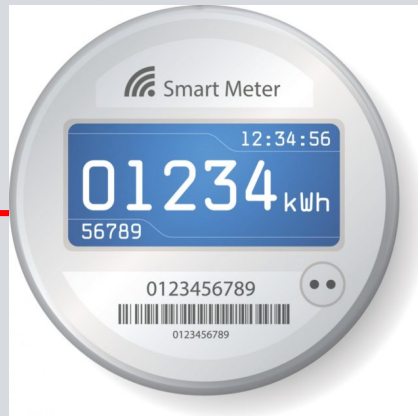
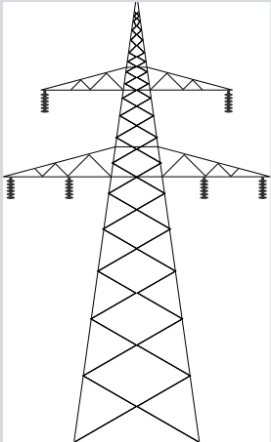


Automated building modelling based on Smart-Meter Monitoring Data

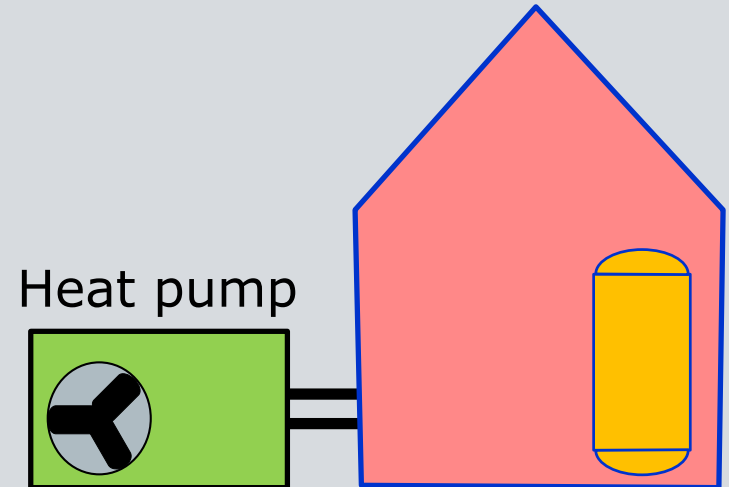
Andreas Melillo, Jörg Worlitschek, Philipp Schütz
Lucerne University of Applied Science and Arts
philipp.schuetz@hslu.ch

Why to care about building models?

Energy grid



Residential heating system



Exemplary applications:

Utilities:

- Load prediction
- Extension planning

End-users:

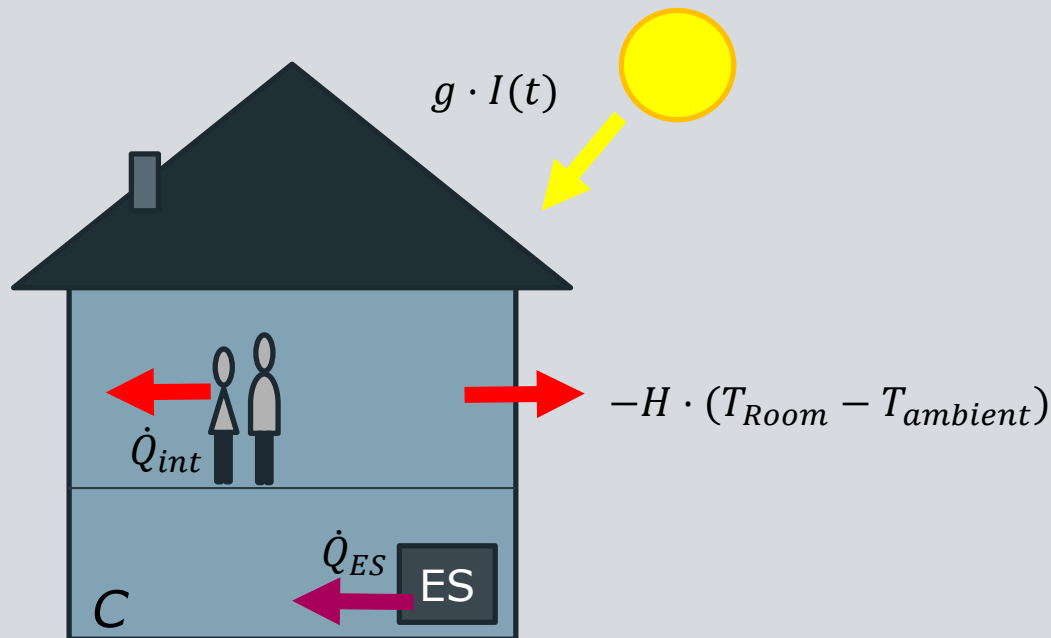
- Performance indicator
- Retrofitting planning

Policy makers:

- System models

Which building model?

Energy-balance model for dynamics of room temperature



Parameters:

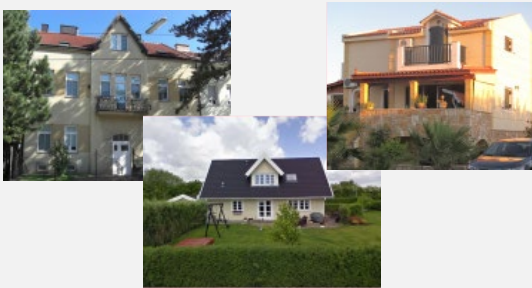
- Building capacity C
- Losses H
- Solar gain g
- Usage profiles

$$C \frac{\partial T_{room}}{\partial t} = -H (T_{room} - T_{ambient}) + gI + \dot{Q}_{internal} + \dot{Q}_{Es}$$

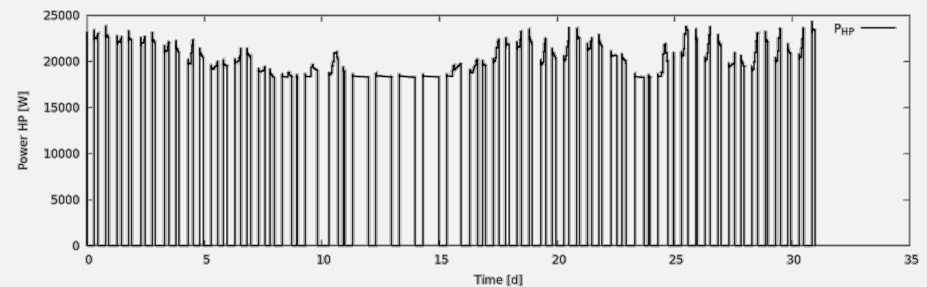
Adapted from H. Burmeister et al, Energy and Buildings 28, p.167-177, 1998.

How can we identify the building parameters?

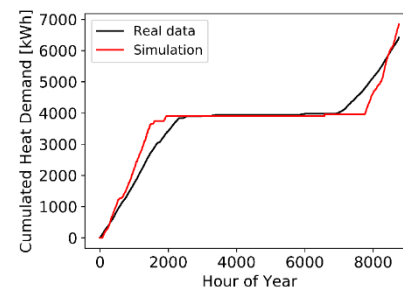
Building / heating system properties



Time resolved heat demand profile



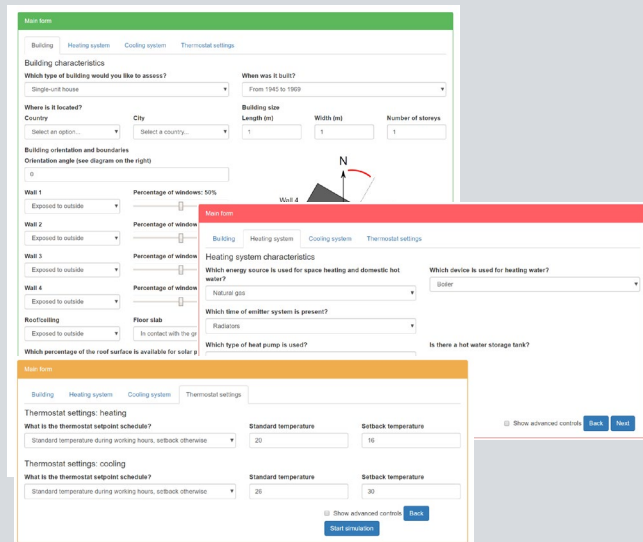
Optimise parameters based on L2-norm



Heat4Cool - Retrosim

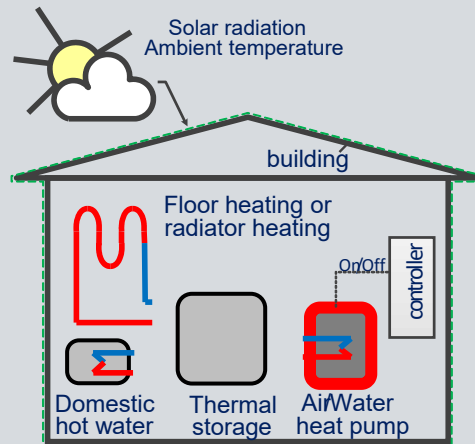
Retrofitting recommender tool

Simple User Interface



The screenshot shows the 'Main form' of the Retrosim tool. It is divided into several sections: 'Building characteristics' (including building type, location, and size), 'Building orientation and boundaries' (including orientation and boundaries), 'Heating system characteristics' (including heating system type, water source, and radiator type), and 'Thermostat settings' (including heating and cooling setpoint schedules). The interface is user-friendly with dropdown menus, checkboxes, and input fields.

Simulator



Assessment of different retrofit options

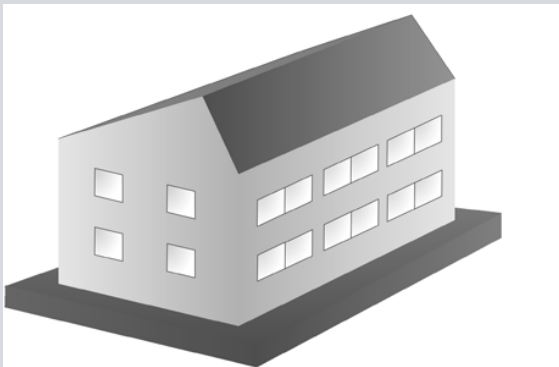


Does it work?

Self-consistency check:

Are parameters of reference simulations correctly reproduced?

Reference Buildings:



Single-family houses (SFH) in Zurich, CH

SFH15: Model for Minergy building
15 kWh/m²/a space heating demand

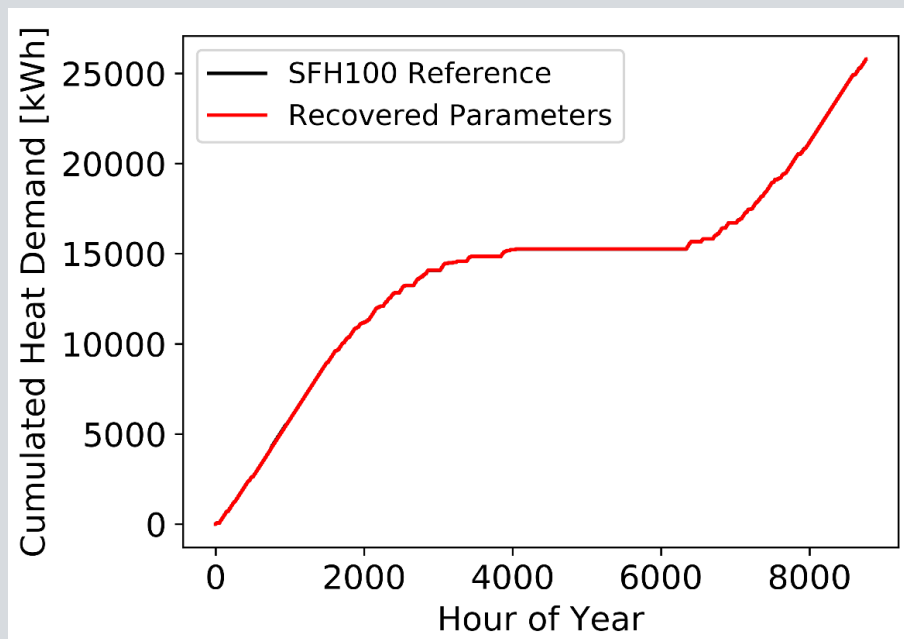
SFH45: Modern Swiss building
45 kWh/m²/a space heating demand

SFH100: Retrofitted building
100 kWh/m²/a space heating demand

Adapted from R. Dott, et al. The reference framework for system simulations of IEA SHC Task 44, HPP Anex 38, Part B, 2013

Reproduction of heating demand time series

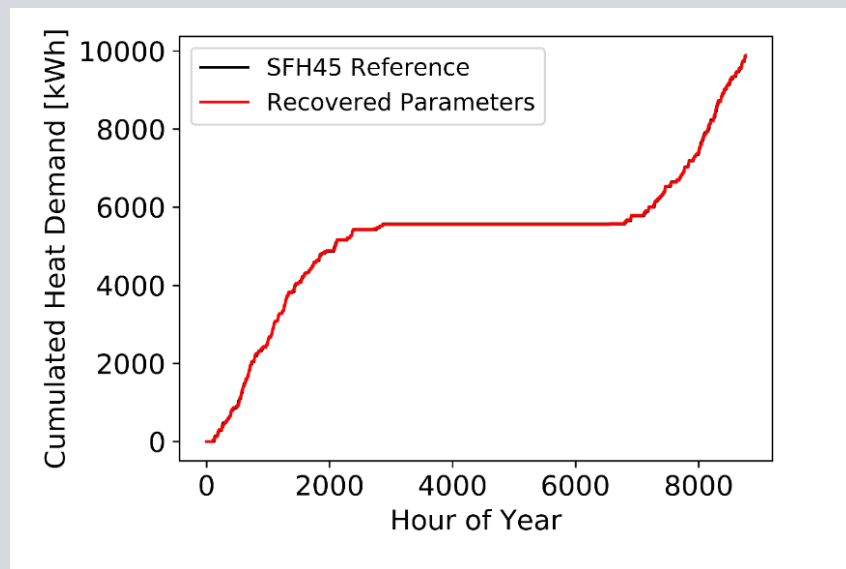
Cumulated space heating demand for SFH100



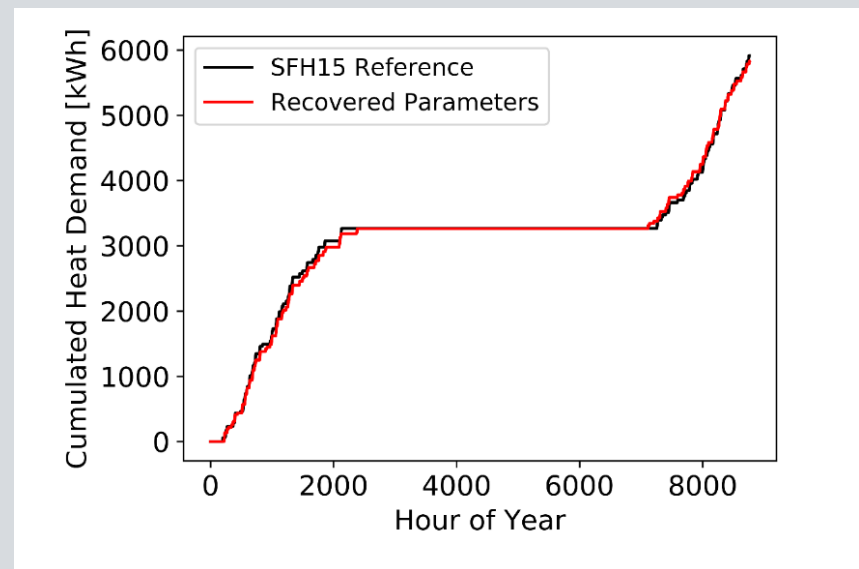
- Total annual space heating demand reproduced up to 4 kWh / 0.01%
- Undiscernible profiles for space heating demand of SFH100

What about the other reference buildings?

SFH45: Modern Building



SFH15: Minergy Building



Observations:

- Self-consistency check passed also for other building types
- Total annual space heating demand well reproduced
- Minor deviations for Minergy-type building

How are the building properties reproduced?

Deviations of extracted properties

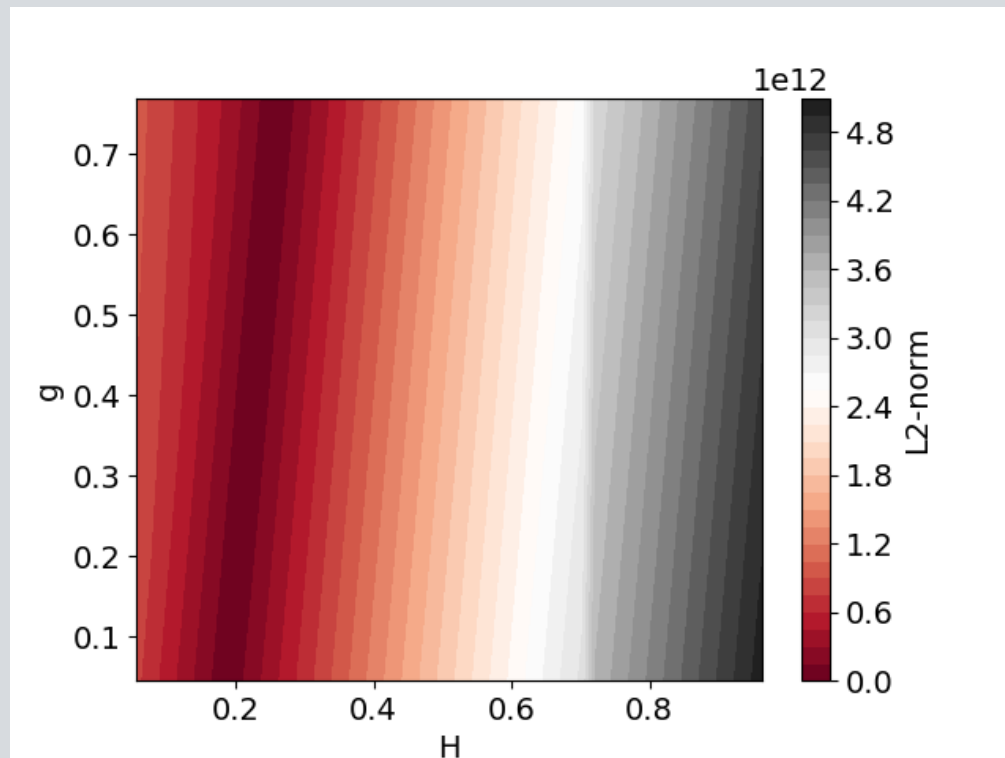
Parameter	SFH100	SFH45	SFH15
Losses H	- 1 %	+ 1 %	- 17 %
Solar gain g	- 1 %	+3 %	- 23 %
Capacity C	+ 8 %	- 25 %	- 12 %

Observations:

- Losses and solar gain of SFH100 and SFH45 accurately reproduced
- Capacity deviates strongly
- Parameters of Minenergy building consistently underestimated

How could we explain the deviations?

Deviations of simulated and actual heat demand time series

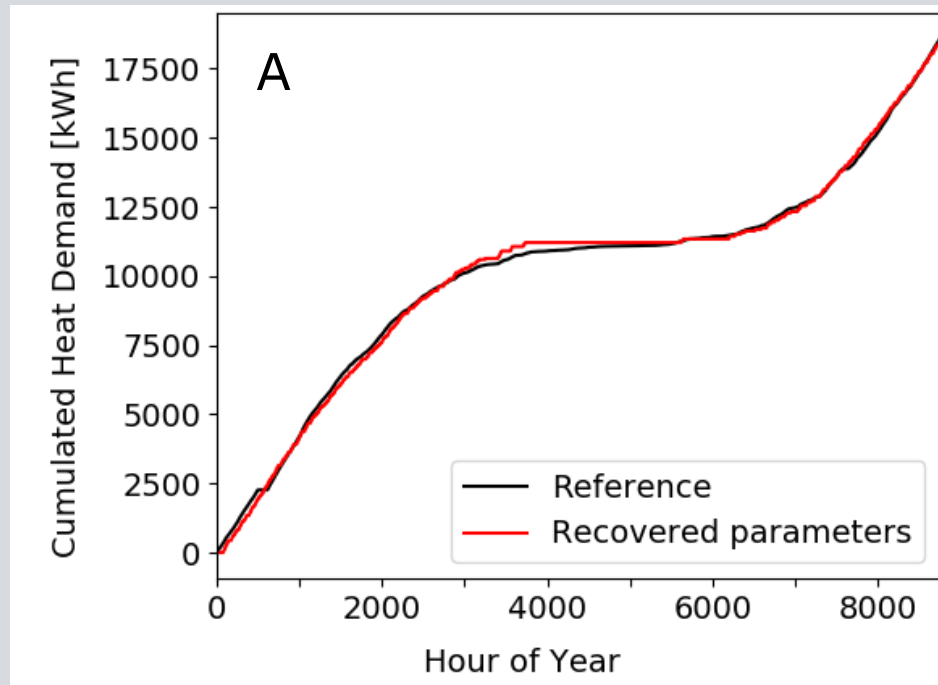


Observation:

Many pairs of solar gain G and losses H yield comparable values of the metric

Does it also work for real-world buildings?

Results real-world building in UK



Data source:

Monitoring campaign from Renewable heat premium payment scheme (RHPP)

Old building (<1919) with 4+ rooms and ground source HP

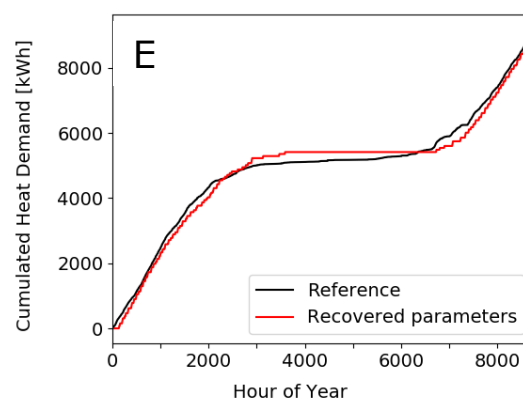
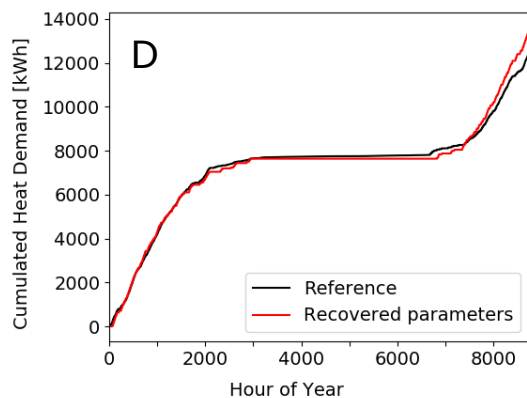
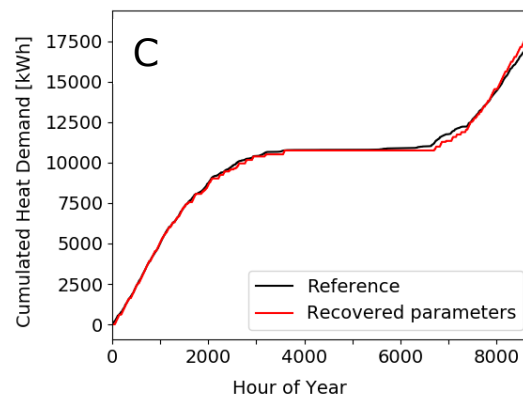
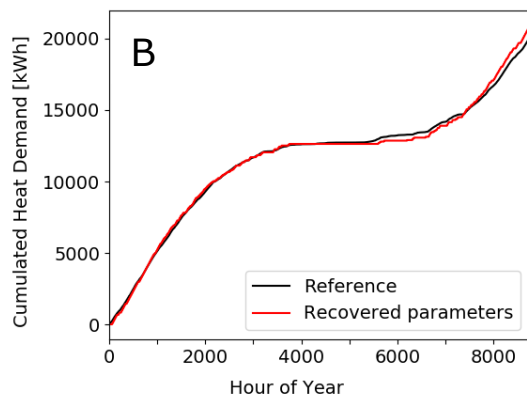
Observation:

Good reproduction of heat demand time series

Data from Lowe, R., Department of Energy and Climate Change. (2017). *Renewable Heat Premium Payment Scheme: Heat Pump Monitoring: Cleaned Data, 2013-2015*. [data collection]. UK Data Service. SN: 8151

Further results for RHPP data set

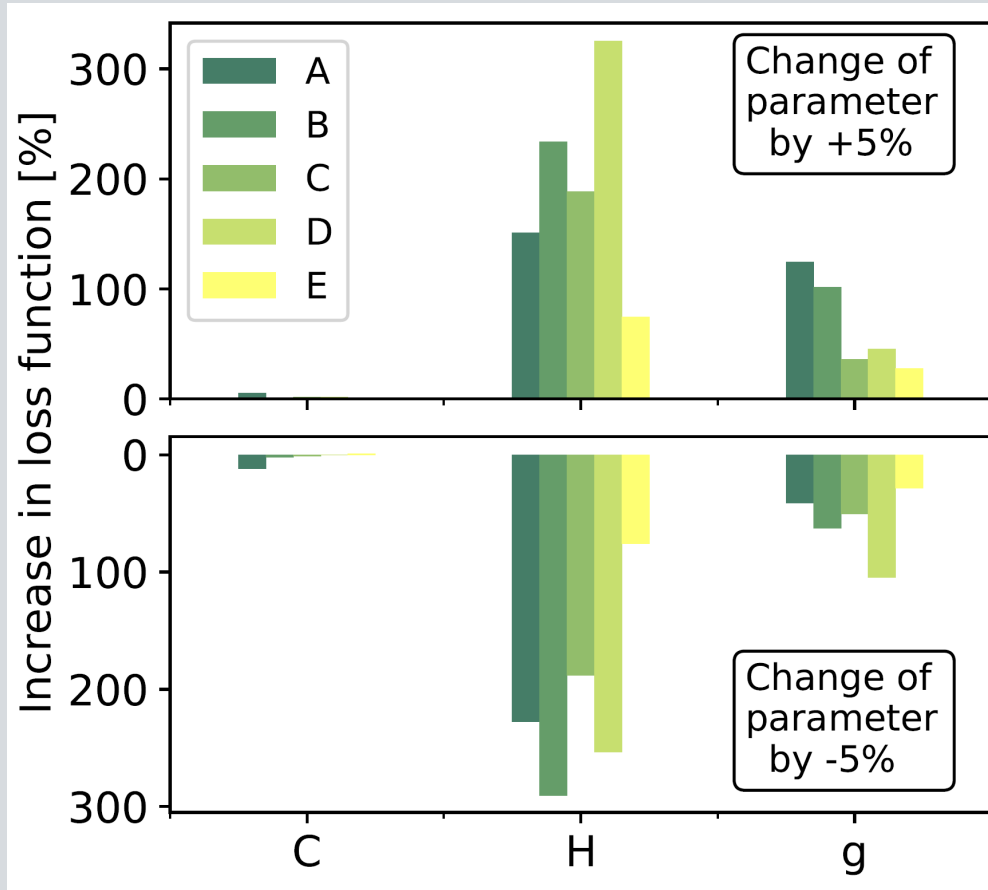
Results for 4 additional real-world buildings



Observation:
Good reproduction of total annual space heating demand and demand profile

ID	Deviation
A	-1 %
B	+4 %
C	+5 %
D	+9 %
E	-2 %

Sensitivity of parameters on loss function



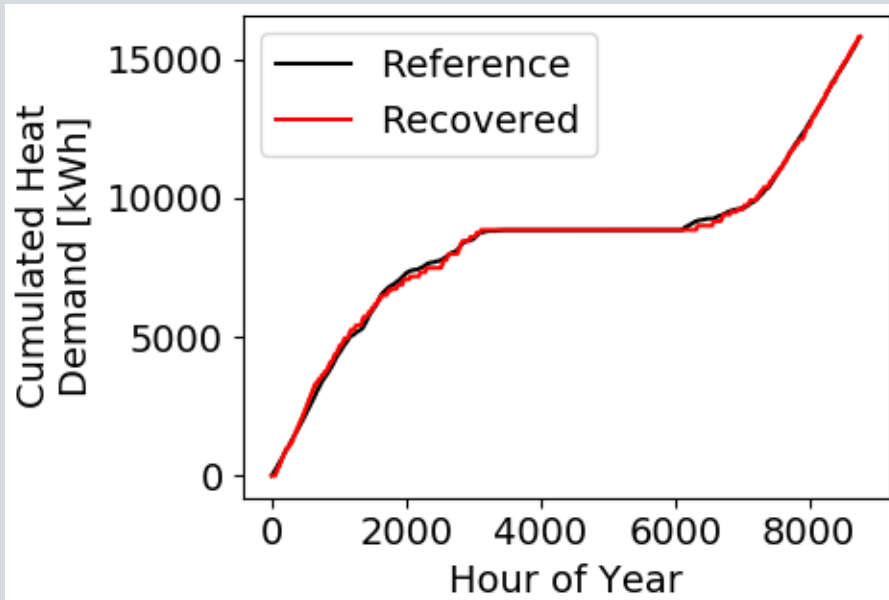
Question:

How much changes the L2-norm if building parameters are changes by +/- 5 %?

Observation:

- Losses have by far the biggest impact
- Capacity plays only a minor role
- Impact depends only slightly on considered building

Application on real-world smart meter data



Data set:

Real building in Bern (CH)
Power profile of heat pump

Observation:

Good reproduction of annual
heat demand and profile

Approach:

- Download temperature profiles of matching period from Meteosuisse
- Transform power to generated heat flux by COP table of heat pump

Conclusion and Outlook

Conclusions

- Modelling of a building from Smart Meter data is possible
- Dynamic behaviour can be reproduced accurately
- Extracted building properties for test cases match except for buildings with very low demand

Outlook

- Extraction of heat pump profile from aggregated measurement of whole building
- Comparison of extracted building parameters for real buildings

Acknowledgements



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Forschung und Innovation SBF**

Innosuisse – Swiss Innovation Agency

Lucerne University of
Applied Sciences and Arts

**HOCHSCHULE
LUZERN**



 **Storage**
Swiss Competence Centers
for Energy Research



tiko

