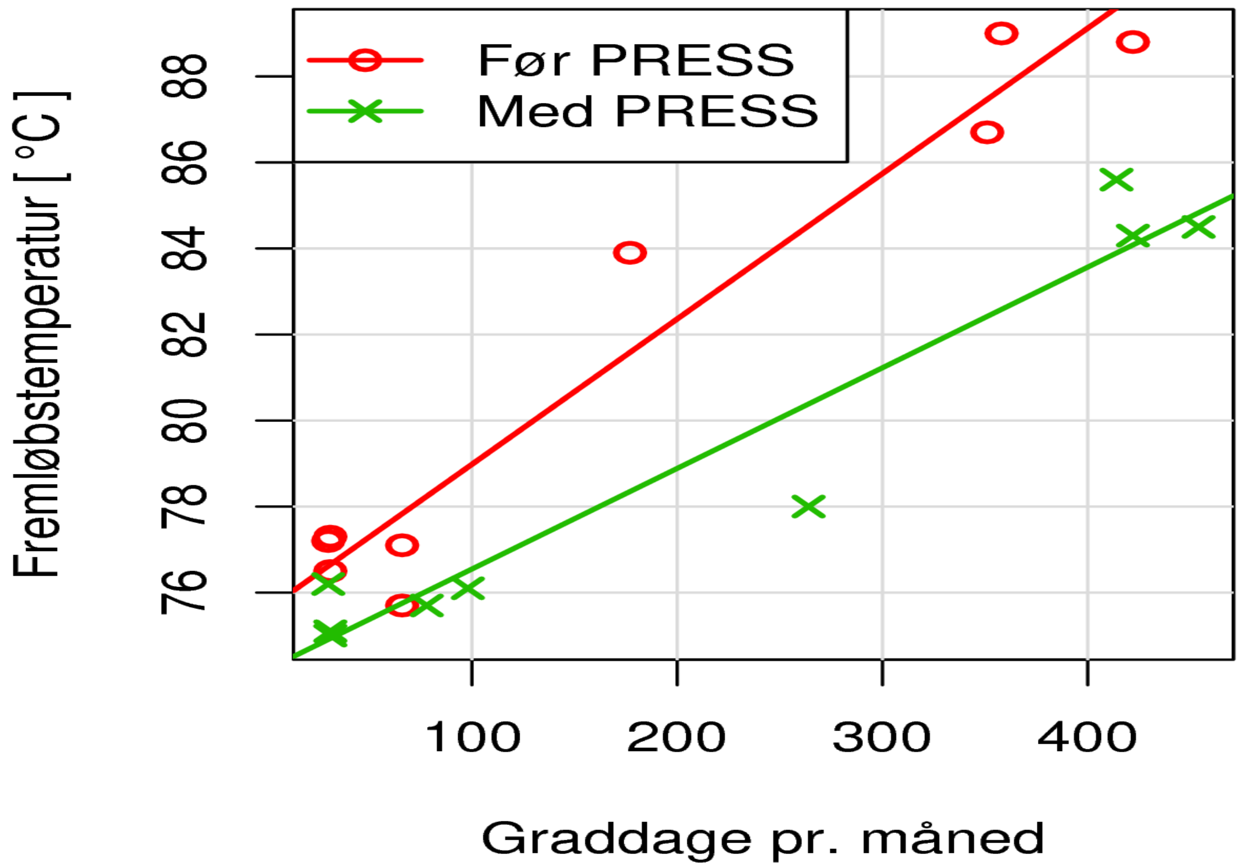


90
85
80
75
70
65
T_F [°C]
0
10
20
T_U [°C]

Characteristics
30%, 40%, 50%



Supply temperature with/without data intelligent control



Savings
(Reduction of heat loss = 18.3 pct)

	Varmekøb		Elkøb	
	GJ	1000kr	kWh	1000kr
Før PRESS	653,000	30,750	499,000	648
Med PRESS	615,000	28,990	648,000	842
Forskel	37,400	1,760	-149,000	-194

Total besparelse (9 første måneder af normalår): **1,566,000kr**

Besparelse for et normalår:

- $12/9 \times$ 1,566,000kr $=$ **2.1 mill.**
- Imidlertid står jan.–sept. (75% af året) kun for ca. 65% af graddagen i er normalår.
- 1,566,000kr$/0.65 =$ **2.4 mill.**

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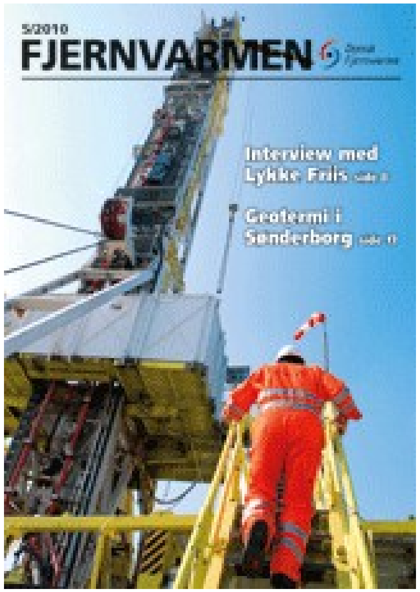
Control of Temperatures in DH Systems



Styring af temperatur rummer kæmpe sparepotentiale

Lesson learned:

- Control using **simulation** of temperature gives **up to 10 pct reduction** of heat loss.
- Control using **data and predictions** gives **up to 20 pct. reduction** of heat loss.

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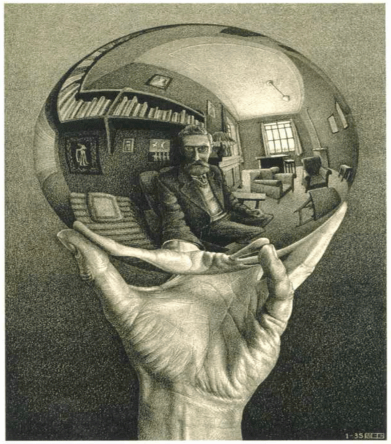
Which approach to use?

- Use **simulation based** control if:
  - No access to data from the DH network
  - Want an evaluation of new operational scenarios
- Use **prediction based** control if:
  - Access to network data online
  - Want to used meteorological forecasts automatically
  - Want to combine MET forecasts with local climate data
  - Want automated update of models

Data Intelligent Temperature Optimization for DH Systems

- Able to take advantage of information in data
- Self-calibrating models for the DH network
- 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.



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Data Intelligent Temperature Optimization using Meter Data

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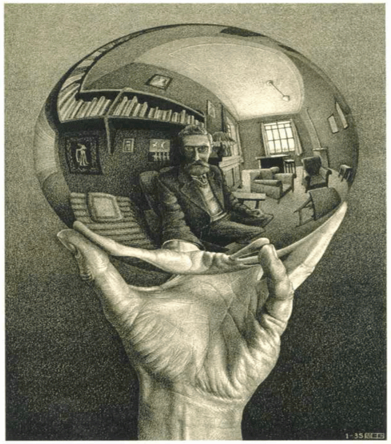
Data Int. Temp. Opt (v.4.0)

- Big Data Analytics – more specific:
- Take advantage of (smart) meter readings
- Use of all available MET forecast
- Combination of MET forecasts with data from local climate stations
- New grey-box models



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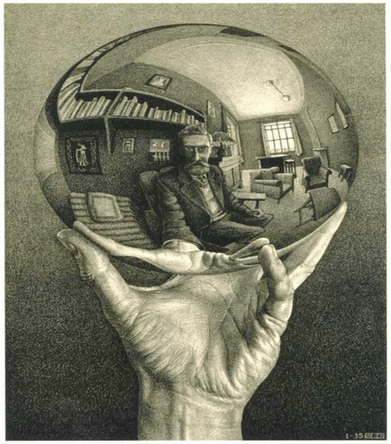
Data Intelligent Temperature Optimization Using Smart Meter Reading

- 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 net
- Find users with a high flow
- Intell. Control – energy, emission, costs, peak,..
- Use user installations to store energy locally
- Time-varying prices – active use of end-users
- Establish a possibility for effect limitations

  (should be reflected in the contract)



For more information ...

See for instance

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www.smart-cities-centre.org

www.citiesinnovation.org

...or contact

– Henrik Madsen (DTU Compute)

hmad@dtu.dk