

# **Supplementary Information for article: “Calibration of Building Performance Simulations for Zero Carbon Ready Homes: Two Open Access Case Studies in Controlled Conditions”**

Christopher Tsang<sup>a,\*</sup>, Richard Fitton<sup>a</sup>, Xinyi Zhang<sup>a</sup>, Grant Henshaw<sup>a</sup>, Heidi Diaz Hernandez<sup>a</sup>, David Farmer<sup>a</sup>, David Allinson<sup>b</sup>, Anestis Sitmalidis<sup>a</sup>, Mohamed Dgali<sup>a</sup>, Ljubomir Jankovic<sup>a</sup>, William Swan<sup>a</sup>

<sup>a</sup>Energy House Labs, School of Science, Engineering and Environment, University of Salford, Manchester, M5 4WT, UK

<sup>b</sup> Building Energy Research Group (BERG), School of Architecture, Building and Civil Engineering, Loughborough University, LE11 3TU

\* Corresponding author: [c.tsang1@salford.ac.uk](mailto:c.tsang1@salford.ac.uk)

## **1 Purpose of this document**

This supplementary information package contains detailed technical data to support the paper “Calibration of Building Performance Simulations for Zero Carbon Ready Homes: Two Open Access Case Studies in Controlled Conditions”. This information will enable readers to develop an energy model of these two homes after reading the paper and refer to this supplementary information.

## **2 Energy House 2.0 facility**

The Energy House 2.0 is a globally recognised facility specifically designed for conducting comprehensive evaluations of building performance. It consists of two separate chambers, each capable of accommodating two family homes, allowing for a total capacity of four homes. These chambers feature a 1200 mm deep soil-filled pit that is insulated from the surrounding ground, ensuring an isolated environment unaffected by external weather conditions. With insulated walls and ceilings, the chambers provide a controlled environment that remains unaffected by fluctuations in the weather.

To regulate the conditions within each chamber, a large Heating, Ventilation, and Air Conditioning (HVAC) system is employed. Additionally, supplementary weather rigs are utilised to simulate various environmental effects, enabling precise control over the chamber's climate. These effects include temperature ranging from -20 °C to 40 °C, relative humidity varying from 20% to 90%, wind, rain, solar radiation with intensities reaching up to 1200 W/m<sup>2</sup>, and snowfall. The facility offers the flexibility to maintain a consistent temperature and relative humidity or adjust them to align with seasonal or daily patterns. Please refer to Figure S1 for a visual representation of the facility.



**Figure S1 – Energy House 2.0 Facility.**

### 3 Geometry

This section provides comprehensive geometric data for modelling both houses (Table S1). Tables S2 and S3 detail the floor areas for individual zones, while Tables S4 and S5 specify window dimensions. TFH's and eHome2's dimensions are illustrated in their respective elevation plans (Figures S2 and S3). Floor plans indicating partition walls and doors for thermal zone modelling are included in the paper.

**Table S1: Overall building dimensions according to floor plan**

	TFH	eHome2
Building footprint	8.99m × 6.29m	9.44m × 5.95m
Floor area	86.96 m <sup>2</sup>	86.84 m <sup>2</sup>
Ground floor ceiling height	2.39 m	2.69 m
First floor ceiling height	2.35 m	2.30 m
Thickness of internal floor	0.34 m	0.31 m
Roof Pitch	35 degrees	45 degrees

**Table S2: TFH floor area according to floor plan**

	Zone	Floor area (m <sup>2</sup> )
Ground Floor	Living Room	14.18
	Dining	8.46
	Kitchen	8.21
	Hall	7.37
	WC	2.67
	Store 1	1.14
	Store 2	1.14
	Store 3	0.77
First Floor	Bedroom 1	11.86
	Bedroom 2	8.64
	Bedroom 3	7.69
	Landing	6.24
	Bathroom	4.15
	En-suite	3.92
	Store 4	0.52

**Table S3: eHome2 floor area according to floor plan**

	Zone	Floor area (m <sup>2</sup> )
Ground Floor	Living Room	17.17
	Hall	7.81
	Kitchen	7.77
	Dining	6.35
	WC	2.79
	Store 1	1.68
First Floor	Bedroom 1	12.29
	Bedroom 2	9.86
	Bedroom 3	7.51
	Landing	6.09
	Bathroom	3.89
	En-suite	3.19
	Store 2	0.44

**Table S4: Window dimensions for TFH**

		Window length (m)	Window height (m)	Window area (m <sup>2</sup> )
Ground Floor	Dining (French Door)	2372.5	2100	4.982
	Kitchen	1247.5	1050	1.310
	Living Room	1810	1800	3.258
	WC	640	1060	0.678
	Hall	977.5	2260	2.209
First Floor	Bedroom 1	1810	1200	2.172
	Bedroom 2	1247.5	1421.5	1.773
	Bedroom 3	1205	1210	1.458
	Ensuite	1247.5	1200	1.497
	Bathroom	685	1060	0.726

**Table S5: Window dimensions for eHome2**

	Zone	Window length (m)	Window height (m)	Window area (m <sup>2</sup> )
Ground Floor	Kitchen	910	1200	1.092
	Dining (French Door)	1810	2100	3.801
	Dining	910	2100	1.911
	Living room	1810	1500	2.715
	Living room (Window 2)	910	2100	1.911
	Hall (Front door)	1023	2100	2.148
First Floor	Bedroom 1	910	1200	1.092
	Bedroom 2	910	1950	1.774
	Bedroom 3	910	1200	1.092
	Landing	685	1050	0.719
	Bathroom	685	1050	0.719
	En-suite	910	1950	1.774



Figure S2: a) Front, b) rear, c) left and d) back elevations of TFH

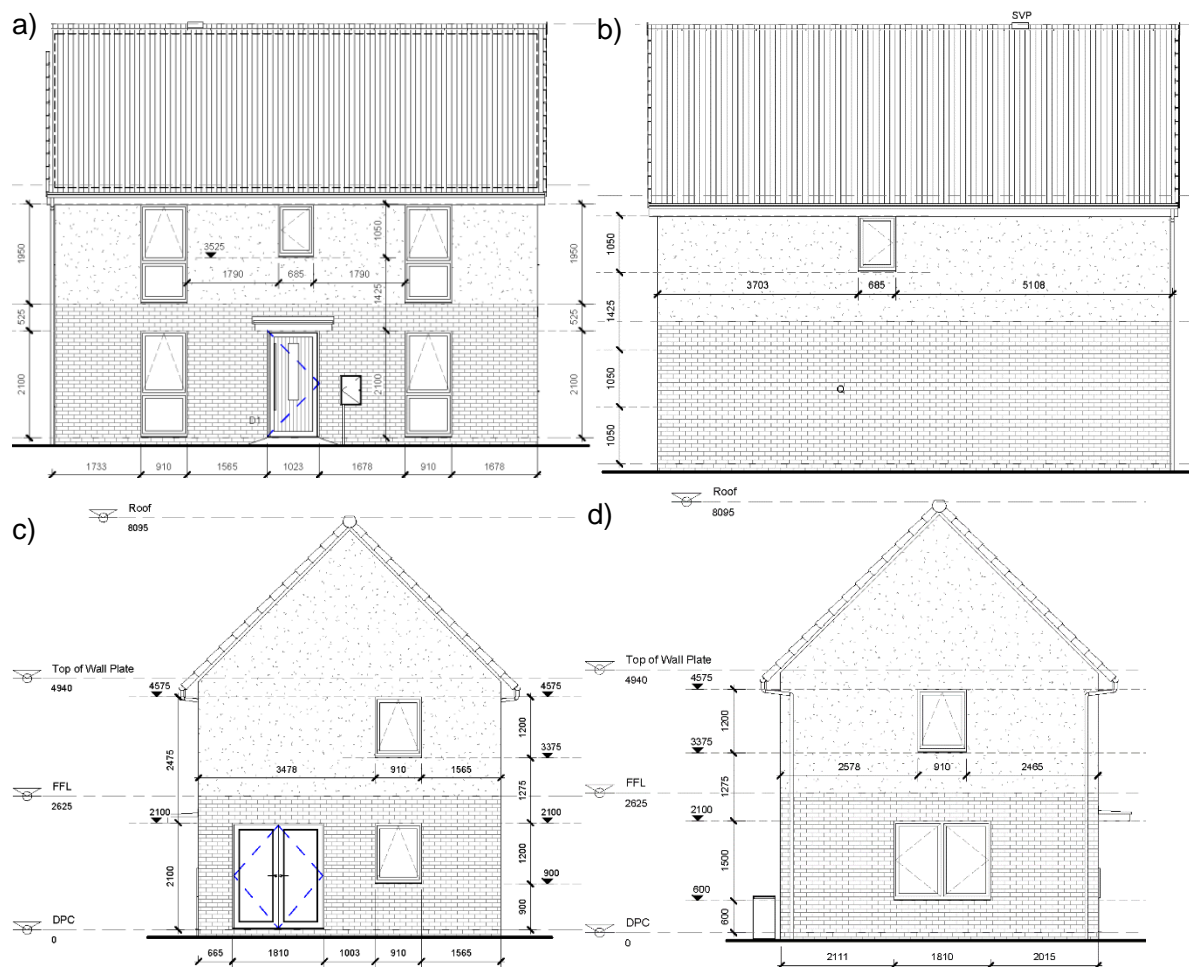


Figure S3: a) Front, b) rear, c) left and d) back elevations of eHome2

## 4 Material thermal properties

Tables S6 present the thermal properties (thermal conductivity, specific heat capacity, and density) of all construction materials used in TFH and eHome2, respectively. These are assumptions used in DesignBuilder.

Table S6: TFH and eHome2 material thermal properties

Category	Envelope	Material	Conductivity (W/mK)	Specific heat (J/kgK)	Density (kg/m3)
Insulation materials	External wall	Knauf FrameTherm® Roll 35	0.035	840	140
	External wall	PIR insulation board	0.022	1000	700
	External wall	TFR35 Insulation	0.035	1030	24
	Loft ceiling	Knauf Insulation Loft Roll 44	0.044	1030	24
	External door	Standard Insulation	0.04	840	12
Structural Materials	External wall	Brick outer leaf	0.77	800	1700
	External wall	Oriented Strand Board	0.13	1700	650
	External wall	Standard Aircrete (Blockwork)	0.15	800	1700
	Pitched roof	Concrete Tile (roofing)	1.5	1000	2100
Board Materials	External wall	Knauf Wallboard	0.19	1000	700
	Loft ceiling	Gyproc Wallboard	0.19	1000	700
	External wall	BG glassroc x	0.1865	1000	1000
	Internal partitions	Gypsum Plasterboard	0.25	1000	900
Finishing Materials	External wall	Weber Monocouche Render	1	1000	1300
	External wall	Weberwall brick slip	0.72	840	1920
	External wall	Weberend LAC rapid base	0.45	840	1920
	External wall	Webersill TF finish	0.45	840	1920

Flooring Materials	Ground floor	NUG375+75MM Screed	0.058	1400	15
	Internal floor	Caberdek chipboard floors	0.14	2093	800
Thermal bridges	External wall	Wooden frame	0.12	896	2800
	External wall	Wooden battens	0.13	896	2800
	External wall	Standard Aircrete	0.88	896	2800
Other materials	Pitched roof	Roofing Felt	0.19	837	960
	External door	Painted Oak	0.19	2390	700

## 5 Construction details

### 5.1 External wall

Tables S7-9 show three variations of external wall constructions for TFH: two brick walls with different service zone thicknesses (25mm and 38mm) and one rendered wall. Table S10-11 show two variations of external constructions for eHome2: brick wall and rendered wall.

**Table S7: Brick external wall construction with 25mm service zone**

Layer	Material	Thickness (mm)	Conductivity (W/mK)	Combined thermal resistance (m <sup>2</sup> K/W)
External Finish	Brick outer leaf	102.5	0.77	0.133
Cavity	Slightly ventilated cavity	50	-	0.71
Sheathing	Oriented Strand Board	9	0.13	0.069
Main insulation	Knauf FrameTherm® Roll 35, 15% bridging with wooden frame ( $\lambda = 0.12$ W/mK)	89	0.035	1.866
Additional insulation	PIR insulation board	40	0.022	1.818
Service Void	Service void, 11.8% bridging with wooden battens ( $\lambda = 0.13$ W/mK)	25	-	0.518
Internal finish	Knauf Wallboard	15	0.19	0.079

**Table S8: Brick external wall construction with 38mm service zone**

Layer	Material	Thickness (mm)	Conductivity (W/mK)	Combined thermal resistance (m <sup>2</sup> K/W)
External Finish	Brick outer leaf	102.5	0.77	0.133
Cavity	Slightly ventilated cavity	50	-	0.71
Sheathing	Oriented Strand Board	9	0.13	0.069
Main insulation	Knauf FrameTherm® Roll 35, 15% bridging with wooden frame ( $\lambda = 0.12$ W/mK)	89	0.035	1.866
Additional insulation	PIR insulation board	40	0.022	1.818
Service Void	Service void, 11.8% bridging with wooden battens ( $\lambda = 0.13$ W/mK)	38	-	0.518
Internal finish	Knauf Wallboard	15	0.19	0.079

**Table S9: Rendered external wall construction**

Layer	Material	Thickness (mm)	Conductivity (W/mK)	Combined thermal resistance (m <sup>2</sup> K/W)
External Finish	Weber Monocouche Render	20	1.0	0.022
Blockwork	Blockwork, 6.7% bridging with standard Aircrete ( $\lambda = 0.12$ W/mK)	100	0.15	0.684
Sheathing	Oriented Strand Board	9	0.13	0.069
Main insulation	Knauf FrameTherm® Roll 35, 15% bridging with wooden frame ( $\lambda = 0.12$ W/mK)	89	0.035	1.866
Additional insulation	PIR insulation board	40	0.022	1.818
Service Void	Service void, 11.8% bridging with wooden battens ( $\lambda = 0.13$ W/mK)	25	-	0.518

Internal finish	Knauf Wallboard	15	0.19	0.079
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**Table S10: Brick external wall construction for eHome2**

Layer	Material	Thickness (mm)	Conductivity (W/mK)	Combined thermal resistance (m <sup>2</sup> K/W)
External finish	Weberwall brick slip finishing system	15	0.72	0.021
External board	BG glassroc x	12.5	0.1865	0.067
Cavity	Ventilated cavity	25	-	0.71
Sheathing	Oriented Strand Board	9	0.13	0.069
Outer Insulation	TFR35 Insulation, 8.8% bridging with flange ( $\lambda = 0.13$ )	47	0.035	0.947
Core insulation	TFR35 Insulation, 1.7% bridging with flange ( $\lambda = 0.13$ )	151	0.035	3.831
Inner insulation	TFR35 Insulation, 8.8% bridging with flange ( $\lambda = 0.13$ )	47	0.035	0.947
Additional sheathing	Oriented Strand Board	9	0.13	0.069
Service void	Service void with 8.8% bridging with wooden battens ( $\lambda = 0.13$ )	35	-	0.518
Internal Finish	Gyproc Wallboard	15	0.19	0.079

**Table S11: Rendered external wall construction for eHome2**

Layer	Material	Thickness (mm)	Conductivity (W/mK)	Combined thermal resistance (m <sup>2</sup> K/W)
External finish	Webersill TF finish coat and Weberend LCA rapid base coat	7.5	0.72	0.0104
External board	BG glassroc x	12.5	0.1865	0.067
Cavity	Ventilated cavity	25	-	0.71
Sheathing	Oriented Strand Board	9	0.13	0.069
Outer Insulation	TFR35 Insulation, 8.8% bridging with flange ( $\lambda = 0.13$ )	47	0.035	0.947
Core insulation	TFR35 Insulation, 1.7% bridging with flange ( $\lambda = 0.13$ )	151	0.035	3.831
Inner insulation	TFR35 Insulation, 8.8% bridging with flange ( $\lambda = 0.13$ )	47	0.035	0.947
Additional sheathing	Oriented Strand Board	9	0.13	0.069
Service void	Service void with 8.8% bridging with wooden battens ( $\lambda = 0.13$ )	35	-	0.518
Internal Finish	Gyproc Wallboard	15	0.19	0.079

## 5.2 Loft ceiling

Table S12 and 13 show the loft ceiling construction for TFH and eHome2 respectively.

**Table S12: Loft ceiling construction for TFH**

Layer	Material	Thickness (mm)	Conductivity (W/mK)	Combined thermal resistance (m <sup>2</sup> K/W)
Primary insulation	Knauf insulation loft roll	400	0.044	9.097
Secondary insulation	Knauf insulation loft roll, 9% bridging with wooden battens ( $\lambda = 0.13$ )	100	0.044	1.934
Ceiling	Gyproc Wallboard	15	0.19	0.079

**Table S13: Loft ceiling construction for eHome2**

Layer	Material	Thickness (mm)	Conductivity (W/mK)	Combined thermal resistance (m <sup>2</sup> K/W)
Primary insulation	Isover Spacesaver roof insulation	300	0.044	6.818
Secondary insulation	Isover Spacesaver roof insulation, 9% bridging with wooden battens ( $\lambda = 0.13$ )	100	0.044	2.092
Ceiling	Gyproc Wallboard	15	0.19	0.079

### 5.3 Pitched roof

Table S14 show the pitched roof construction for both TFH and eHome2

**Table S14: Pitched roof construction for TFH and eHome2**

Layer	Material	Thickness (mm)	Conductivity (W/mK)	Thermal resistance (m <sup>2</sup> K/W)
External tile	Concrete tiles (roofing)	10	1.5	0.007
Ventilation	Air gap	10	-	0.15
Underlayment	Roofing Felt	5	0.19	0.026

### 5.4 Internal partitions

Table S15 show the internal partition construction for both TFH and eHome2

**Table S15: Internal partition construction for TFH and eHome2**

Layer	Material	Thickness (mm)	Conductivity (W/mK)	Thermal resistance (m <sup>2</sup> K/W)
Surface 1	Gypsum plasterboard	15	0.19	0.079
Air space	Air gap	100	-	0.15
Surface 2	Gypsum plasterboard	15	0.19	0.079

### 5.5 Internal floor

Table S16 and 17 show the internal floor construction for TFH and eHome2 respectively.

**Table S16: Internal floor construction for TFH**

Layer	Material	Thickness (mm)	Conductivity (W/mK)	Thermal resistance (m <sup>2</sup> K/W)
Floor surface	Caberdek chipboard floor	22	0.13	0.169
Air space	Air gap 300mm	300	-	0.230
Ceiling	Gyproc wallboard	15	0.19	0.079

**Table S17: Internal floor construction for eHome2**

Layer	Material	Thickness (mm)	Conductivity (W/mK)	Thermal resistance (m <sup>2</sup> K/W)
Floor surface	Caberdek chipboard floor	22	0.13	0.169
Sheathing	Oriented Strand Board	15	0.13	0.115
Air space	Air gap 254mm	254	-	0.230
Ceiling	Gyproc wallboard	15	0.19	0.079

### 5.6 Ground floor

Table S18 show the ground floor construction for both TFH and eHome2



**Table 18: Ground floor construction for TFH and eHome2**

Layer	Material	Thickness (mm)	Conductivity (W/mK)	Thermal resistance (m <sup>2</sup> K/W)
Floor construction	450 mm NUG375+75 mm Screed	450	0.058	7.759

## 5.7 Window thermal properties

Table S19 show the detailed windows specification for both TFH and eHome2

**Table S19: TFH and eHome2 windows specifications**

Property	Value
Glazing Overview	28mm Double Glazed
External Pane	4mm Saint Gobain Diamant
Internal Pane	4mm Saint Gobain Planitherm One T FG
Gas Fill Details	90% Argon 10% Air
Spacer Bar	Swisspacer Ultimate/Thermobar
Centre Pane glazing U-value	1.07 W/(m <sup>2</sup> K)
Overall Window U-value with frame	1.20 W/(m <sup>2</sup> K)
Glazing g-value (Solar Hot Gain Coefficient)	0.51

## 5.8 External door

The TFH front door is manufactured by Firth Doors and Hardware. It has a U-value of 1.0 W/m<sup>2</sup>K and dimensions of 914mm width providing a clear opening of 850mm. Note that for modelling purposes, use the provided U-value. Table S20 show the external door construction for both TFH and eHome2.

**Table S20: External door construction for TFH and eHome2**

Layer	Material	Thickness (mm)	Conductivity (W/mK)	Thermal resistance (m <sup>2</sup> K/W)
Door construction	Painted Oak	35	0.19	0.184

## 6 Chamber conditions

Tables S21 and 22 present the daily chamber conditions over an 8-day period for two prototype homes (TFH and eHome2) tested in Energy House 2.0, showing identical controlled environmental parameters with consistent values except for wind direction which varies hourly according to the CIBSE Manchester weather file (\*).

**Table S21: Daily chamber conditions in TFH**

Parameter/ Day	1	2	3	4	5	6	7	8
Dry Bulb temperature (°C)	5.3	5.2	5.3	5.2	5.3	5.3	5.3	5.3
Dew point temperature (°C)	2.31	2.16	2.31	2.16	2.31	2.31	2.31	2.31
Relative humidity (%)	81	81	81	81	81	81	81	81
Atmospheric Pressure (Pa)	101325	101325	101325	101325	101325	101325	101325	101325
Horizontal Infrared Radiation Intensity from Sky (W/m <sup>2</sup> )	269.87	269.59	269.87	269.59	269.87	269.87	269.87	269.87
Global Horizontal Radiation (Wh/m <sup>2</sup> )	0	0	0	0	0	0	0	0
Direct Normal Radiation (Wh/m <sup>2</sup> )	0	0	0	0	0	0	0	0
Diffuse Horizontal Radiation (Wh/m <sup>2</sup> )	0	0	0	0	0	0	0	0
Wind Direction (-)	*	*	*	*	*	*	*	*
Wind Speed (ms <sup>-1</sup> )	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2

Total Sky Cover (-)	0	0	0	0	0	0	0	0
Opaque Sky Cover (-)	0	0	0	0	0	0	0	0
Snow Depth (cm)	0	0	0	0	0	0	0	0
Liquid Precipitation Depth (cm)	0	0	0	0	0	0	0	0

**Table S22: Daily chamber condition in eHome2**

Parameter/ Day	1	2	3	4	5	6	7	8
Dry Bulb temperature (°C)	5.3	5.2	5.3	5.2	5.3	5.3	5.3	5.3
Dew point temperature (°C)	2.31	2.16	2.31	2.16	2.31	2.31	2.31	2.31
Relative humidity (%)	81	81	81	81	81	81	81	81
Atmospheric Pressure (Pa)	101325	101325	101325	101325	101325	101325	101325	101325
Horizontal Infrared Radiation Intensity from Sky (W/m <sup>2</sup> )	269.87	269.59	269.87	269.59	269.87	269.87	269.87	269.87
Global Horizontal Radiation (Wh/m <sup>2</sup> )	0	0	0	0	0	0	0	0
Direct Normal Radiation (Wh/m <sup>2</sup> )	0	0	0	0	0	0	0	0
Diffuse Horizontal Radiation (Wh/m <sup>2</sup> )	0	0	0	0	0	0	0	0
Wind Direction (-)	*	*	*	*	*	*	*	*
Wind Speed (ms <sup>-1</sup> )	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Total Sky Cover (-)	0	0	0	0	0	0	0	0
Opaque Sky Cover (-)	0	0	0	0	0	0	0	0
Snow Depth (cm)	0	0	0	0	0	0	0	0
Liquid Precipitation Depth (cm)	0	0	0	0	0	0	0	0