Measured indoor temperature, weather, infiltration, and ventilation in synthetically occupied test houses: summer 2021, UK

IMPROVE Project
Improving the Predictions of Overheating

Guidance for modellers

2022

(Version 1)

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Version	Amendment	Page	Editor	Date
1.0	First release	N/A	BMR	22/03/2022

Contents

1 Introduction

This document provides details of the experimental work conducted in the Loughborough Matched Pair test houses during summer 2021 for the IMPROVE project (IMproving the PRedictions of OVErheating). The dataset is also described in another publication (Roberts et al. 2022). Detailed descriptions of the test house floorplans, site plans, geometry, construction, windows, window coverings are available elsewhere (Roberts et al. 2019a).

1.1 Project Aim

The aim of the work is to improve the prediction of summertime indoor temperatures by dynamic thermal models for the purposes of overheating risk assessments. The outcome will be enhanced modelling processes to increase the reliability of overheating predictions.

1.2 Project Objectives

The work will be completed in two phases: a measurement phase and a modelling phase.

- Objective 1: In one synthetically occupied test house and one unoccupied house, measure indoor air, operative, and surface temperatures and outdoor weather conditions during summer.
- Objective 2: Use the measurement data gathered to investigate ways to improve the prediction of indoor temperatures using dynamic thermal models. Test methods to close the gap between measured and modelled results.

1.3 Document Aim

The aim of this guidance document is to provide the necessary information to allow other researchers to understand and use the dataset for their own research purposes. It accompanies further information in Roberts et al. 2022. Building energy modellers were the group in mind when designing and creating this dataset. However, we hope it will be of use to others as well.

2 Phase 1: Experiments to measure summertime indoor temperatures

The Loughborough Matched Pair test houses were used for all measurements of indoor temperature, infiltration rate, and ventilation rate (Figure 1). Monitoring of the indoor temperatures took place simultaneously in both houses over 5 months, or 153 days, from 1 May to 30 September (inclusive) (Table 1).

Details of test house location, description, geometry, site plan, construction, and airtightness has been provided previously (see Roberts et al. 2018, 2019a) and largely remained the same since the previous study and will not be repeated here. Minor updates to the construction information provided in Roberts et al. 2019a are noted below:

1. The solid kitchen floor was measured to be 175 mm thick in the West house and 180 mm thick in the East house.
2. The wall below the front double bedroom bay windows was found not to have a brick internal skin, but a board (assumed fibreboard) internal skin.
3. The U-value of the external walls has been measured as 1.57 W/m^{2}K.

The exterior face of all windows were cleaned in both houses on 15/07/2021.

Figure 1: The Loughborough Matched Pair. The West house is on the left of the photograph, the East house on the right.

2.1 Synthetic occupancy

In both houses, throughout the monitoring, the trickle vents were closed, the exterior doors were closed, there was no mechanical extract ventilation, boilers (heating systems) were turned off, and there was no secondary heating.

In the West house (Figure 1) was unoccupied: no internal heat gains, no window opening, no internal door use, no internal shading use (kept open at all times) (Table 1). All the internal doors were propped open.

The East house (Figure 1) was occupied: internal heat gains were emitted (Table 2), windows operated in the living room and bedrooms, internal doors operated in the bedrooms and were propped open in the other rooms, and curtains and blinds operated in all rooms (Table 1).

On 4 June at 23:15, due to a power cut on the first floor of the East house (which included the z-wave controller), the windows, curtains, and internal doors did not open at 09:00 as scheduled. First floor internal heat gains turned off, and ground floor internal heat gains did not change as planned at 00:00 (living room), and 09:00 (living room and kitchen). This was rectified within 2 hours.

Occasionally, internal heat gain devices (lightbulbs) broke and so the internal heat gains are not always the same each day. Single bedroom electricity consumption data are not available between 01/05 and 09/05 due to a malfunction with the measuring device. However, heat gains were generated during these times, and the hourly average for the remaining 144 days was used.

Table 1: Overview of synthetic occupancy

<table>
<tr><th rowspan="3">House</th><th colspan="3">Experiments</th><th rowspan="3">Description</th><th rowspan="3">Room</th><th rowspan="3">Windows open [a]</th><th rowspan="3">Shading open [a]</th><th rowspan="3">Internal doors open [a]</th><th rowspan="3">Internal heat gains</th></tr>
<tr><th colspan="2">Dates</th><th rowspan="2">Duration (days)</th></tr>
<tr><th>From</th><th>To</th></tr>
<tr><td>West</td><td>01/05/21</td><td>30/09/21</td><td>153</td><td>Unoccupied</td><td>All rooms</td><td>Never</td><td>Never</td><td>Always</td><td>No</td></tr>
<tr><td rowspan="3">East</td><td rowspan="3">01/05/21</td><td rowspan="3">30/09/21</td><td rowspan="3">153</td><td rowspan="3">Occupied</td><td>Living room</td><td>09:00-22:00</td><td rowspan="3">08:00-22:00</td><td>Always</td><td rowspan="3">Yes</td></tr>
<tr><td>Bedrooms</td><td>Always</td><td>08:00-22:00</td></tr>
<tr><td>Other rooms</td><td>Never</td><td>Always</td></tr>
</table>

[a] Closed at all other times.
Note: all times in BST.

Table 2: Internal heat gain schedules in the East house

Room	Time period (hh:mm) [a]	Nominal gains for the East house [b]			Mean measured total power (W)
		Source (W)	Power (W)	Total power (W)	
Living room	09:00-17:59	3 adults (75% gain)	169	229	213
		Equipment	60		
	18:00-21:59	3 adults (75% gain)	169	346	407
		Equipment	150		
		Lighting	27		
	22:00-23:59	Equipment	60	60	60
	00:00-08:59	Equipment	35	35	45
Kitchen	09:00-17:59	3 adults (25% gain)	56	106	97
		Equipment	50		
	18:00-19:59	3 adults (25% gain)	56	368	408
		Equipment	300		
		Lighting	12		
	20:00-21:59	3 adults (25% gain)	56	118	96
		Equipment	50		
		Lighting	12		
	22:00-08:59	Equipment	50	50	54
Front double bedroom	08:00-08:59	2 adults (100% gain)	150	230	199
		Equipment	80		
	09:00-21:59	1 adult (100% gain)	75	155	143
		Equipment	80		
	22:00-22:59	2 adults (100% gain)	150	261	239
		Equipment	80		
		Lighting	31		
	23:00-07:59	2 adults (70% gain)	105	115	89
		Equipment	10		
Rear double bedroom	08:00-08:59	2 adults (100% gain)	150	230	203
		Equipment	80		
	09:00-21:59	1 adult (100% gain)	75	155	147
		Equipment	80		
	22:00-22:59	2 adults (100% gain)	150	261	247
		Equipment	80		
		Lighting	31		
	23:00-07:59	2 adults (70% gain)	105	115	106
		Equipment	10		
Single bedroom	08:00-22:59[c]	1 adult (100% gain)	75	155	141
		Equipment	80		
	23:00-07:59[c]	1 adult (100% gain)	53	53	57

[a] All times in BST.
[b] Rounded to nearest whole Watt.
[c] Excludes 01-05-2021 00:00 to 09-05-2021 10:00 (inc.) due to voltage measuring plug malfunction.

2.2 Sensors, locations, and monitoring periods

2.2.1 Measurement of indoor temperatures, window operation, and internal heat gains

Measurement of dry bulb and operative temperature was conducted in all rooms and both loft (attic) spaces using U-type thermistors calibrated in a water bath against a calibrated thermometer. To measure dry bulb temperature, the thermistors were hung on a tripod and shielded from solar radiation. To measure operative temperature U-type thermistors were encased in a 40 mm black globe and hung on a tripod. Locations and monitoring periods are shown in Figure 2 and listed in Table 4.

Surface temperatures were measured in the front double bedrooms, rear double bedroom, and living rooms of both houses. In the East house, surface temperature was also measured on the landing (Figure 2 and Table 4). A T-type thermocouple was affixed to the surface being measured using an adhesive material. Full contact between the thermocouple and surface was ensured. At the end of the monitoring period, all the thermocouples were positioned in the same room, affixed to the same surface, to check calibrate them.

The binary status of the operable windows in the living room, e.g. open or closed, was monitored using a contact sensor affixed to each window (Table 3). A notification was sent to the measurement team at each change in state to ensure windows were open and closed when scheduled to be.

Electricity consumption of the internal heat gain devices was measured by a Plogg electricity metering plug in each room where there was an internal heat gain (Table 3). Data are available from each room with a heat gain from the start of the monitoring period (01/05/21) to the end of the monitoring period (30/09/21), except in the East house single bedroom due to technical issues (available from 09/05/21-30/09/21). Each hourly timestamp contains the total electricity consumption for that hour. (E.g. 09:00 = 09:00-09:59).

Table 3: Summary of indoor equipment used and uncertainty

Data type	**Variable**	**Device**	**Measurement interval (mins)**	**Uncertainty (±)**
Indoor temperature	Dry bulb	U-type thermistor connected via wire to DT85 DataTaker	1	0.3°C
	Operative	U-type thermistor at centre of 40 mm black globe connected via wire to DT85 DataTaker	1	0.3°C
	Surface	T-type thermocouple fixed to surface with self-adhesive pad connected to Hobo UX120-014M 4-Channel Thermocouple Data Logger	15	1.0°C
Window operation	Binary status (open/closed)	Samsung SmartThings Multipurpose magnetic contact sensor with ZigBee wireless connection to IoT smart home controller	1	N/A
Internal heat gains	Electricity consumption	Plogg electricity metering plug	60	1%

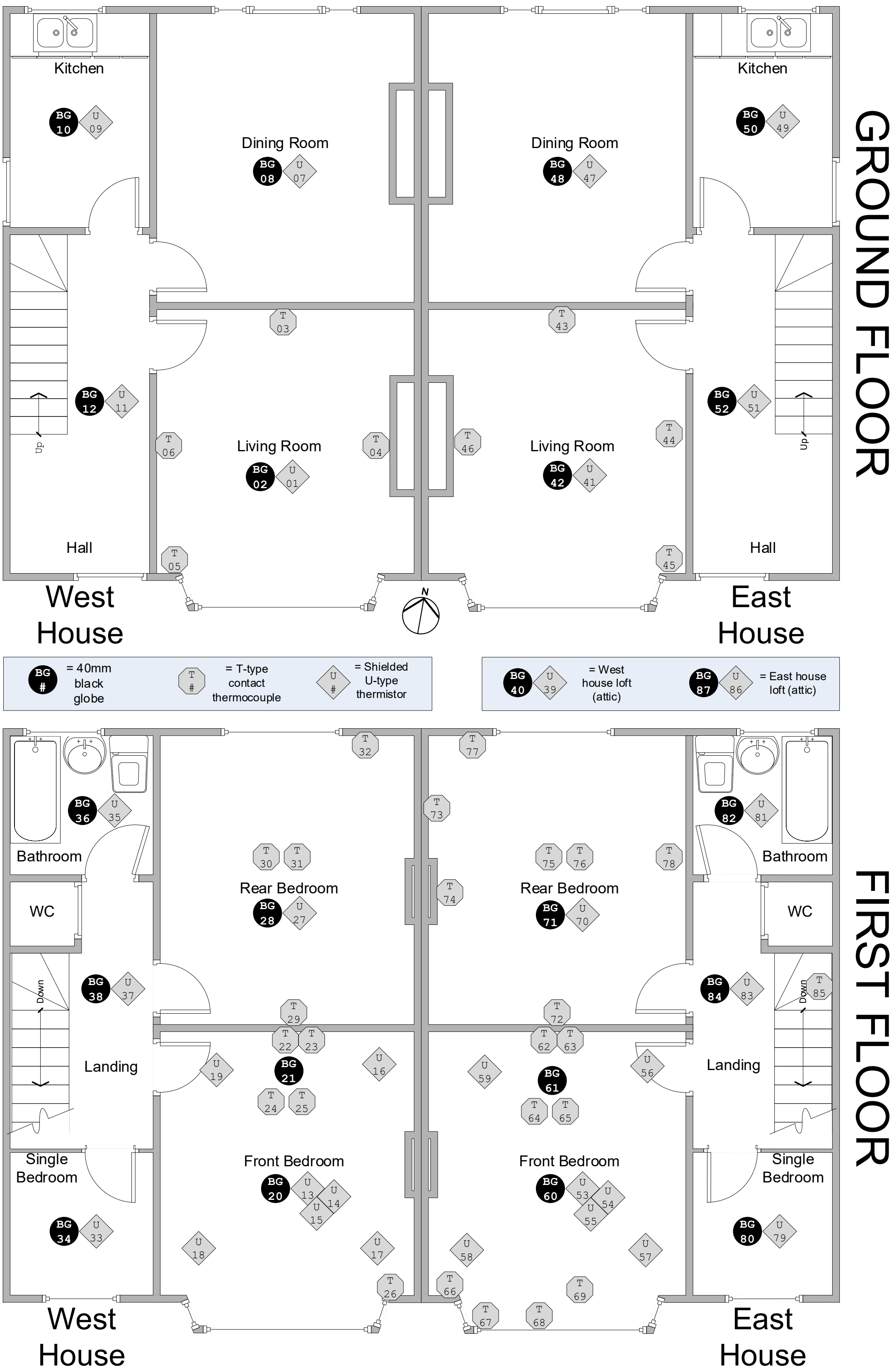

Figure 2: Floorplan with sensor locations. Refer to Table 4 for information on sensor height from floor.

Table 4: Description of sensor locations and data periods. Dates are inclusive. Sensor codes correspond to Figure 2.

Room	Sensor type	Location in room	Height from floor (m)	West house			East house		
				Sensor code	Data period (dd/mm/2021)		Sensor code	Data period (dd/mm/2021)	
					From	To		From	To
Living room	U	Centre	1.1	U01	01/05	30/09	U41	01/05	30/09
	BG	Centre	1.1	BG02	01/05	30/09	BG42	01/05	30/09
	T	Dining room party wall	1.1	T03	09/07	30/09	T43	09/07	30/09
	T	Hall party wall	1.1	T04	09/07	30/09	T44	09/07	30/09
	T	Internal surface of external wall [a]	1.1	T05	09/07	30/09	T45	09/07	30/09
	T	Adjoining house party wall (chimney breast)	1.1	T06	09/07	30/09	T46	09/07	30/09
Dining room	U	Centre	1.1	U07	01/05	30/09	U47	01/05	30/09
	BG	Centre	1.1	BG08	01/05	30/09	BG48	01/05	30/09
Kitchen	U	Centre	1.1	U09	01/05	30/09	U49	01/05	30/09
	BG	Centre	1.1	BG10	01/05	30/09	BG50	01/05	30/09
Hall	U	Centre	1.1	U11	01/05	30/09	U51	01/05	30/09
	BG	Centre	1.1	BG12	01/05	30/09	BG52	01/05	30/09
Front double bedroom	U	Centre	1.1	U13	01/05	30/09	U53	01/05	30/09
	U	Centre	2.2	U14 [c]	30/05	30/09	U54	30/05	30/09
	U	Centre	0.1	U15 [c]	30/05	30/09	U55	30/05	30/09
	U	Northeast corner	1.1	U16 [c]	30/05	30/09	U56	30/05	30/09
	U	Southeast corner	1.1	U17 [c]	30/05	30/09	U57	30/05	30/09
	U	Southwest corner	1.1	U18 [c]	30/05	30/09	U58	30/05	30/09
	U	Northwest corner	1.1	U19 [c]	30/05	30/09	U59	30/05	30/09
	BG	Centre	1.1	BG20	01/05	30/09	BG60	01/05	30/09
	BG	North third, central	1.1	BG21	29/05	30/09	BG61	28/05	30/09
	T	Rear bedroom party wall	1.1	T22	07/06	30/09	T62	07/06	30/09
	T	Rear bedroom party wall	0.6	T23	07/06	11/08	T63	07/06	30/09
	T	Ceiling	2.4	T24	07/06	30/09	T64	07/06	30/09
	T	Floor	0.0	T25	07/06	30/09	T65	07/06	30/09
	T	Internal face of external wall (brick area) [b]	1.1	T26	11/08	30/09	T66 [d]	09/06	30/09
	T	Internal face of external wall (tile hung area)	0.4	NA	NA	NA	T67 [d]	09/06	30/09
	T	Radiator	0.4	NA	NA	NA	T68 [d]	09/06	30/09
	T	Internal face of external wall (upper bay intersect)	2.2	NA	NA	NA	T69 [d]	09/06	30/09
Rear double bedroom	U	Centre	1.1	U27	01/05	30/09	U70	01/05	30/09
	BG	Centre	1.1	BG28	01/05	30/09	BG71	01/05	30/09
	T	Front bedroom party wall	1.1	T29	11/08	30/09	T72	11/08	30/09
	T	Adjoining house party wall (north of chimney breast)	1.1	NA	NA	NA	T73	11/08	30/09
	T	Adjoining house party wall (chimney breast)	1.1	NA	NA	NA	T74	11/08	30/09
	T	Ceiling	2.4	T30	11/08	30/09	T75	11/08	30/09
	T	Floor	0.0	T31	11/08	30/09	T76	11/08	30/09
	T	Internal face of external wall (brick area) [a]	1.1	T32	11/08	30/09	T77	11/08	30/09
	T	Bathroom party wall	1.1	NA	NA	NA	T78	11/08	30/09
Single bedroom	U	Centre	1.1	U33	01/05	30/09	U79	01/05	30/09
	BG	Centre	1.1	BG34	01/05	30/09	BG80	01/05	30/09
Bathroom	U	Centre	1.1	U35	30/05	30/09	U81	01/05	30/09
	BG	Centre	1.1	BG36	01/05	30/09	BG82	01/05	30/09
Landing	U	Centre	1.1	U37 [c]	30/05	30/09	U83	30/05	30/09
	BG	Centre	1.1	BG38	29/05	30/09	BG84	28/05	30/09
	T	Internal face of external wall (next to stairs)	0.6	NA	NA	NA	T85	05/09	30/09
Loft (attic)	U	Centre	1.1	U39	01/05	30/09	U86	01/05	30/09
	BG	Centre	1.1	BG40	01/05	30/09	BG87	01/05	30/09

[a] Affixed to the wall on the west side of the window in the West house; affixed to the wall on the east side of the window in the East house.
[b] Affixed to the wall on the east side of the window in the West house; affixed to the wall on the west side of the window in the East house.
[c] Data gap between 04/06/2021 00:00 and 04/06/2021 09:00.
[d] Data gap between 17/09/2021 02:00 and 20/09/2021 09:00.

2.2.2 Air velocity

Periodic measurement of air velocity in the party wall cavity recorded air velocities of less than <0.05 m/s.

2.2.3 Measurement of weather conditions

Weather data were measured in four locations: at the test houses and at three sites on campus (Figure 3, Table 5, and Table 6). The test house weather station did not gather data for 21 hours and 51 minutes between 17/06/21 at 18:15 and 18/06/21 at 15:06.

Table 5: Weather stations

Station name	Station code	Location	Data from	Data to	Variables measured
Test house	TH	Ground-mounted on a 10m high pole in the north-facing garden to the rear of the test house.	01/0/2021 [a]	30/09/2021	Dry bulb temperature; wind speed; wind direction; global horizontal irradiance.
School of Architecture, Building and Civil Engineering	ABCE	Roof-mounted on S-building on Loughborough University campus.	28/01/2021	30/09/2021	Dry bulb temperature; relative humidity, wind speed; wind direction; global horizontal irradiance, diffuse irradiance, precipitation.
Geography department	GEOG	Ground-mounted in field on Loughborough University campus.	01/01/2021	TBC (see email)	Dry bulb temperature; relative humidity, wind speed; wind direction; global horizontal irradiance, precipitation, pressure.
Centre for Renewable Energy Systems Technology	CREST	Roof-mounted on Sir David Davies building on Loughborough University campus.	TBC (currently trying to access this data)	TBC (currently trying to access this data)	Dry bulb temperature, global horizontal irradiance, diffuse irradiance, direct normal irradiance.

[a] Except for dry bulb temperature which is available from 01/05/2021.

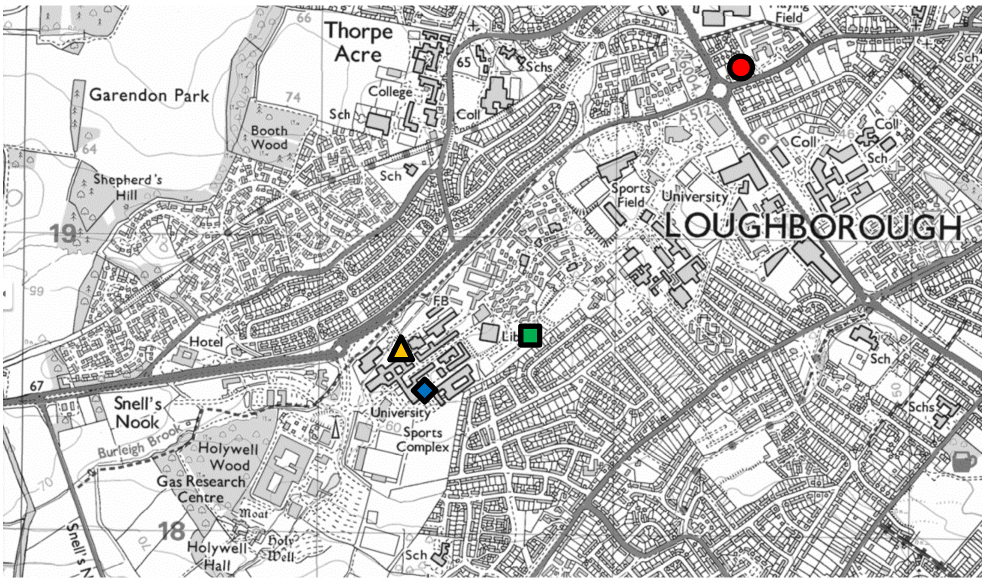

Figure 3: Location of the four weather stations. Red dot = TH; orange triangle = ABCE; green square = GEOG; blue diamond = CREST.

Table 6: Weather data collection devices, measurement intervals, and uncertainty

Data type	Weather station site	Device	Units	Measurement interval	Height from ground (m)	Uncertainty (±)
Dry bulb temperature	TH	U-type thermistor [a]	°C	20 seconds	1.1	0.3°C
	ABCE	Thermistor [a]	°C	10 minutes	20	
	GEOG	Combined temperature and relative humidity probe [a]	°C	1 minute	2	0.4°C
Relative humidity	ABCE	Transducer	%	10 minutes	20	2%
	GEOG	Combined temperature and relative humidity probe	%	1 minute	2	2% over 10-90%; 4% over 0-100%
Wind speed	TH	Ultrasonic anemometer	m/s	20 seconds	10	2%
	ABCE	Cup anemometer	m/s	10 minutes	20	0.1 m/s
	GEOG	Ultrasonic anemometer	m/s	1 minute	2	2%
Wind direction	TH	Ultrasonic anemometer	°	20 seconds	10	3°
	ABCE	Wind vane and 10K potentiometer	°	10 minutes	20	4°
	GEOG	Ultrasonic anemometer	°	1 minute	2	3°
Global horizontal solar irradiance	TH	Pyranometer	W/m^2	20 seconds	10	5%
	ABCE	Pyranometer	W/m^2	10 minutes	20	8%
	GEOG	Thermopile sensor	W/m^2	1 minute	2	5%
Diffuse horizontal solar irradiance	ABCE	Pyranometer	W/m^2	10 minutes	20	5%
	CREST	Pyranometer with shading ball mounted on sun tracker[b]	W/m^2	1 minute	20	3%
Direct normal solar irradiance	CREST	Pyrheliometer mounted on sun tracker[1]	W/m^2	1 minute	20	3%
Precipitation	ABCE	Tipping bucket raing gauge	mm	10 minutes	20	0.2 mm/tip
	GEOG	Tipping bucket rain gauge	mm	1 minute	2	0.2 mm/tip
Pressure	ABCE	Barometric pressure sensor	hPa	10 minutes	20	0.35 hPa
	GEOG	Barometric pressure sensor	hPa	1 minute	2	0.35 hPa

[a] Shielded from solar radiation and rain.
[b] Pyranometers mounted on heated ventilators to reduce dew and frost formation on domes.

2.3 Weather file creation

The data collected from the four weather stations were compared to check for the reliability of each measurement. Data were then selected to create a single weather file. The CIBSE DSY1 Nottingham weather file was used to fill the gaps prior to 1 April and after 30 September to create a complete, annual, weather file.

For the period 1 May to 30 September (inclusive) the global horizontal irradiance (GHI), wind speed, and wind direction were taken from the test house (TH) weather station. During the same period, relative humidity data were taken from the ABCE weather station. Dry bulb temperature was taken from the ABCE station between 1 and 30 April, then from the TH station from 1 May to 30 September. Diffuse solar irradiance was calculated from the TH station GHI using the same direct/diffuse fractions recorded by the ABCE station. Cloud cover was calculated similarly but comparing to the fractions from the CIBSE DSY1 weather file.

Where there were gaps in weather data from the TH station, data from the CREST station were used (GHI) and the ABCE station (dry bulb temperature, wind speed and direction).

3 Infiltration and ventilation

Previous work has found that infiltration rates in the test houses are lower in summer than would be derived from air permeability data using the "divide-by-20" method (Roberts et al. 2021). As such, infiltration was measured during this monitoring period using tracer gas. One whole house infiltration test was done during the July 2021 heatwave (Table 7). The recorded infiltration agreed with the findings of Roberts et al. 2021, and so no further infiltration tests were done.

Ventilation rates in the East house bedrooms were measured during the July 2021 heatwave (Table 7). All tests were done after the bedroom doors had closed at 22:00 (i.e. single sided ventilation). The curtains were also closed at this time, and previous ventilation measurements in these houses have shown ventilation rates to be lower with curtains closed compared to open (Roberts 2020).

For the infiltration and ventilation tracer gas tests, the tracer gas decay method was used as described in Roberts (2020) and Roberts et al. (2021). Fans were used to mix the house/room air, except in the single bedroom due to its small volume.

Table 7: Description and results of the tracer gas infiltration and ventilation measurements

House	Start date/time (dd/mm/yy hh:mm)	End date/time (dd/mm/yy hh:mm)	Duration (hh:mm)	Air change rate, ach (1/h)	Flow rate (l/s)	r^2
West	16/07/21 12:16	16/07/21 18:53	06:37	0.22	12.78	>0.99

Table 8 Measured single-sided ventilation rates

House	Room[a]	Start date/time (dd/mm/yy hh:mm)	End date/time (dd/mm/yy hh:mm)	Duration (hh:mm)	Air change rate (1/h)	Flow rate (l/s) [b]	r^2
East	Front double bedroom	21/07/21 00:12	21/07/21 01:12	01:00	2.12	19.79	>0.99
		21/07/21 22:23	21/07/21 22:59	00:36	3.69	34.44	>0.99
		22/07/21 22:48	22/07/21 23:48	01:00	2.11	19.69	>0.99
	Rear double bedroom	21/07/21 00:06	21/07/21 02:28	02:22	0.76	7.30	>0.99
		21/07/21 22:18	21/07/21 23:44	01:26	0.92	8.84	>0.99
		22/07/21 22:46	23/07/21 00:46	02:00	0.75	7.21	>0.99
	Single bedroom	21/07/21 00:13	21/07/21 01:13	01:00	2.72	7.56	>0.99
		21/07/21 22:32	21/07/21 23:32	01:00	2.21	6.14	>0.99

[a] See Figure 2.

[b] Converted from air change rate.

4 Format of data release

All temperature and weather data were converted to hourly means. Internal heat gain data were provided as hourly totals. Mean hourly data comprise all data collected during the following hour. For example, data for 12:00 comprise all the data recorded between 12:00 and 12:59. Internal heat gain totals comprise all the data consumed in the hour, e.g. data for 12:00 comprise the total consumption between 12:00 and 12:59.

File formats for data release are provided (Table 8). The files are listed in the README included with the dataset.

Table 9: Guide to file format for data release

Data type	Code	Example
West house	West	"West_..."
East house	East	"East_..."
Dry bulb temperature	AT	"West_AT_..."
Operative temperature	BG	"West_BG_..."
Surface temperature	ST	"West_ST_..."
Internal heat gains	IHG	"East_IHG_..."
Hourly means or totals	hourly	"West_AT_hourly…"

5 Acknowledgements

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We thank Dr Richard Hodgkins and Dr Tom Betts for providing the weather data from, respectively, the Geography and CREST weather stations at Loughborough University.

We acknowledge Max Eastwood who measured the U-values of external walls and the depth of the kitchen floor slab.

Use of the test houses would not be possible without the ongoing maintenance and 24-hour security provided by Loughborough University.

6 References

Roberts, B.M., Allinson, D. and Lomas, K.J., 2018. A matched pair of test houses with synthetic occupants to investigate summertime overheating. Journal of Sustainable Design and Applied Research, 6(1), 29-38.

Roberts, B.M., Allinson, D. and Lomas, K. 2019a. Prediction of overheating in synthetically occupied UK homes: dataset for validating dynamic thermal models of buildings. Loughborough University Research Repository (Figshare). https://doi.org/10.17028/rd.lboro.8094575.

Roberts, B.M., 2020. Ventilation and shading to reduce overheating in UK homes: an evaluation using matched pair test houses with synthetic occupants (Doctoral dissertation, Loughborough University).

Roberts, B.M., Allinson, D. and Lomas, K.J., 2021. Evaluating methods for estimating whole house air infiltration rates in summer: implications for overheating and indoor air quality. International Journal of Building Pathology and Adaptation.

Roberts, B.M., Abel, B., Allinson, D., Crowley, J., Salehi, B., Rashid, T. and Lomas, K. J. (2022). A dataset from synthetically occupied test houses for validating model predictions of overheating. CIBSE Technical Symposium, April 2022, UK.

7 Uncited, but relevant, publications

Roberts, B.M., Allinson, D., Diamond, S., Abel, B., Das Bhaumik, C., Khatami, N. and Lomas, K.J., 2019b. Predictions of summertime overheating: Comparison of dynamic thermal models and measurements in synthetically occupied test houses. Building Services Engineering Research and Technology, 40(4), 512-552.