Field validation of house rating software predictions and Darwinian's thermal comfort thresholds

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Validation

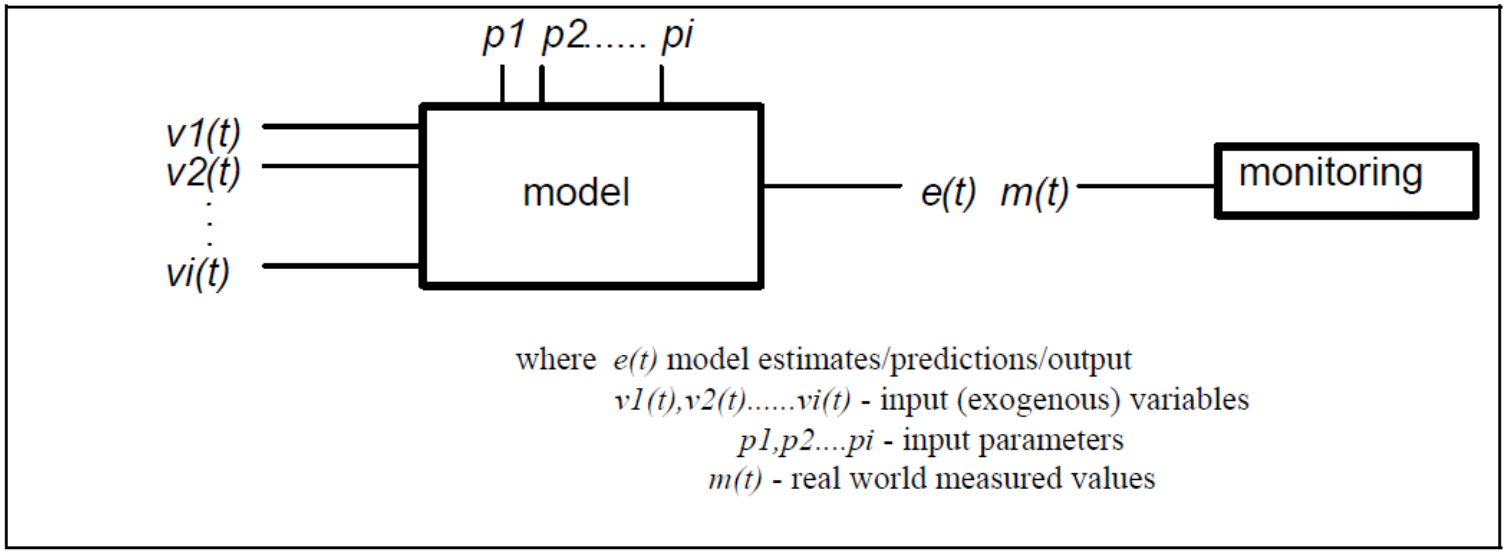
Any assessment of a proposed dwelling to evaluate the extent of possible overheating relies on one important issue – that, with sufficient accuracy, the complex software model reliably approaches the reality of behaviour.

Empirical field validation of a thermal performance simulation program looks at the correspondence between reality as measured (or at least a sub-system of reality) and the model predictions.

The program we are talking about is the NatHERS energy-efficient software developed by CSIRO.

Specifically the simulation engine known as Chenath.

A thermal simulation program can be considered a black box model. The model is a computer code describing the complex physics of heat flow, air flow and the occupant use of the building, all of which can vary with time.



- The input parameters *(pi)* include things like the dimensions of the building, the thermal properties of materials, thermostat settings, etc
- The Input variables (*vi (t)*) include the weather, the occupant use patterns, etc
- Validation is about seeing how close the output *e(t)* matches the measured data *m(t)*

Empirical Validation References

1. ASHRAE standard 140-2014. Standard 140-2014: Standard Method of Test for the Evaluation of Building Energy Analysis Computer Programs. ASHRAE, Atlanta, Georgia, USA, 2014. 552

2. Cowan J. *International Performance Measurement & Verification Protocol.* Volume 1 The U.S. Department of Energy; Springfield, VA, USA: 2002. International performance measurement and verification protocol: Concepts and Options for Determining Energy and Water Savings-Vol. I.

3. International Energy Agency (2016), Reliable building energy performance characterisation based on full scale dynamic measurements, EBC Annex 58, Belgium.

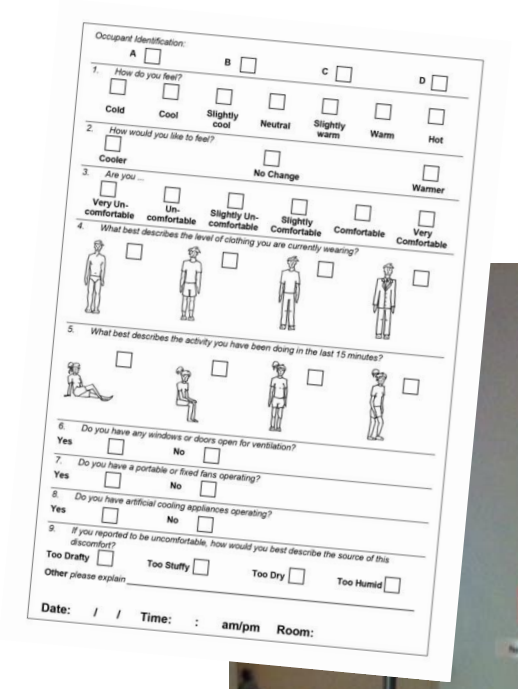
Monitoring

We are relying on data collected in Darwin houses during two PhD projects.

- Daniel monitored 20 households (designed to be naturally ventilated) located in Darwin and surrounds including Palmerston and Howard Springs areas, from June 2013 to May 2014.
- During the period March 2020 to February 2021, Damiati, conducted a similar monitoring exercise in Darwin and surrounding areas, that included a number of houses in the Palmerston, Howard Springs and Wagait Beach areas. In this case 30 houses and 8 apartments were included in the study.
- In each study the conditions in living rooms and main bedroom were monitored at 30 minute intervals. Included temperature (dry bulb & globe), humidity & air-speed.
- In each study the occupants completed thermal comfort surveys. In 2013/14 ,N=2415 and in 2020/21, N=4996.
- The 30 minute weather data for each study was taken from the BOM station closest to the house. Included temperature, humidity, wind & solar radiation.

Monitoring Equipment

2013/14


Occupant Identification:

A B C D

1. How do you feel?

Cold | Cool | Slightly cool | Neutral | Slightly warm | Warm | Hot

2. How would you like to feel?

Cooler | No Change | Warmer

3. Are you ...

Very Uncomfortable | Uncomfortable | Slightly Uncomfortable | Slightly Comfortable | Comfortable | Very Comfortable

4. What best describes the level of clothing you are currently wearing?

5. What best describes the activity you have been doing in the last 15 minutes?

6. Do you have any windows or doors open for ventilation?

Yes | No

7. Do you have a portable or fixed fans operating?

Yes | No

8. Do you have artificial cooling appliances operating?

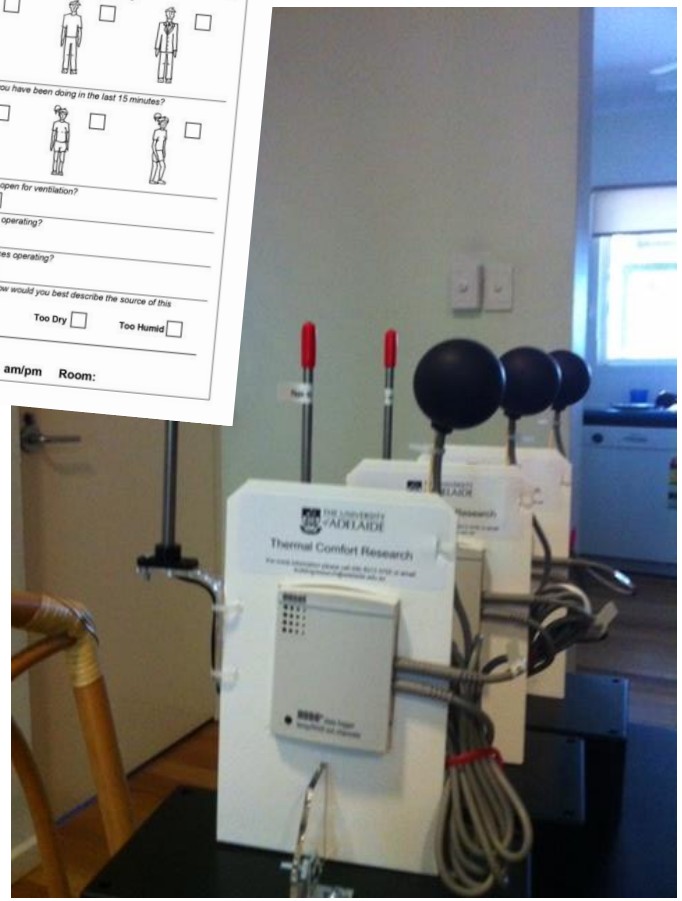
Yes | No

9. If you reported to be uncomfortable, how would you best describe the source of this discomfort?

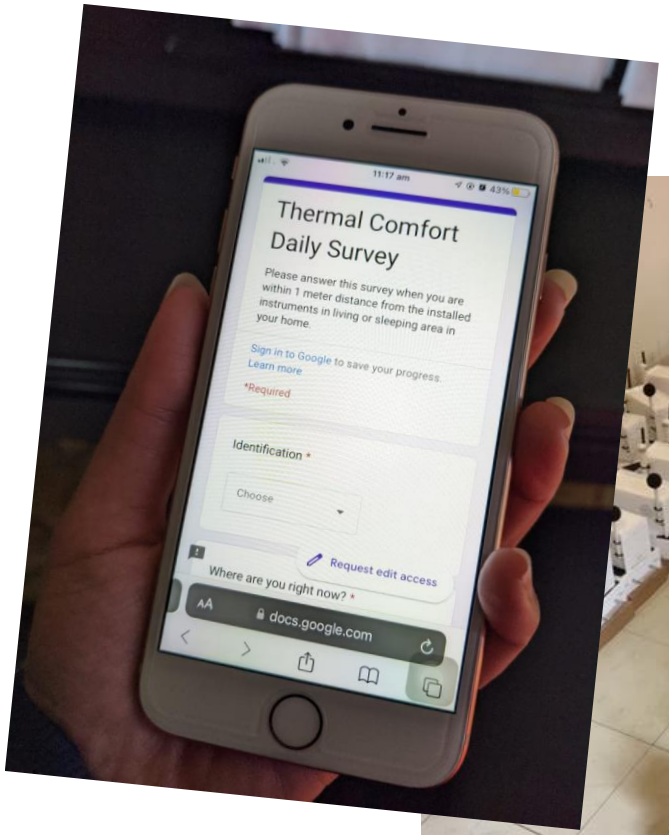
Too Drafty | Too Stuffy | Too Dry | Too Humid

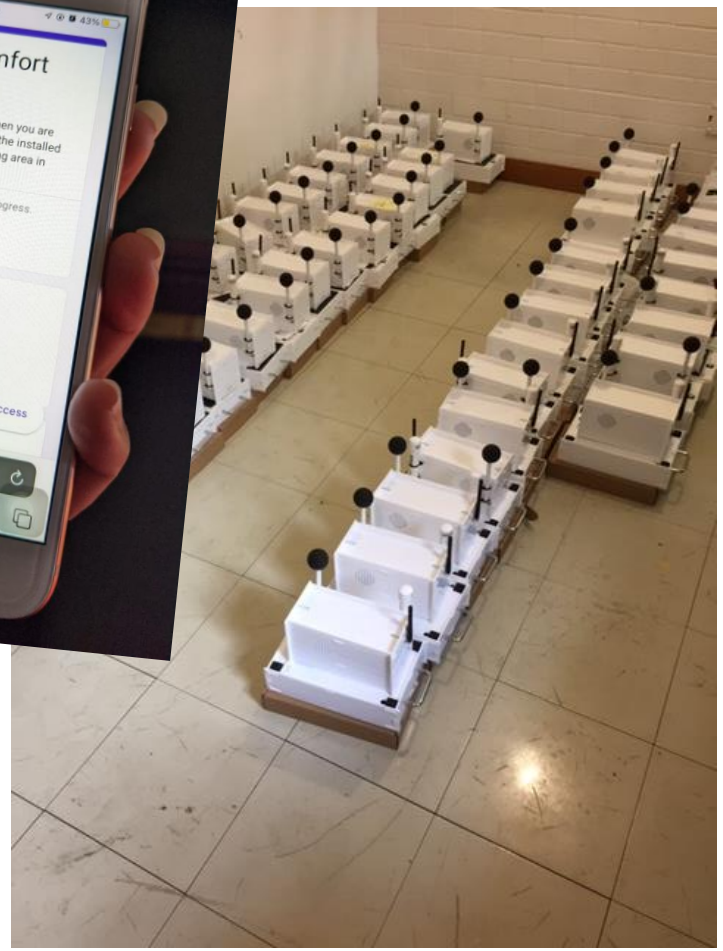
Other please explain

Date: / / Time: : am/pm Room:



2020/21





Some of the Houses Monitored

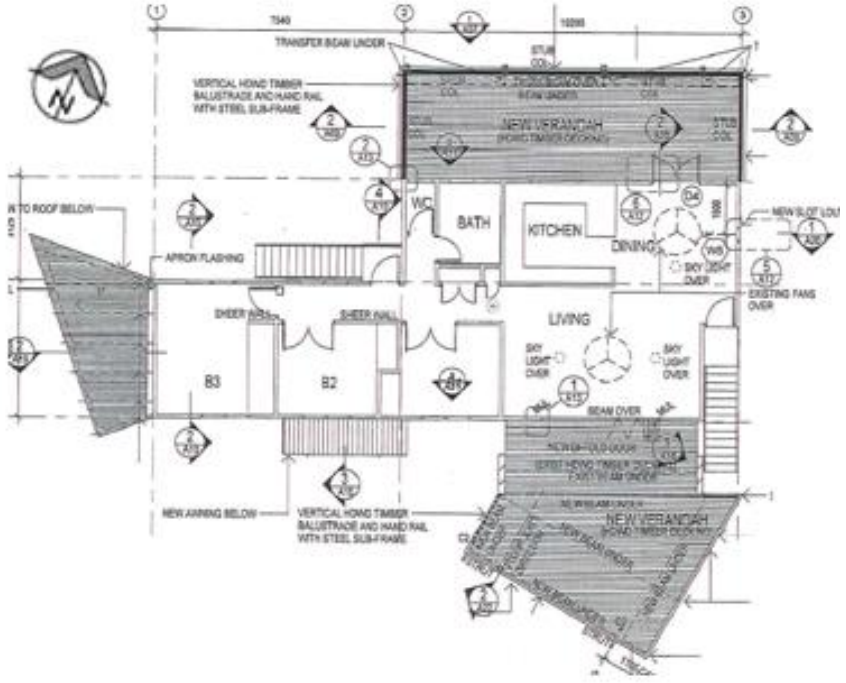
Validation of *Chenath* software

The question –

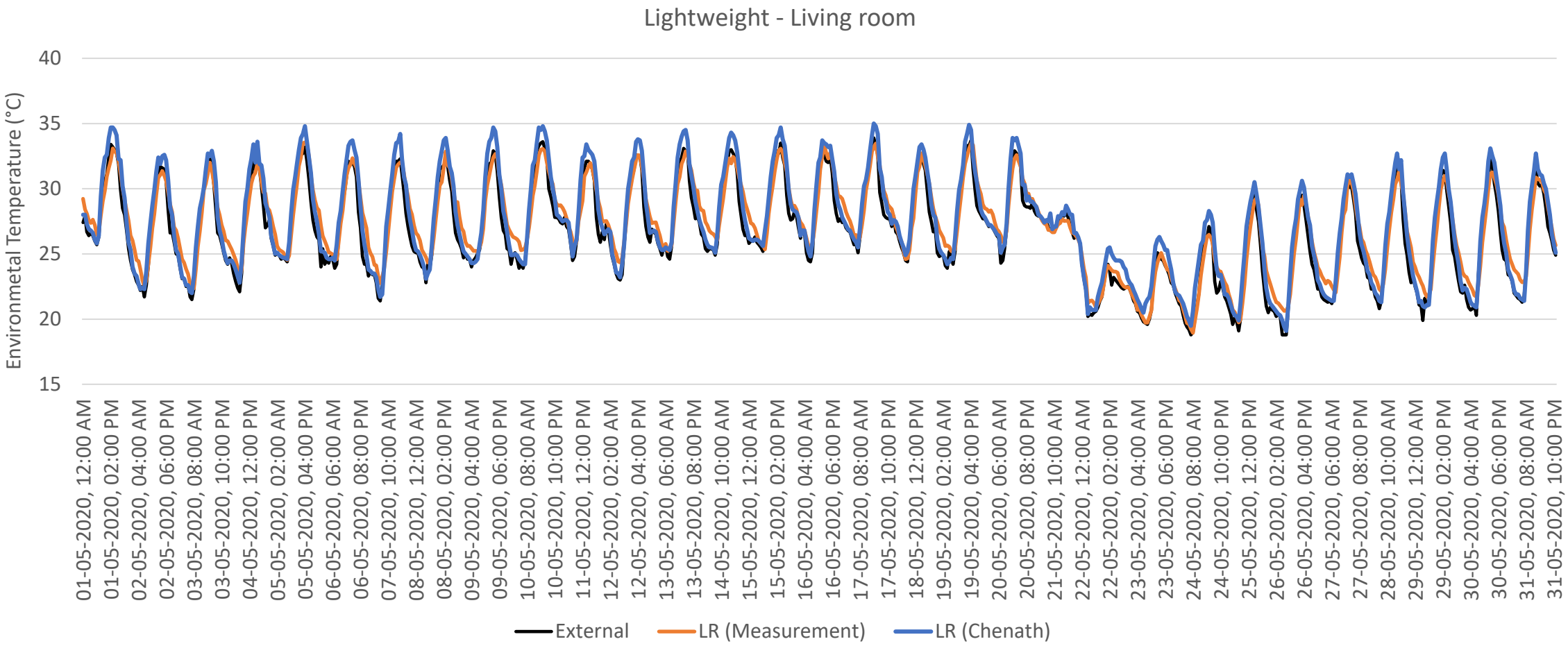
“Can the Chenath software reliably predict the temperatures in a range of building types?”

House 38 – High-set Lightweight

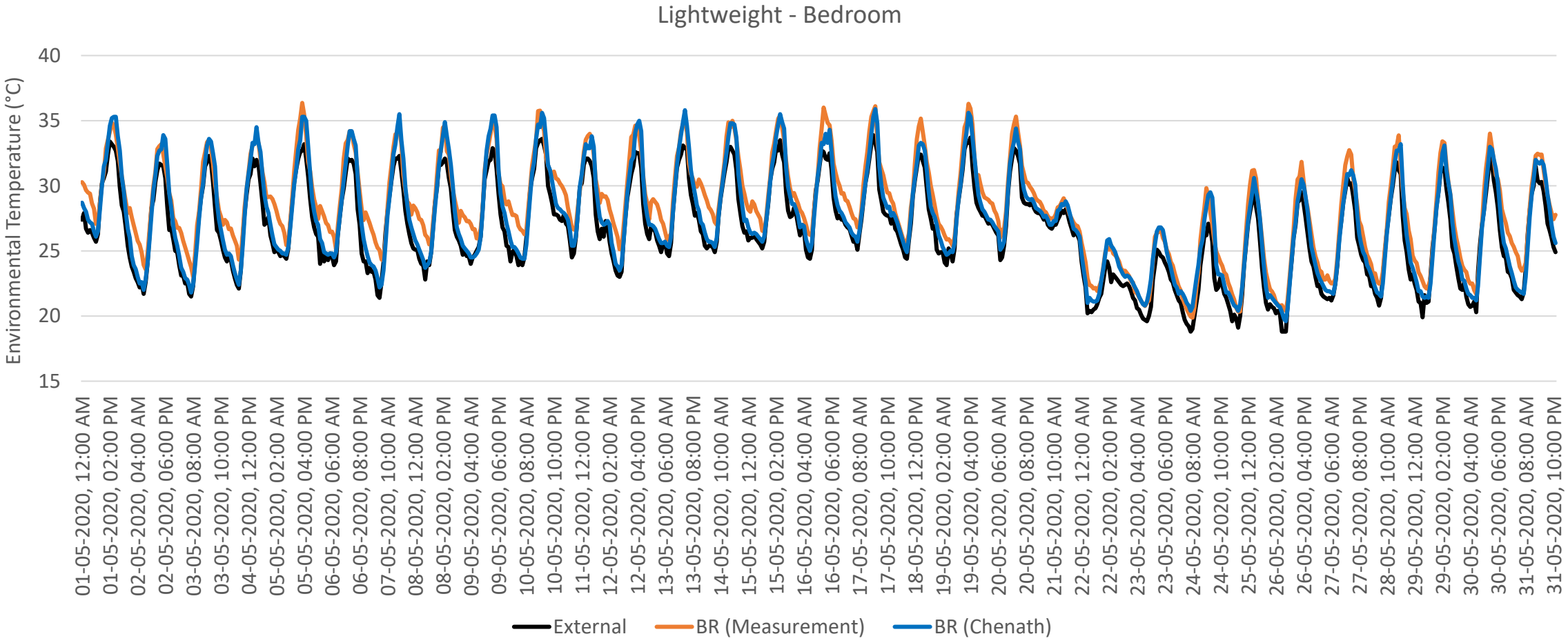
A modified Northern Territory Housing Commission House Type H18. Lightweight construction, louver windows, timber floors. Houses built in this era typically had reflective foil, only, in their roofs and walls.



House 38 – High-set Lightweight

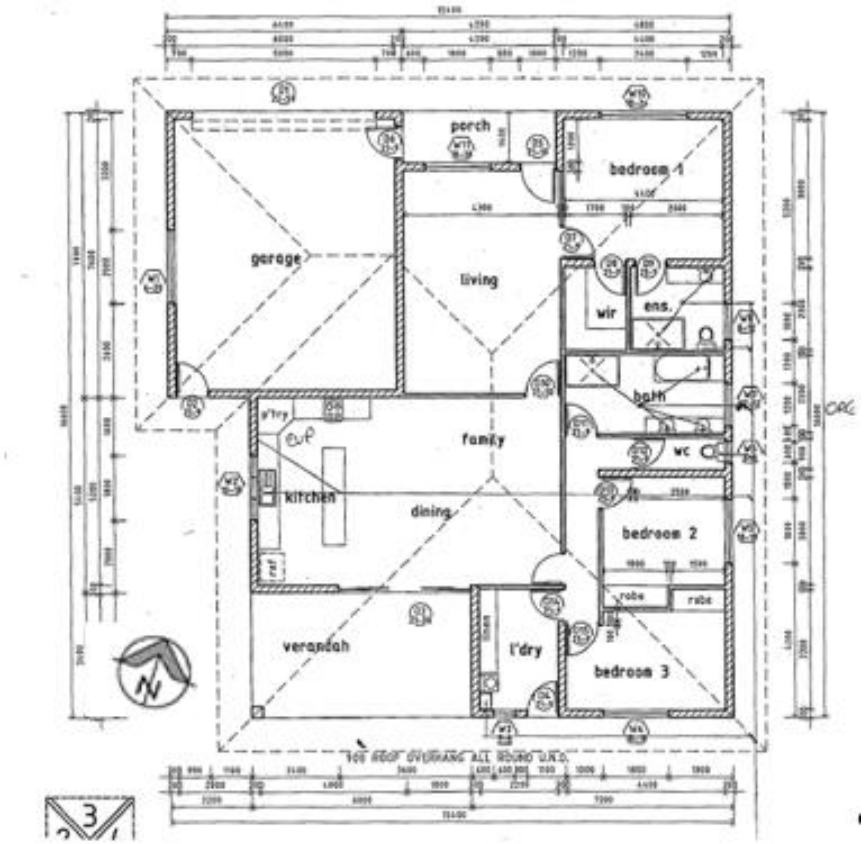


House 38 – High-set Lightweight



House 23 – Slab-on-ground Heavyweight

Single level house floor area 162 m2 (excluding garage and verandah), constructed in 2007 in accordance with BCA requirements. White colourbond steel roof with reflective foil. 190mm Blockwork with no insulation. Aluminium window single glazed tint. Plasterboard ceiling with no insulation, ceiling to roof space. Concrete slab-on-ground floor.



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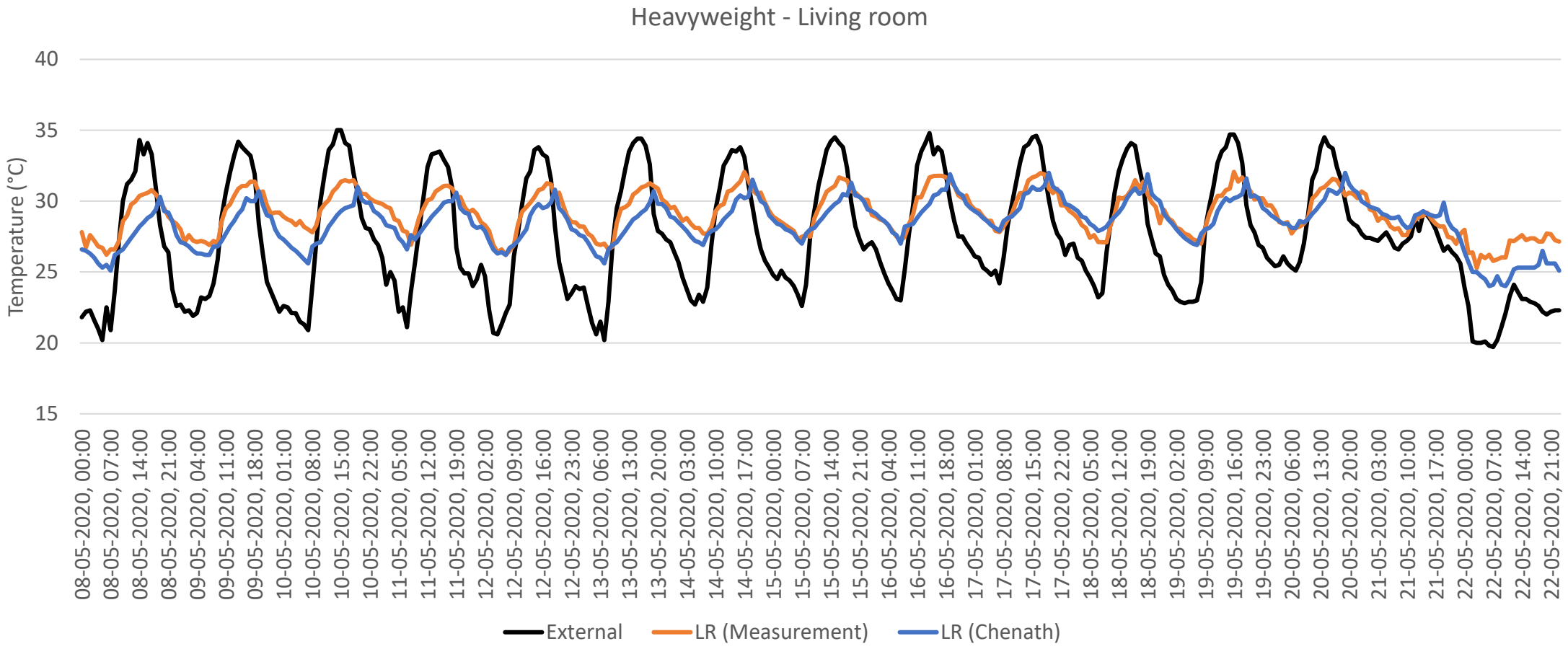

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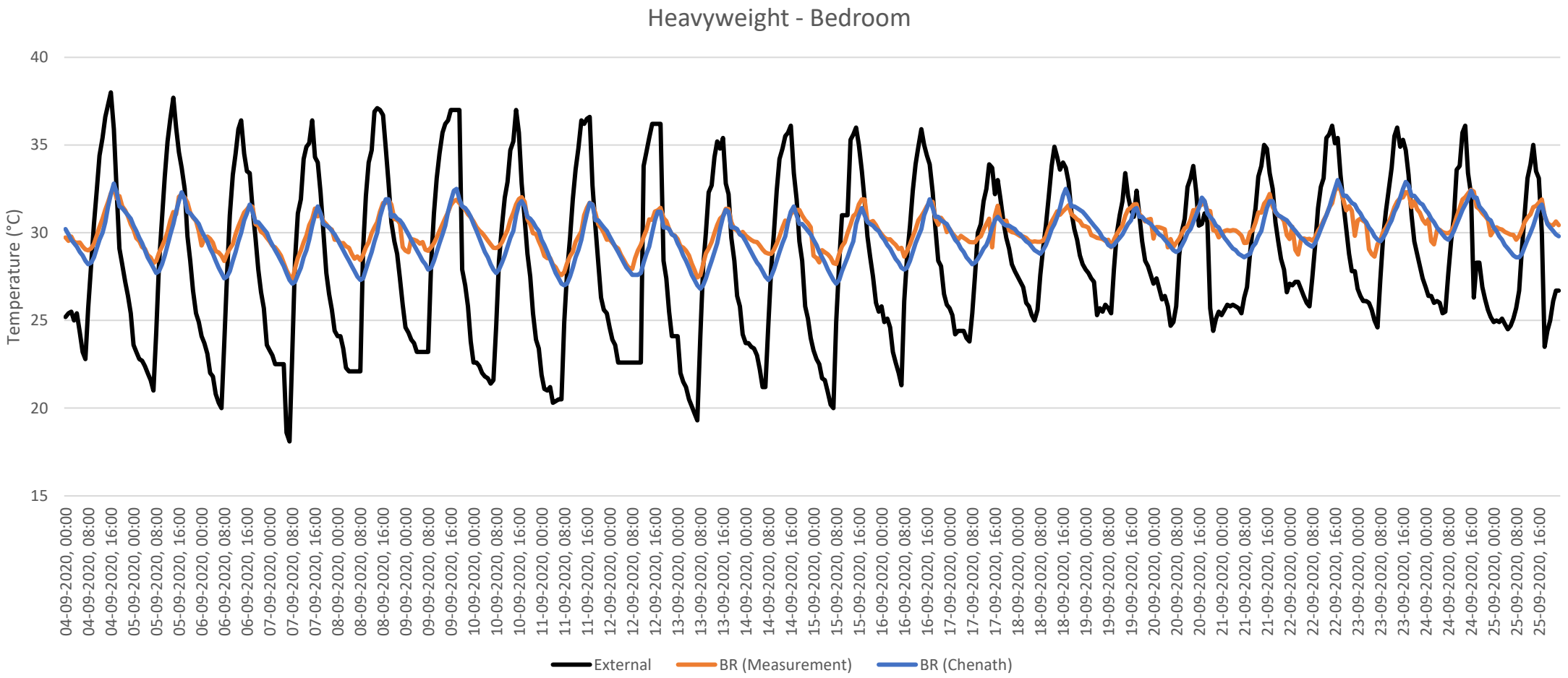
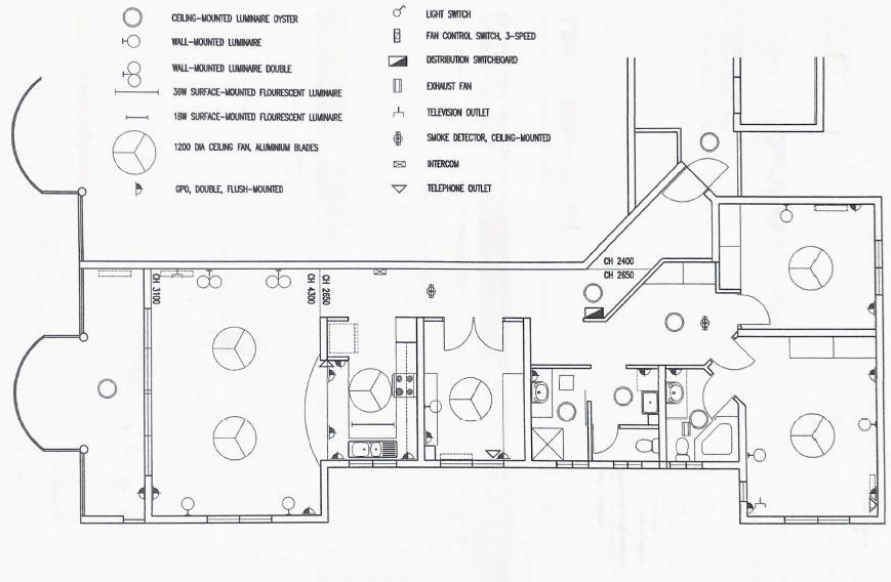
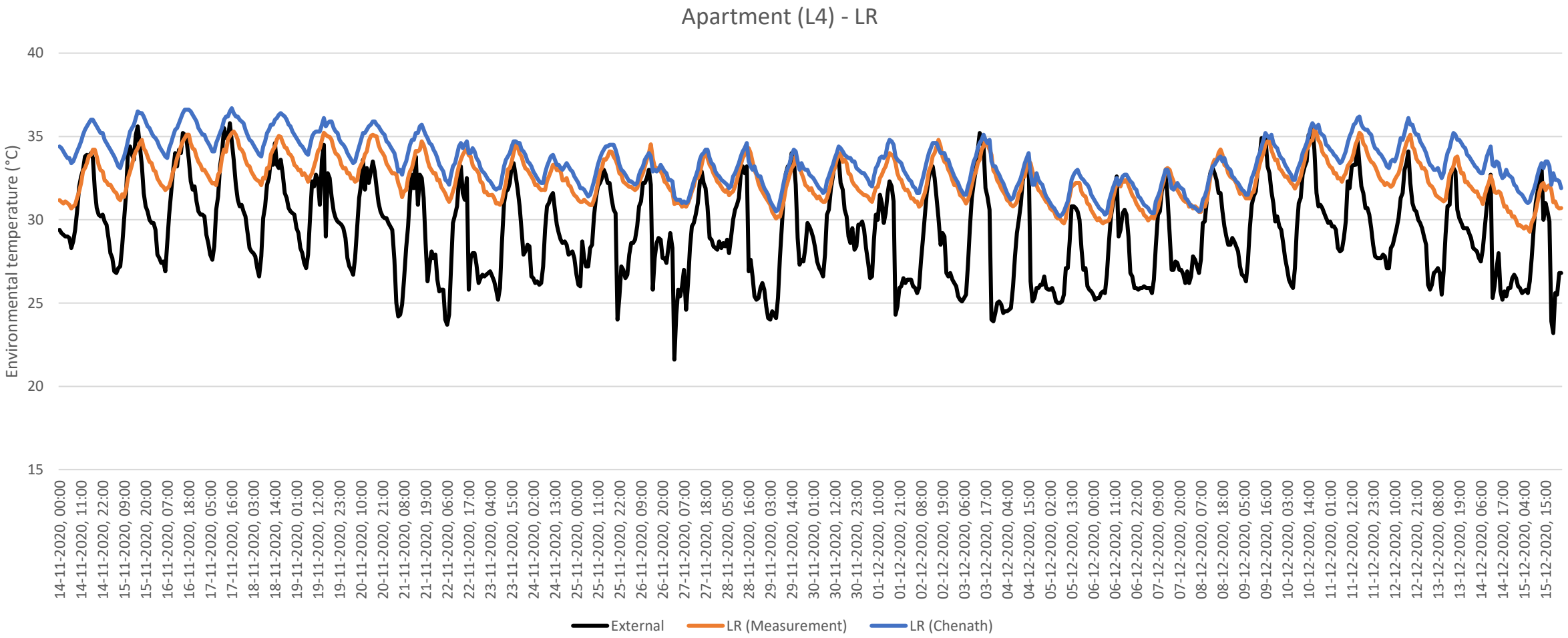


House 21 – Apartment

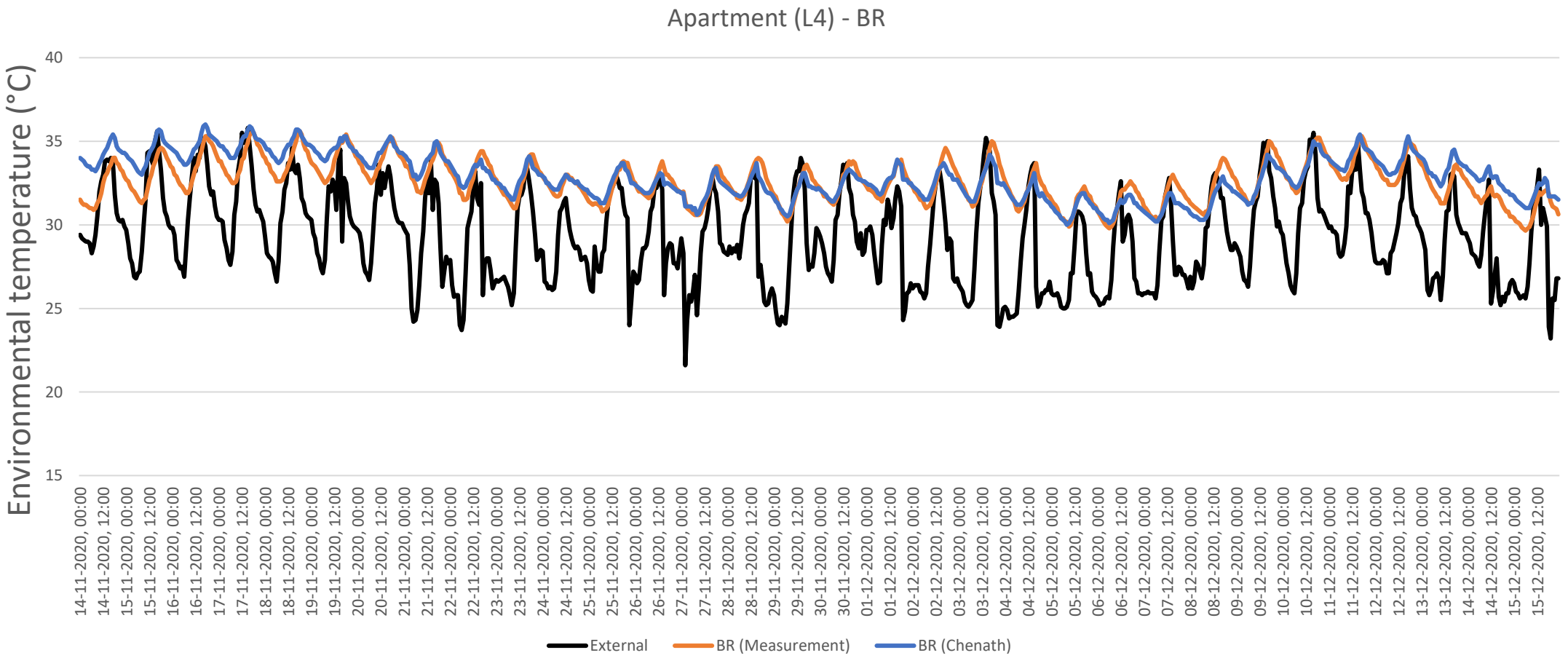
The top floor of a 4-storey apartment complex with floor area 131 m^2 consisting of an open-plan kitchen-living area, two bedrooms and a home office. Construction is of concrete, with single glazed sliding door and windows and a North-facing balcony facing the sea. Most of the windows have casement-type internal shading of opaque louvres.



House 21 – Apartment



House 21 – Apartment



Statistics of Validation

***MBE* (Mean Bias Error)** is the average or the errors and is generally a good predictor of the overall behaviour of a simulation.

$$MBE = \frac{\sum_{i=1}^{n}(m_i - s_i)}{n}$$

Where m_i is the "real" value and s_i is the simulated one and n is the number of data points (eg number of hours). Positive values mean that the model under-predicts the "real" value, and a negative one means over-prediction.

***NMBE* (Normalised Mean Bias Error)**

$$NMBE = \frac{1}{\overline{m}} \frac{\sum_{i=1}^{n}(m_i - s_{i)}}{n - p} \times 100(\%)$$

$\overline{m}$ is the mean of measured values, p is the number of adjustable variables (taken as either 0 o1)

***CV(RMSE)* (Coefficient of Variation of the Root Mean Squared Error)** is a good measure the uncertainty inherent in a model.

$$CV(RMSE) = \frac{1}{\overline{m}} \sqrt{\frac{\sum_{i=1}^{n}(m_i - s_i\ )^2}{n - p}} \times 100\ (\%)$$

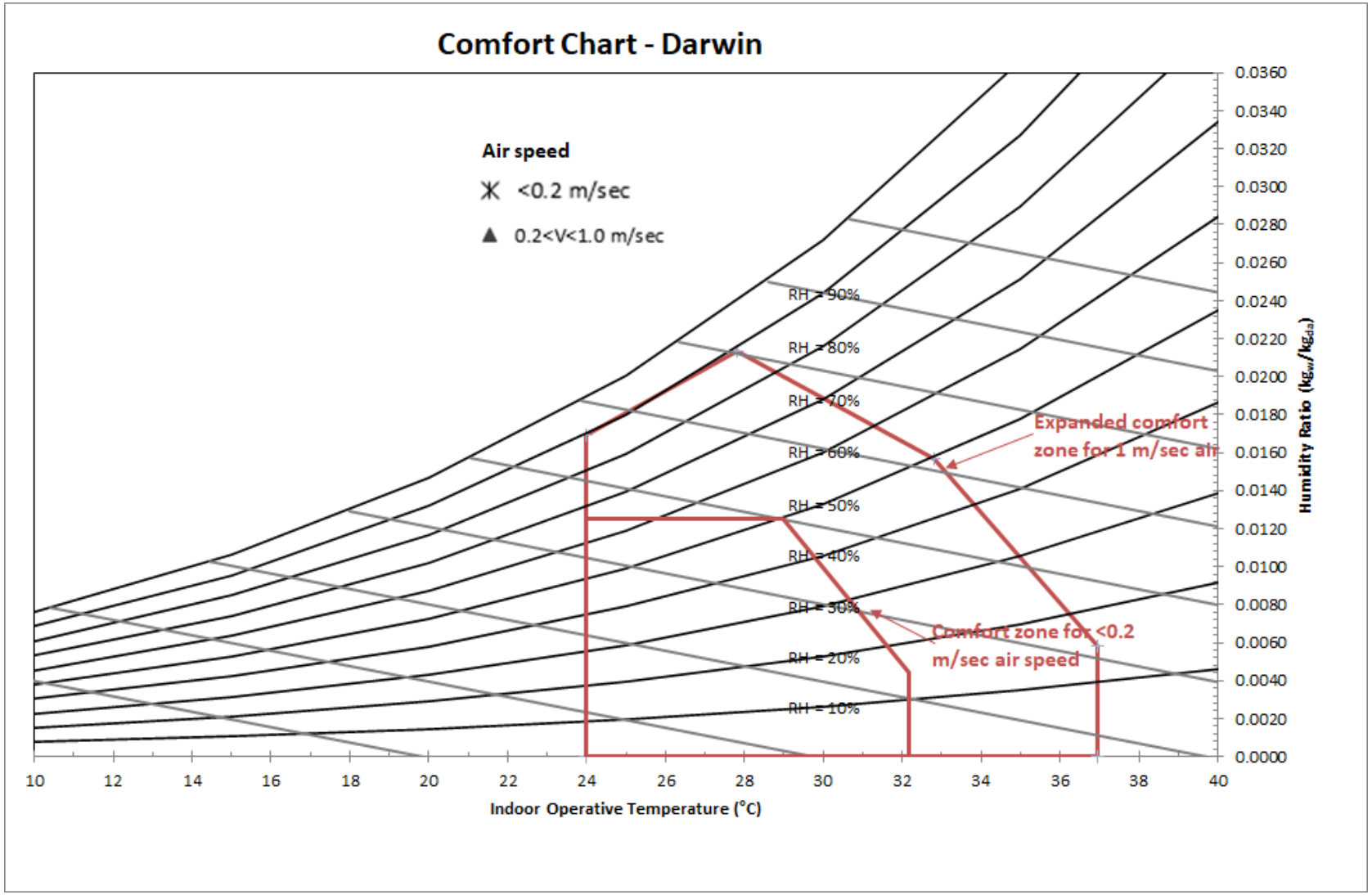
Validation Results

House	MBE		NMBE		CV(RMSE)	
Room	LV	BR	LV	BR	LV	BR
H38	-0.23K	0.86K	-0.86%	3.05%	4.40%	4.50%
H23	0.65K	0.31K	2.20%	1.02%	3.70%	2.23%
H21	-1.00K	-0.26K	-3.07%	-0.81%	3.72%	2.23%
Criteria for Satisfactory Validation MBE ±5% of average measured value	±1.36 ±1.46 ±1.62	±1.42 ±1.50 ±1.63	±5%	±5%	10%	10%

Conclusion: Over a range of houses in Darwin Chenath is sufficiently accurate to provide reliable estimates of temperature.

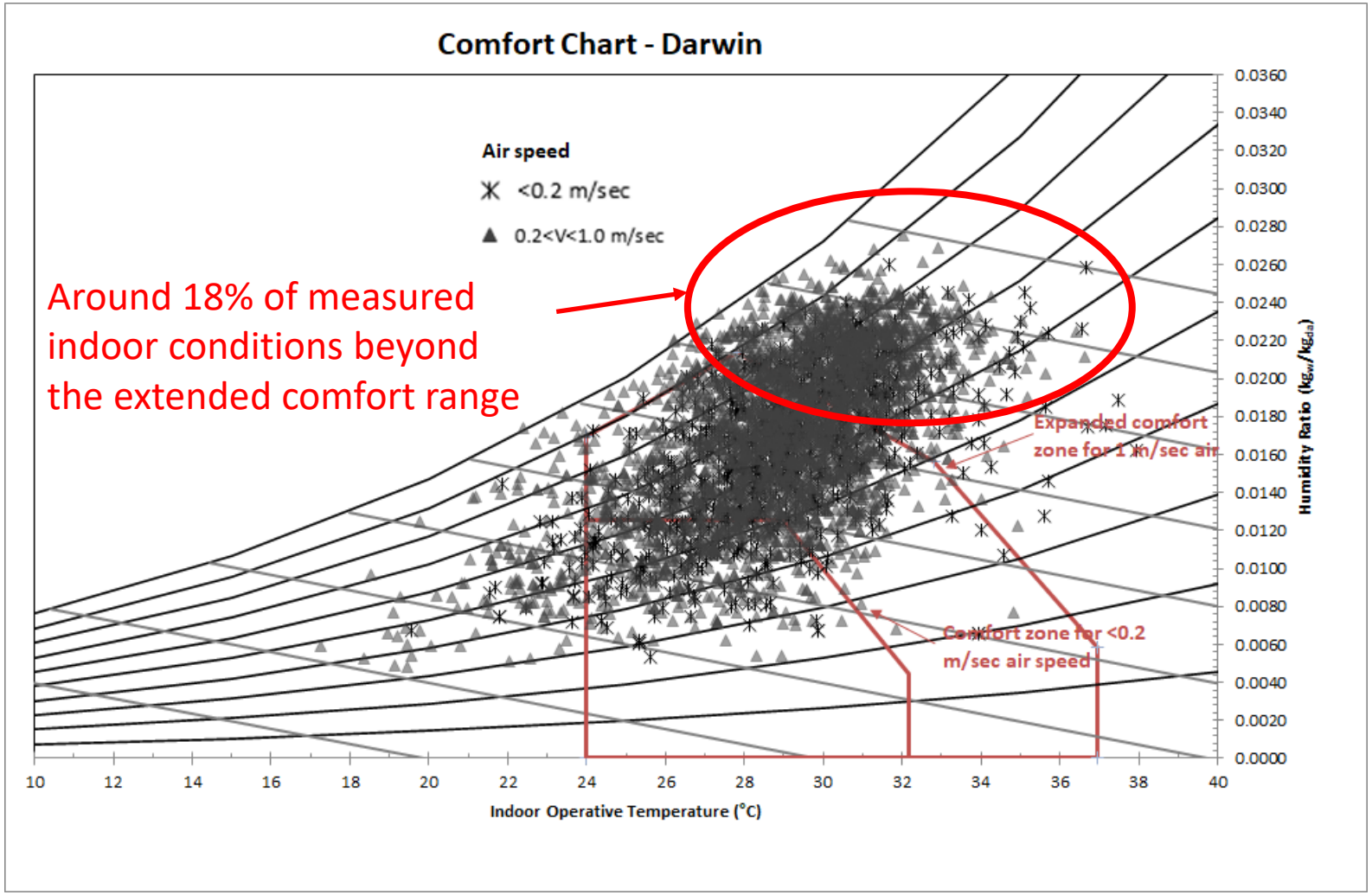
Comfort Thresholds in Darwin

Is there an issue?



Comfort Thresholds in Darwin

Is there an issue?

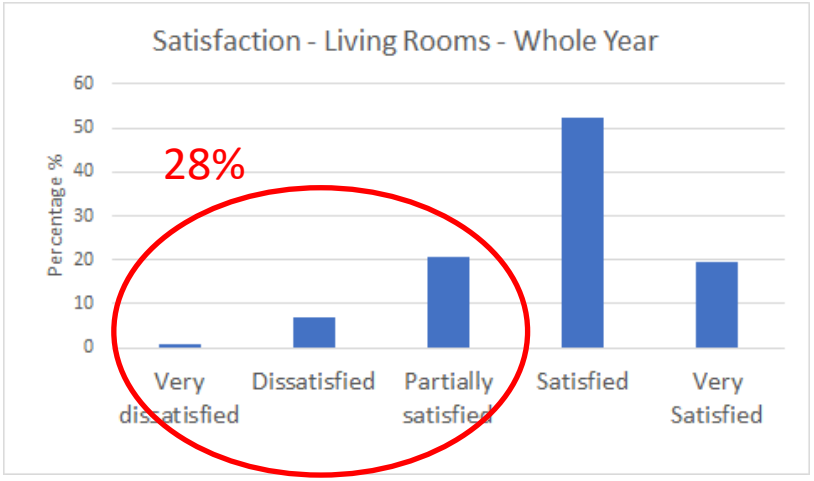


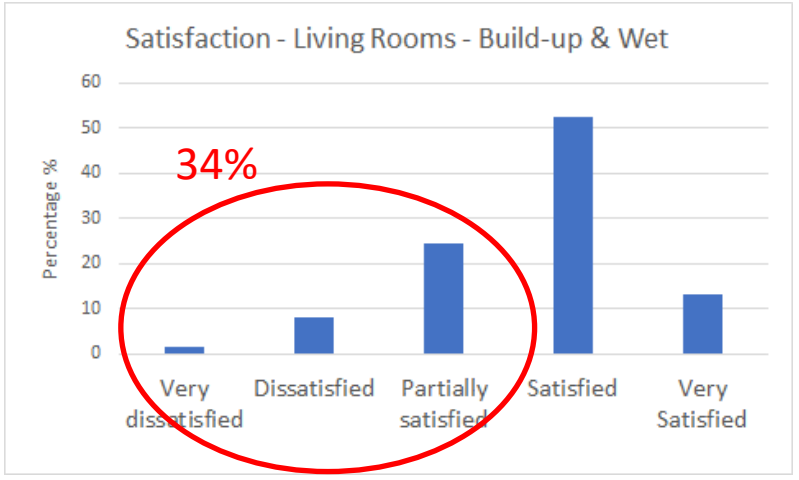
Note: No AC operating

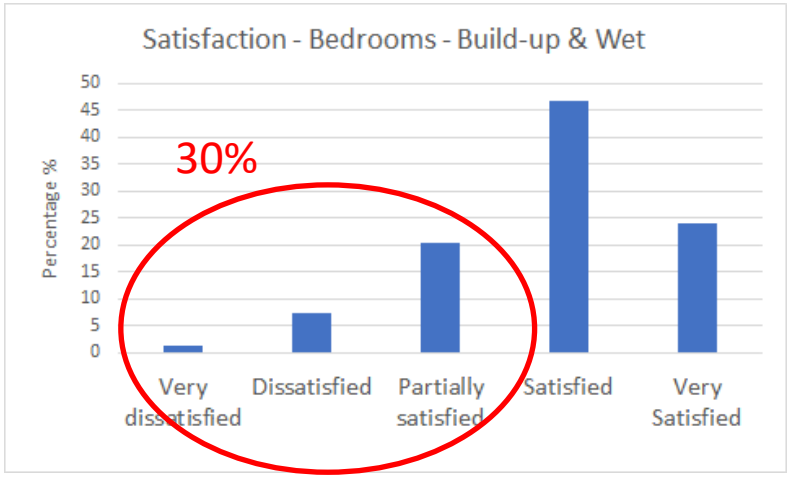
Comfort Thresholds in Darwin

Is there an issue?

Occupant Survey Question: How satisfied are you with the temperature in this room?

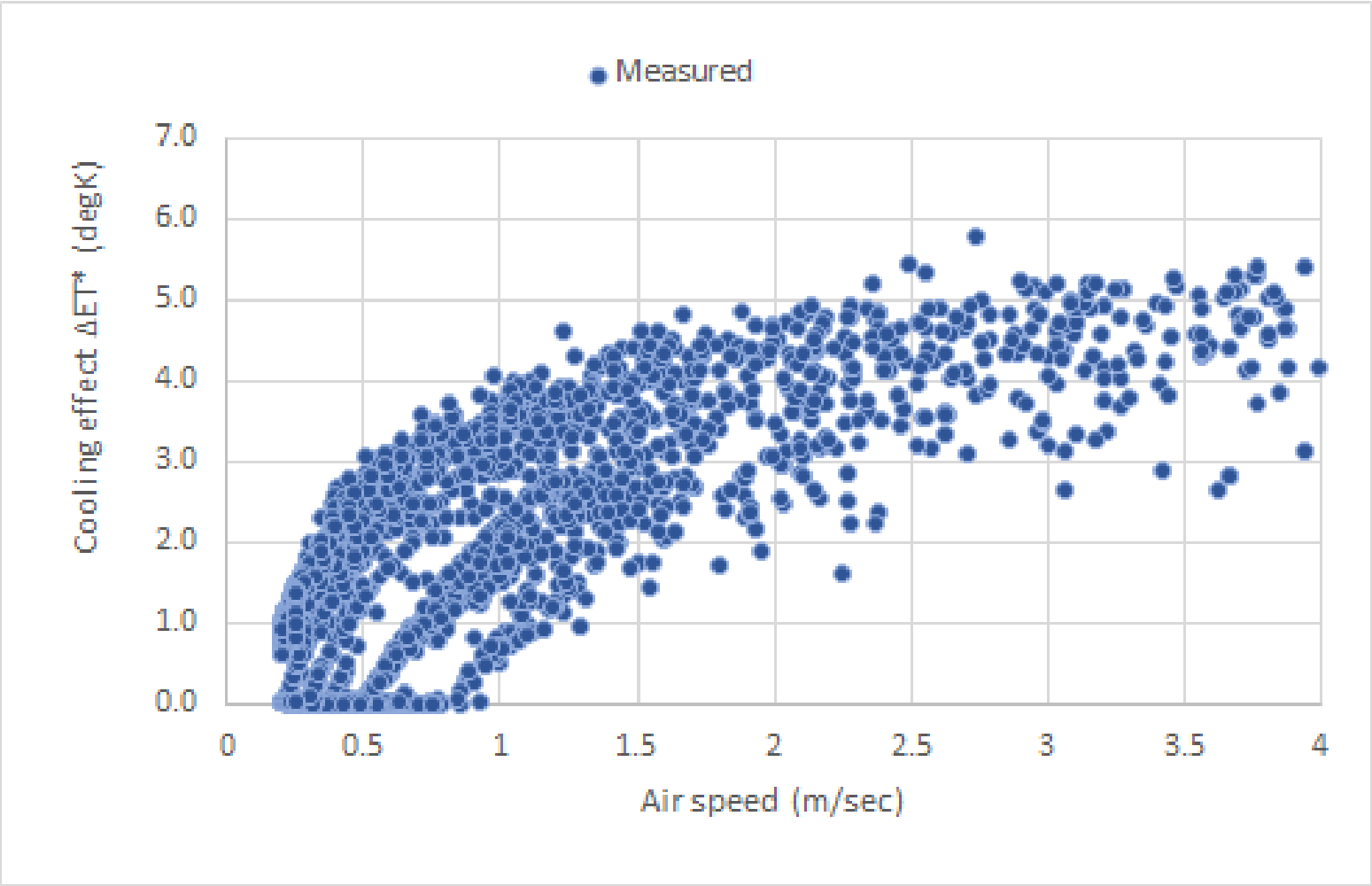




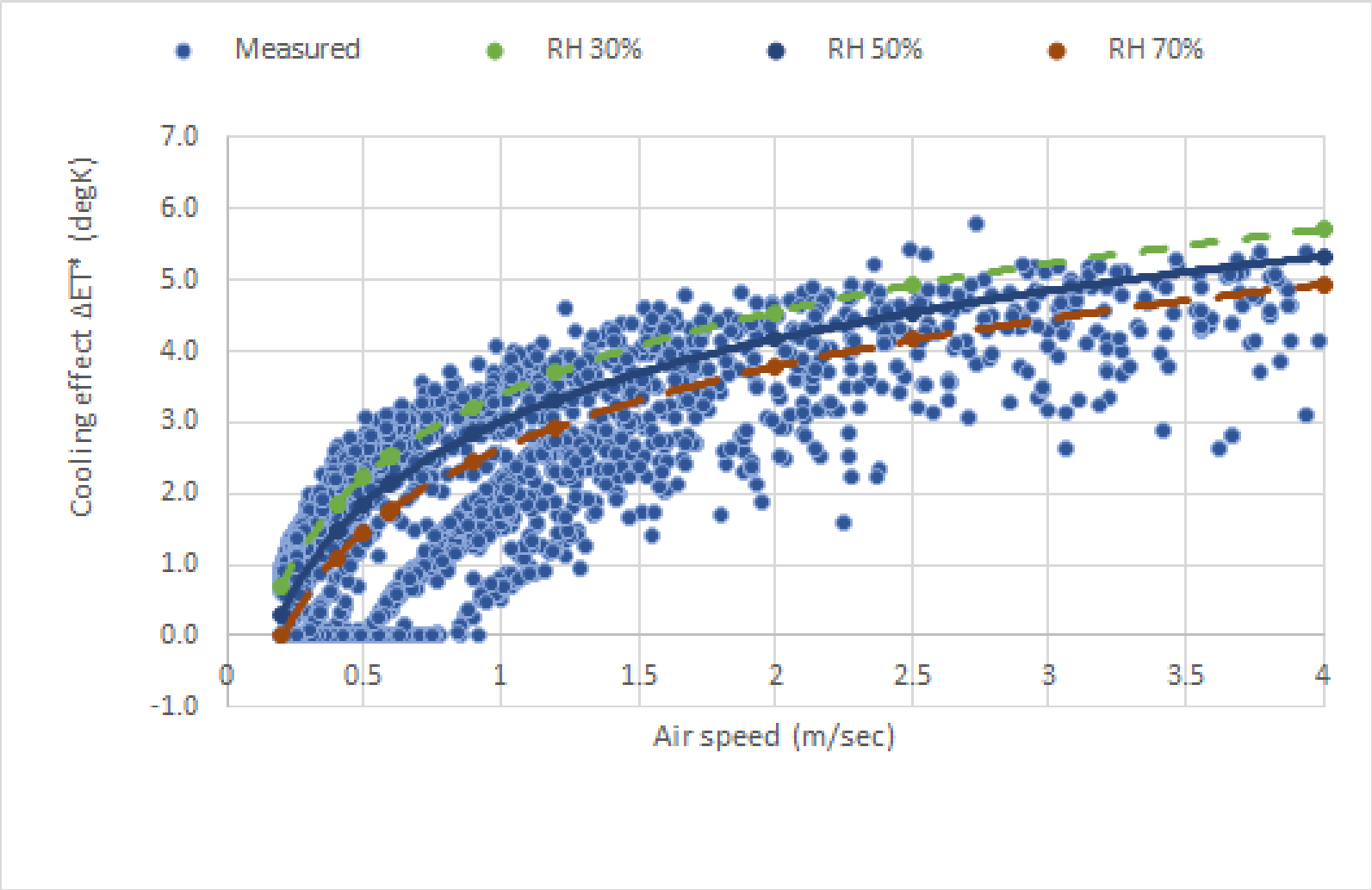


Assessing Overheating
Steps in Developing a Comfort Metric

Cooling due to air movement



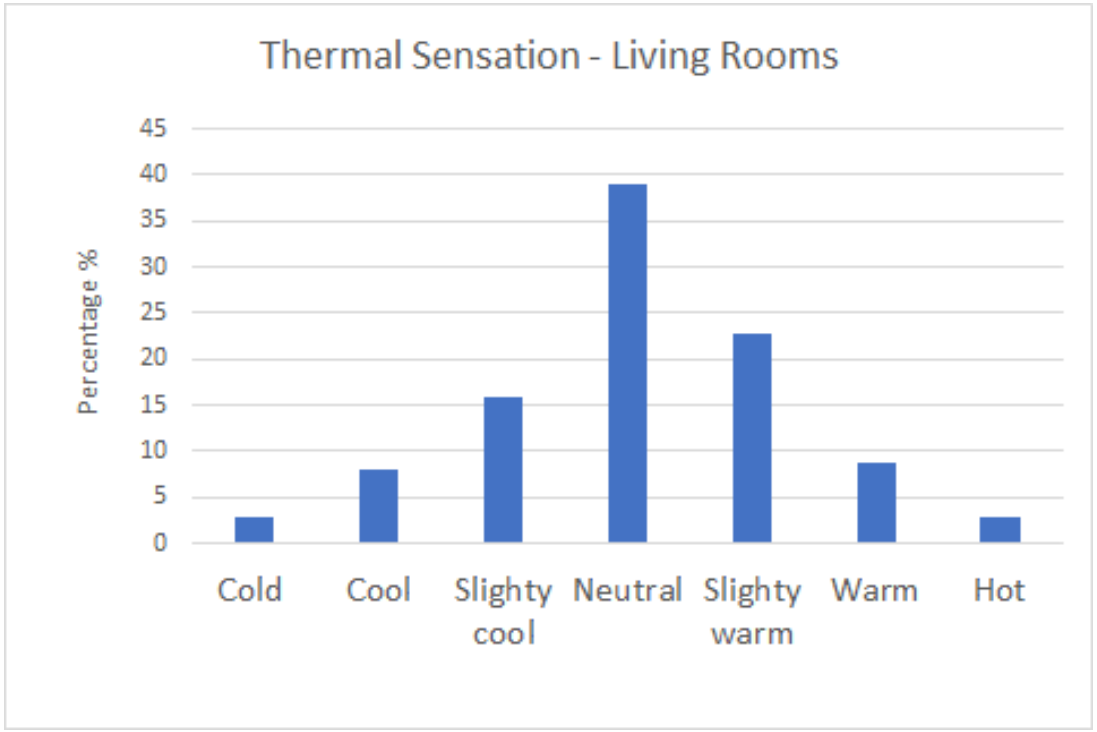
Cooling due to air movement



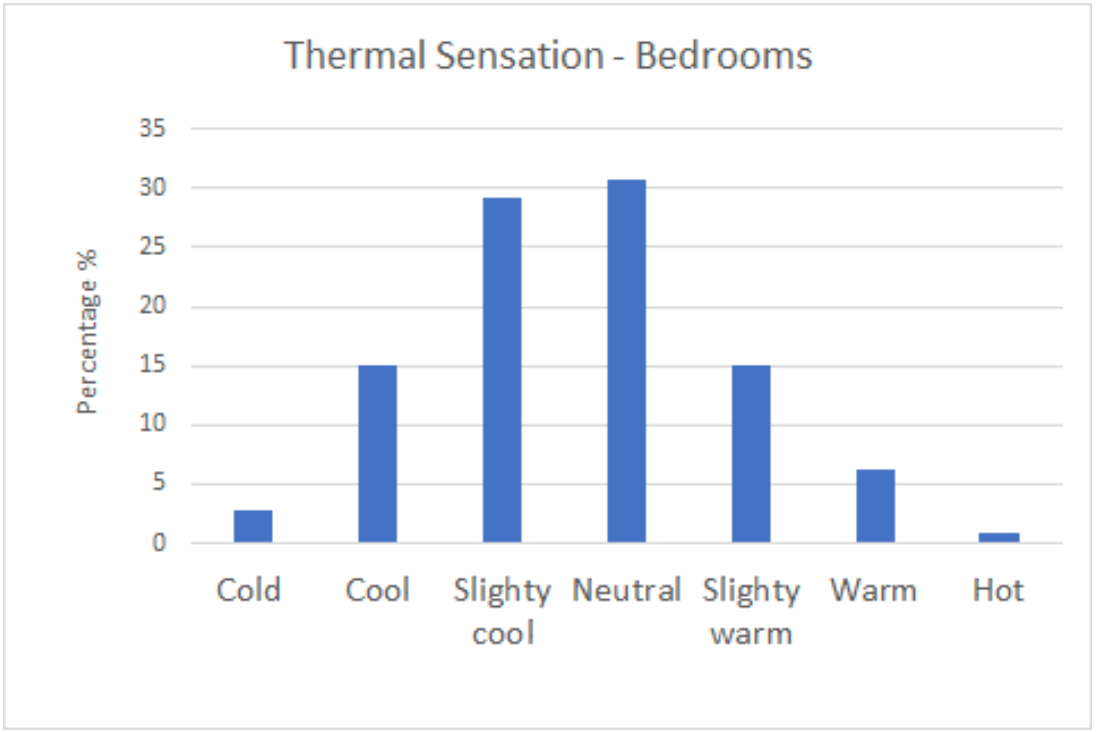
Thermal Sensation

Occupant Survey Question: How do you feel right now?

Occupant Survey Question: How would you like to feel? – cooler, no change, warmer



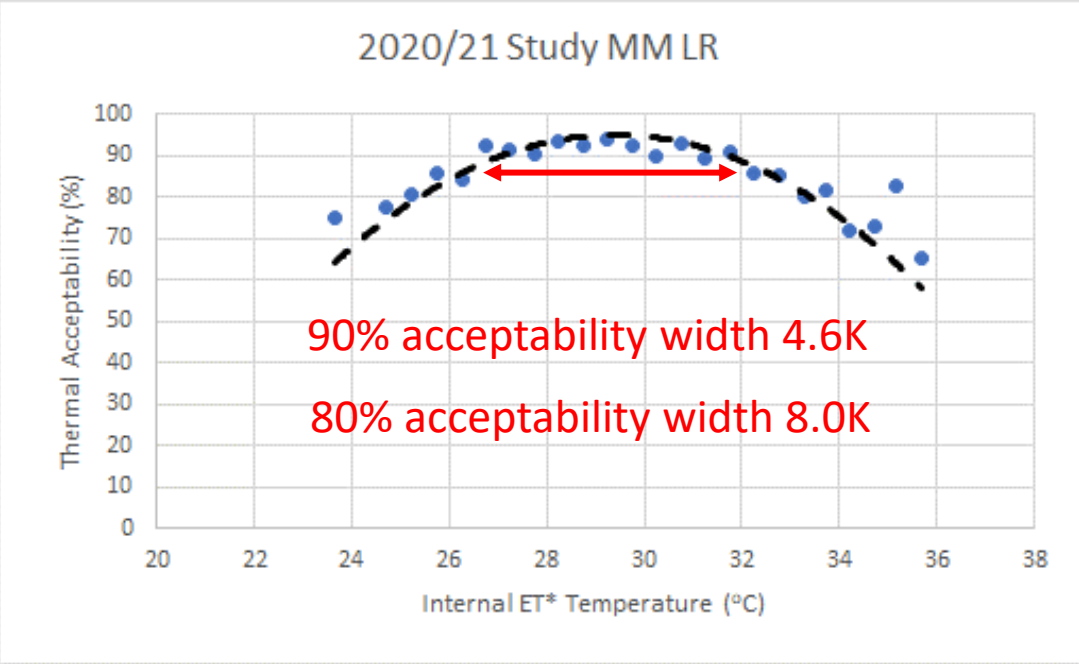
N=2668

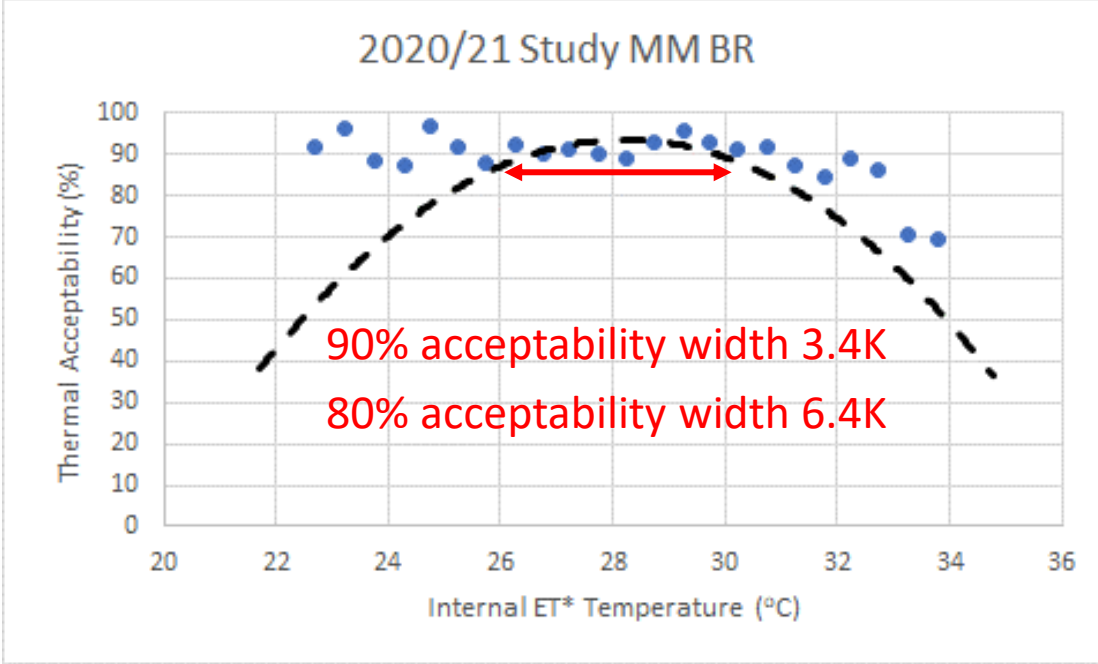


N=1188

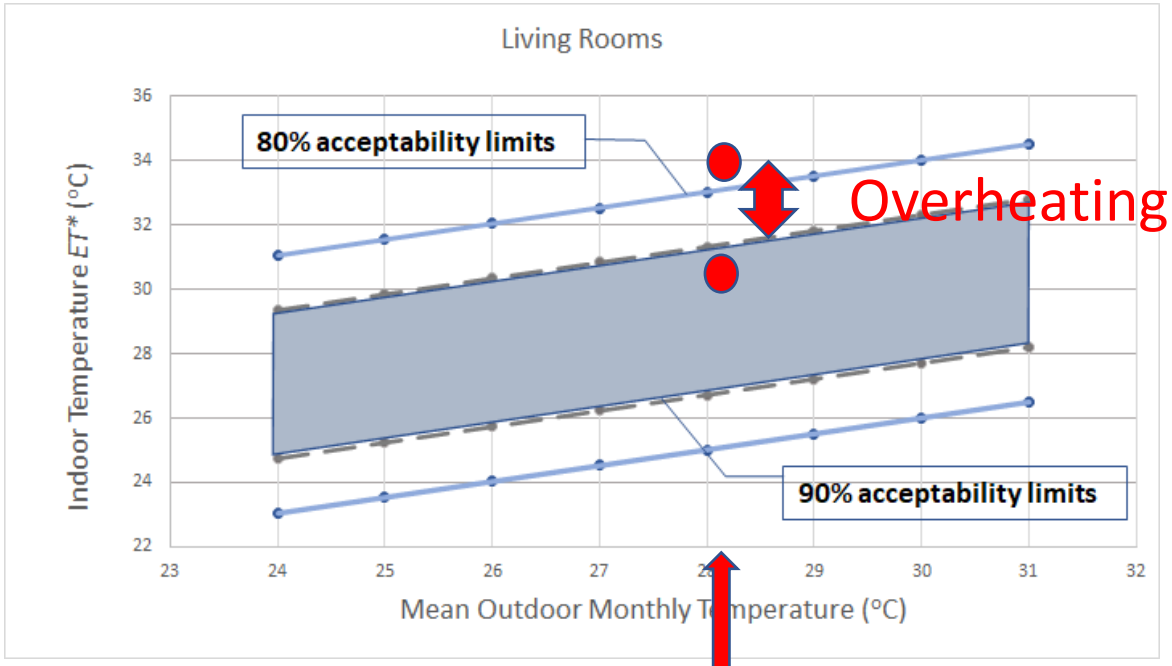
Note: No AC, Natural ventilation only with fans

Acceptability

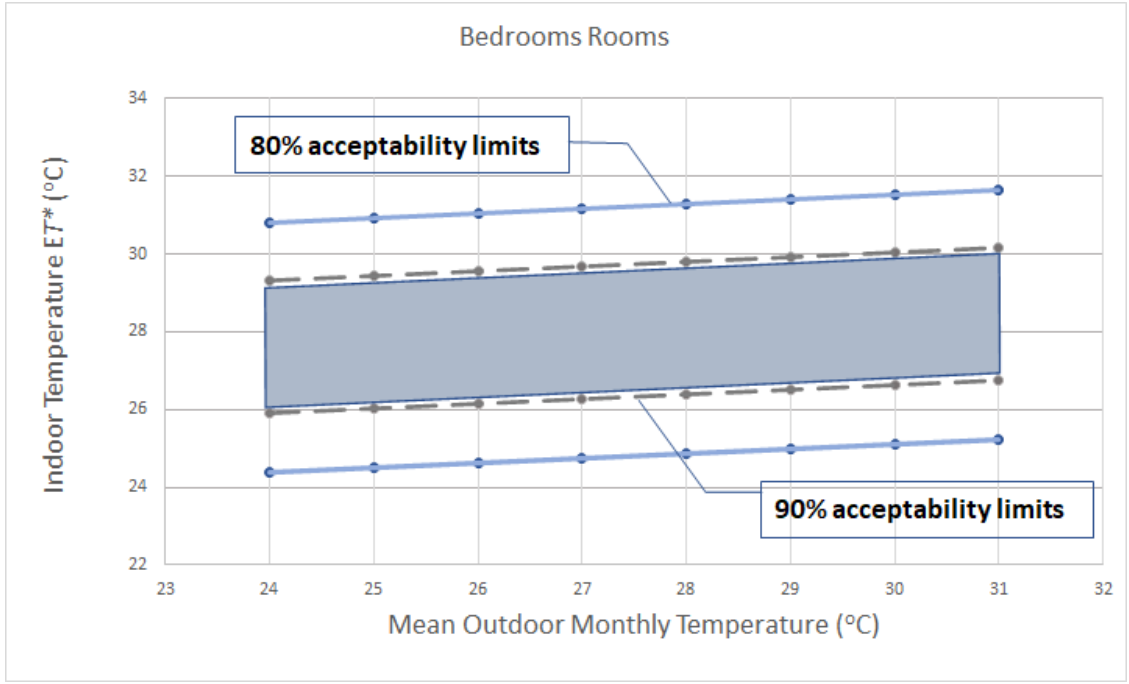




Adaptive Comfort Thresholds for Darwin



Average Jan/Feb Temperature



Thank you

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