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Some perspectives for use of data in DH systems

CITIES Aarhus Workshop

NAVITAS, Aarhus, January 2017

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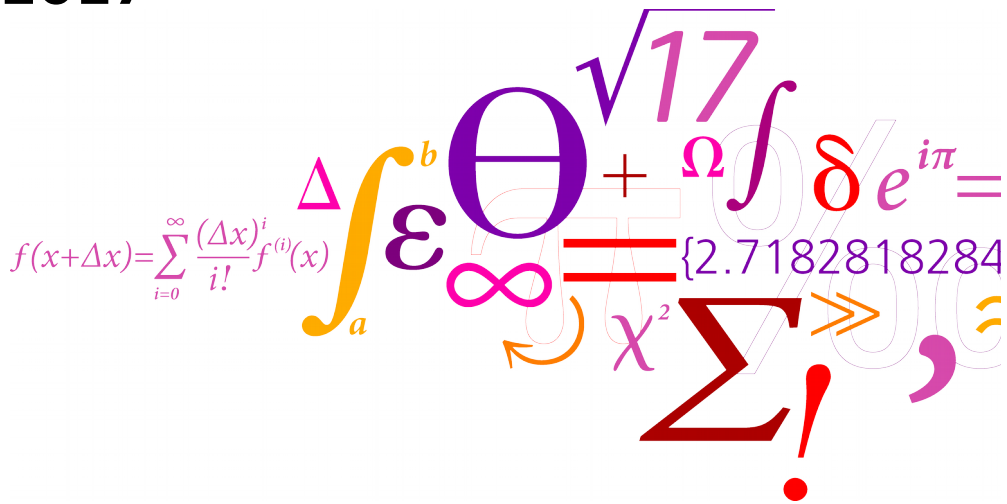


DTU Compute
Department of Applied Mathematics and Computer Science

Contents

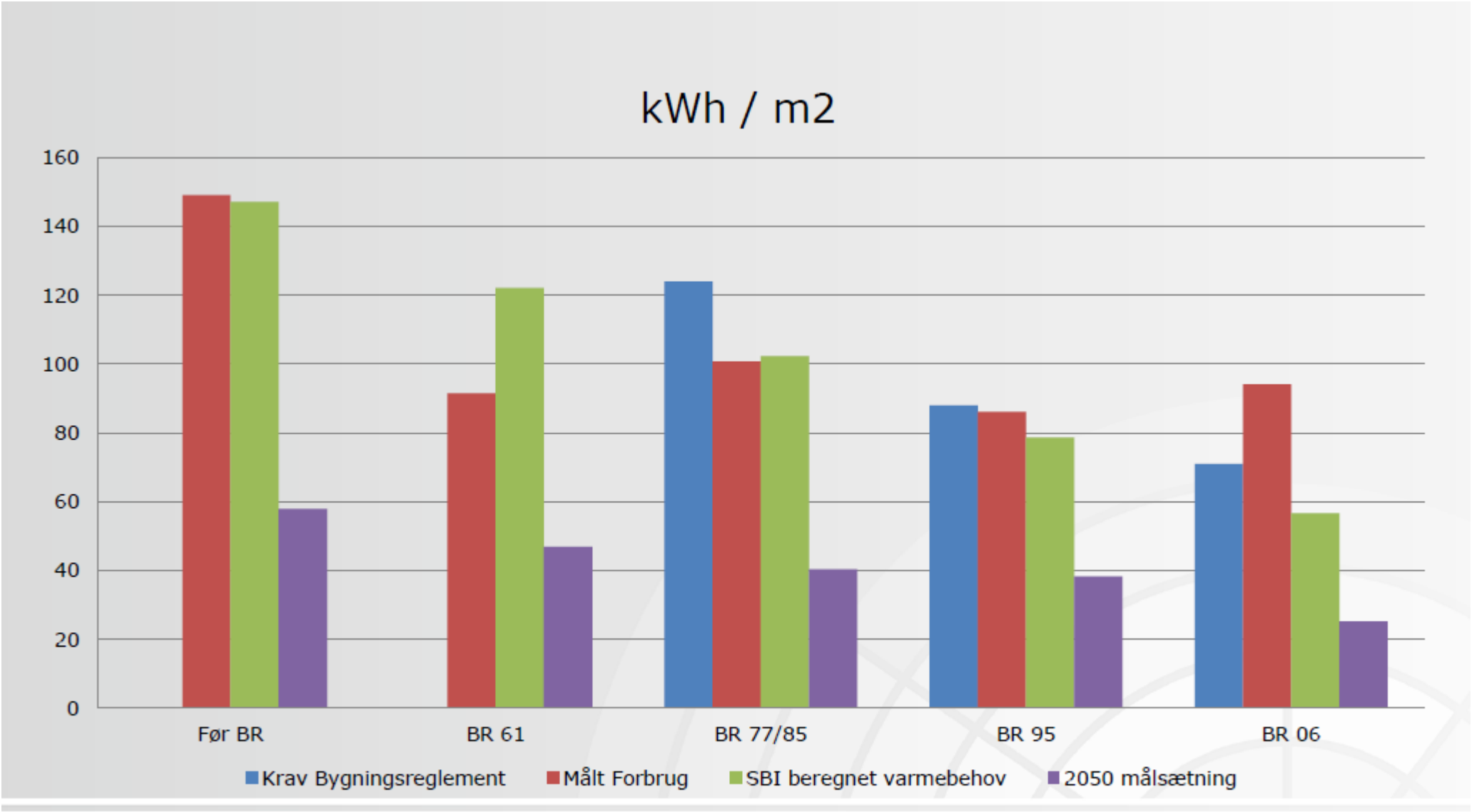
- A single sensor (smart meter) (UA, ..)
- Several sensors (dyn.)
- Modeling and operation of DH systems
- Price-based control in DH systems

In all cases: MET data is used

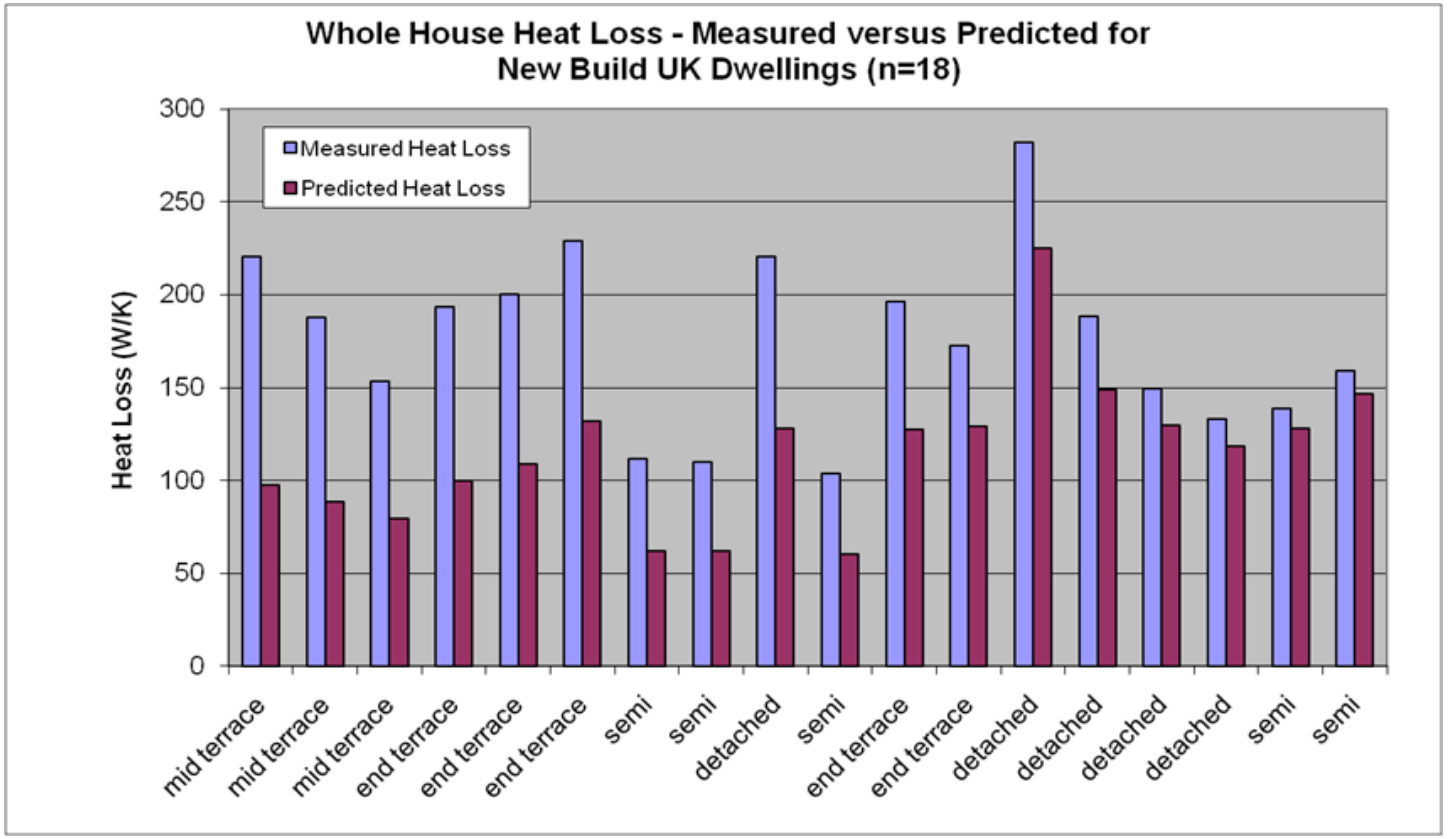
Case Study No. 1

Modelling of Thermal Performance of Buildings using Meter Data

Energy consumption in DK



Examples (2)



Measured versus predicted energy consumption for different dwellings

Using Data from Smart Meters

- Energy labelling
- Estimation of UA and gA values
- Estimation of energy signature
- Estimation of dynamic characteristics
- Estimation of time constants

Results

	UA W/°C	σ_{UA}	gA^{max} W	wA_E^{max} W/°C	wA_S^{max} W/°C	wA_W^{max} W/°C	T_i °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
.	.	.	.	.	.	.	.	.

Perspectives for using data from Smart Meters

- Reliable Energy Signature.
- Energy Labelling
- Time Constants (eg for night set-back)
- Proposals for Energy Savings:
  - Replace the windows?
  - Put more insulation on the roof?
  - Is the house too untight?
  - .....
- Optimized Control
- Integration of Solar and Wind Power using DSM

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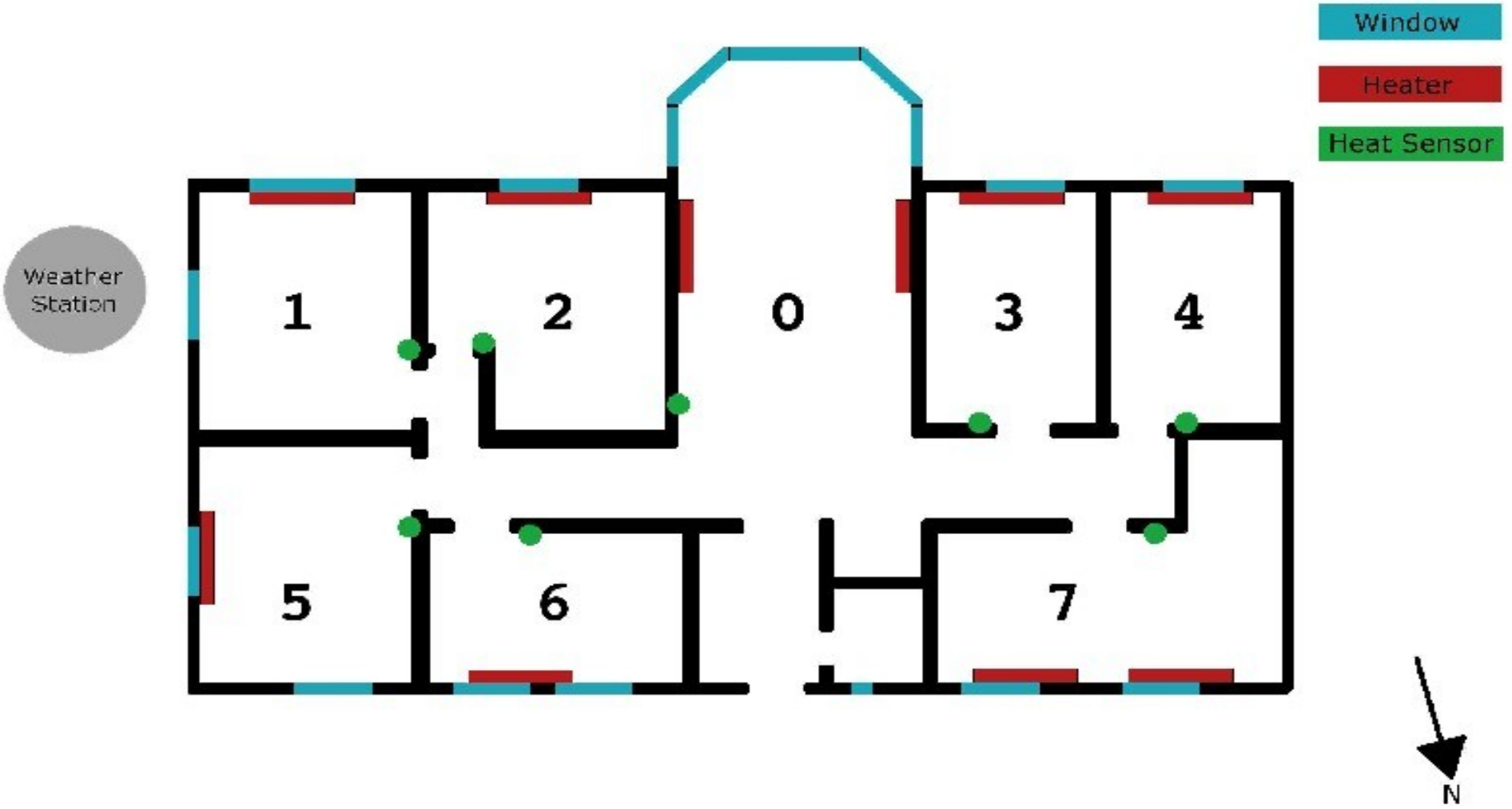
Case study No. 2

Modelling the thermal characteristics of a small office building

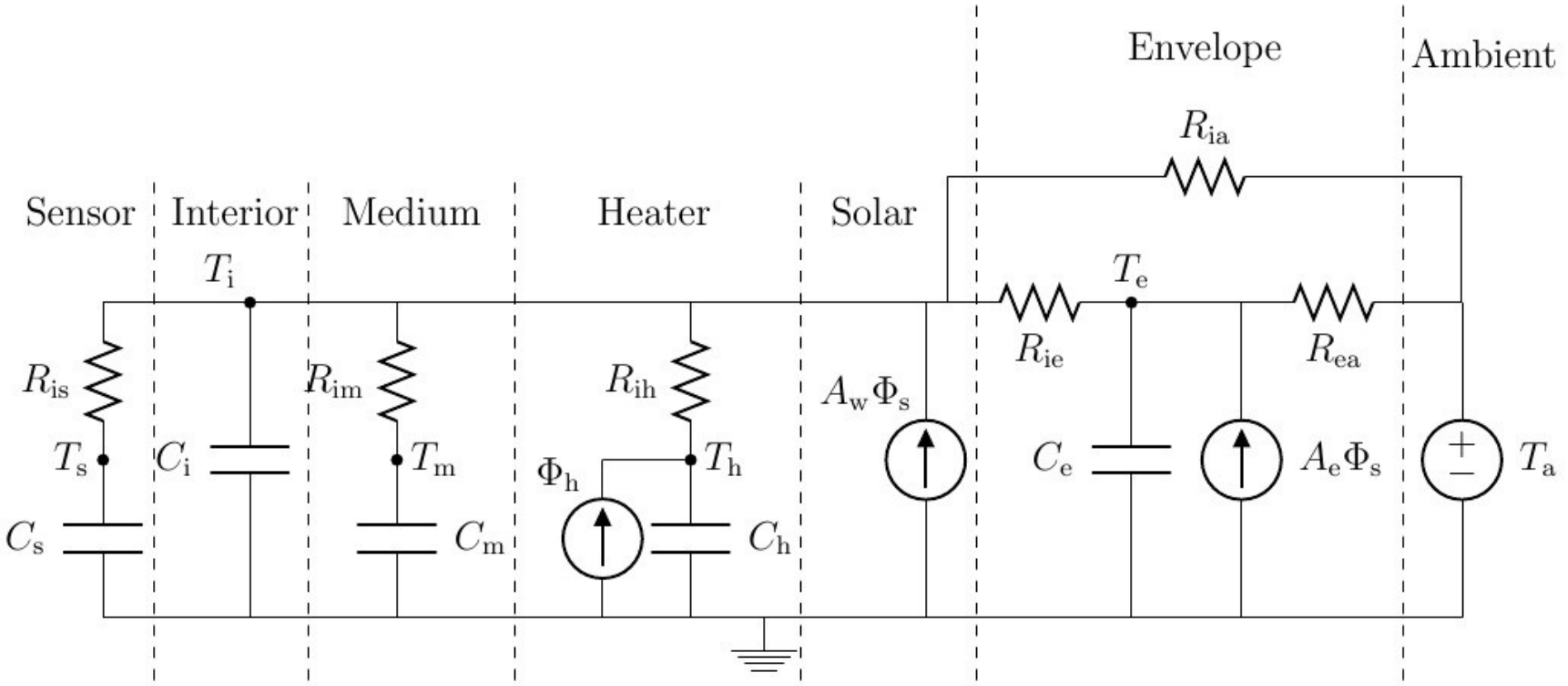
Using More Sensors

- A model for the thermal characteristics of a small office building

Flexhouse at SYSLAB (DTU Risø)



Model found using Grey-box modelling (..... using CTSM-R – http://smart-cities-centre.org/software-solutions/)



Case study No. 3

Models for DH Systems

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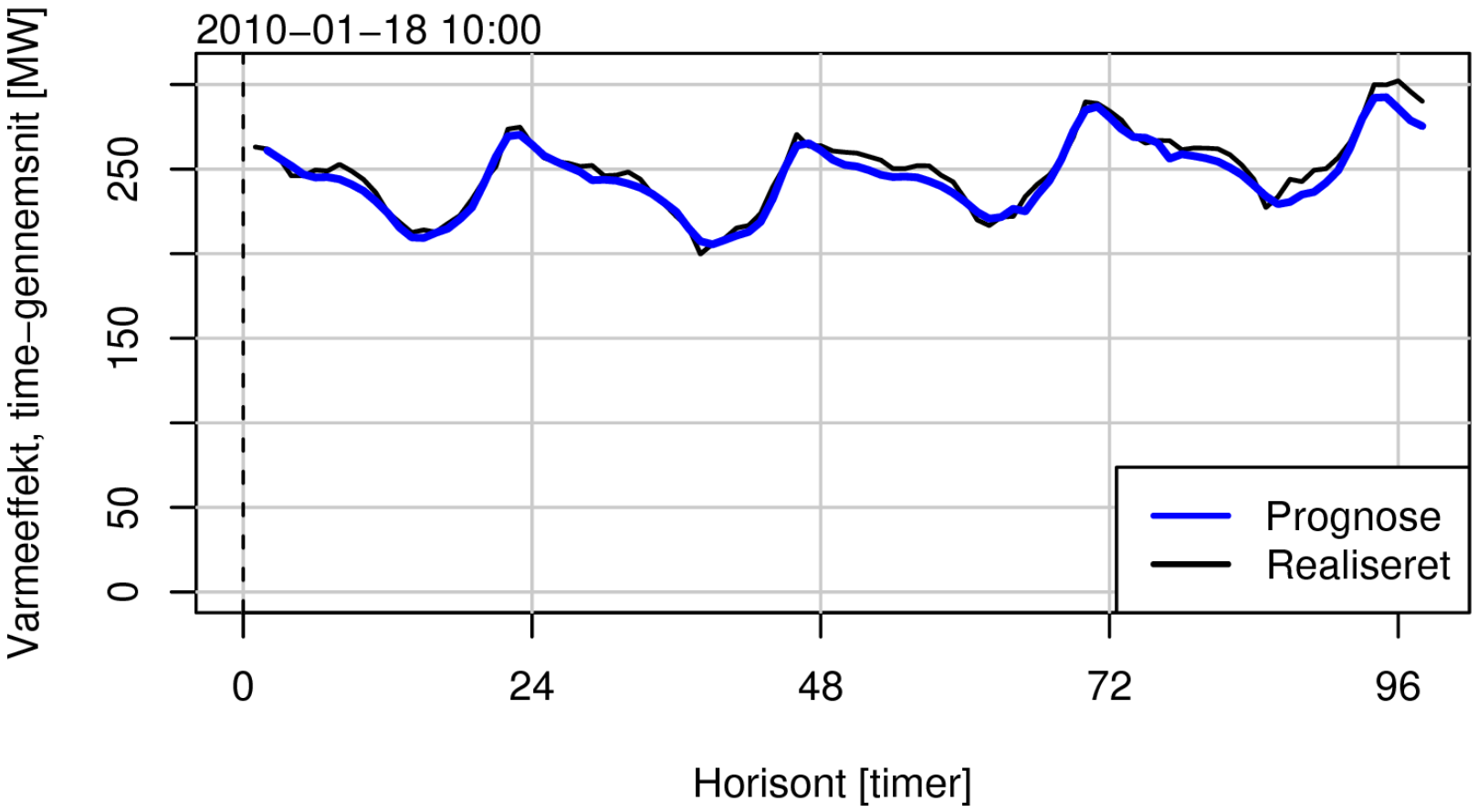
Heat Load forecasts – up to 96 h ahead



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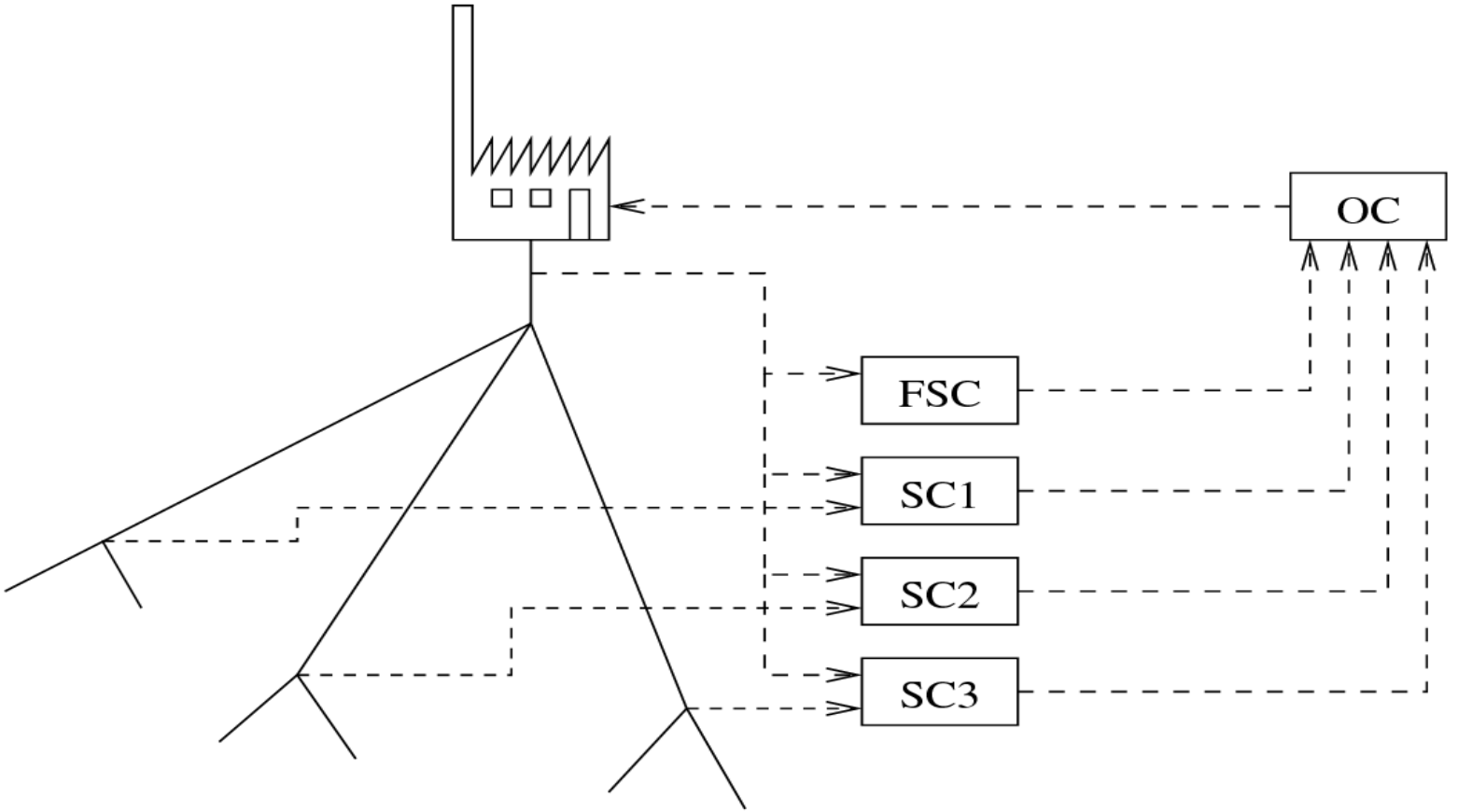
Models and Controllers
(Highly simplified!)



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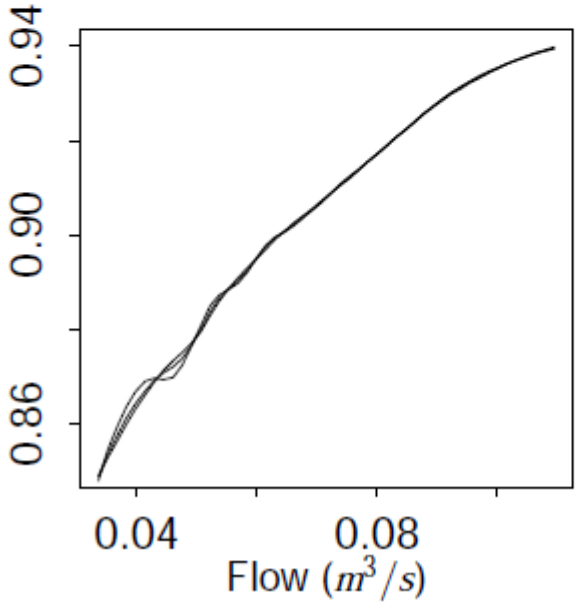
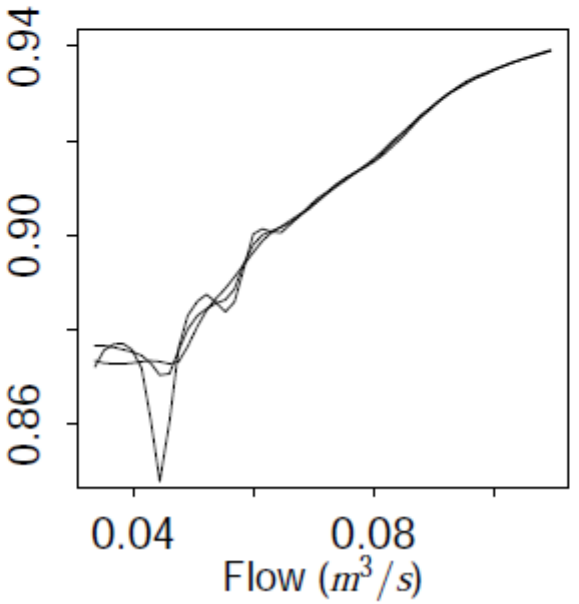
Characteristics

30%, 40%, 50%

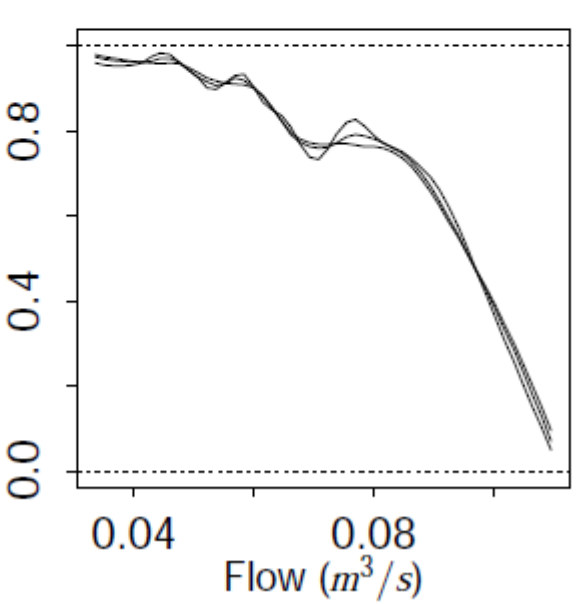
Stationary gain of FIR



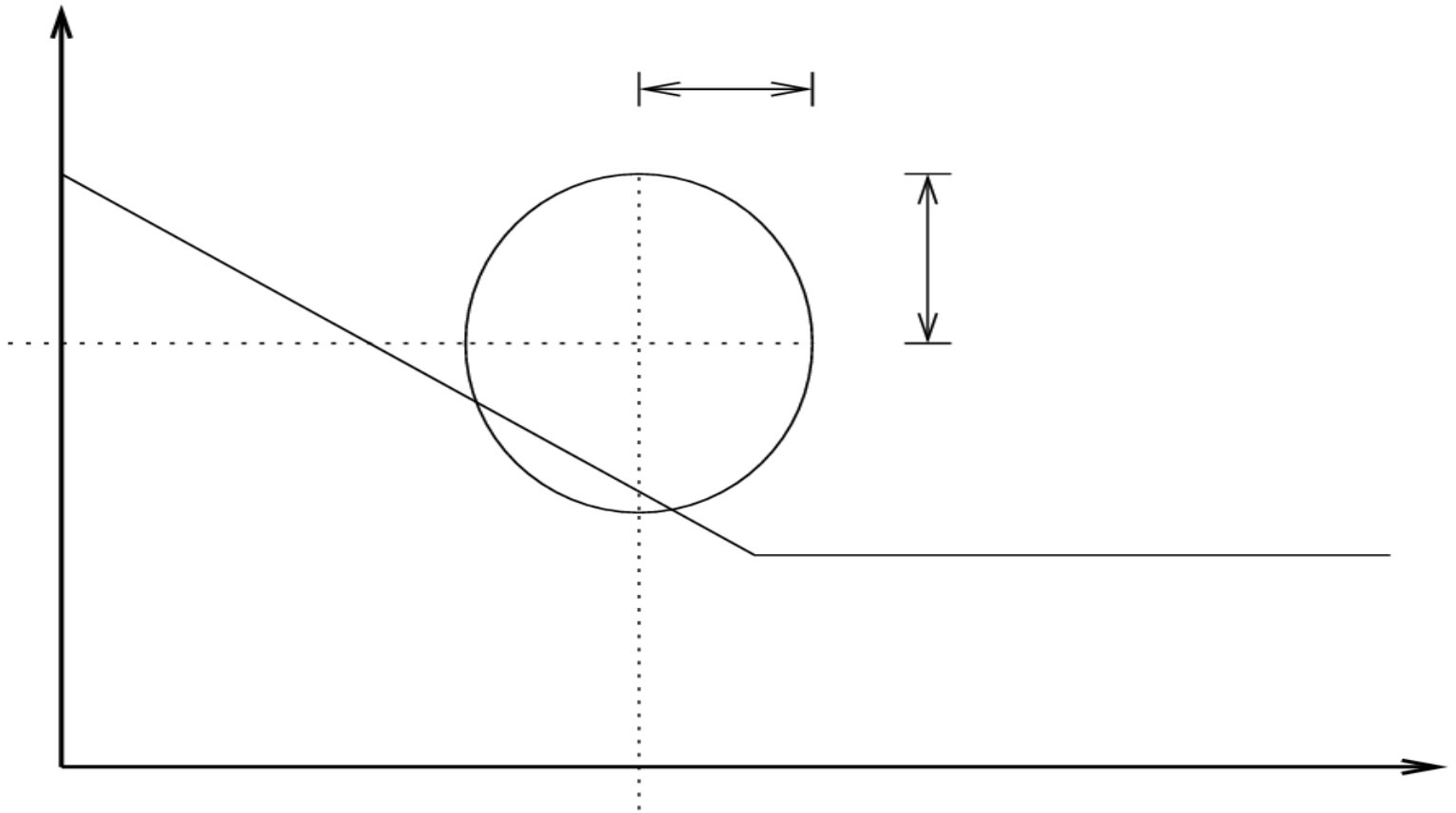
Stationary gain of ARX



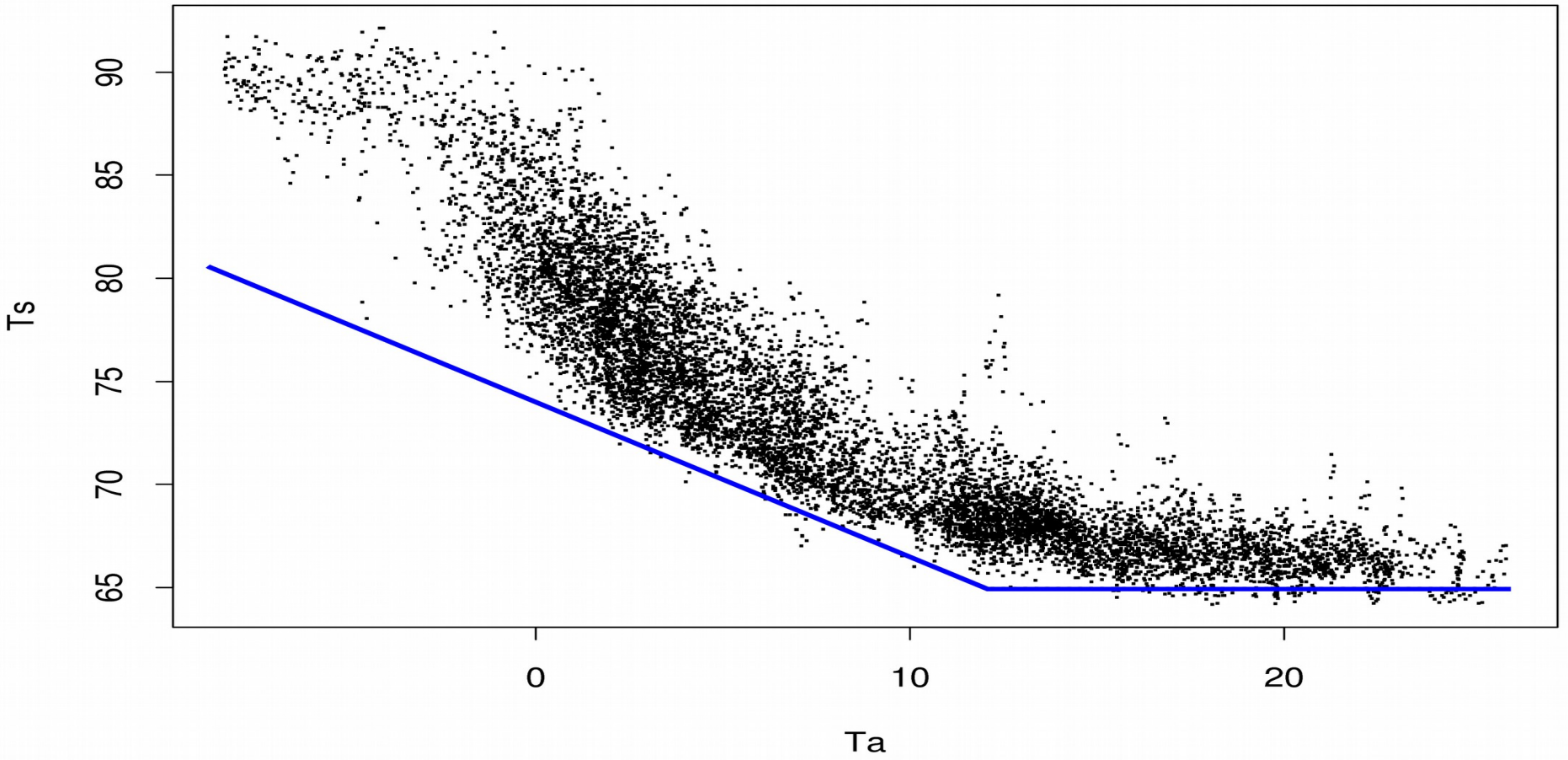
Pole of ARX



Prob. constraints
Controller set-points



Observed User Temp.



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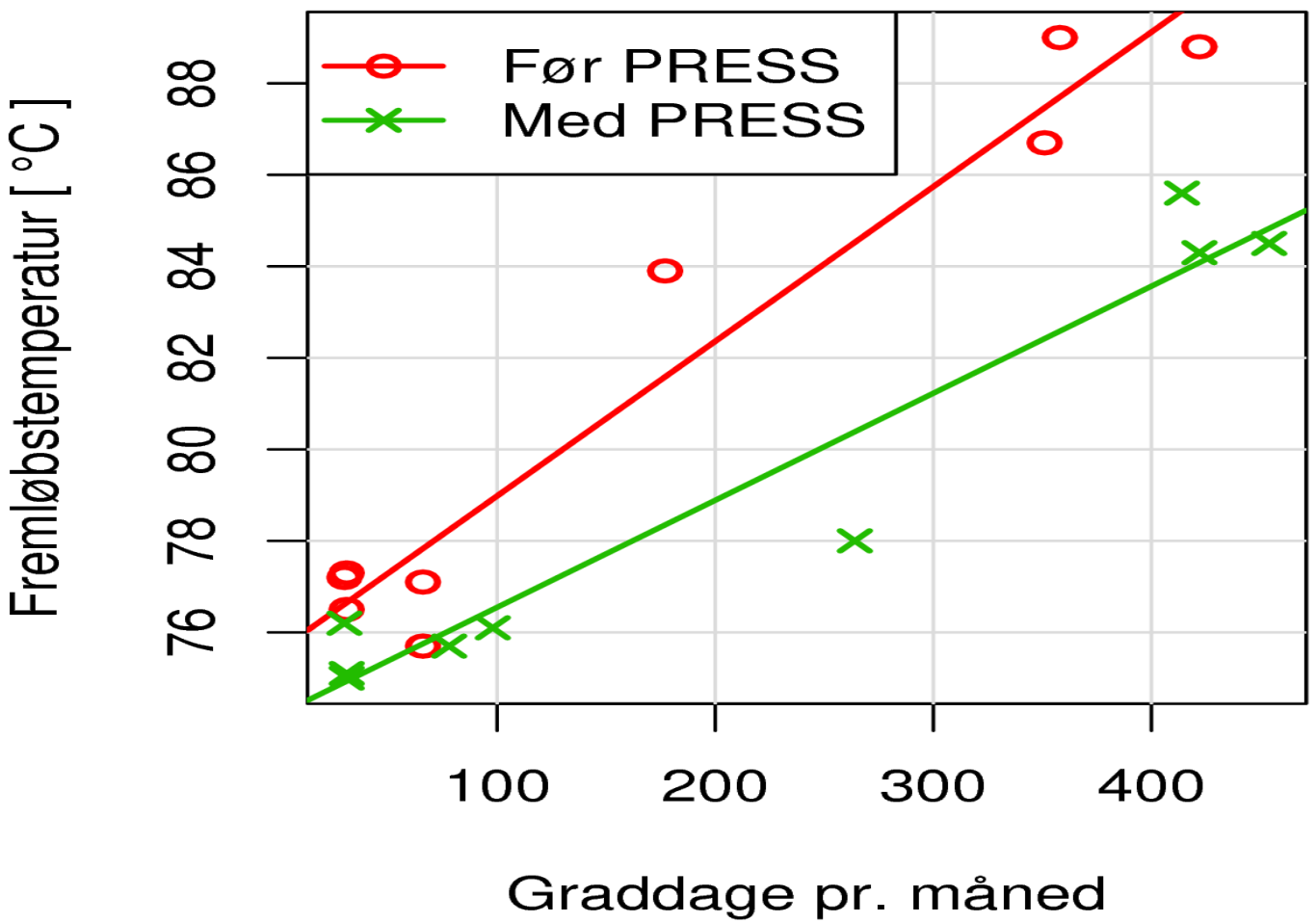
Supply temperature with/without predictive control



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Savings
(Reduction of heat loss = 18.3 pct)

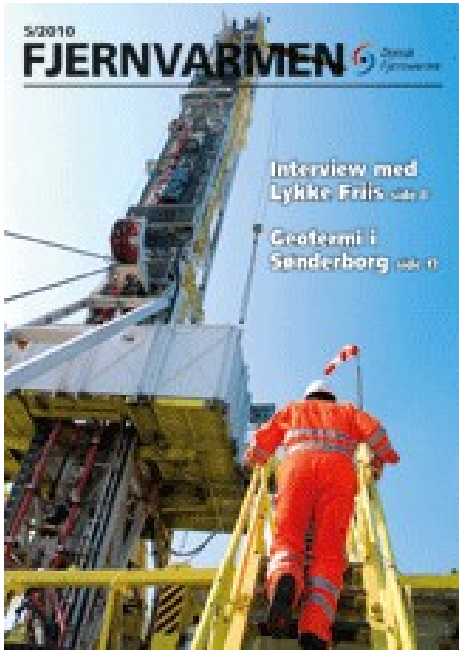
	Varmekøb		Elkøb	
	GJ	1000kr	kWh	1000kr
Før PRESS	653,000	30,750	499,000	648
Med PRESS	615,000	28,990	648,000	842
Forskel	37,400	1,760	-149,000	-194

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.**

Control of Temperatures in DH Systems



FJERNVARMEN | 5 2010

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.

Which approach to use?

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

Case study No. 4

Storage of Energy Using the Thermal Mass of Buildings

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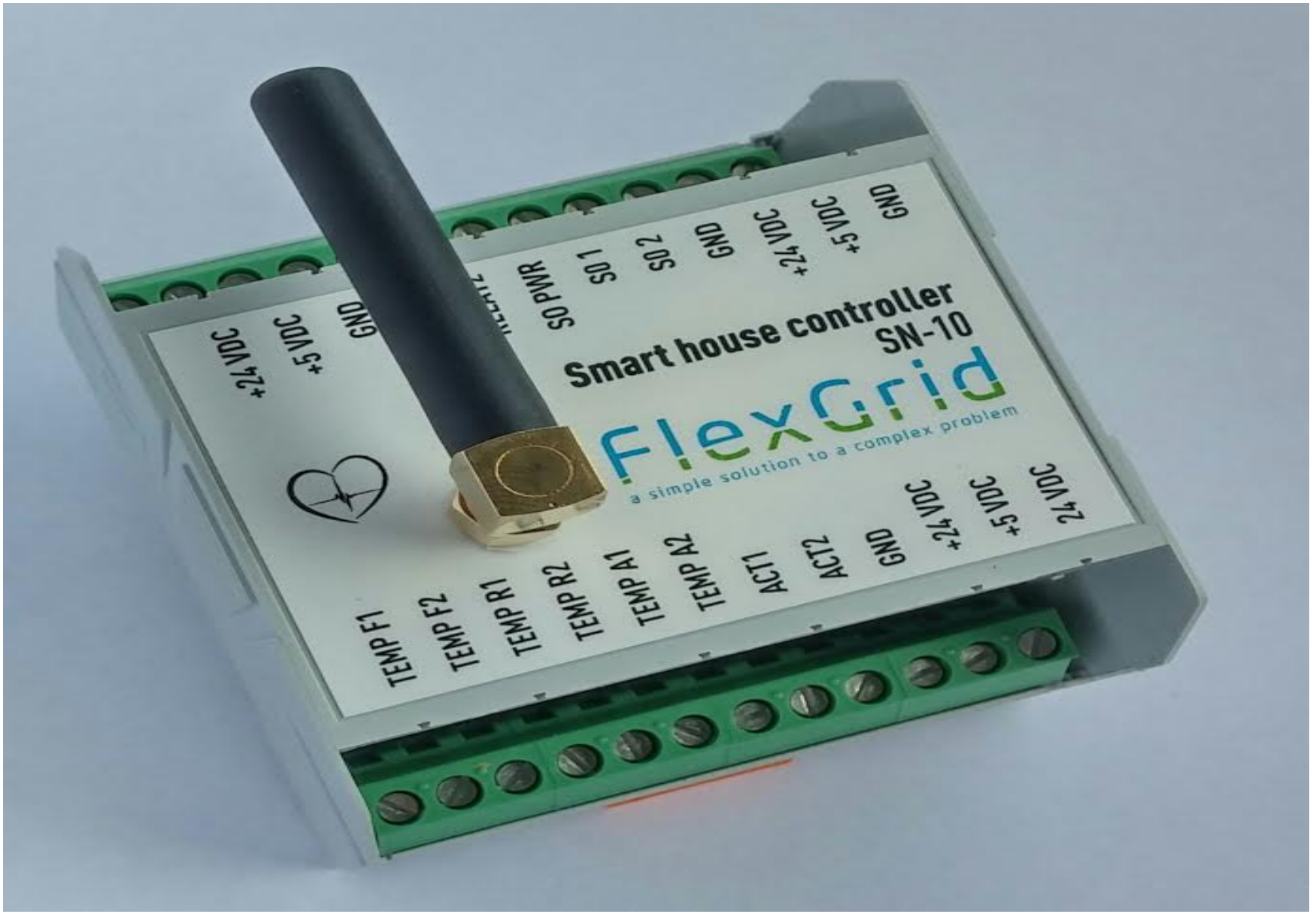
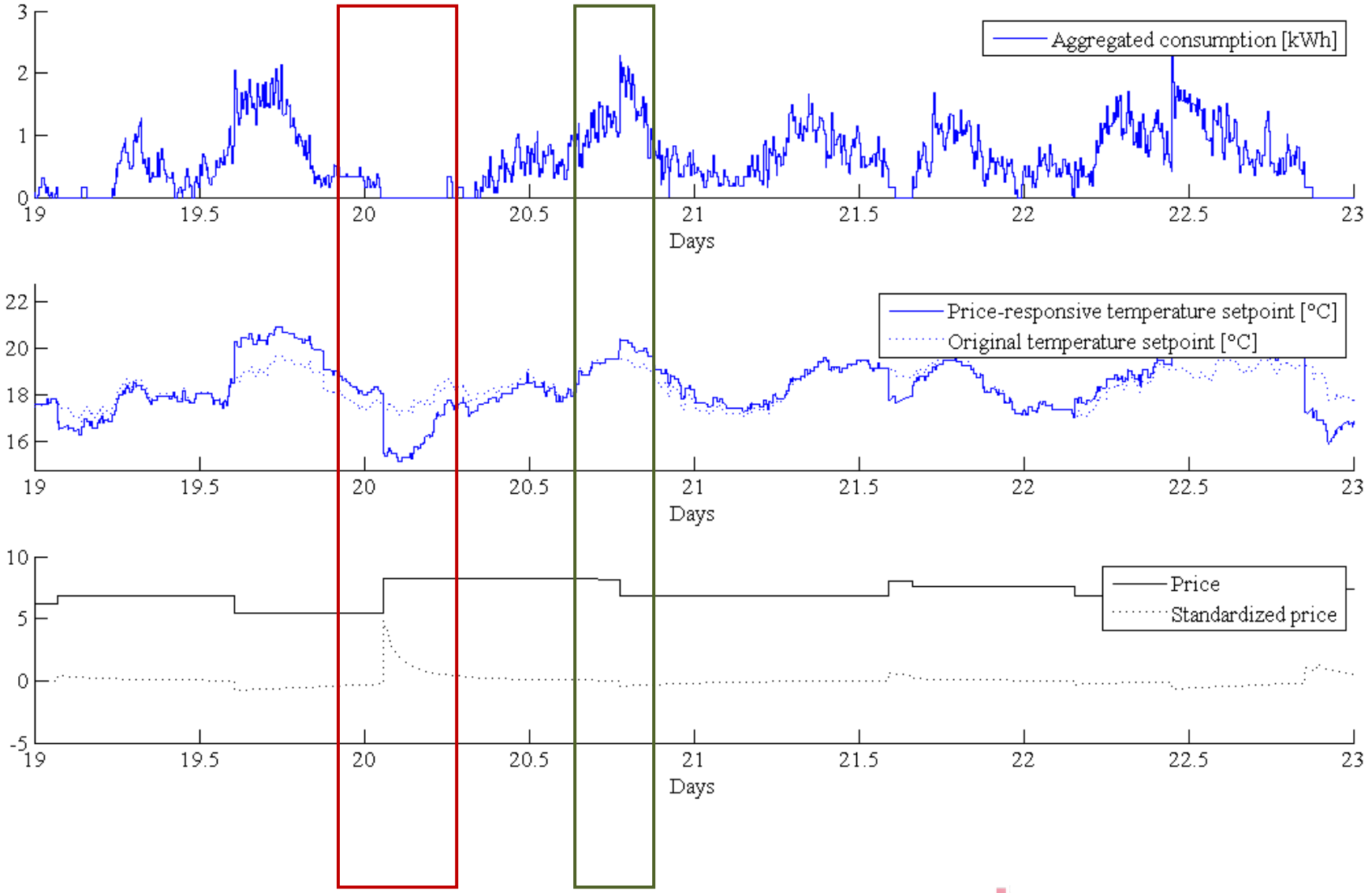
SN-10 Smart House Prototype



Aggregation (over 20 houses)



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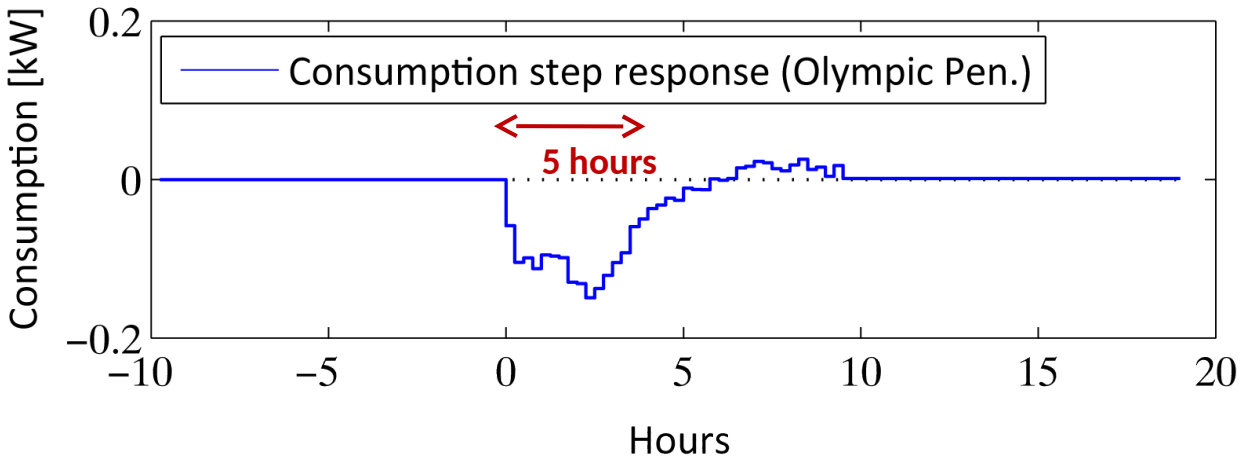
Non-parametric Response on Price Step Change

Model inputs: price, minute of day, outside temperature/dewpoint, sun irrandiance

Olympic Peninsula



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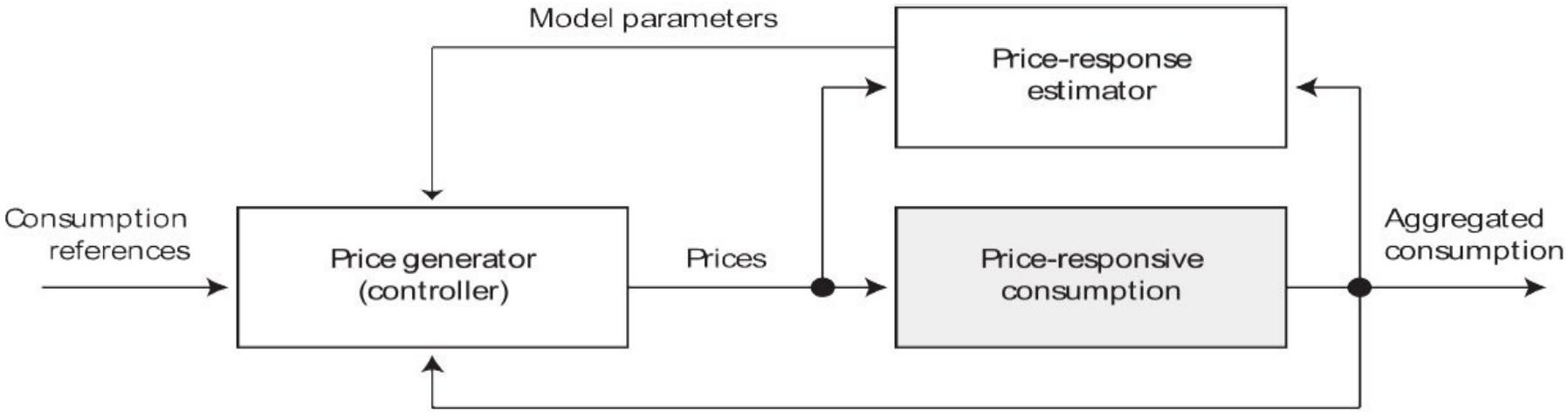
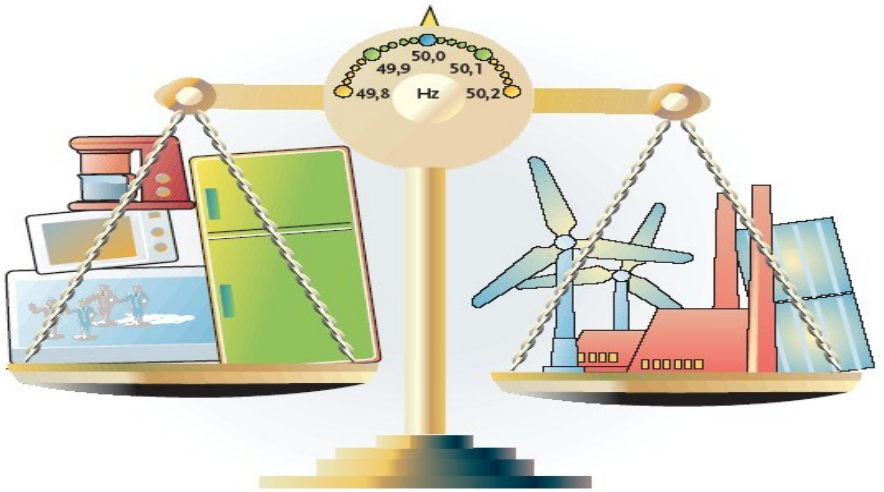
Control of Energy Consumption

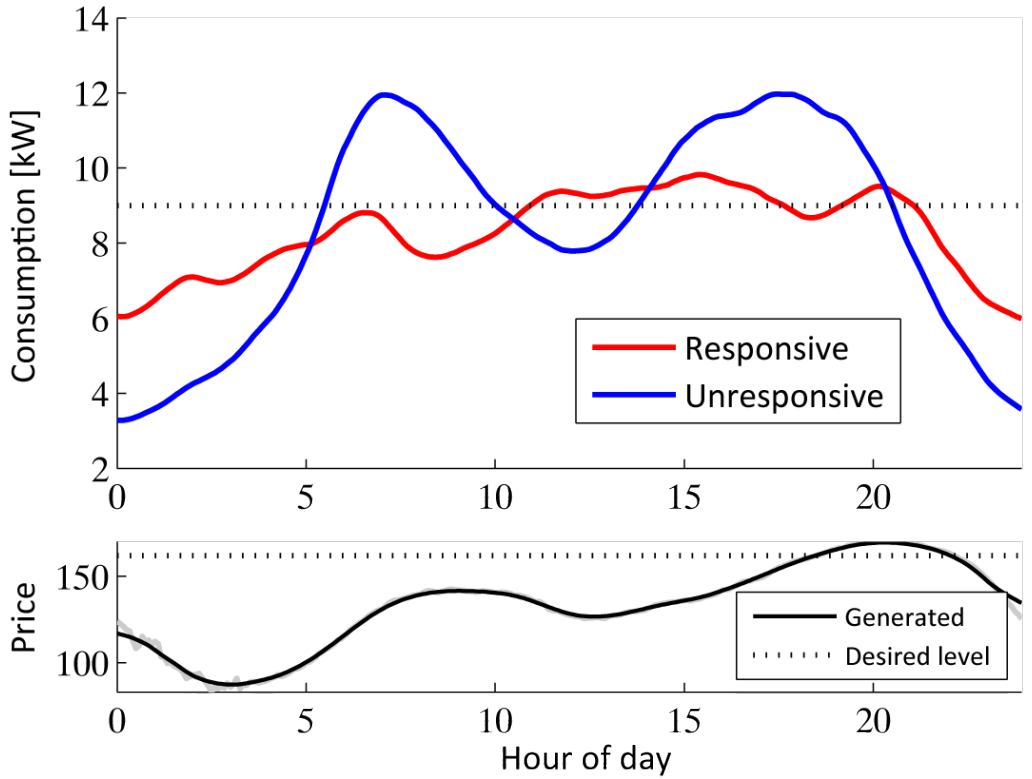




Control performance

With a price penality avoiding its divergence

- Considerable **reduction in peak consumption**
- Mean daily consumption shift



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For more information ...

- See for instance

  www.henrikmadsen.org

  www.smart-cities-centre.org

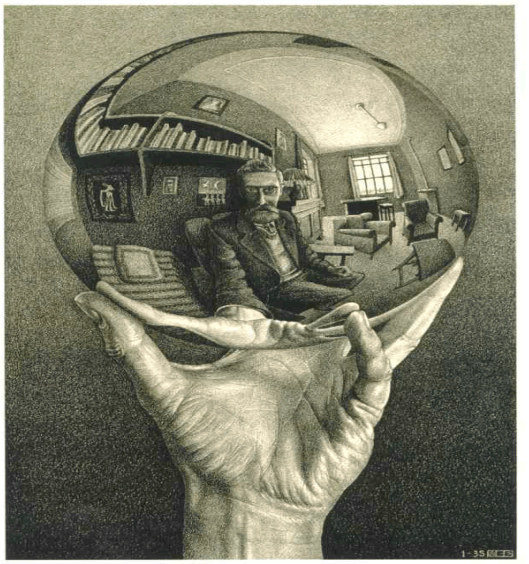
- ...or contact
  - Henrik Madsen (DTU Compute)

    hmad@dtu.dk

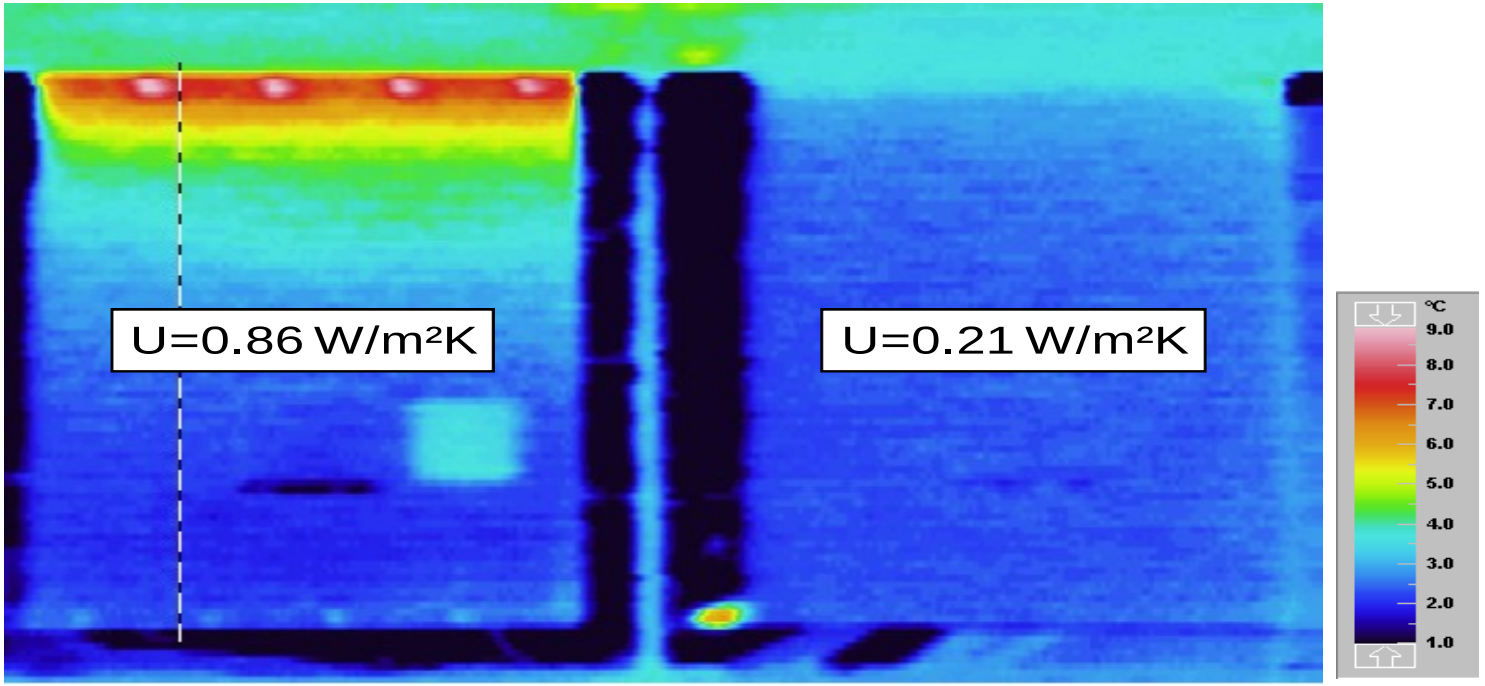
- Acknowledgement CITIES (DSF 1305-00027B)

Some of the other Demo-Projects in CITIES

- Control of WWTP (with ED, Kruger, ..)
- Heat pumps (Grundfos, Enfor, EconGRID,)
- Supermarket cooling (Danfoss, TI, ..)
- Summerhouses (SE, ONE, NEAS, ..)
- Green Houses (NeoGrid, Fjv. Fyn, ..)
- CHP (EMD, Dong, ...)
- Industrial production
- EVs (optimal charging) (Eurisco, mv.)
- .....



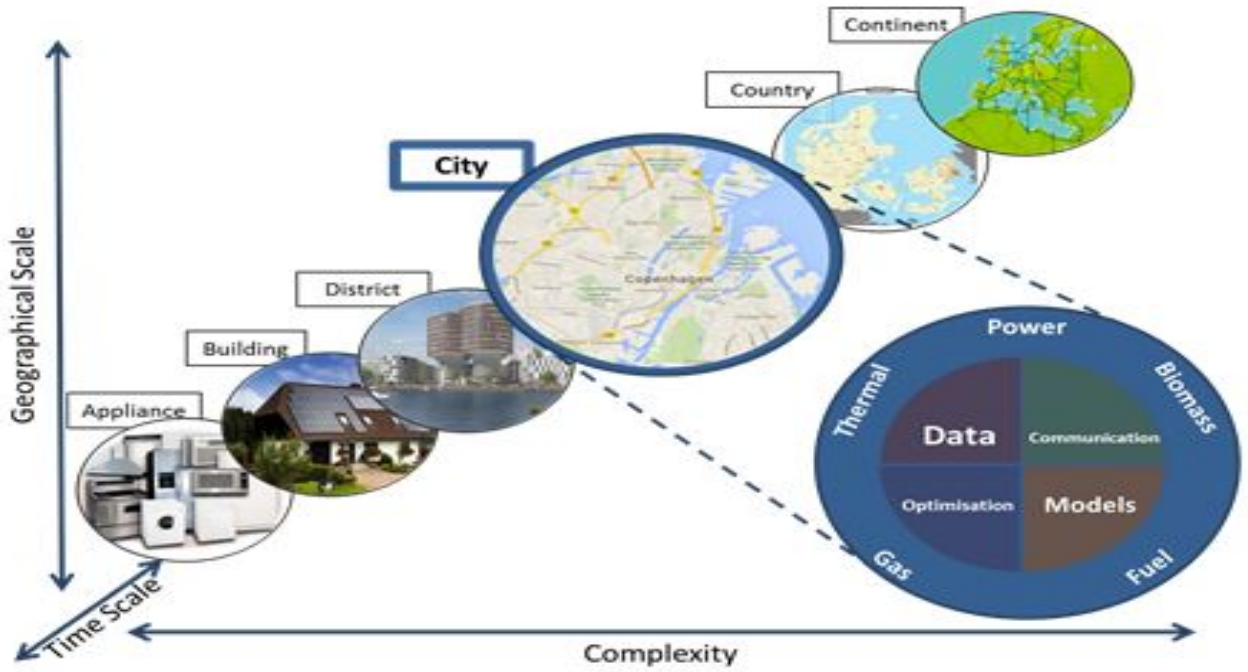
Example



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

Temporal and Spatial Scales

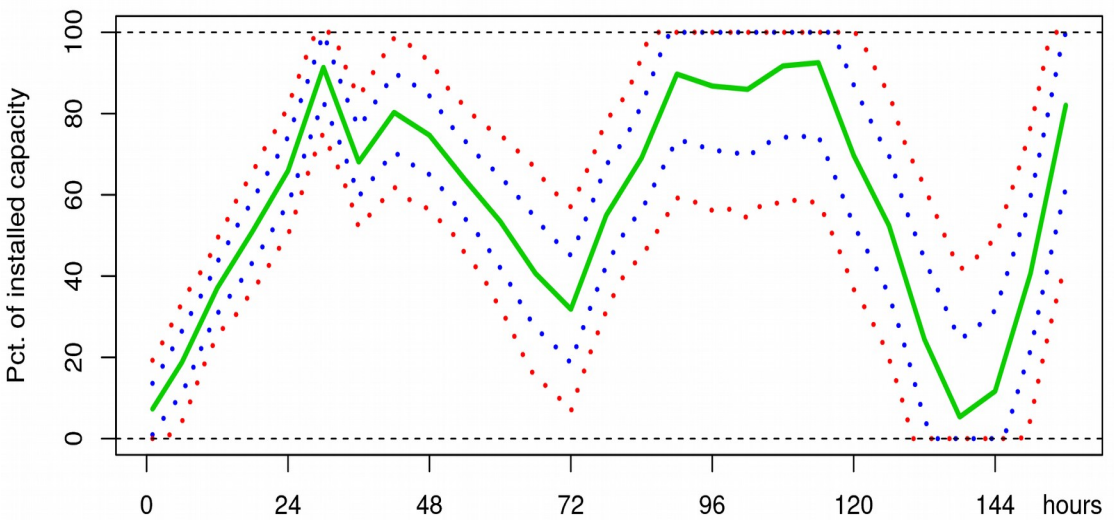
A ***Smart-Energy Operating-System (SE-OS)*** is used to develop, implement and test of solutions (layers: data, models, optimization, control, communication) for ***operating flexible electrical energy systems*** at **all scales**.

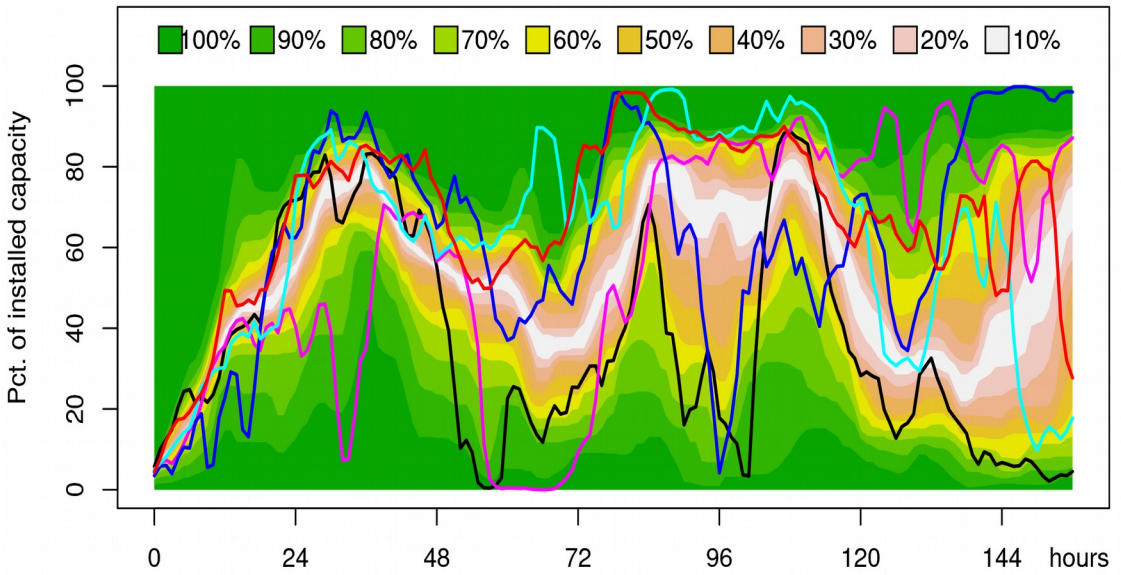


Forecasting is Essential

Tools for Forecasting: (Prob. forecasts)

- Power load
- Heat load
- Gas load
- Prices (power, etc)
- Wind power prod.
- Solar power prod.
- State variables (DER)





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