Energy Efficiency and use of data from Smart Meters

CITIES workshop
DTU, May 2014

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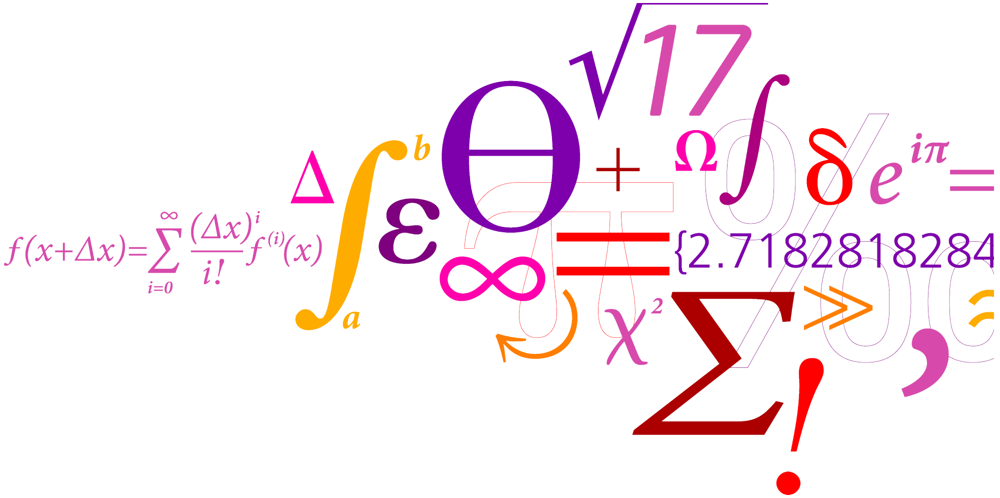

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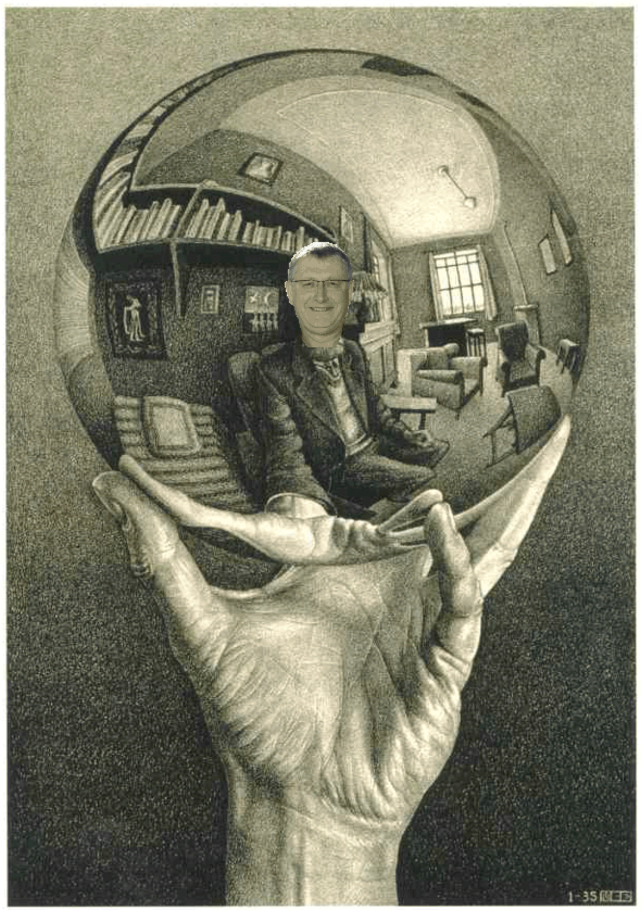


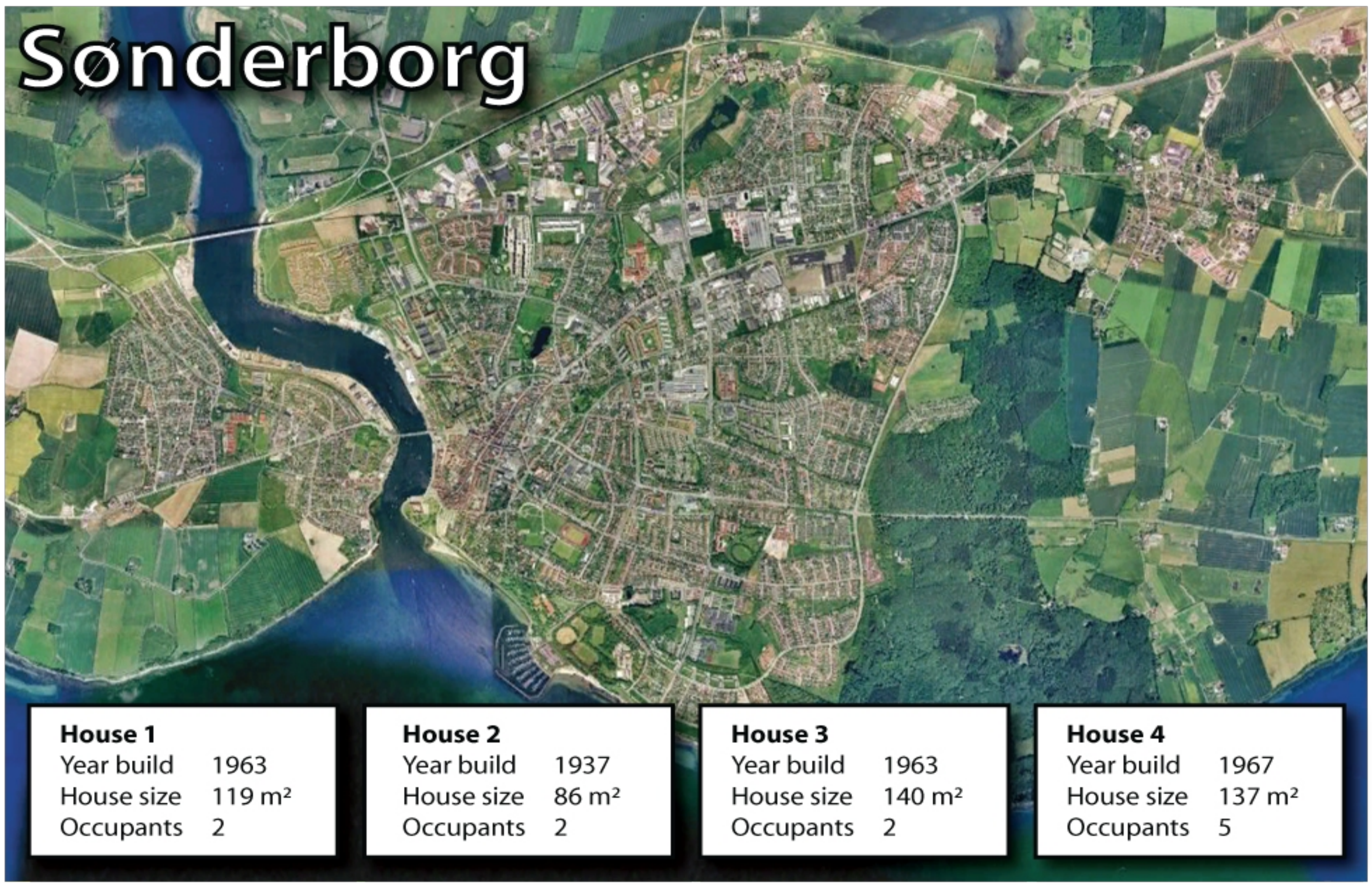
- Smart Meters and data splitting
- Smart Meters and Thermal Characteristics
  - Problem setting
  - Simple tool

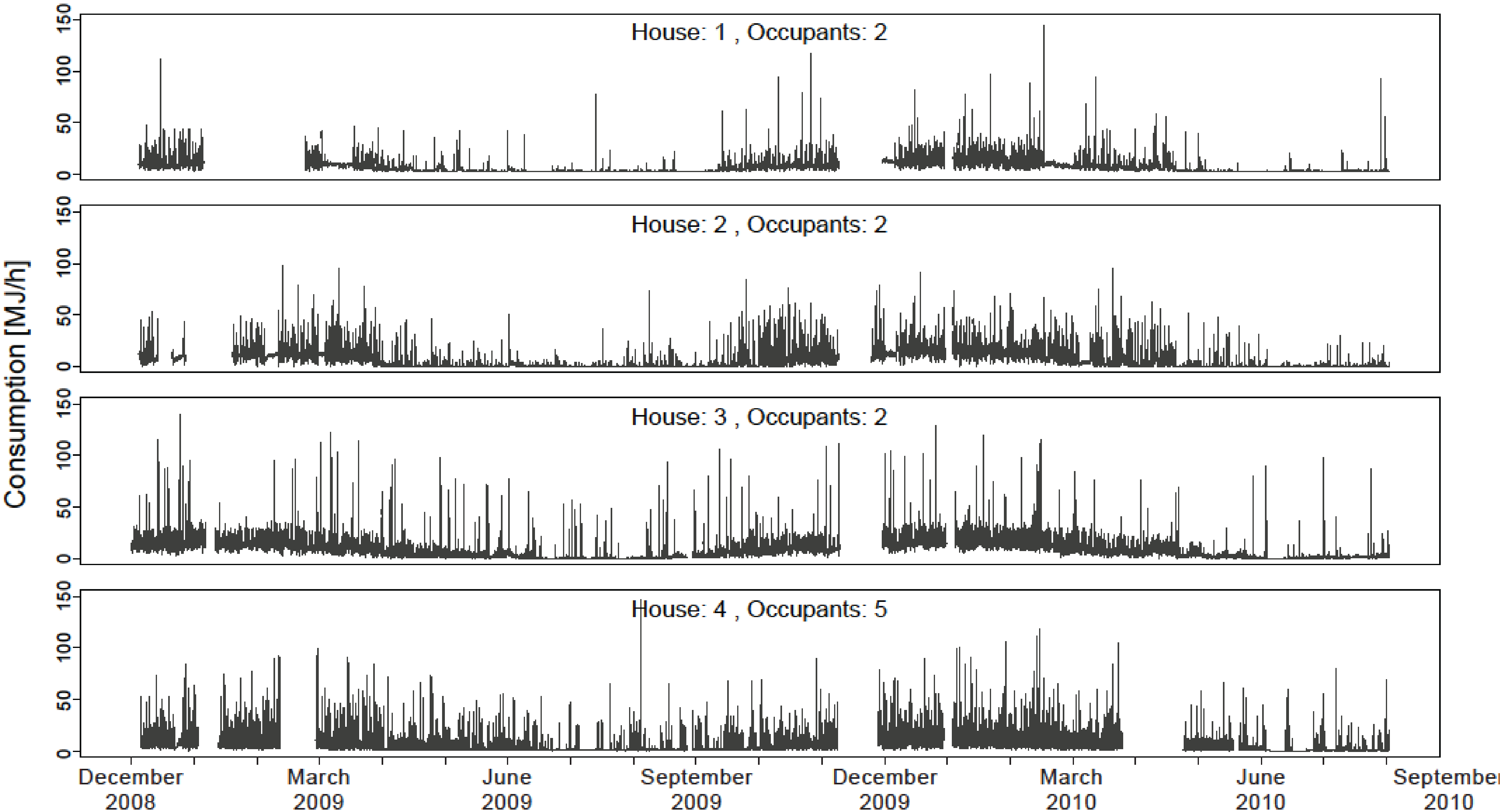
Case Study No. 1

Split of total readings into space heating and domestic hot water using data from smart meters

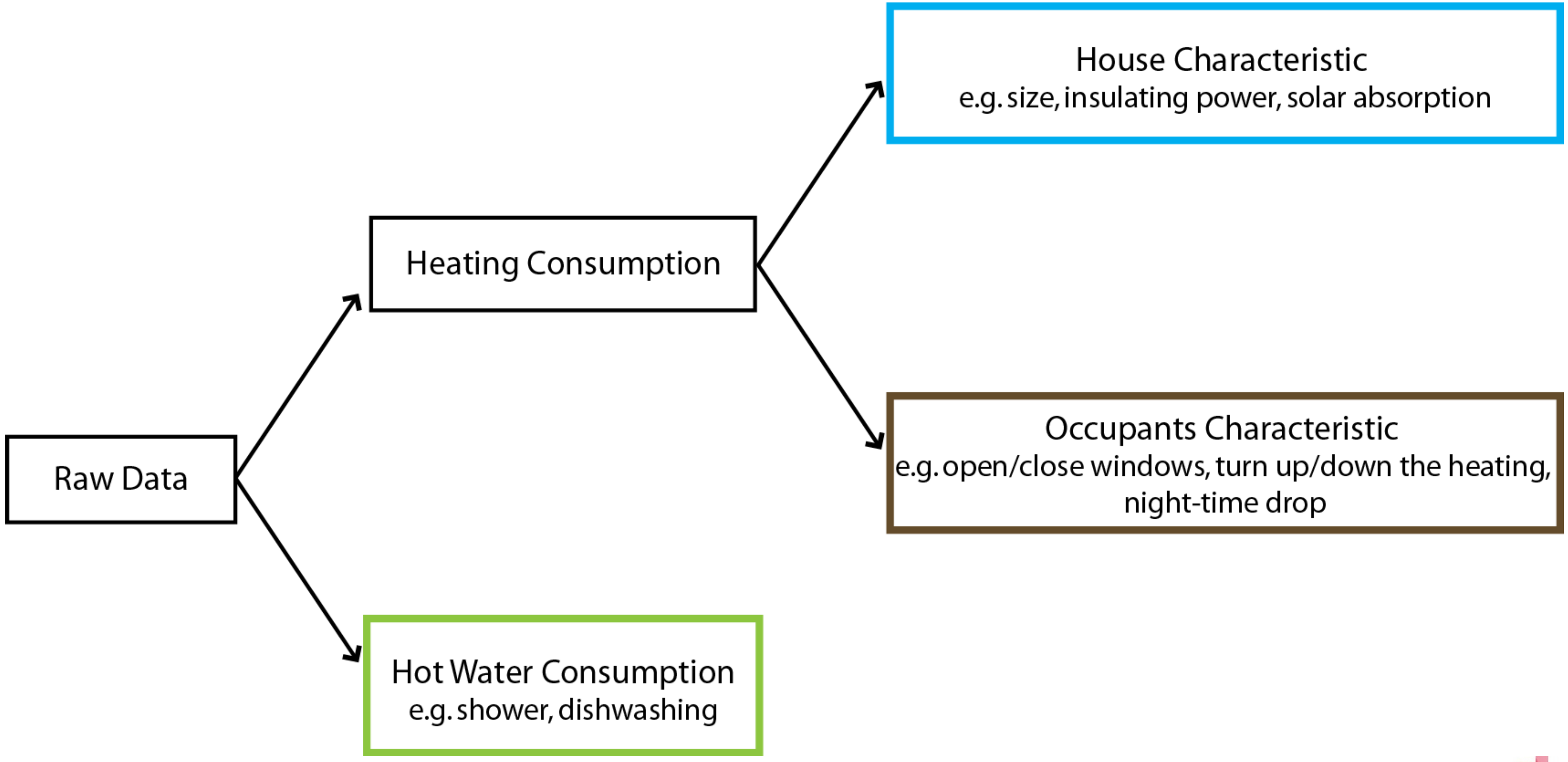
Data

- 10 min averages from a number of houses

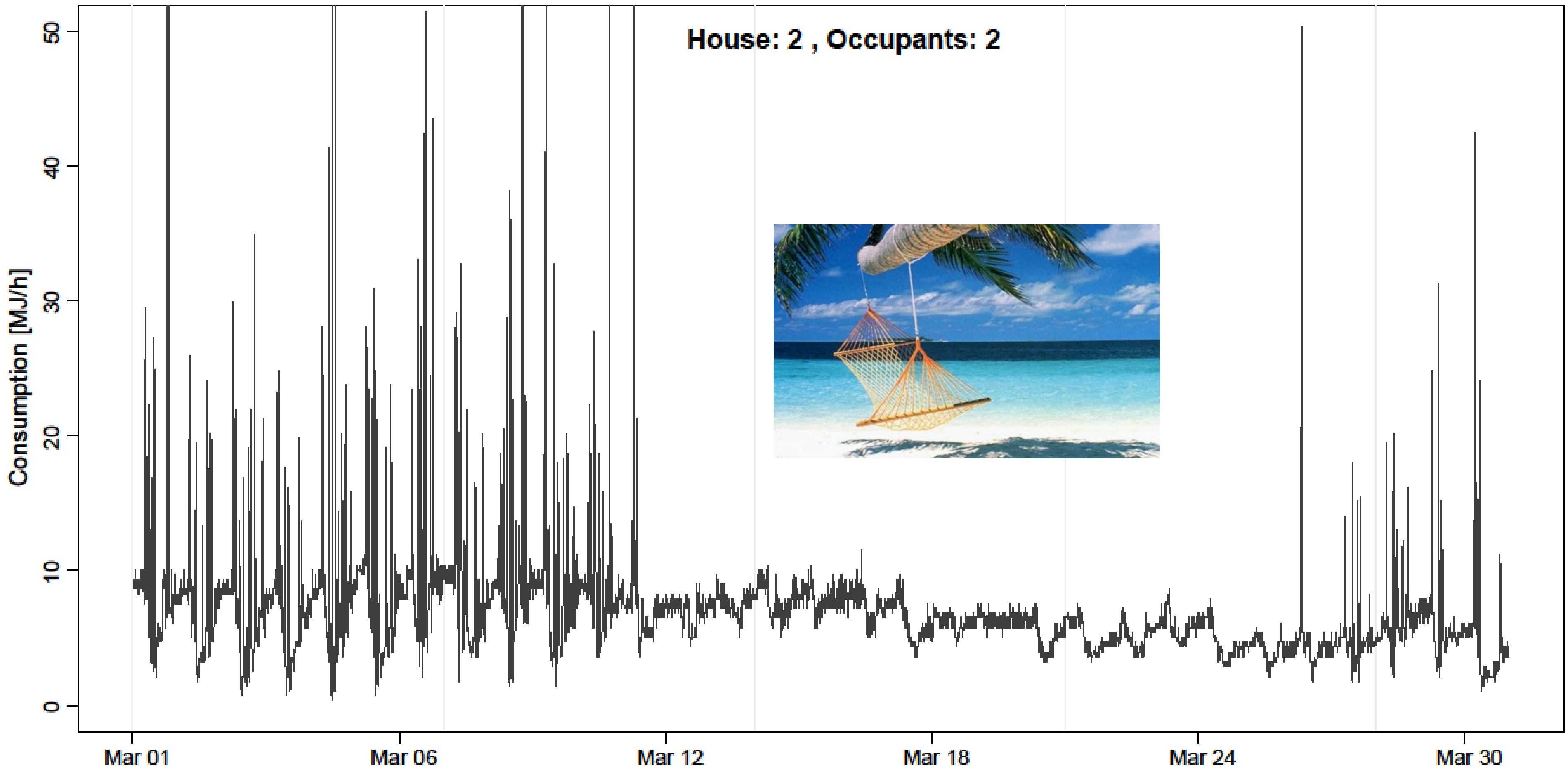



House: 1 , Occupants: 2
House: 2 , Occupants: 2
House: 3 , Occupants: 2
House: 4 , Occupants: 5
Consumption [MJ/h]
0
50
100
150
December 2008
March 2009
June 2009
September 2009
December 2009
March 2010
June 2010
September 2010

Data separation principle



Holiday period



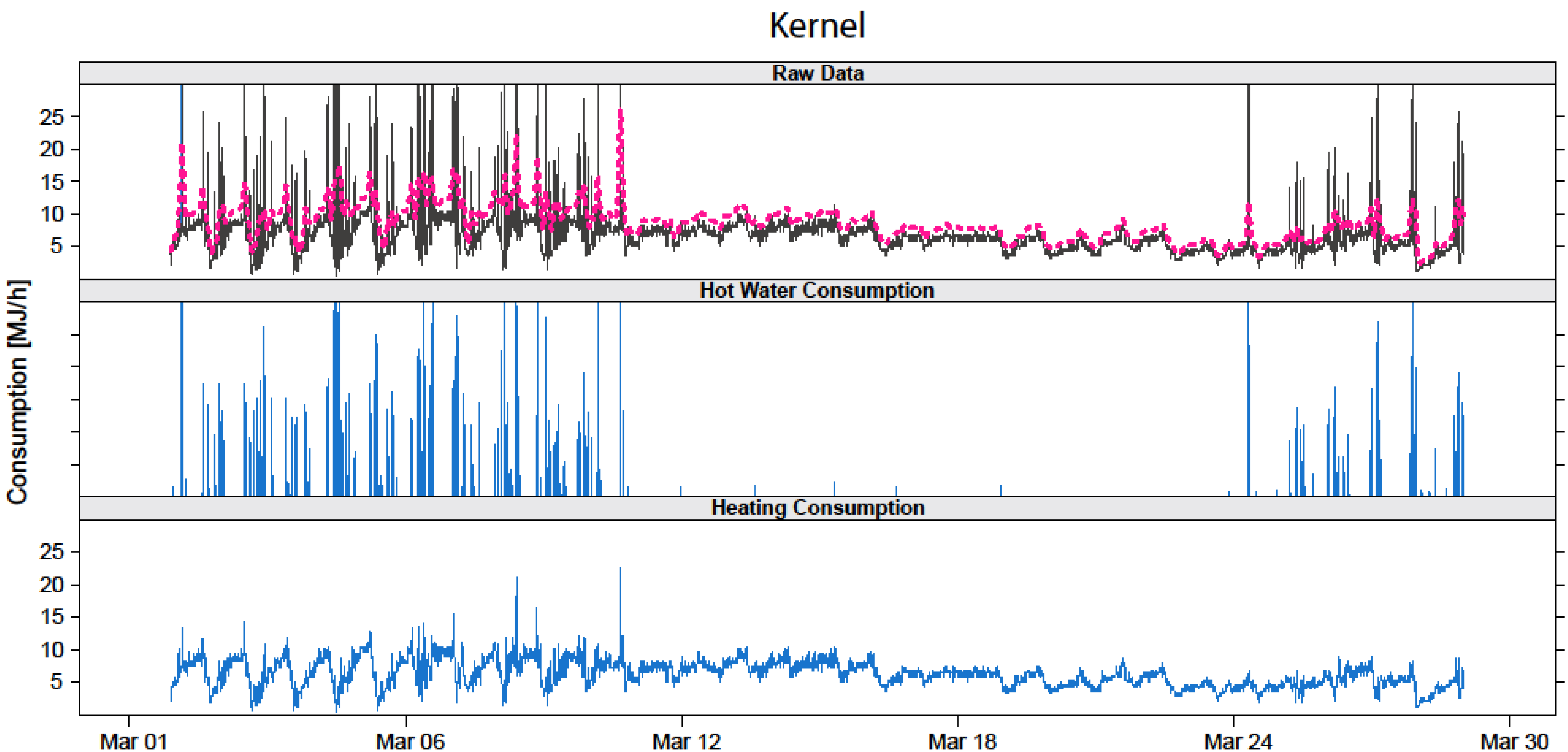
Non-parametric regression

$$\hat{g}(x) = \frac{\sum_{s=1}^{N} Y_s k\{\frac{x-X_s}{h}\}}{\sum_{s=1}^{N} k\{\frac{x-X_s}{h}\}}$$

$$k(u) = \frac{1}{2\pi} \exp\{-\frac{u^2}{2}\}$$

Weighted average

Every spike above $1.25 \cdot \hat{g}(x)$ Is regarded as hot water use.



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Robust Polynomial Kernel

To improve the kernel method

Rewrite the kernel smoother to a Least Square Problem

$$\arg\min_{\theta} \frac{1}{N} \sum_{s=1}^{N} w_s(x) \left(Y_s - \theta\right)^2 \qquad w_s(x) = \frac{k\{x - X_s\}}{\frac{1}{N}\sum_{s=1}^{N} k\{x - X_s\}}$$

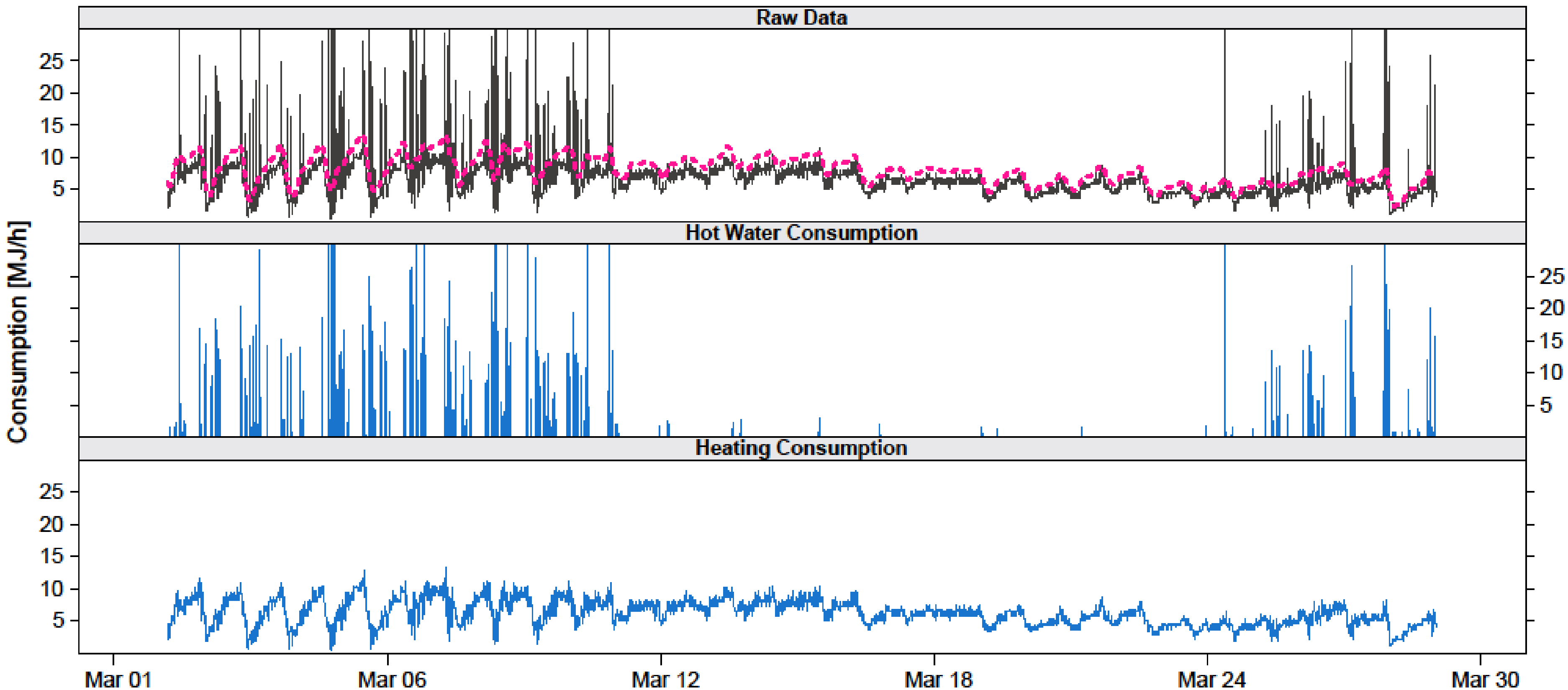
Make the method robust by replacing $(Y_s - \theta)^2$ with

$$\rho_{\text{Huber}}(\varepsilon) = \begin{cases} \frac{1}{2\gamma}\varepsilon^2 & \text{if } |\varepsilon| \leq \gamma \\ |\varepsilon| - \frac{1}{2}\gamma & \text{if } |\varepsilon| > \gamma \end{cases} \qquad \varepsilon_s = Y_s - \theta$$

Make the method polynomial by replacing θ with

$$P_s = \theta_0 + \theta_1(X_t - x) + \theta_2(X_t - x)^2$$

Robust Polynomial Kernel



Case Study No. 2

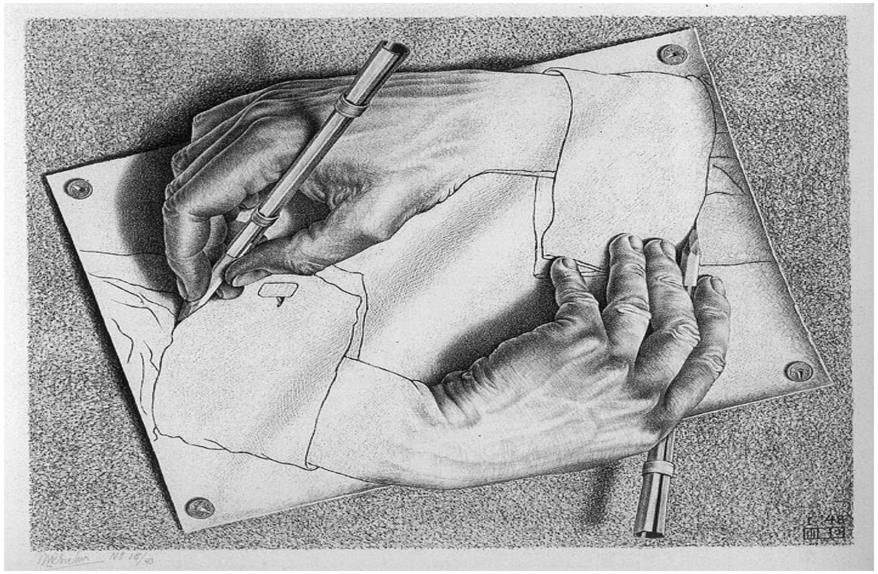
Identification of Thermal Performance using Smart Meter Data

Characterization using Smart Meter Data

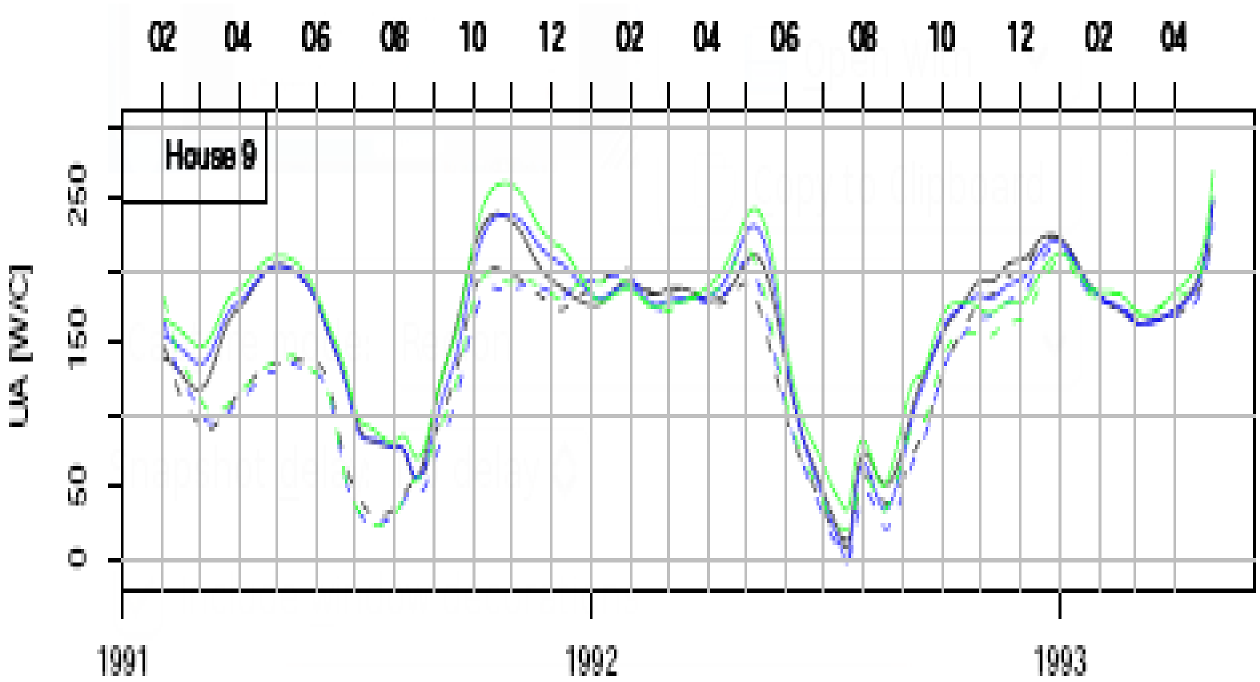
- Separation of usage and building effect on heat load
- Energy labelling
- Estimation of UA and gA values
- Wind induced ventilation (directional)
- Indoor temperature and other non-weather dependent losses are estimated

Energy Labelling of Buildings

- Today building experts make judgements of the energy performance of buildings based on drawings and prior knowledge.
- This leads to 'Energy labelling' of the building
- However, it is noticed that two independent experts can predict very different consumptions for the same house.



Find the heating season



Simple estimation of UA-values

- Consider the following model (t=day No.) estimated by kernel-smoothing:

$$Q_t = Q_0(t) + c_0(t)(T_{i,t} - T_{a,t}) + c_1(t)(T_{i,t-1} - T_{a,t-1}) \qquad (1)$$

- The estimated UA-value is

$$\hat{UA}(t) = \hat{c}_o(t) + \hat{c}_1(t) \qquad (2)$$

Results

	UA	σ_{UA}	gA^{max}	wA_E^{max}	wA_S^{max}	wA_W^{max}	T_i
	W/°C		W	W/°C	W/°C	W/°C	°C
4218598	211.8	10.4	597.0	11.0	3.3	8.9	23.6
4218600	98.7	10.8	-96.2	23.6	10.1	13.0	22.3
4381449	228.2	12.6	1012.3	29.8	42.8	39.7	19.4
4711160	155.4	6.3	518.8	14.5	4.4	9.1	22.5
4711176	178.5	7.3	800.0	1.9	-7.6	8.5	26.4
4836681	155.3	8.1	591.0	39.5	28.0	21.4	23.5
4836722	236.0	17.7	1578.3	4.3	3.3	18.9	23.5
4986050	159.6	10.7	715.7	10.2	7.5	7.2	20.8
5069878	144.8	10.4	87.6	3.7	1.6	17.3	21.8
5069913	207.8	9.0	962.5	3.7	8.6	10.6	22.6
5107720	189.4	15.4	657.7	41.4	29.4	16.5	21.0

Notice: Still some issues with negative values but often they are not significiant.

Based on measurements from the heating season **2009/2010** your typical indoor temperature during the heating season has been estimated to **24** ^oC. If this is not correct you can change it here [24] ^oC.

If your house has been left empty in longer periods with a partly reduced heat supply you have the possibility of specifying the periods in this [calendar].

According to BBR the area of your house is **155** m^2 and from **1971**.

Based on BBR information it is assumed that **you do not use any supplementary heat supply**. If this is not correct you can specify the type and frequency of use here:

- Wood burning stove used [0] times per week in cold periods.
- Solar heating [y/n], approximate size of solar panel [0] $\times$ [0] meters.

Based on the indoor temperature **24** ^oC, the use of a wood burning stove **0** times per week, and **no** solar heating installed, the response of your house to climate is estimated as:

- The response to outdoor temperature is estimated to **200** $W/^oC$ **which given the size and age of your house is expectable**[a].
- On a windy day the above value is estimated to increase with **60** $W/^oC$ **when the wind blows from easterly directions. This response to wind is relatively high and indicates a problem related to the air sealing on the eastern side of the house.**
- On a sunny day during the heating season the house is estimated to receive **800** W as an average over 24 hours. **This value is quite expectable.**

[a]Many kind of different recommendations can be given here.

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Perspectives for using Smart Meters

- Reliable Energy Signature.
- Energy Labelling
- There will be outliers
- Statistical techniques for outlier detection and uncertainties
- Proposals for Energy Savings:
  - Replace the windows?
  - Put more insulation on the roof?
  - Is the house too untight?
  - ......

Conclusions

- Smart Meters (or frequent readings) can give:
  - Split of total readings into hot tap water and the rest
  - Energy signatures / labels of buildings
  - Advanced knowledge about potentials for energy savings
  - Naturally, there will be outliers, but we can detect them and deal with them
- All methods need large scale testing before final conclusions