# What can AI do to optimize electricity and thermal demand in buildings?

Igor Sartori – igor.sartori@sintef.no
SINTEF Byggforsk

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## What is energy flexibility?

*The Energy Flexibility of a building or neighborhood is the ability to manage its demand and generation according to local climate conditions, user needs and grid requirements.*

*Definition by the IEA EBC Annex 67 "Energy flexible buildings"*

## What can it be used for?

- Minimize energy cost
- Minimize $CO_2$ footprint of energy use
- Maximise self-consumption
- Minimize energy use during peak hours

**Talking about solutions:**

- Model Predictive Control to activate the buildings' flexibility
- Based on grey-box models (data-driven, mixed physical/statistical) of buildings and building technologies
  - ➢ This is the most challenging (and time consuming) part: model identification and validation

This is the problem

**Talking about ideas:**

- What can AI do to help solve the problem?

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# The future smart energy system (?)

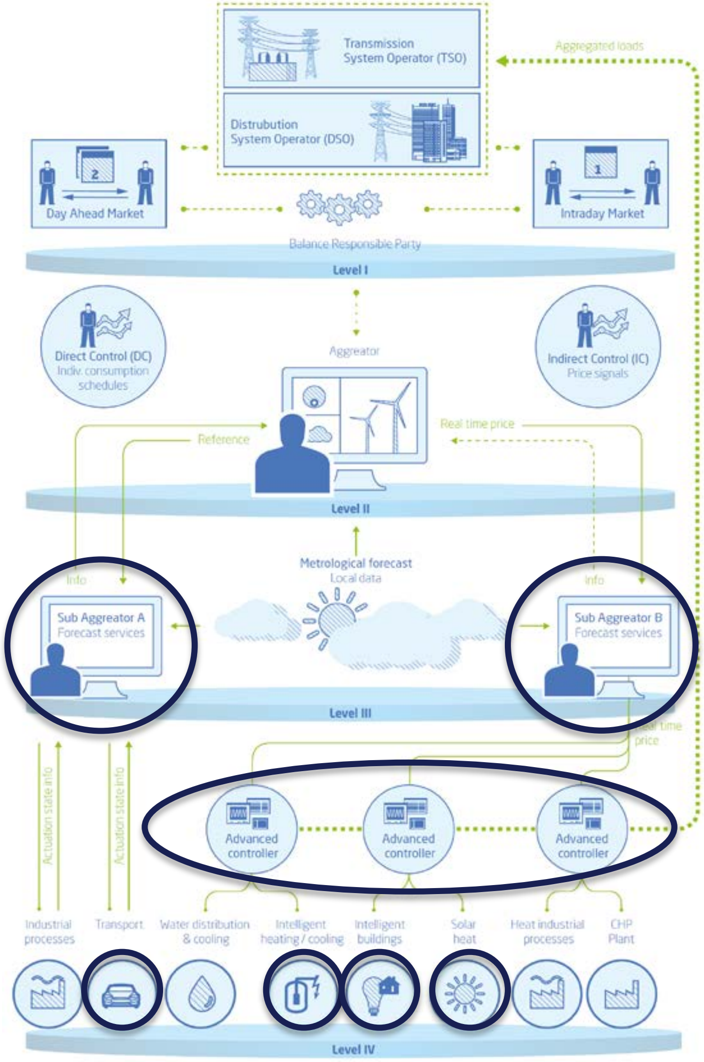
Market

Aggregator(s)
Market pooling

Sub-Aggregator(s)
Area specific

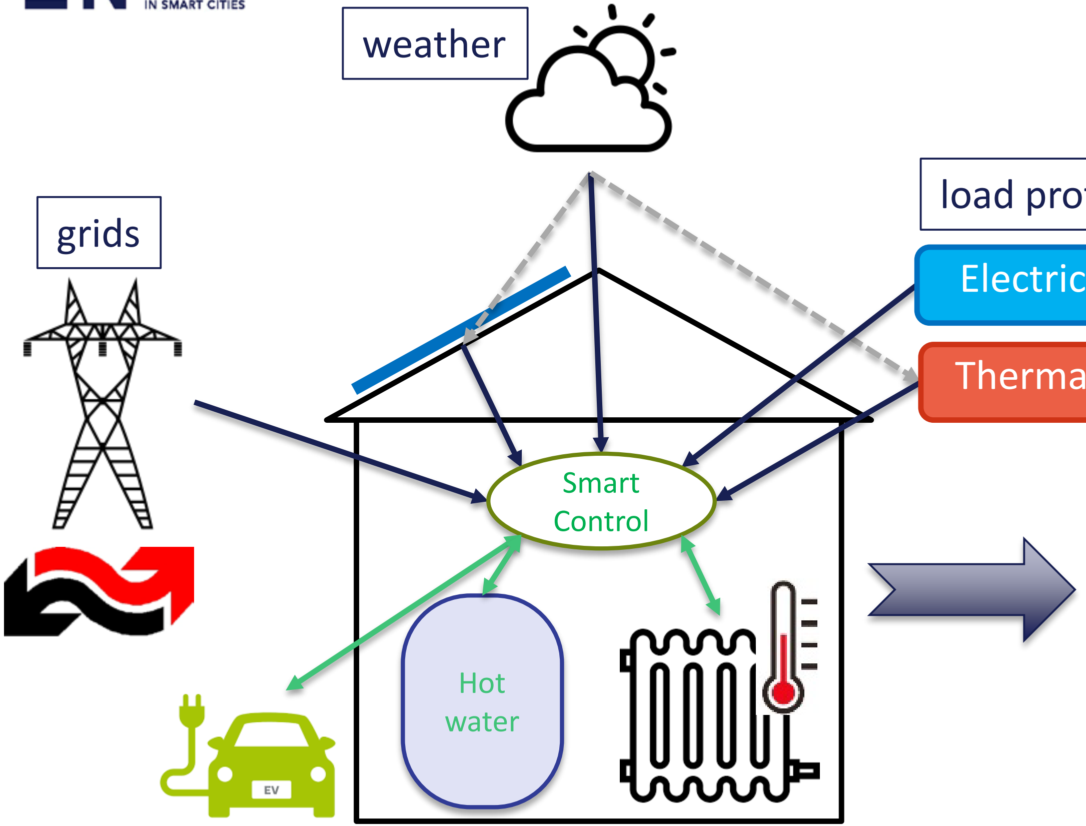
**Requires adequate modeling and control**

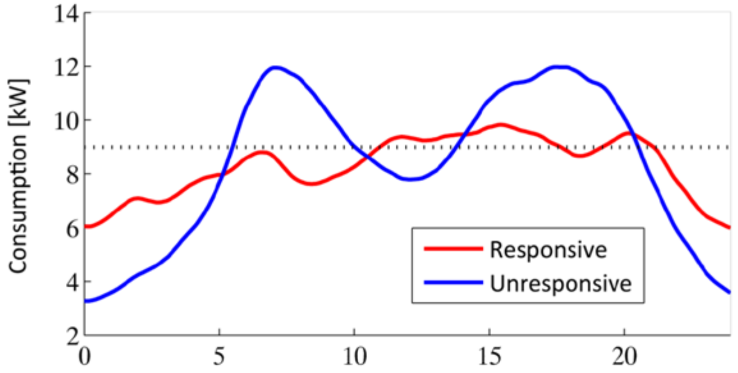
Distributed Energy Resources



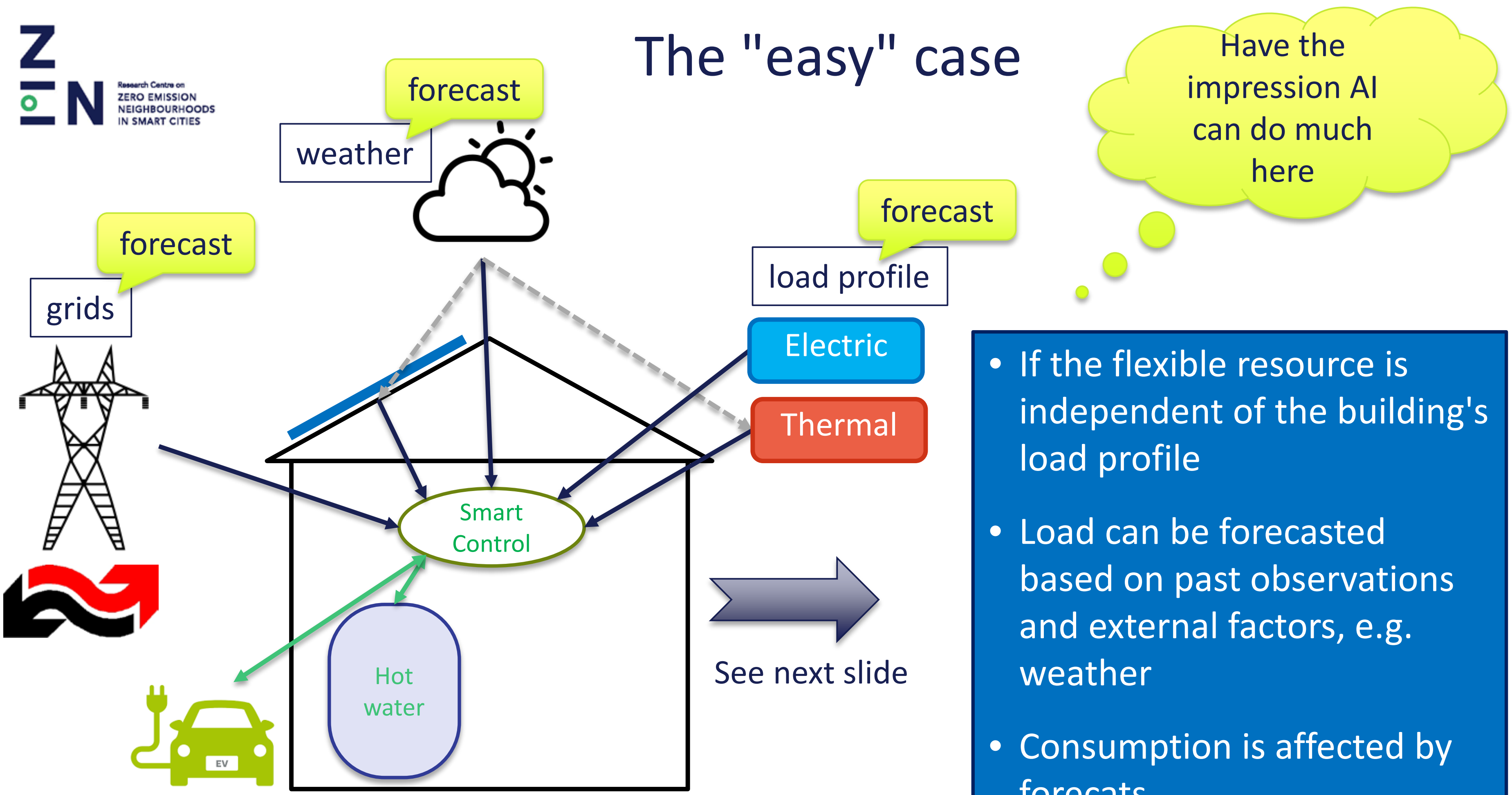

Source: H. Madsen *et al.* (2015)

# Smart control of electric and themal demand



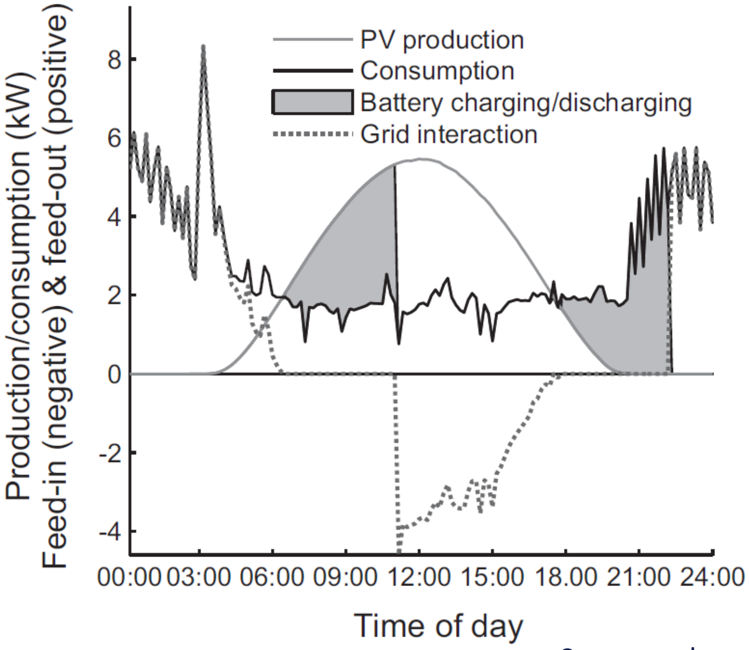
# The "easy" case



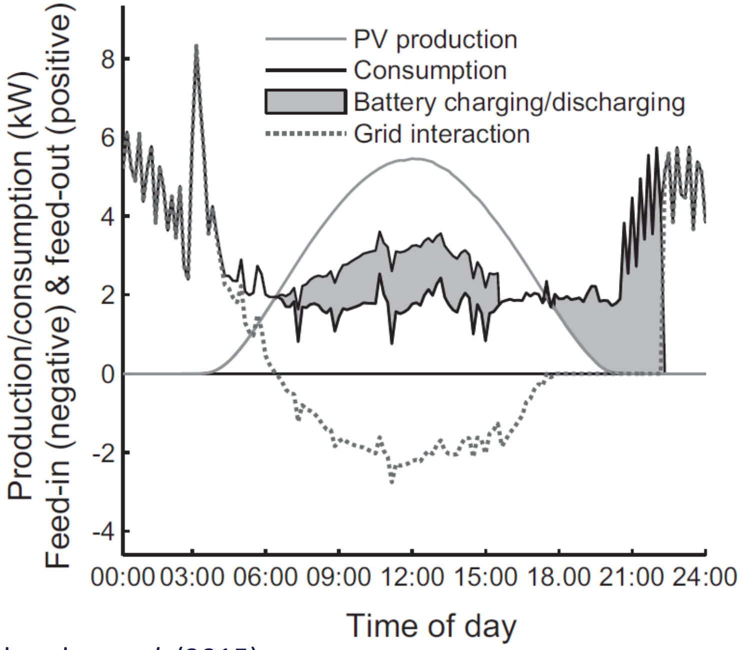

- If the flexible resource is independent of the building's load profile
- Load can be forecasted based on past observations and external factors, e.g. weather
- Consumption is affected by forecats

# Example: charging of battery with PV

## Fast charging



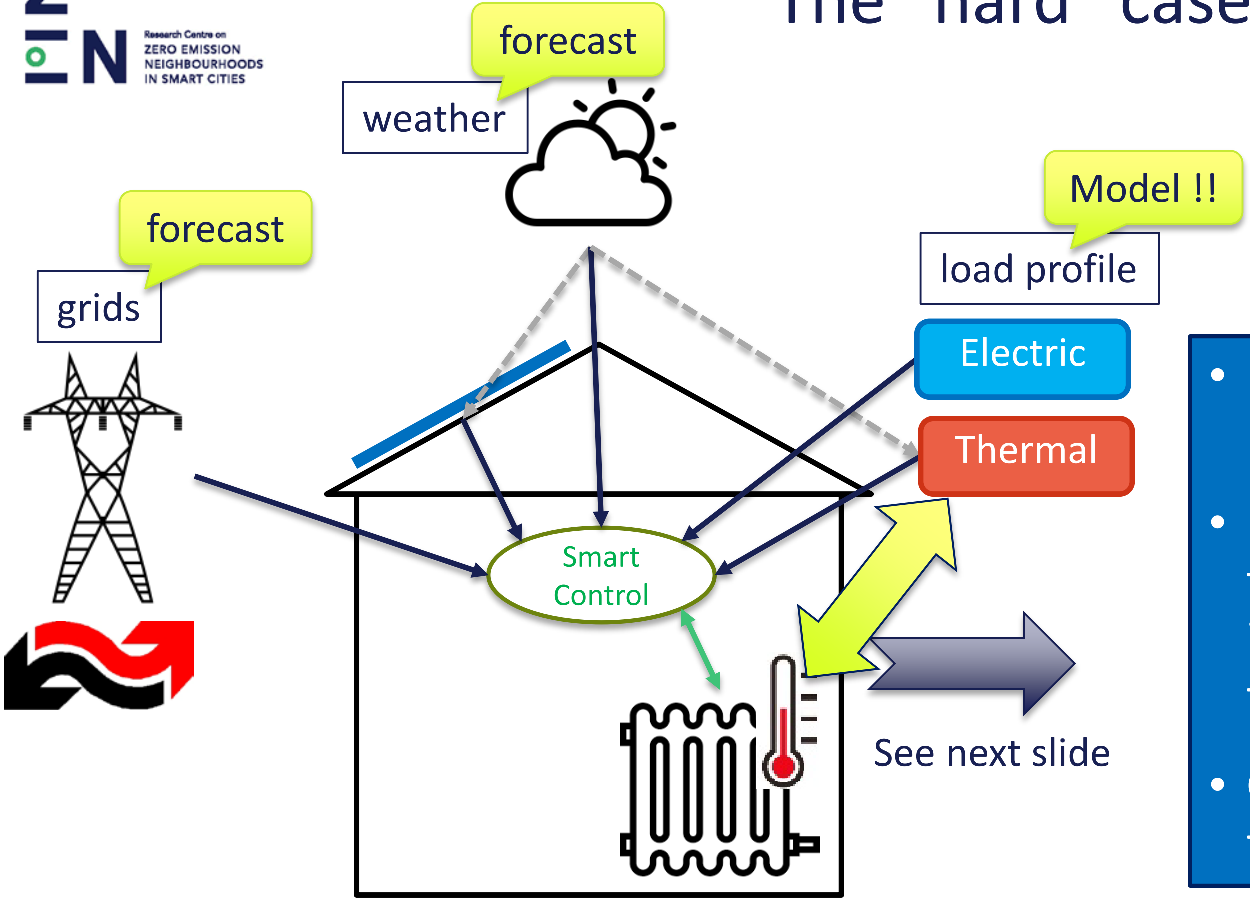

## Limiting peak export



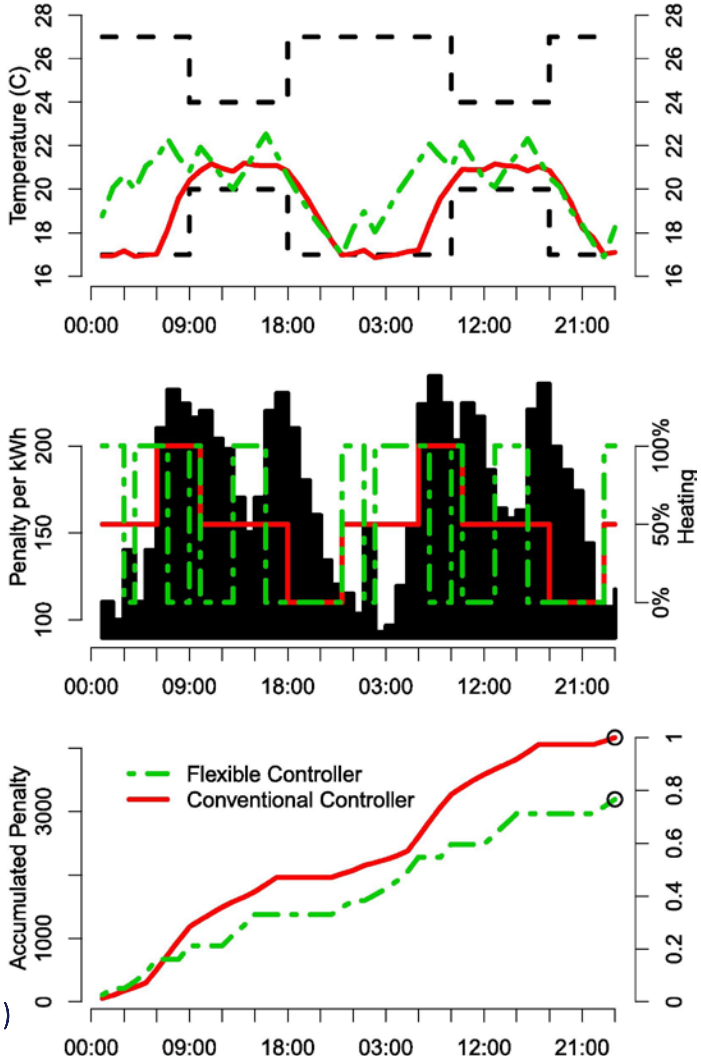

Source: adapted from Luthander *et al.* (2015)

# The "hard" case

What can AI do here ??




- If the flexible resource is the building's load profile itself
- Load must be modelled together with building's internal "states", e.g. indoor temperature
- Consumption is affected by forecast & model used!




Source: Junker *et al.* (2015)

Top plot: An example of the temperature in a building controlled by a penalty-aware controller (green, dashed) and a conventional controller (red, solid). Both controllers are restricted to stay within the dashed lines.

Middle plot: The black shading gives the penalties, while the green and red lines show when the two controllers heat, respectively.

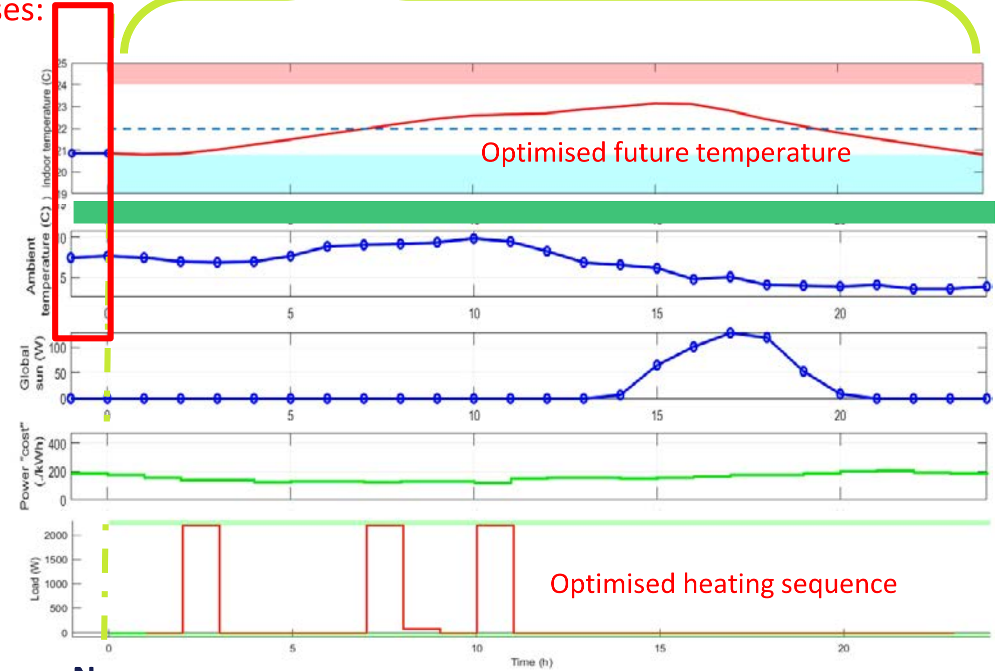
Bottom plot: These graphs illustrate the accumulated penalty for each of the controllers.

# Model Predictive Control



Required forecast and model prediction capability

Thermostat
(heating curve)
uses:




Now

Operational constraints

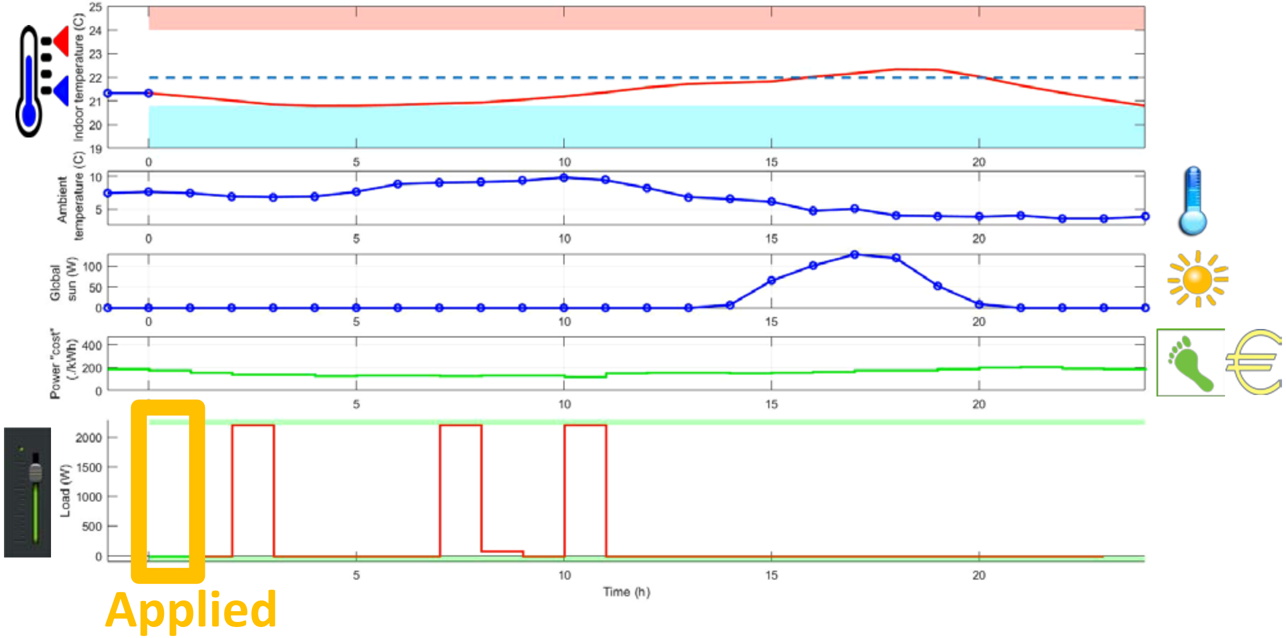
Weather
forecast

Cost
signal

Information
supporting
the decision

Soutrce: Dr. Pierre Vogler Finck, 2017 (Neogrid)

# Example of how Model Predictive Control (MPC) operates




Animation courtesy of Dr. Pierre Vogler Finck, 2017 (Neogrid)

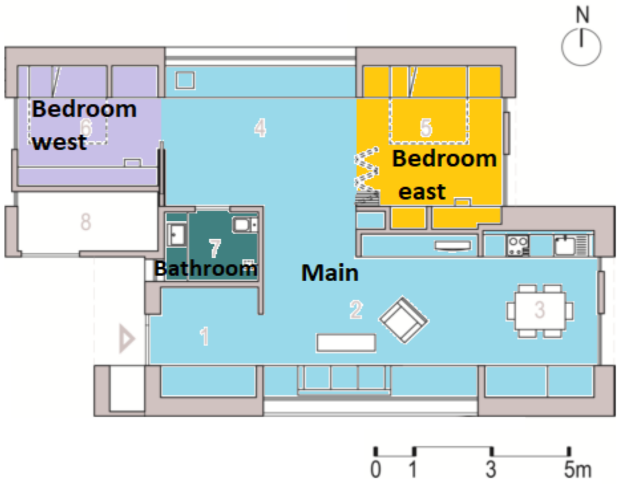
# The ZEB LivingLab at NTNU

**Envelope and structure**

- Super-insulated structure with wooden frame
- PCM in ceiling, and large window areas
- 100 m² inhabitable area, several rooms

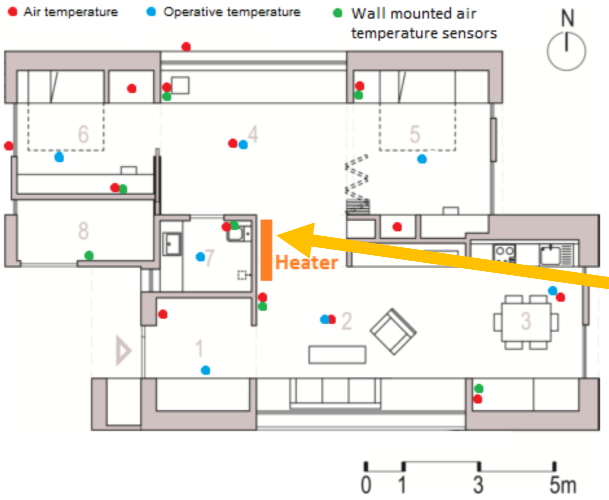
**Energy production**

- PV on roof + solar collectors on facade




Source: Goia, Finocchiaro, Gustavsen (2015)

# Heating setup for experiments



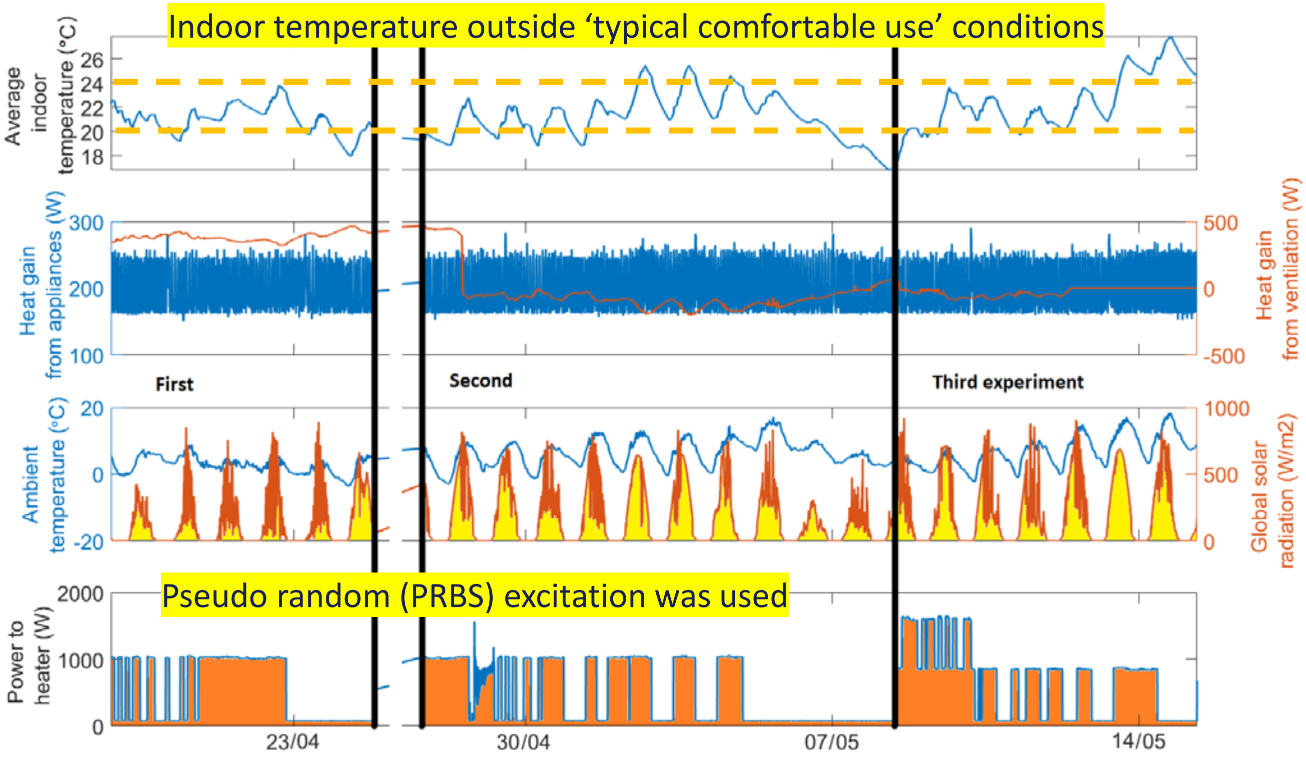

Heating thermostats are disabled for PRBS (replaced by distant control)

An electrical heater was added

In practise, it is important to **make experiments with the heating device which will be controlled by MPC**

Sources: Goia, Finocchiaro, Gustavsen (2015); Dr. Pierre Vogler Finck (Neogrid)

# Dedicated experiments were carried out to gather data




*Sources: Vogler-Finck, Clauß, Georges (2017); Bacher, Madsen (2011)*

# Example: a (very) simple grey-box model

**Input**

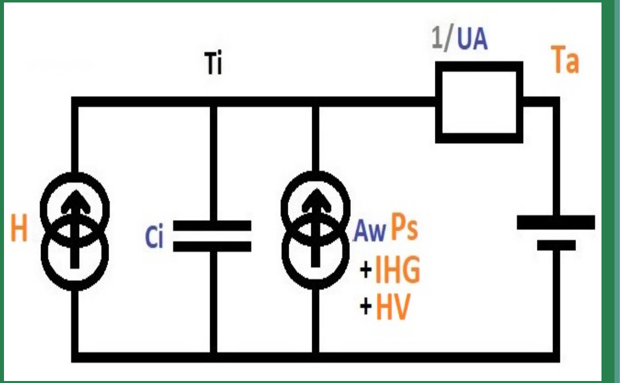
**H** (power to heater)

**Disturbances**

**Ps** (global solar irradiance)

**HV** (heat gain from ventilation)

**IHG** (internal heat gains)




**Parameters:**

**Ci** (heat capacity)

**UA** (heat loss)

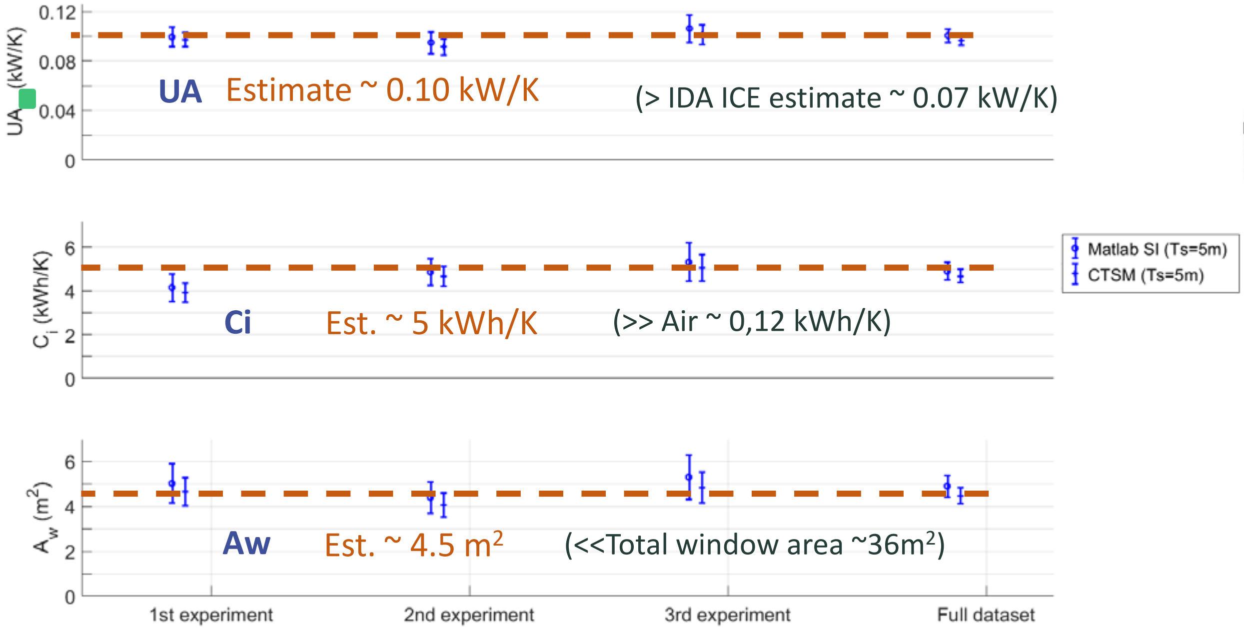
**Aw** (solar gain)

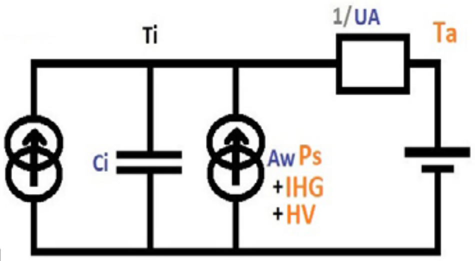
**Output**

**Ti** (equivalent indoor temperature)

Source: Dr. Pierre Vogler Finck (Neogrid)

# Model parameters identification



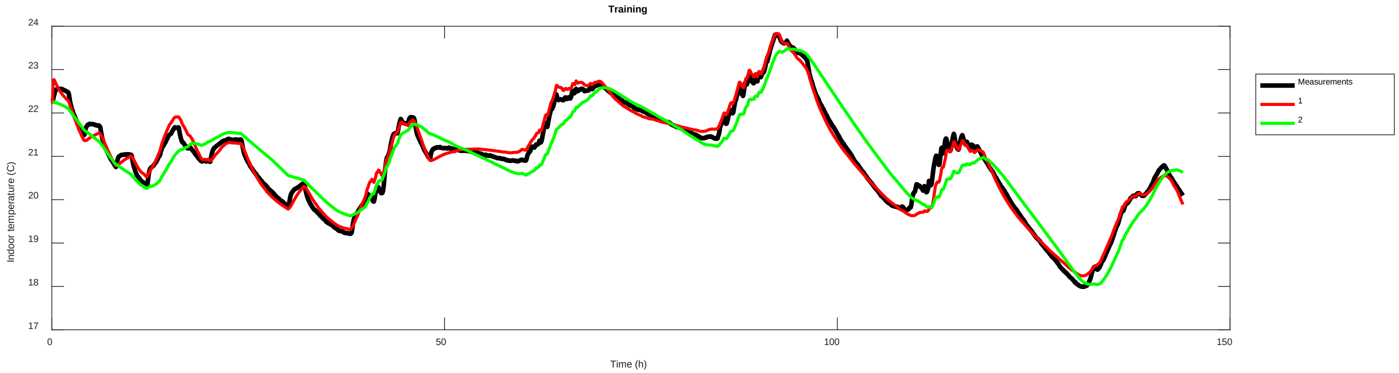




**Parameters:**

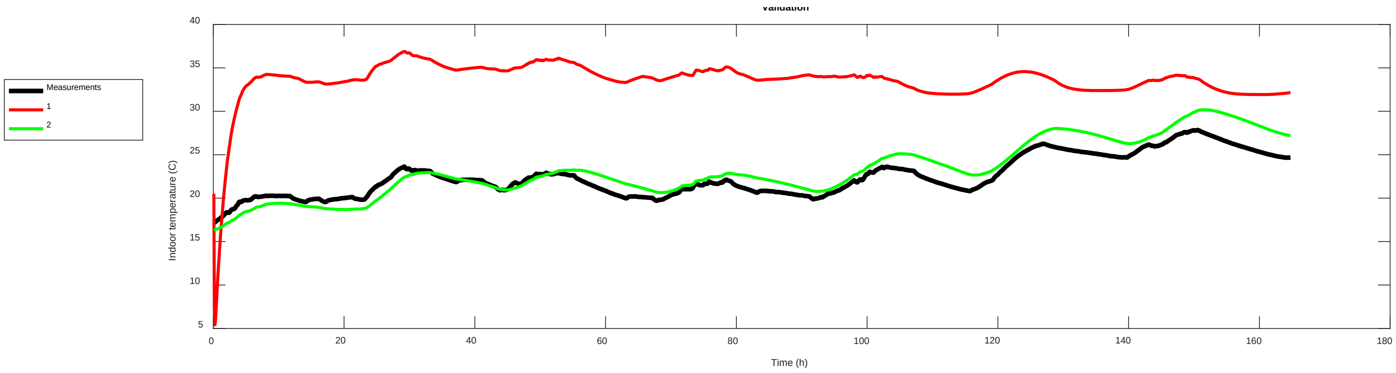
- **UA** (heat loss)
- **Ci** (heat capacity)
- **Aw** (solar gain)

Source: Vogler-Finck et al. (2018)

# Model validation




Model 1 appears to be a better fit on training data – but it is  not ROBUST



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# Summary

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- Only after that a (grey-box) model has been validated, a building/neighborhood can be controlled in "real time" with MPC so to *manage its demand and generation according to local climate conditions, user needs and grid requirements*

- But how do we move from detailed and dedicated experiments to large scale modelling without intrusive measurements?

- AI solves it and we relax ??

# Thanks fo your attention !

# References

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