Programme Area: Smart Systems and Heat

Project: WP1 Integrated Electrical Heat

Title: Integrated Electric Heat – Description of Modelling Code

Abstract:

This deliverable provides a description of Modelling Code. This report was produced to support the analysis work done for BEIS for their input to IEA Annex 42.

Context:

The Integrated Electric Heating Project provided a modelling tool to evaluate the opportunities and challenges for electric heating to meet UK household requirements. The tool will be used to create and evaluate upgrade pathways for a small number of housing archetypes informed by detailed information gathered from dwelling participating in the recent Home Energy Management System trial.

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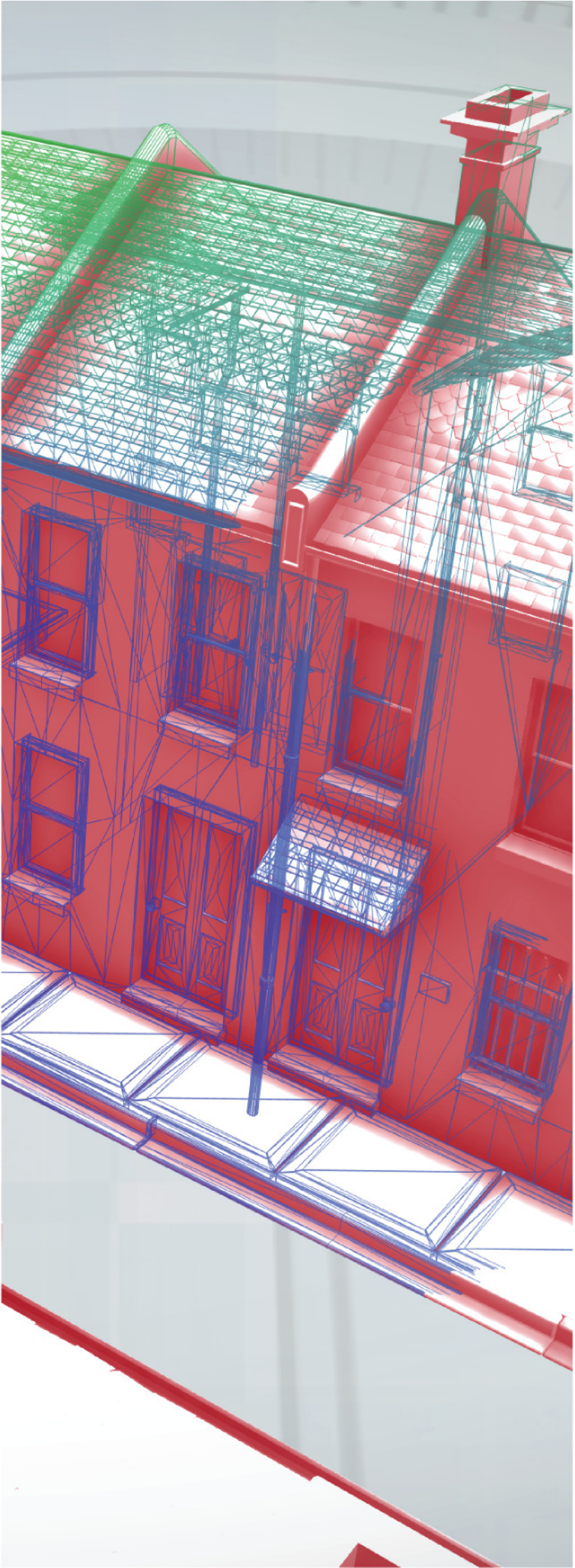

Smart Systems and Heat Phase 1

Integrated Electric Heat

Explanation of Modelling Code

ESC Project Number ESC00045

ETI Project Number SS9003

Version V1.0

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Energy Technologies Institute Smart Systems and Heat Programme

“Creating future-proof and economic local heating solutions for the UK”

- Connecting together – the understanding of consumer needs and behaviour with the development and integration of technologies and new business models into…
- Delivering enhanced knowledge amongst industry and public sector
- Resulting in industry and investor confidence to implement from 2020 which enables a UK heat transition

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Integrated Electric Heat – Description of Modelling Code

Supporting simulations for BEIS response to IEA Annex 42

14/03/2017

Contents

Description of results file BEIS DSR Results_080317.xlsx

This document is a description of the simulation runs and results file provided to Oliver Sutton at BEIS in support of the IEA Annex 42 work using the ETI funded Integrated Electric Heat model

Column name in results file	***Description***
Base Case	A name for each simulation which contains all of the meta-data for that simulation
Building	Building type used for simulation (see BHSDD for more details): B2 (Building 2): 1919-1944 Semi-Detached, useable floor area of 90m^2, 7.7% of building stock in uninsulated form (represents a greater proportion with variable insulation and thermal mass) B4 (Building 4): 1965-1980 detached, useable floor area of 200m^2, 5.3% of building stock in uninsulated form (represents a greater proportion with variable insulation and thermal mass) B5 (Building 5): Post 1990 detached, useable floor area of 115m^2, 4.4% of building stock in uninsulated form (represents a greater proportion with variable insulation and thermal mass)
Heating system	Heating system used for simulation (see BHSDD for more details): ASHP: Air-To-Water Air Source Heat Pump. An air source heat pump is used for space heating and is supplemented by an immersion heater in the DHW storage tank to assist in domestic hot water (DHW) production. HHP: Hybrid Heating System with ASHP and gas boiler. For Building 2, gas boiler is a combi gas fired boiler. For Building 4 and 5, gas boiler is a gas fired system boiler which includes a hot water tank for DHW delivery.
Sim #	Number identifier of simulation within batch
DSR event	DSR event identifier: see Table 3 for details
DSR length	Length of DSR event (hours) as identified from DSR event identifier (see Table 3)
Prior Temp increase	Temperature increase prior to DSR event (°C) as identified from DSR event identifier (see Table 3)
Insulation thickness	Thickness of insulation in external walls: L (low), M (medium), H (high). See Table 4 for values of insulation thickness (mm)
Thermal mass	Thermal mass of lumped mass parameter representing thermal mass of internal walls and possibility of additional thermal mass in external walls: D (default) or M (medium) calculated thermal mass of internal walls in living zone (downstairs) and night zone (upstairs), L (low) equal to default thermal mass minus 20%, H (high) equal to default thermal mass plus 20%. See Table for values of thermal mass (J/K)
Hotwater storage	Size of DHW storage tank: D (default), H (high). See Table 6 for values of hot water storage (litres)
Weather	Weather file used for simulation period: Avg (average winter weather) has average temperature of 7.7 °C and simulations are over a 30-day period, Cold (cold winter weather) has average temperature of 2.3 °C and simulations are over a 14-day period. Plots of external temperature within weather files are shown in Figure 1
Heatpump power	Power of heat pump in simulation (kW)

Table 1 Meta-data for simulations

Column name in results file	***Explanation of result KPI***
Base Case	Name identifier of simulation
Total Gas Consumption (kWh)	Sum of gas consumption over whole simulation period (if applicable)
Total Electrical Consumption (kWh)	Sum of electricity consumption over whole simulation period (if applicable)
Month Gas Consumption (kWh)	=Total Gas Consumption (kWh) * (30/14) to make comparable values for 14 day and 30 day simulations (applied to 14-day Cold weather simulations only)
Month Electrical Consumption (kWh)	Total Electrical Consumption (kWh) * (30/14) to make comparable values for 14 day and 30 day simulations (applied to 14-day Cold weather simulations only)
Monthly CO_2 emissions (kg)	= Gas CO_2 emission factor ($kgCO_2$ / kWh) * Total (or Month) Gas Consumption (kWh) + Electricity CO_2 emission factor ($kgCO_2$ / kWh) * Total (or Month) Electricity Consumption (kWh)
Monthly cost (£)	= Gas cost per unit (£ / kWh) * Total (or Month) Gas Consumption (kWh) + Electricity cost per unit (£ / kWh) * Total (or Month) Electricity Consumption (kWh)
Average Temp at end of DSR (LivingZone)	Averaged value of all “Day_[x] Temp at end of DSR (LivingZone)”
Total days below 20 ℃ at end of DSR (LivingZone)	Total number of days in which “Day_[x] Temp at end of DSR (LivingZone)” is less than 20 ℃
Total days below 19 ℃ at end of DSR (LivingZone)	Total number of days in which “Day_[x] Temp at end of DSR (LivingZone)” is less than 19 ℃
Total days below 18 ℃ at end of DSR (LivingZone)	Total number of days in which “Day_[x] Temp at end of DSR (LivingZone)” is less than 18 ℃
Total % Time below Tset during DSR (LivingZone)	Sum of total values of “Day_[x] % Time below Tset (LivingZone)”, divided by total number of days in simulation
Total % Time below Tset -1 during DSR (LivingZone)	Sum of total values of “Day_[x] % Time below Tset -1 (LivingZone)”, divided by total number of days in simulation
Total % Time below Tset -2 during DSR (LivingZone)	Sum of total values of “Day_[x] % Time below Tset -2 (LivingZone)”, divided by total number of days in simulation

Day_[x] Temp at end of DSR (LivingZone)	Temperature in Living zone at the time that the DSR event ends, on day [x] of simulations
Day_[x] % Time below Tset (LivingZone)	Percentage of DSR period in which temperature in living zone is less than 20 ℃, on day [x] of simulations
Day_[x] % Time below Tset -1 (LivingZone)	Percentage of DSR period in which temperature in living zone is less than 19 ℃, on day [x] of simulations
Day_[x] % Time below Tset -2 (LivingZone)	Percentage of DSR period in which temperature in living zone is less than 18 ℃, on day [x] of simulations
Day_[x] Temp at end of DSR (NightZone)	Temperature in Night zone at the time that the DSR event ends, on day [x] of simulations
Day_[x] % Time below Tset (NightZone)	Percentage of DSR period in which temperature in night zone is less than 20 ℃, on day [x] of simulations
Day_[x] % Time below Tset -1 (NightZone)	Percentage of DSR period in which temperature in night zone is less than 19 ℃, on day [x] of simulations
Day_[x] % Time below Tset -2 (NightZone)	Percentage of DSR period in which temperature in night zone is less than 18 ℃, on day [x] of simulations
Day_[x] Text average	Average external temperature, on day [x] of simulations

Table 2 Description of key performance indicators (KPIs)

DSR length (hours)	**Temperature increase prior to DSR event (℃) ***	**All day occupancy (heating period 05:00 – 22.30)**		**Two occupied periods during day (heating period 05:00 – 08:00 and 17:00 – 22:00)**	
		DSR event identifier	**DSR event time**	**DSR event identifier**	**DSR event time**
1	1	HHg	18:00 – 19:00	HHgg	17:00 – 18:00
2	1	HHh	18:00 – 20:00	HHhh	17:00 – 19:00
3	1	HHi	18:00 – 21:00	HHii	16:30 – 19:30
2	2	HHj	18:00 – 20:00	HHjj	17:00 – 19:00
3	2	HHk	18:00 – 21:00	HHkk	16:30 – 19:30

Table 3 Description of DSR event details.

*Temperature is increased for 4 hours before the DSR event, despite the allocated heating period

Building	Insulation low	Insulation medium	Insulation high
Building 2	60mm air gap, 0mm blown wall insulation	60mm air gap, 40mm blown wall insulation	0mm air gap, 60mm blown wall insulation
Building 4	6 mm insulation		100 mm insulation
Building 5	5 mm insulation	40 mm insulation	80 mm insulation

Table 4 Details of insulation levels for each building

Building	Thermal mass default / medium	Thermal mass low	Thermal mass high
Building 2	6.70 MJ/K	4.25 MJ/K	8.06 MJ/K
Building 4	11.20 MJ/K	8.20 MJ/K	13.40 MJ/K
Building 5	8.24 MJ/K	6.60 MJ/K	9.90 MJ/K

Table 5 Details of thermal mass levels for each building

Building	Hot water storage default	Hot water storage high
Building 2 (ASHP only)	150 litres	300 litres
Building 4 (ASHP and HHP)	150 litres	300 litres
Building 5 (ASHP and HHP)	150 litres	300 litres

Table 6 Details of hot water storage levels for each building

Aside

- Ventilation levels have not been included in simulation runs. All simulations have value of approx. 0.6 ach. Wallace, Emmerich & Howard-Reed (2002)[1] identified a mean air change rate of 0.65 ach with a standard deviation of 0.56 ach.

[1] Wallace, L.A., Emmerich, S.J. and Howard-Reed, C., 2002. Continuous measurements of air change rates in an occupied house for 1 year: the effect of temperature, wind, fans, and windows. Journal of Exposure Science and Environmental Epidemiology, 12(4), p.296.

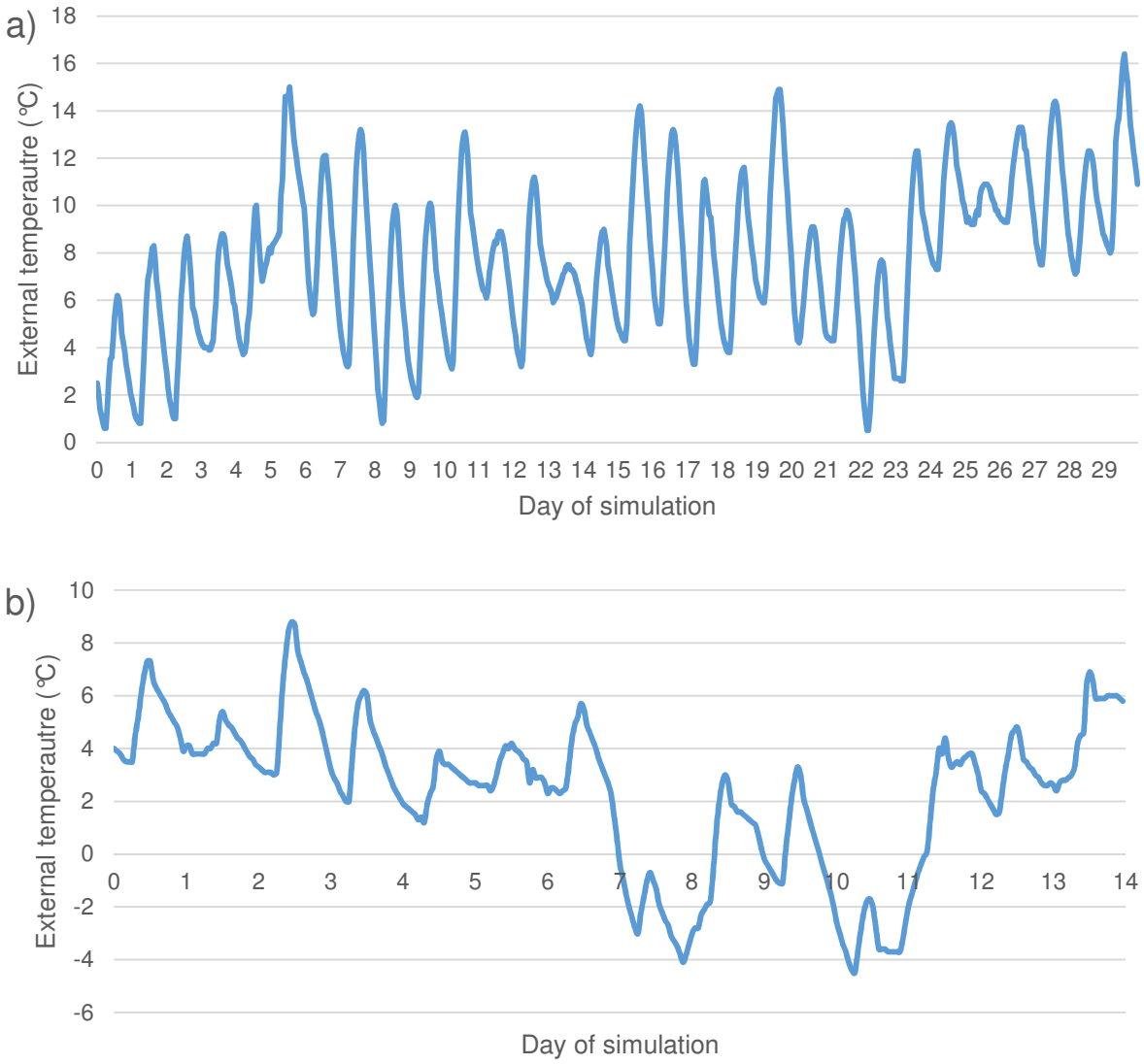

Figure 1 External temperature of weather plots for a) average weather (30 days) and b) cold weather (14 days)

Document Control

Type:	Report
Title:	Description of Modelling Code
ETI Project Number:	SS9003
ESC Project Number:	ESC00045
Version:	1.0
Status*:	Draft
Restrictions**:	Confidential
Completion Date:	14/03/2017

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Revision History

Date	Version	Comments
14/03/2017	V1.0	First Version
	V	
	V	
	V	
	V	
	V	

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