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REDUCEDHEATCARB

Research on Energy Data Utilization for Carbon Emission Decline by Heat pumps and Efficiency, while Assuring Thermal Comfort Achievement in Residential Buildings

Who?

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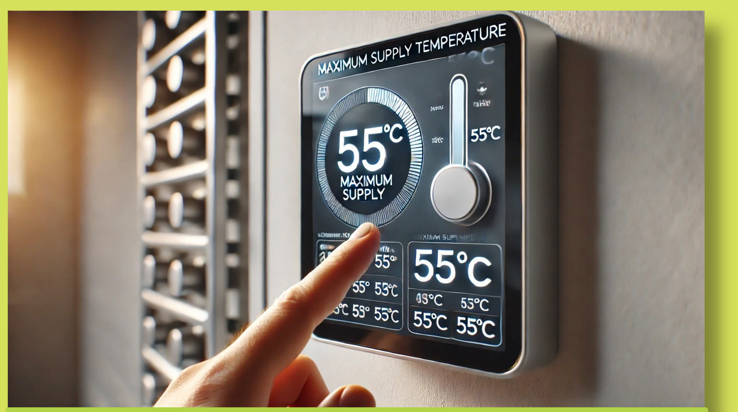
What?

Can we predict the expected effect of the interventions below for a specific home using a few weeks of monitoring data, more accurately than label inspections or address-specific data from online registries? Is online thermostat data sufficient, or do we also need smart meter or additional measurement device data?

Heating Interventions

Lower thermostat program



Lower maximum supply temperature

Switch to hybrid heat pump

Switch to all-electric heat pump

Data Collection

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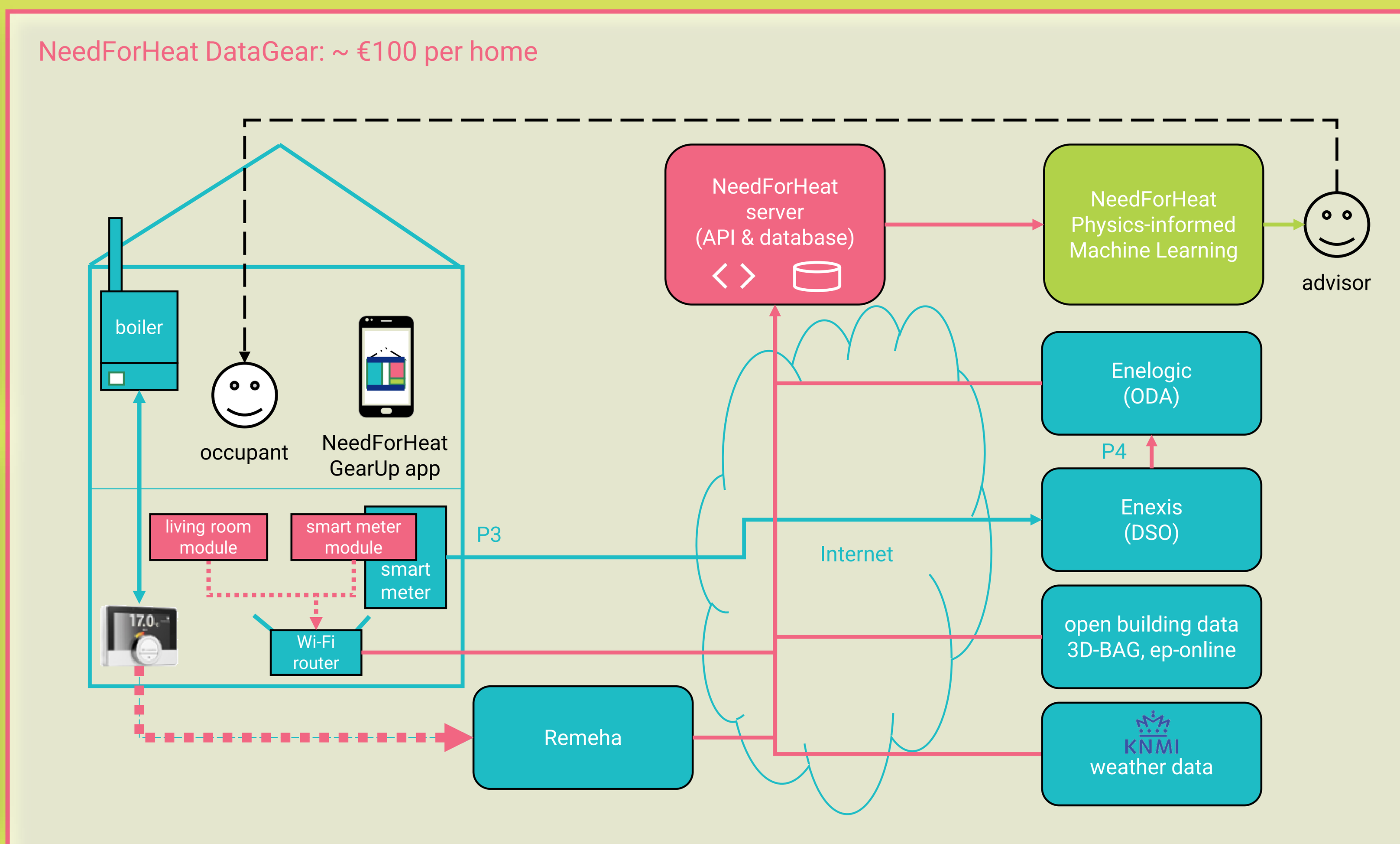
Open-source software & hardware

smart meter module

living room module



Time Series Data Collected

Category	Measured Data	Remeha	KNMI	Enelogic	Living R.	Smart M.
Comfort	setpoint temperature & program	✓				
	indoor temperature	✓			✓	
Weather	outdoor temperature	✓	✓			
	wind		✓			
	sunshine: global horizontal irradiation		✓			
Installation	supply & return temperature	✓				
	load, CH/DHW, max supply temperature	✓				
Energy	electricity used & returned			✓		✓
	gas used			✓		✓
Occupancy, Ventilation	CO_2 concentration				✓	
	occupancy (Bluetooth presence)				✓	

Subjects & Data

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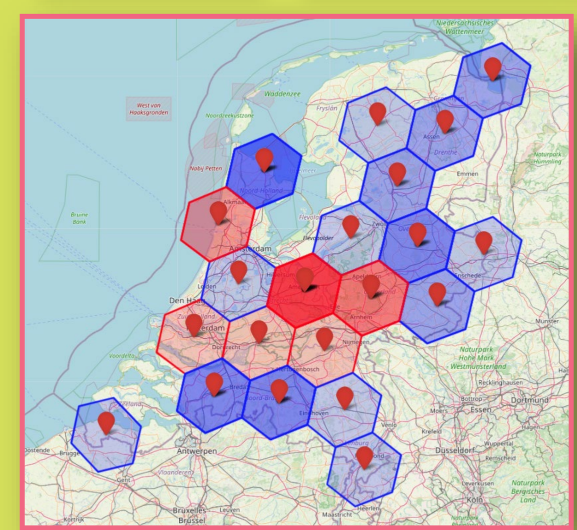
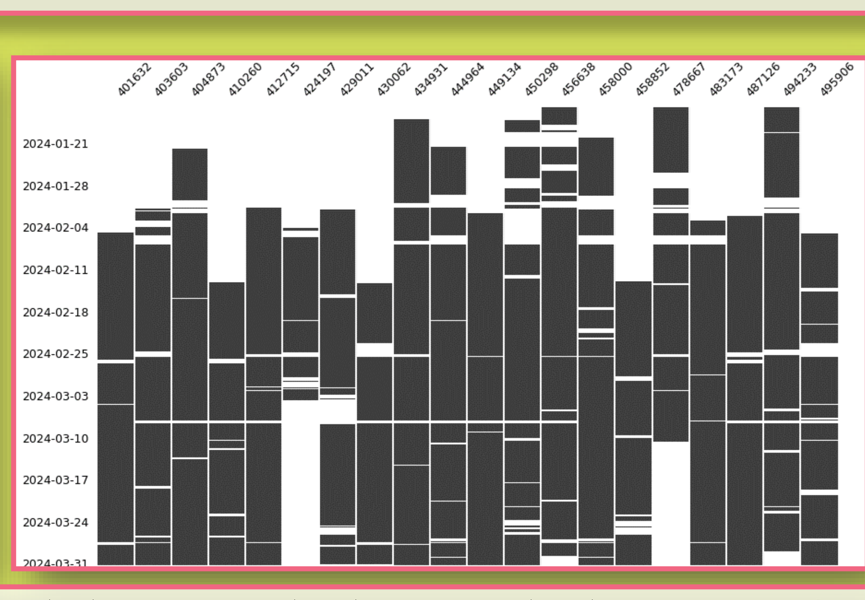
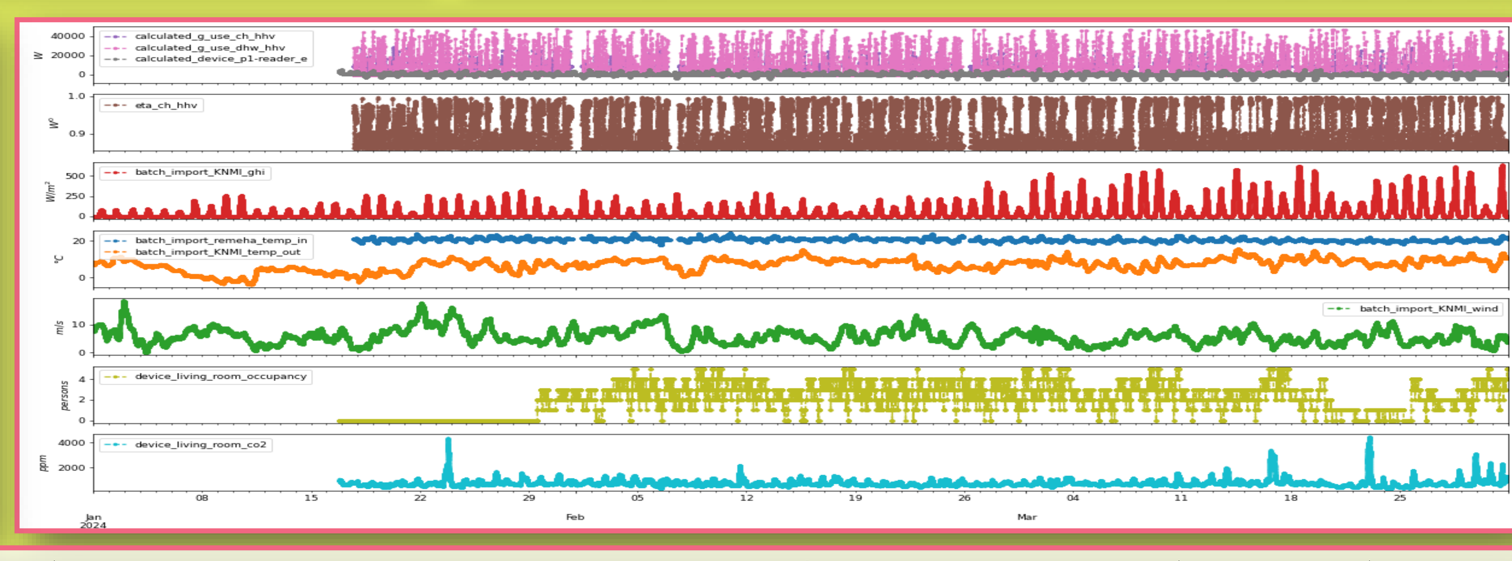
Dataset & metadata







3350 homes invited; 171 survey responses (5%); 45 included (26%); 42 invited (93%); 20 monitored fully (48%); 52.7 M data points measured; 49.9 M sane; 350 M after temporal interpolation (1 min interval)

Analysis Method

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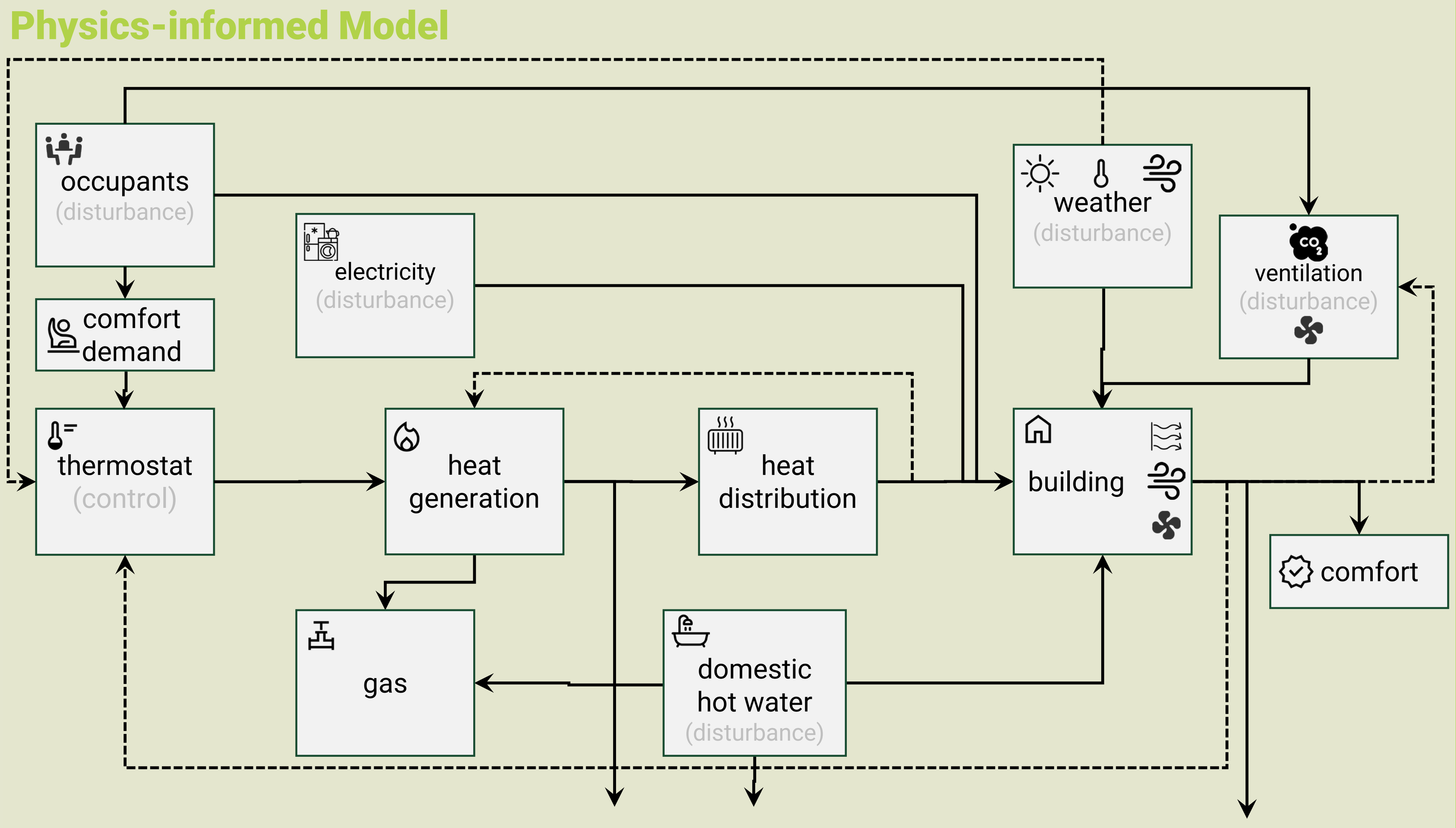
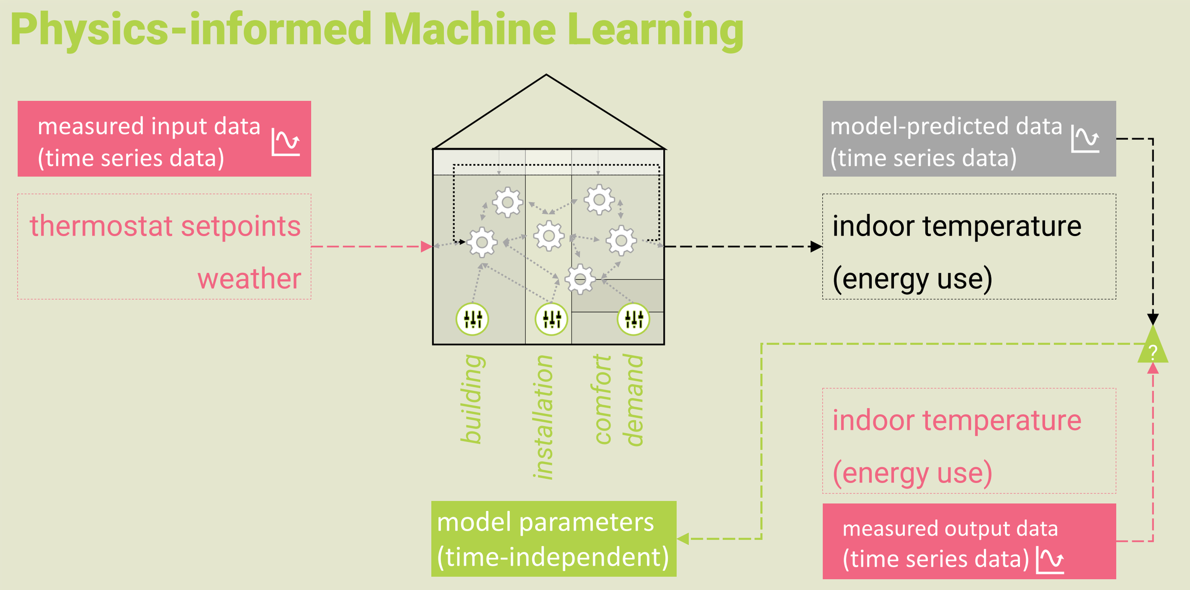
GEKKO Python model implementation

Physics-informed Model



Physics-informed Machine Learning



GEKKO Python Model Implementation (Core)

```
heat_gain_bldng__W = m.Intermediate(heat_dist__W + heat_sol__W + heat_int__W)
heat_loss_bldng__W = m.Intermediate(heat_loss_bldng_cond__W + heat_loss_bldng_inf__W + heat_loss_bldng_vent__W)
heat_tr_bldng__W_K_1 = m.Intermediate(heat_tr_bldng_cond__W_K_1 + heat_tr_bldng_inf__W_K_1 + heat_tr_bldng_vent__W_K_1)
th_mass_bldng__Wh_K_1  = m.Intermediate(heat_tr_bldng__W_K_1 * th_inert_bldng__h)
m.Equation(temp_indoor__degC.dt() == ((heat_gain_bldng__W - heat_loss_bldng__W)  / (th_mass_bldng__Wh_K_1 * s_h_1)))

m.options.IMODE = 5        # Simultaneous Estimation
m.options.EV_TYPE = 2      # RMSE
m.solve(disp=False)
```

Preliminary Results

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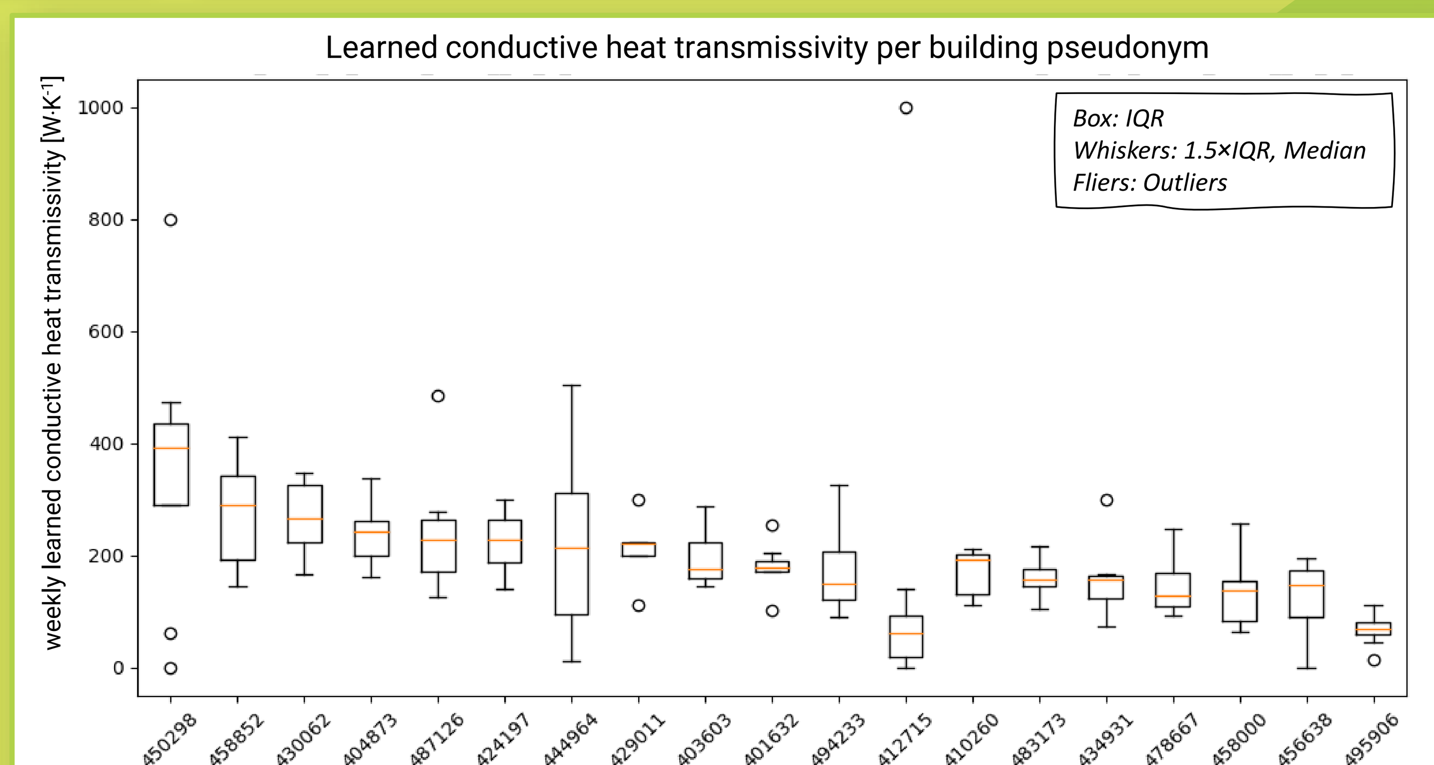
Scan for more results

Heat Performance Signature: Parameters to Learn

Scope	Symbol	Unit	Description
Building	$H_{bldng;cond}$	$W \cdot K^{-1}$	Conductive heat transmissivity of the building
	C_{bldng}	$Wh \cdot K^{-1}$	Thermal mass of the building
	τ_{bldng}	h	Thermal inertia of the building
	A_{sol}	m^2	Effective total horizontal solar aperture
	A_{inf}	m^2	Effective total infiltration aperture of the building
Heat Generation	$\eta_{ch;hhv}$	W^0	Average efficiency of the heat generation system
Heat Distribution	H_{dist}	$W \cdot K^{-1}$	Heat transmissivity of the heat distribution system
	C_{dist}	$Wh \cdot K^{-1}$	Thermal mass of the heat distribution system
	τ_{dist}	h	Thermal inertia of the heat distribution system
Comfort	$T_{set;avg}$	$°C \cdot wk^0$	Comfort Demand: time-weighted average temperature setpoint
	$\Delta T_{in;out;avg}$	$K \cdot wk^0$	Heat Demand: time-weighted average indoor-outdoor difference
	f_{comf}	wk^0	Comfort: proportion of time indoor temperature in comfort zone



Preliminary Conclusions

- **Building parameters:** Can be learned from a few weeks of data.
- **Heat generation efficiency:** Calculable from monitored data.
- **Ventilation:** Learnable from CO_2 and occupancy but may not significantly enhance heat loss predictions.

- **Heat distribution parameters:** Learning in progress.
- **Compare intervention prediction with label inspections and address-specific data:** Future task.
- **Online thermostat data sufficiency:** Future task.