

Citywide hourly dynamic heat load forecasts using building archetype modeling

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SCOPE OF WORK:

1. To apply and demonstrate the application of a data-driven stochastic calibration methodology to infer physics-based building archetype models of a building stock.
2. Apply archetype building models to predict the hourly district heating energy use for an entire year.
3. Predictions are compared to actual meter readings.



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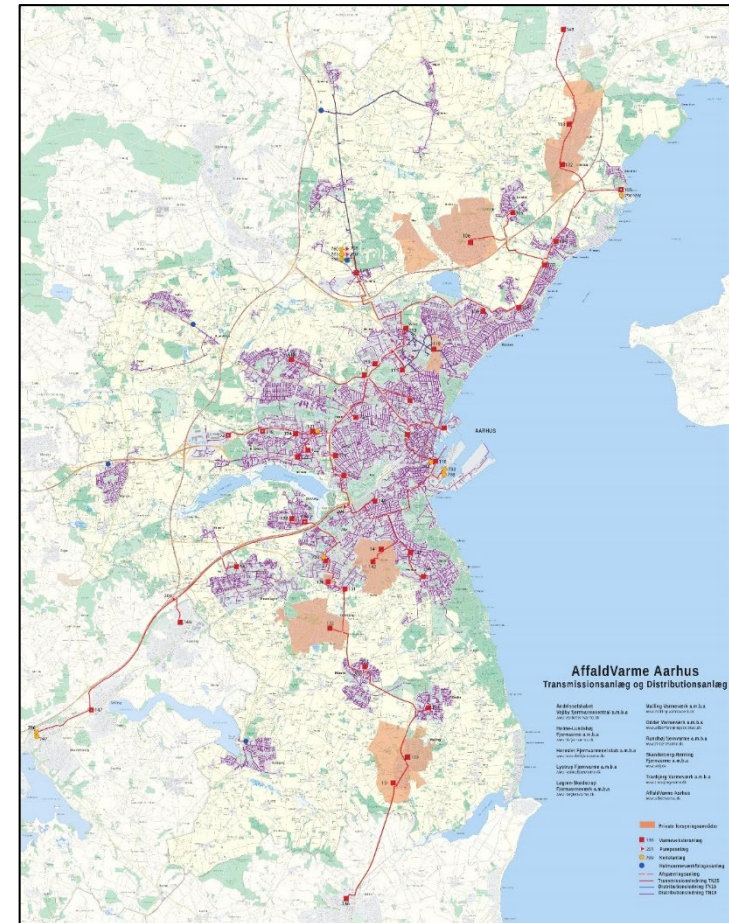


TEST CASE:

- District heating system of Aarhus, Denmark.
- 23,000 detached single-family houses (SFH's).
- Two years of hourly DH meter readings of all buildings.
 - 1-year training period: 1-1-2017 up until 31-12-2017.
 - 1-year testing period: 1-1-2018 up until 31-12-2018.



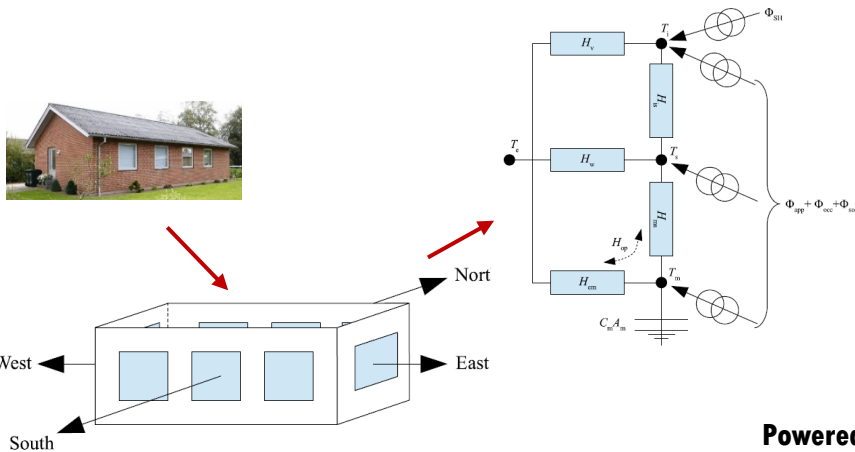
- “Danish Building Register” (BBR) data for all buildings (construction year, heated area, floors, etc.)
- Measured weather data during the two years.



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METHOD (1/2):

- Building stock was segmented into 11 archetypes.
- All buildings were assigned a geometric model, a heating energy model and a DHW model.



Archetype, k	Example	Building period	Segmentation argument
Archetype 1		Before 1851	
Archetype 2		1851-1930	Shift in building tradition
Archetype 3		1931-1950	Cavity walls introduced
Archetype 4		1951-1960	Insulated cavity walls introduced
Archetype 5		1961-1972	First energy requirements in BR1961
Archetype 6		1973-1978	Tightened energy requirements in BR1972
Archetype 7		1979-1998	Tightened energy requirements in BR1978.
Archetype 8		1999-2006	Tightened energy requirements in BR1998.
Archetype 9		2007-2010	Tightened energy requirements in BR2006/BR2008
Archetype 10		2011-2015	Tightened energy requirements in BR2010
Archetype 11		After 2015	Tightened energy requirements in BR2015

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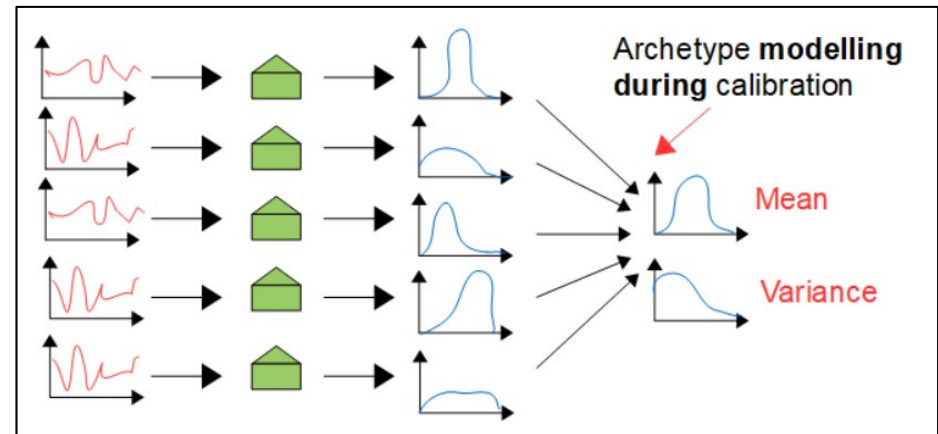


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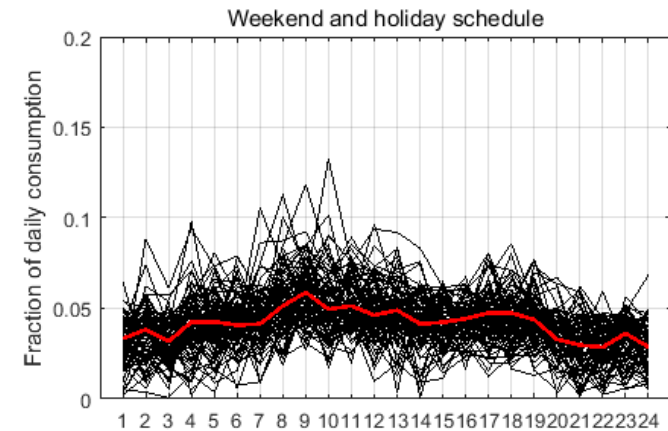
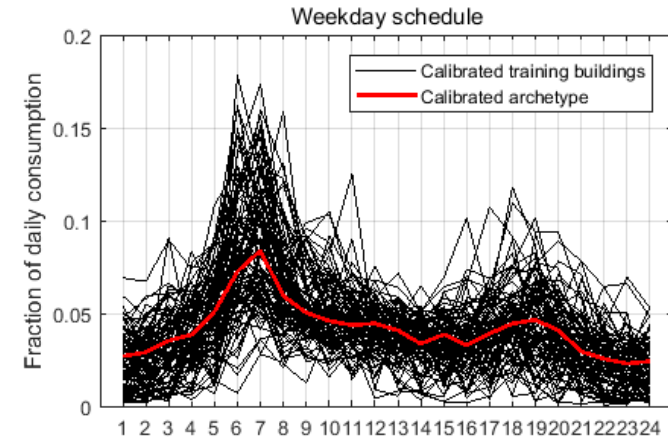
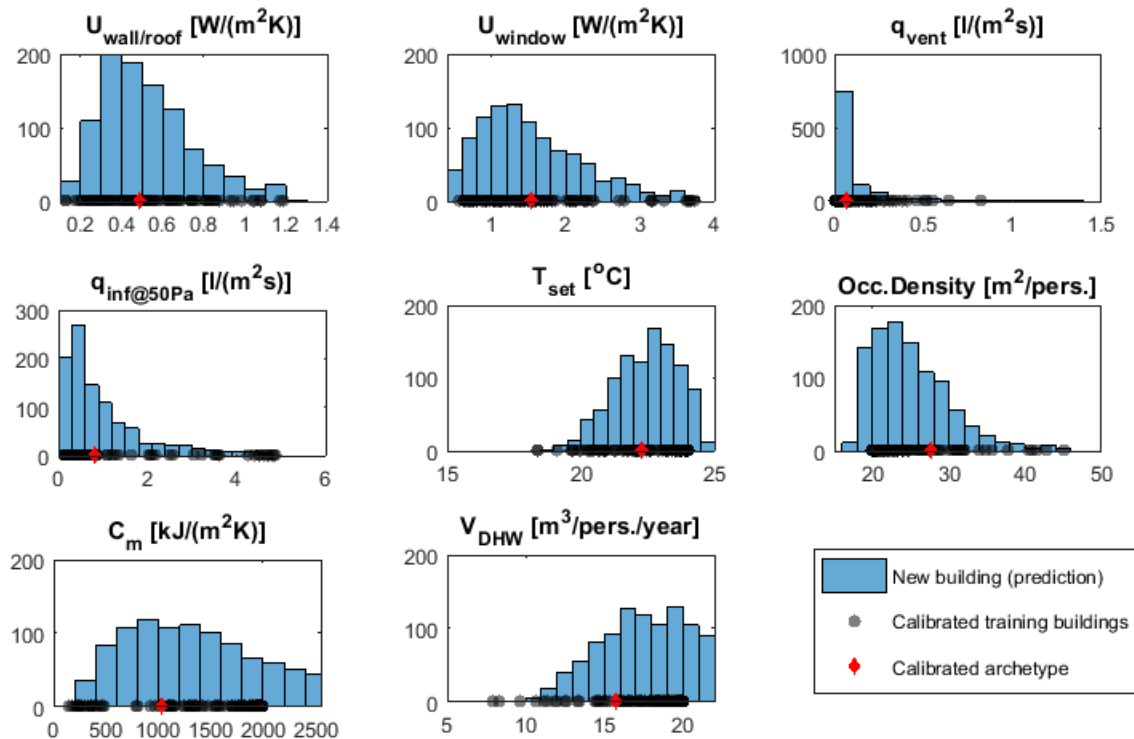
METHOD (2/2):

- Uncertain model input parameters were identical for all buildings within archetypes.
- The stochastic calibration methodology (see paper) was applied to tune 8 model input parameters per archetype.
- Hourly heating data from 100 training buildings per archetype.



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RESULTS (1/3):



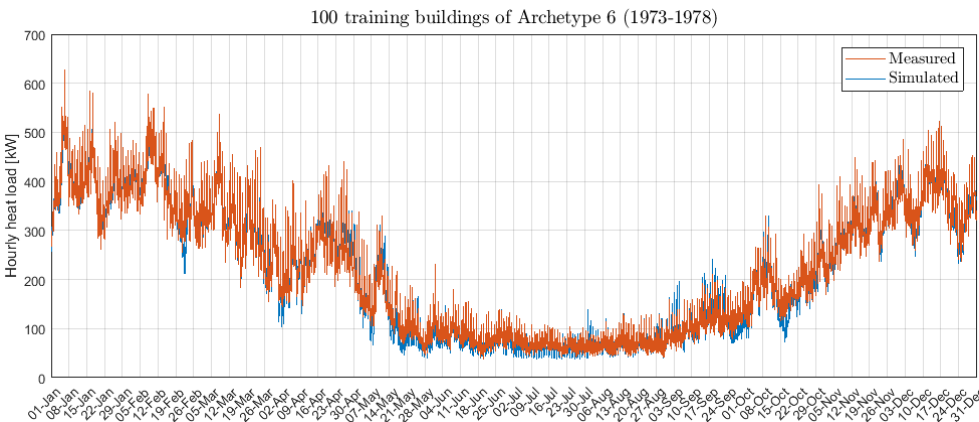
RESULTS (2/3):

- Predictive performance for Archetype 6 (1973-1978).
- Similar results for the other archetypes.

100 archetype **training** buildings calibrated using 2017 data.

Accuracy:

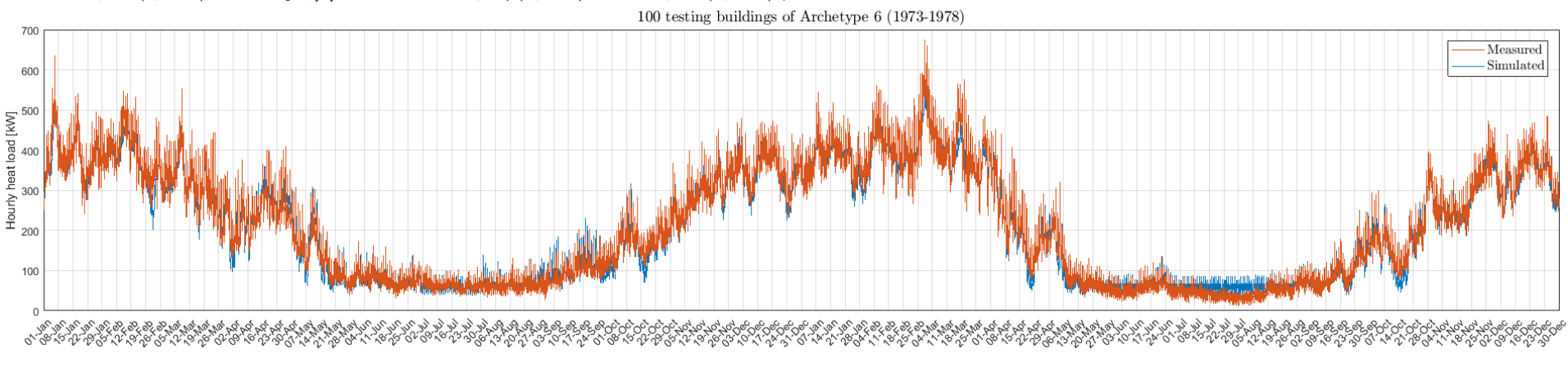
- Bias < 1%
- Hourly absolute error < 10%



100 **holdout testing** buildings predicted for 2017+2018

Accuracy:

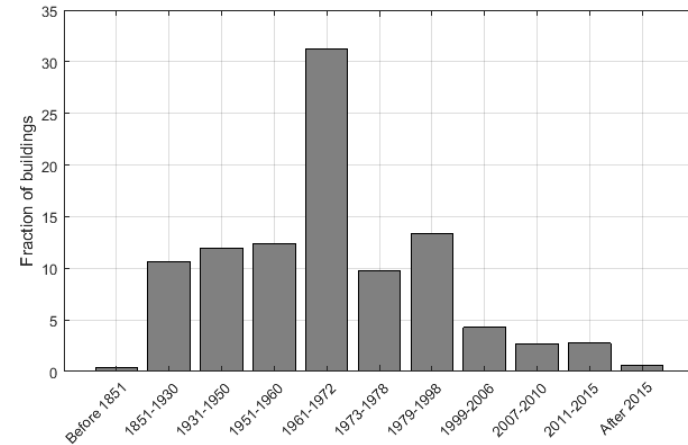
- Bias < 2%
- Hourly absolute error < 15%



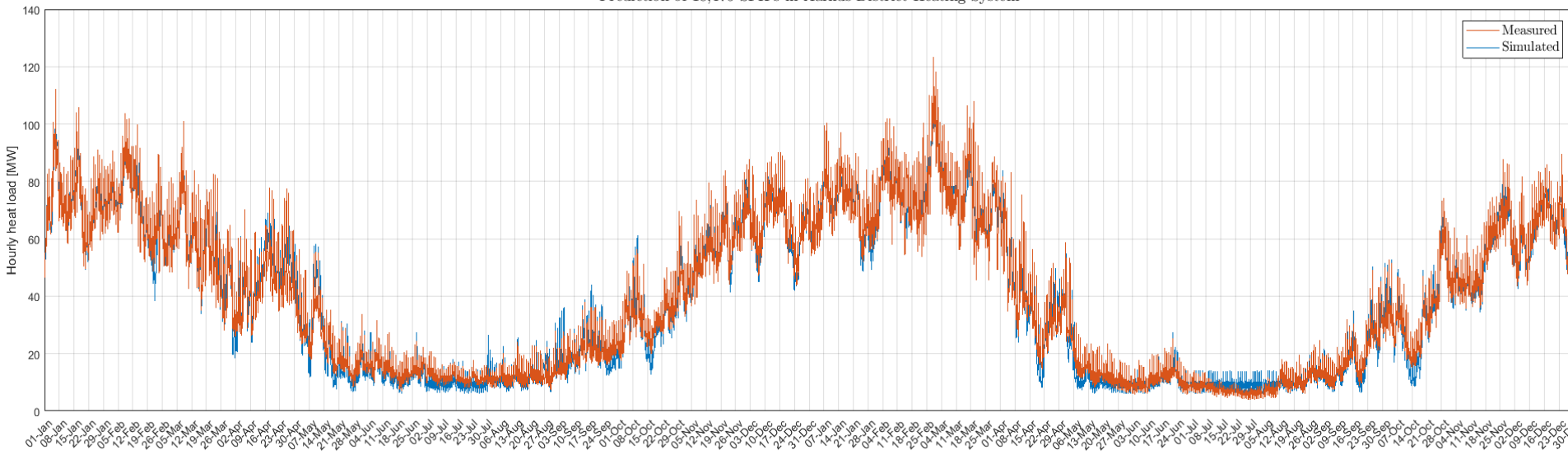


RESULTS (3/3):

- Prediction of aggregated heat load of SFH's in Aarhus.
- Validation data for 18,475 SFH's were available.
- Simulation time on laptop for 100 stochastic repetitions: Approx. 4 hours.
- Prediction accuracy:
 - Mean bias: -0.3%.
 - Mean absolute hourly error: 11.8%.









Prediction of 18,475 SFH's in Aarhus District Heating System



APPLICATIONS OF FRAMEWORK

- Short-term heat load forecasts:
 - Daily and weekly forecasts of the production needs in any geographic area of the network.
 - Only weather forecasts are needed for predicting building heat loads once archetypes are calibrated.

- Strategic energy planning and analysis:
 - Sizing district heating networks for new urban areas.
 - Analyzing the effects of energy renovation of different archetypes.
 - Analyzing the effect of demand response and energy flexibility of the building stock.
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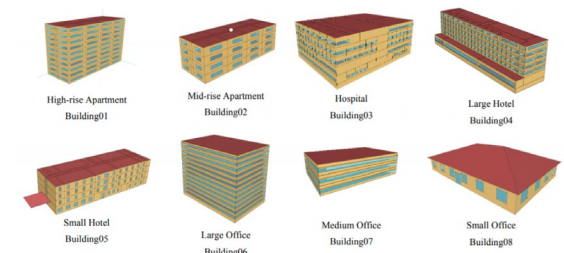
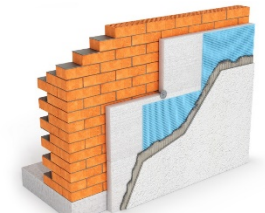
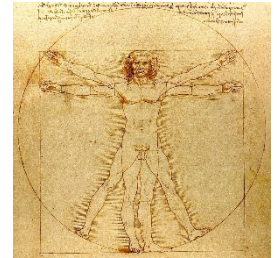
Thu Jun 12	Fri Jun 13	Sat Jun 14	Sun Jun 15	Mon Jun 16	Tue Jun 17
Variable cloudiness	Isolated showers	Isolated showers	Cloudy periods	Cloudy periods	Isolated showers
					
20 °C	18 °C	18 °C	20 °C	19 °C	18 °C



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FUTURE WORK

- Improving model behaviour:
 - Better representation of DHW consumption (maybe a seasonal effect?)
 - Trueness of parameter identification (additional measurement parameters in training buildings?)
- Other building categories:
 - It may be difficult to apply the archetype modeling approach to non-domestic buildings, such as factories, shops and buildings used for cultural applications.



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Thank you for your attention

Martin Heine Kristensen



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