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# How can high-resolution temperature traces be used to assess dwelling thermal performance?

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MRes Dissertation Project in collaboration with Passiv System Ltd.

## INTRODUCTION

In the context of UK dwelling thermal energy efficiency, performance monitoring and estimation is strongly focused around results from theoretical building physics models; however, these have been shown to have systematic deviations from reality. Conventional empirical validation methods are equipment intensive and require the dwelling to be vacated, effectively restricting their use to case studies. An alternate approach was proposed based on space temperature trace data, collected non-intrusively from occupied dwellings, with the aims of opening up the potential for large scale feedback. The focus of this project was to investigate the feasibility of this approach.

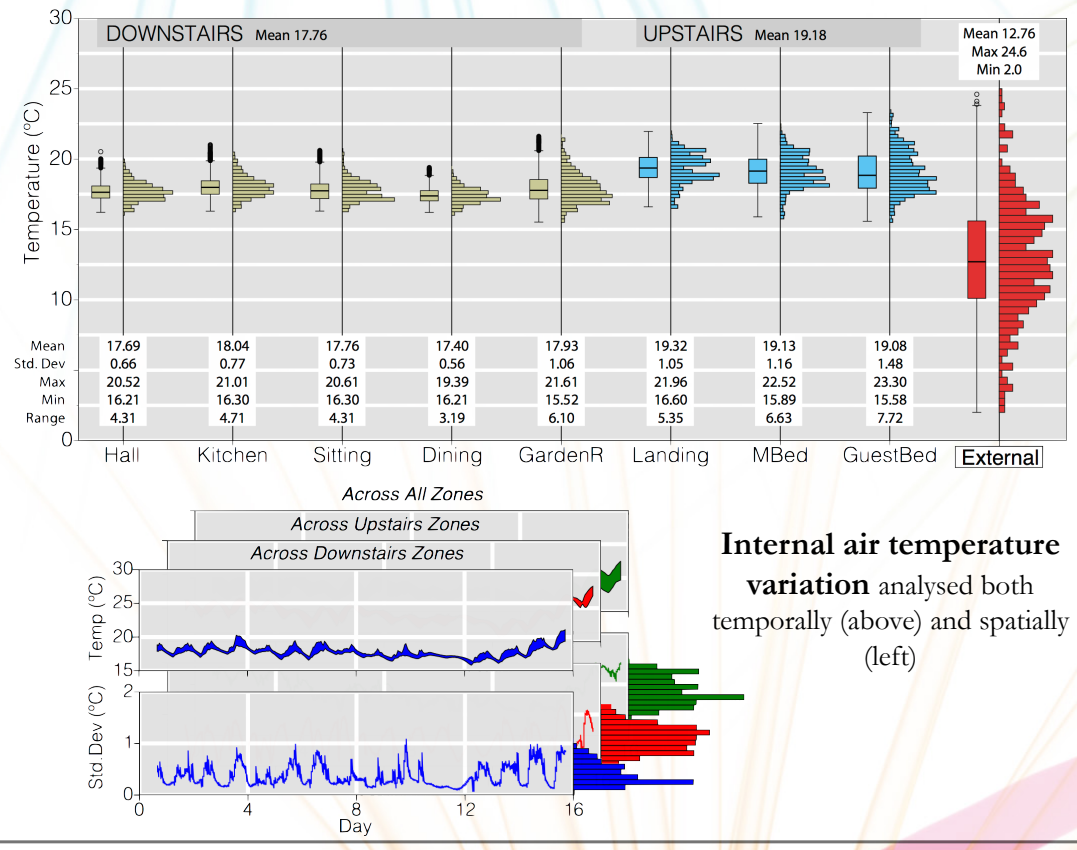
The empirical approach taken focused on monitoring up to 24 temperature nodes in three archetypal case study dwellings.


DECREASING THEORETICAL THERMAL PERFORMANCE

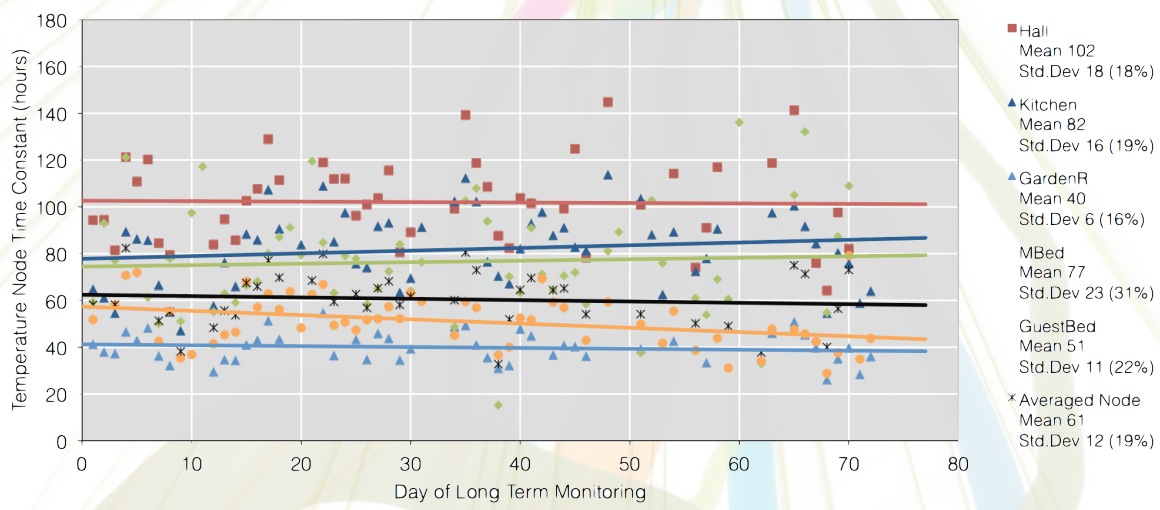
## RESULTS

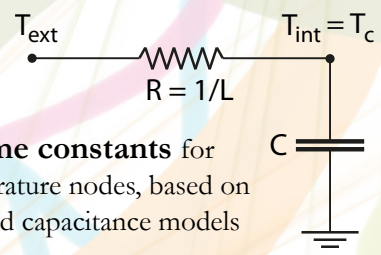
Four types of temperature observation, related to dwelling fabric performance, were determined and subsequently explored through analysis of the temperature data collected:

1. Inter-zone temperature relationships
2. Intra-zone temperature relationships
3. Rate of overnight internal temperature decay
4. Magnitude of short term fluctuations in internal air temperatures




**Internal air temperature variation** analysed both temporally (above) and spatially (left)




**Thermal time constants** for monitored temperature nodes, based on first order lumped capacitance models

$$\Delta T_{(t)} = \Delta T_{(0)} e^{-\frac{t}{\tau}}$$

$\Delta T_{(t)}$ Temperature difference between the node and external ambient at time $t$

$\tau$ Thermal time constant

**EXAMPLE ANALYSIS FROM SITE 2**

Two of the phenomena were found to have a quantitative relationship to main descriptors of fabric performance:

- the **natural balance of the dwelling internal air temperature** above the external ambient, which represents the ratio of incidental heat gains to the heat loss coefficient; and
- the **rate of overnight internal temperature decay**, or time constant, which represents the ratio of thermal mass to the heat loss coefficient.

- The ratio form of the resultant energy metrics were established as a fundamental limit of temperature-only based analysis.
- The application of the metrics is therefore limited to longitudinal analysis e.g. before and after an efficiency retrofit, or direct feedback on their associated representation within the SAP calculation
- The metrics suffered from large variations in results, both in part from their current basic method, but also due to the fundamental nature of temperature as a continuous variable in both space and time.

## CONCLUSIONS

How many point temperatures are required to form the ubiquitous 'average' dwelling temperature?
Where should the measurements be taken?
How should the points be aggregated?

The project established the intrinsic challenges to the use of space temperature to produce successful and repeatable metrics. Translation of these ideas to conventional applications suggest that space temperature monitoring, as an entire field, has an unfounded basis, focused around an arbitrary 'average' which is ill defined. It is proposed that greater clarity of thought is required regarding the different purposes measures of temperature are used for, and that a more nuanced approach is required for progression within the field.

### Ph.D. Research Topic

"Improved methods for measurement of ventilation rates in occupied dwellings"

Ventilation accounts for a significant proportion of space heating energy demand in dwellings. As airtightness of the envelope is improved, it is of increasing importance that the dedicated ventilation systems installed operate effectively. The current common methods of measuring ventilation rates in occupation only indicate the average ventilation rate, which may appear satisfactory; however, there may be significant periods of under and over ventilation resulting in poor indoor air quality and energy wastage respectively.

**OBJECTIVE:** To develop an improved method of measuring the ventilation rate in occupied dwellings which can capture the variations over time, with the potential for remote data collection. These are in addition to remaining cost effective, robust and non-intrusive.

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