Thermocill

Product Performance Verification Report

November 2020

Contents

1. Background & Product Description

Thermocill Ltd. have developed an innovative passive energy efficiency product called Thermocill which is placed underneath a window board in a home. It replaces the standard window board with a similar looking unit which contains a channel to redirect warm air from a radiator underneath a window, up towards the windowpane. This creates a wall of warm air adjacent to the windowpane.

The wall of warm air generated by Thermocill is claimed to reduce the amount of heat loss through the window, thus reducing the dwelling's heating demand. Raising the temperature around the window frames is also claimed to reduce problems associated with condensation and moisture.

Thermocill requested product performance verification from EST, based on submitted evidence that their product provide financial, carbon and energy savings for customers as well as reduced condensation within the home.

During the testing of the product, two iterations are considered: the original Thermocill which was tested at the Salford Energy House and an optimised version created through an optimisation process by the University of Manchester. The optimised version is going into production and therefore claims must relate to this system.

2. Evaluation of Evidence

2.1. Experimental work (Salford Energy House)

Reference:	Report#1-Experiments
Dated:	23 July 2020
Author name:	Dr Majeed Oladokun and Dr Richard Fitton
Author address:	G16a Cockcroft Building University of Salford Manchester M5 4WT

This report covered the experimental work carried out at the Salford Energy House. The original version of the Thermocill unit was tested during this phase of development. The work was carried out according to relevant standards which indicate the methodology was effective.

2.1.1. Experimental Set Up

Experiments were carried out in the Thermal Comfort Laboratory with the set up shown in Figure 1. For full details, please refer to the original report. Measurements were carried out with room temperature set points of 21°C and 23°C for test cases where Thermocill was installed on a window which had a radiator underneath it. These were compared to control scenarios where Thermocill was not installed. Each scenario was run for 9 hours.

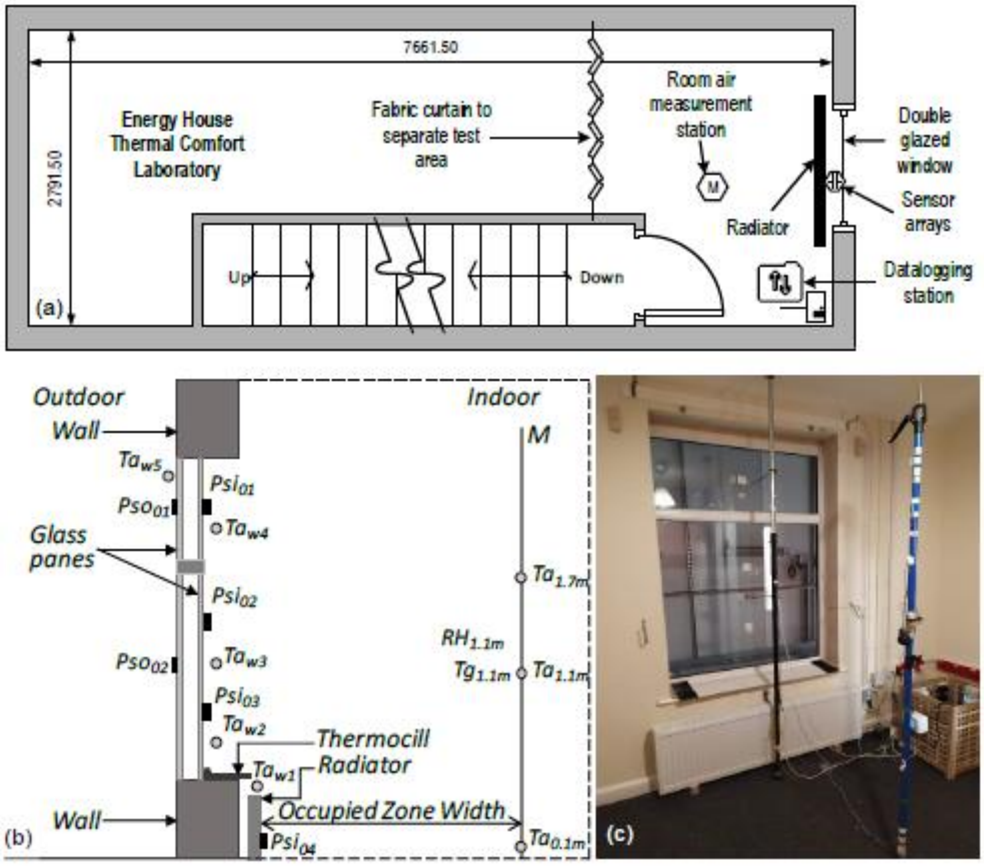


Figure 1: Experimental Setup showing (a) test layout in the Salford Energy House thermal comfort laboratory, (b) simplified schematic of the measurement points, and (c) physical model in the Salford Energy House thermal comfort laboratory.

Specific U-values for the various portions of the test room were not mentioned in the report, however, these were provided by Salford Energy House on demand and are presented in Table 1.

Table 1: U-values for building fabric used in Salford Energy House experiments

S/N	Element	Data Source	U-Value (W/m^{2}K)
1	External Wall	Calibrated EH Model	1.56
2	Internal Wall	Calibrated EH Model	2.095
3	Floor	Calibrated EH Model	1.352
4	Window	Thermocill Experiments	1.65 - 1.73
5	Curtain	Thermocill Experiments	Not measured

2.1.2. Results

The relevant results for this verification process are presented in Table 2. Other data within the report concerned the temperature distribution around the window and thermal comfort, which are not part of the scope of this report.

*Table 2: Relevant experimental results from Salford Energy House. *for heat flux individual values were not in the report so just the percentage change is reported. †Values have been corrected from Salford report after discussion.*

Temperature (°C)	Experiment	U value (W/m^{2}K)	Heat Flux (W/m^{2}K)	Heat up time (mins)	Energy (kWh)
21	Thermocill	1.65	*	77	5.54
	Control	1.71	*	94.5	6.43
	% change	3%	3%	19%†	14%†
23	Thermocill	1.69	*	206.5	8.05
	Control	1.73	*	168	8.32
	% change	2%	1%	-23%†	3%†

The heat up time covered the time taken from switching on the radiator to when the temperature starts to drop initially. The total energy used encompassed the entire experimental period. The percentage values quoted in the report for these two results used the incorrect reference value and these have been corrected in Table 2. It should be noted that the results at 23°C are lower than the 21°C scenario, with the heat up time being worse for the Thermocill case. Any claims should therefore make it clear than the performance is highly susceptible to the set point temperature of the room.

The heat flux and U-value results specifically refer to the glazing U-value. They have both been carried out using standard methods that are correct in themselves, but it is not clear that the methods are appropriate for the Thermocill case. When the change in U-value was modelled in isolation using EST's Dynamic Engine, this resulted in a reduction in space heating energy of only 15 kWh for a total space heating level of approximately 12000 kWh. Therefore, it is clear that the U-value alone does not account for the changes seen by the addition of Thermocill.

The additional savings are thought to arise from the creation of a large air barrier in front of the window from the channelling of air through the Thermocill product. We consider that the U-value that should be compared should include this barrier, however, we are not aware of a suitable method to do this. The only viable alternative would be to consider the U-value of the window not including any changes in air flow, and as the structure of the heat transferring elements of the window have not been changed, we would expect this U-value to be unchanged. It is potentially the case that the small change in U-value recorded is a measure of the effect that the change in air flow has on the effectiveness of the methodology.

EST generally avoids making consumer-facing claims based on the U-value of the glazing alone, as other factors such as the frame, air tightness and solar gain have significant impacts on the overall performance.

2.2. Computational Fluid Dynamics (CFD) report

Reference:	Report#2-Experiments
Dated:	16 June 2020
Author name:	Dr Amir Keshmiri
Author address:	Room C42, George Begg Building, Department of Mechanical, Aerospace and Civil Engineering (MACE), The University of Manchester, M13 9PL, UK.

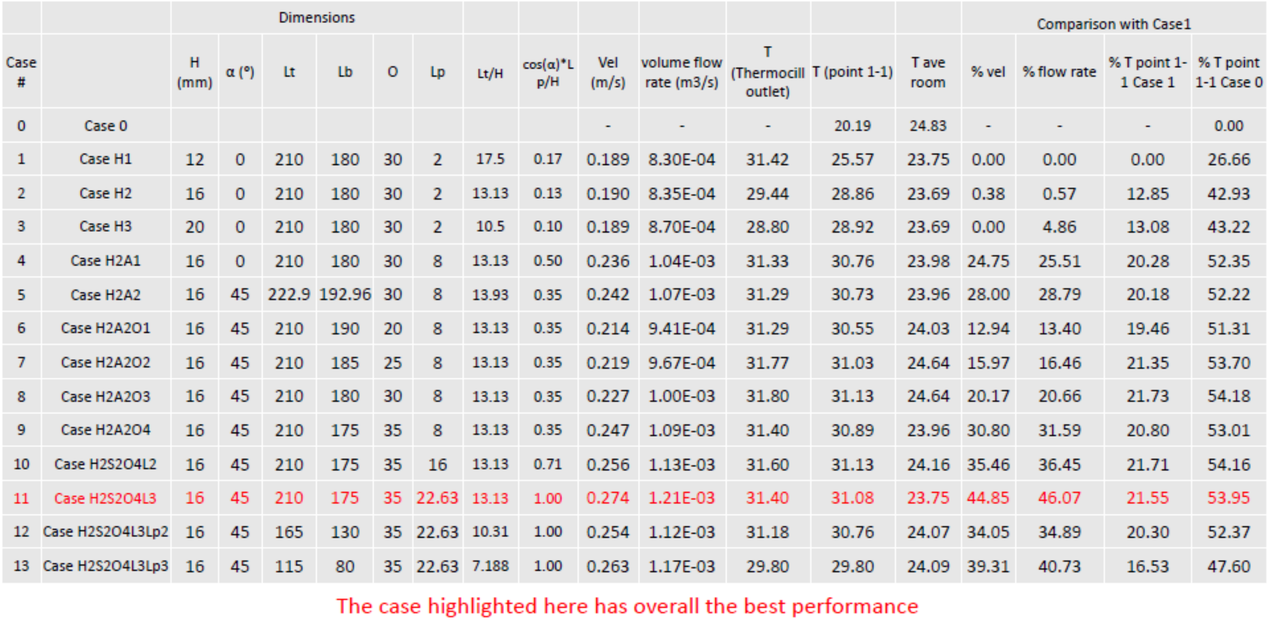
This presentation details the numerical modelling carried out on the Thermocill system and is split into two phases: Baseline simulation and optimisation. The result of this is an optimised product which performs better than the original based on the criteria chosen. As EST has been asked to provide claims for the optimised product, and experimental data is only available for the original, this report must answer the question whether they will perform to similar levels in terms of energy savings and heat up time to complement the findings of Report #1.

2.2.1. Baseline Simulation

The baseline simulation used a full 3D model of the Thermocill system at the Salford Energy House. This model is not that relevant to the verification process as it does not provide a direct comparison to the Salford Energy House experiments – i.e. with temperature probes matching those in the experiment. When discussed with the author, it was stated this was not possible as the CFD model would require a large amount of computational time to match the experiments carried out. Therefore, the comparison between the original and optimised design had to be made using CFD in isolation and specifically only the 2D optimisation model.

2.2.2. Design optimisation

An optimisation was carried out on the original Thermocill design based on the findings of the baseline simulation. A parametric 2D CFD model was created to vary certain geometric properties of the Thermocill unit to improve performance. The report does not specify the exact optimisation algorithm but in discussions with the author it was found that the system was optimised primarily to increase air flow volume and secondly to increase the temperature around the Thermocill outlet. There is no comparison of the input power (modelled as a boundary condition on the radiator) and how the performance varies with this.



		Dimensions													Comparison with Case1			
Case #		H (mm)	α (°)	Lt	Lb	O	Lp	Lt/H	cos(α)*L p/H	Vel (m/s)	volume flow rate (m3/s)	T (Thermocill outlet)	T (point 1-1)	T ave room	% vel	% flow rate	% T point 1-1 Case 1	% T point 1-1 Case 0
0	Case 0									-	-	-	20.19	24.83	-	-	-	0.00
1	Case H1	12	0	210	180	30	2	17.5	0.17	0.189	8.30E-04	31.42	25.57	23.75	0.00	0.00	0.00	26.66
2	Case H2	16	0	210	180	30	2	13.13	0.13	0.190	8.35E-04	29.44	28.86	23.69	0.38	0.57	12.85	42.93
3	Case H3	20	0	210	180	30	2	10.5	0.10	0.189	8.70E-04	28.80	28.92	23.69	0.00	4.86	13.08	43.22
4	Case H2A1	16	0	210	180	30	8	13.13	0.50	0.236	1.04E-03	31.33	30.76	23.98	24.75	25.51	20.28	52.35
5	Case H2A2	16	45	222.9	192.96	30	8	13.93	0.35	0.242	1.07E-03	31.29	30.73	23.96	28.00	28.79	20.18	52.22
6	Case H2A2O1	16	45	210	190	20	8	13.13	0.35	0.214	9.41E-04	31.29	30.55	24.03	12.94	13.40	19.46	51.31
7	Case H2A2O2	16	45	210	185	25	8	13.13	0.35	0.219	9.67E-04	31.77	31.03	24.64	15.97	16.46	21.35	53.70
8	Case H2A2O3	16	45	210	180	30	8	13.13	0.35	0.227	1.00E-03	31.80	31.13	24.64	20.17	20.66	21.73	54.18
9	Case H2A2O4	16	45	210	175	35	8	13.13	0.35	0.247	1.09E-03	31.40	30.89	23.96	30.80	31.59	20.80	53.01
10	Case H2S2O4L2	16	45	210	175	35	16	13.13	0.71	0.256	1.13E-03	31.60	31.13	24.16	35.46	36.45	21.71	54.16
11	Case H2S2O4L3	16	45	210	175	35	22.63	13.13	1.00	0.274	1.21E-03	31.40	31.08	23.75	44.85	46.07	21.55	53.95
12	Case H2S2O4L3Lp2	16	45	165	130	35	22.63	10.31	1.00	0.254	1.12E-03	31.18	30.76	24.07	34.05	34.89	20.30	52.37
13	Case H2S2O4L3Lp3	16	45	115	80	35	22.63	7.188	1.00	0.263	1.17E-03	29.80	29.80	24.09	39.31	40.73	16.53	47.60

The case highlighted here has overall the best performance

Figure 2: CFD optimisation results. Case H1 is the original design and the case highlighted in red is the final optimised system.

Figure 2 presents the results of the optimisation with the optimised case showing a 45% increase in air flow velocity and a 54% increase in temperature at the outlet (point 1-1 in Figure 3) compared to no Thermocill present..

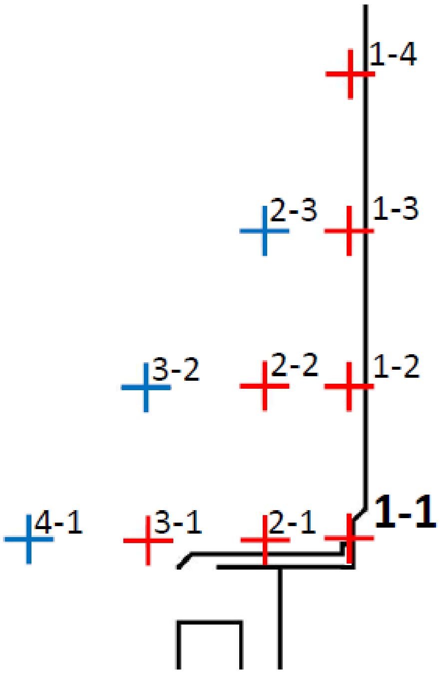


Figure 3: Location of temperature monitors in CFD model. Red indicates the optimised case has an increase in temperature, while blue indicates a decrease in temperature compared to no Thermocill.

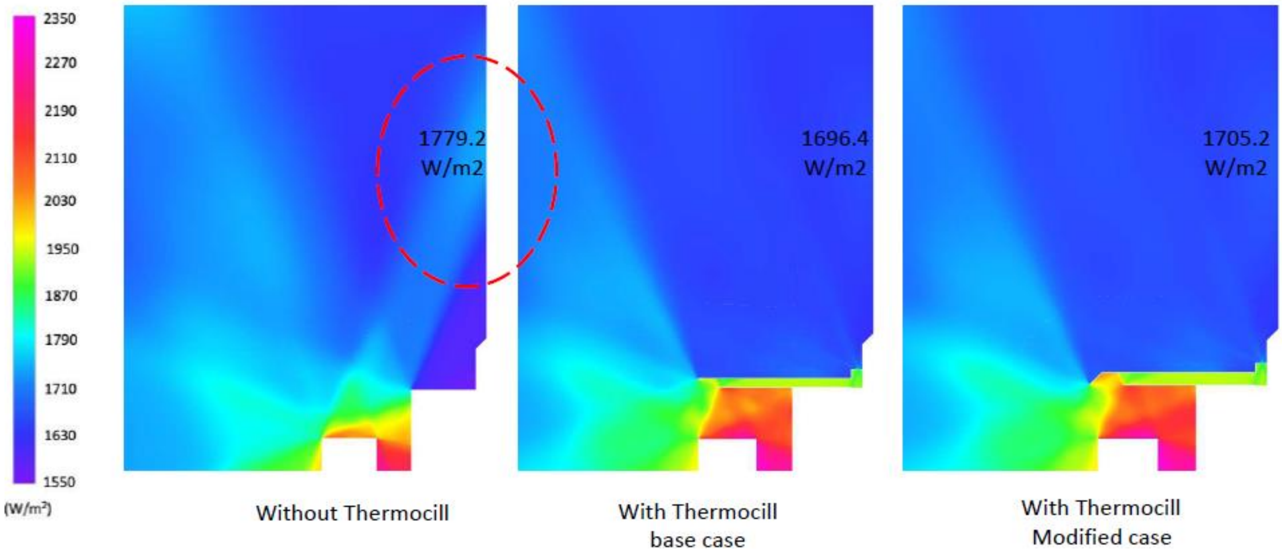


Figure 4: Incident radiation through the window for a specific ray in the without Thermocill scenario. This gives an indication of the relative heat loss between the different cases.

Figure 4 shows the incident radiation of a significant heat loss ray through the window for the original, optimised and no Thermocill cases. The original and optimised case show similar reductions in heat energy for a single ray through the window (5% and 4%, respectively) which suggests the optimised system should have at least a comparable performance. The increase in flow rate and temperature around the outlet are likely to create a larger air pocket in front of the window which may reduce heat loss. It is difficult to relate these two factors (air flow rate and temperature at the outlet) to the percentage energy saving as no evidence has been presented for this specific claim. It is expected the larger air pocket will lead to further savings, but this cannot be said for certain at this stage.

The ultimate output of this report was confidence that the optimised Thermocill device should perform to at least a comparable level as the original in terms of energy saving and heat up time. There is no direct comparison of experimental and numerical data which would allow us to say this with more confidence, nor are the outputs from the studies directly related to the claims required. However, the optimisation results suggest a similar level of radiation through the window which indicated the optimised system will perform as well as the original in terms of heat loss. The increased flow rate of the optimised version does suggest that this will lead to better performance, however there is not sufficient evidence to make an absolute claim that the energy savings or heat up time will improve based on this report.

2.3. Condensation and Energy Modelling Report

Reference:	Report#3-EnergyModelling
Dated:	21 September 2020
Author name:	Dr Amir Keshmiri
Author address:	Room C42, George Begg Building, Department of Mechanical, Aerospace and Civil Engineering (MACE), The University of Manchester, M13 9PL, UK.

This report covers the condensation claims and energy modelling carried out by the University of Manchester (UoM). The condensation modelling analyses the results of the CFD analysis (Report #2) in more detail, while the energy modelling uses industry standard software and the results from the Salford Energy House (Report #1) to estimate the potential savings for a household from the use of Thermocill.

2.3.1. Condensation reduction

The condensation modelling in the report is based purely on the temperature at the Thermocill outlet. It simply uses the Antoine equation which provides an estimate for the vapour pressure of a substance depending on the temperature. This shows an increase of 92% in the vapour pressure at the Thermocill outlet based on temperature.

It is clear that the drying rate significantly increases through use of Thermocill. However, it is difficult to give an exact quantification of this from the evidence provided. The vapour pressure is defined as the pressure exerted by a vapour which is in thermodynamic equilibrium with its condensed phase (solid or liquid) at a given temperature in a closed system and can give an indication of the evaporation rate. However, as we have a more open system the vapour pressure is not the only factor which is relevant. You could consider the entire CFD model as the closed system, however this is a very large system in relation to the size of the condensation water droplets. It is therefore felt that vapour pressure alone is not sufficient to accurately quantify the drying rate. The air flow, which will remove the moist air away from the droplet and allow more water to evaporate plays a significant role in the drying rate, albeit much smaller than that of the temperature, as discussed in the reference quoted in the report.[1] Additionally, the CFD is not, in our opinion, sufficiently validated against experimental models and representative of a typical dwelling (CFD uses an average room temperature of 23.75°C which is higher than a typical room set point of 18°C to 21°C) to be certain of the exact increase in drying rate based purely on vapour pressure. While it is clear the optimised version does significantly improve the air flow and temperature at the bottom of the window, increasing the evaporation rate and therefore improving performance in terms of condensation reduction, the exact quantification of this is not clear from the provided evidence.

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[1] M.C. Ndukwu, Effect of drying temperature and drying air velocity on the drying rate and drying constant of cocoa bean, Agricultural Engineering International: CIGR Journal (2009).

2.3.2. Energy modelling

The energy modelling was carried out using the EnergyPlus engine through an interface called Designbuilder. Designbuilder is an industry standard software and is used by architects, researchers, and builders to estimate the energy consumption of a property. EST received the models from the University of Manchester to examine the work that had been carried out. For full details of the model used, please refer to the Manchester report.

EST identified the following changes that would allow more accurate savings to be calculated:

1. In Manchester's model, the heating setpoint and setback temperatures is 21°C. This results in the customer effectively heating the entire house to 21°C for 24 hour a day. This does not represent a typical heating schedule and would significantly overestimate the total heating requirement of the building, giving an inaccurate heating demand. EST decided to use the standard set back temperature of 16°C to ensure a more representative scenario.

2. The energy saving percentage was mis-interpretated by Manchester who stated that the 16.1% energy saving, corrected to 13.8%, was for the steady-state condition alone when in fact this included the heat up period. Given the steady-state nature of Manchester's temperature schedule, this result is inaccurate for their method. By changing to a setback temperature of 16°C, which would include a heat-up period when the heating came on, the energy saving percentage determined in the lab is thought to be more applicable.

3. The U-value of the external walls is considerably different to that used in the lab. Manchester used a U-value of 0.351 W/m^{2}K, while the Salford Energy House's walls were 1.56 W/m^{2}K. This would lead to a different behaviour in terms of energy saving in each room and result in the 13.8% energy reduction not being valid for Manchester's model. EST changed the external wall U-value to 1.49 to closer match the experimental work which would allow the 13.8% to be valid.

4. In the claims, a scenario with no occupancy was used to estimate the total energy and financial savings for a typical home. This removed any additional heat sources (e.g. from people/equipment) as well as not accounting for domestic hot water within the total energy consumption of the property. EST considers that this scenario would overestimate the space heating demand (and therefore the potential savings) of a property. Therefore, it was determined to include the other heat sources to be more representative of a typical home.

The following methodology was adopted by EST to remodel the energy usage. Three incremental model scenarios were created in EnergyPlus based on the original including all heat sources provided by the University of Manchester for a 3-bed semi-detached property heated by a gas boiler:

1) Changed heating setback temperature to 16°C.

2) Changed U-value of walls to 1.49 to closer match experimental work.

3) Changed heating setback temperature to 0°C (heating set to either on or off).

Scenario 1 and 2 were modelled to address the issues in the Manchester model. The third scenario was used to investigate if the performance of Thermocill at 16°C was likely to have a significant effect on the results. The occupancy, activity and heating schedules used the same values as chosen by the UoM which are derived from the UK National Calculation Methodology published by the government. Where Thermocill was present in the room, the heating demand was reduced by 13.8% as determined through lab experiments. Heating demand values were converted to gas demand using efficiency factors of 85.3% and 70.8% for space heating and domestic hot water, respectively.

Table 3 presents the annual space heating energy consumption of the property per room, indicating which rooms Thermocill is installed. It should be noted that the hall energy consumption increases significantly due to the reduced U-value and specific heating schedule for that room. Scenario 3 was used to quantify the effect of providing additional heating at 16°C, as the effect of Thermocill at this temperature has not been established. The totals between scenarios 2 and 3 differ by approximately 2% which will not have a significant effect on the potential savings figures.

Table 3: Results for the three scenarios modelled by EST in EnergyPlus

Room	**Thermocill Installed?**	**Annual energy consumption (kWh)**		
		Scenario 1	Scenario 2	Scenario 3
Small front bedroom	Yes	361	764	739
Toilet	No	144	285	290
Bathroom	No	262	714	682
Front bedroom	Yes	683	1172	1156
Back bedroom	Yes	839	1344	1369
Hall	No	1196	2401	2418
Living room	Yes	500	1102	951
Kitchen	No	356	721	728
Total		4341	8503	8333

Scenario 2 was chosen as the most representative scenario for a customer. The results of applying a 13.8% saving to the energy consumption of the rooms with Thermocill are presented in Table 4. The following values were assumed for the calculations:

- Gas price of 4.17 p/kWh
- Gas CO_2e factor of 0.208 $kgCO_2e/kWh$
- Annual gas standing charge of £93.39
- Gas space heating efficiency of 85.3%
- Gas domestic hot water efficiency of 70.8%

Table 4: Savings for Scenario 2.

	Heating demand (kWh)	Gas demand (kWh)
Space Heating (no Thermocill)	8503	9968
Hot Water	1819	2570
Total (no Thermocill)	10323	12538
Space Heating (with Thermocill)	7897	9257
Total (with Thermocill)	9716	11827
Total Saving	607	711
Saving (%) – all gas	6%	
Saving (%) – space heating	8%	
Financial Saving (£)	£29.63	
CO2e saving (kgCO$_2$e)	147.7	
Total Gas bill (no Thermocill including standing charge)	£615.82	
Perc saving (with standing charge)	5%	

3. Claims

All statements are correct as of November 2020 and valid for 12 months, subject to the terms and conditions of the Energy Saving Trust Verification Licence Agreement.

3.1. Claim 1: Energy per room

Claim: The energy required to heat a room is reduced by up to 14% with the addition of a Thermocill unit to a window above a radiator.

Caveat: The values are based on a 9-hour heating cycle from experimental work carried out at the Salford Energy House on the original Thermocill design. This assumes a room with double glazed windows, a typical external brick wall construction and a temperature set point of 21°C. Different temperatures and configurations may produce higher or lower savings.

Explanation: These savings are based on testing carried out at the Salford Energy House on the original Thermocill design. Computational Fluid Dynamics simulations demonstrate the optimised new design improves the performance of Thermocill with respect to air flow rate and temperature at the base of the window which could potentially improve the energy savings for a room.

3.2. Claim 2: Heat up time

Claim: The time taken for a room to heat up is reduced by up to 19% by the addition of a Thermocill unit to a window above a radiator.

Caveat: The values are based on experimental work carried out at the Salford Energy House on the original Thermocill design. This assumes a room with double glazed windows, a typical external brick wall construction and a temperature set point of 21°C. Different temperatures and configurations may produce higher or lower savings.

Explanation: These savings are based on testing carried out at the Salford Energy House on the original Thermocill design. Computational Fluid Dynamics simulations demonstrate the optimised new design improves the performance of Thermocill with respect to air flow rate and temperature at the base of the window which could potentially improve the heat up rate of the room.

3.3. Claim 3: Condensation

Claim: The addition of a Thermocill unit to a window above a radiator can significantly reduce the likelihood of condensation at the bottom of the window.

Caveat: Based on numerical studies, the addition of a Thermocill unit increases the temperature around the bottom of the window which produces a higher vapour pressure and therefore reduces the risk of condensation.

Explanation: This is based on Computational Fluid Dynamics (CFD) simulations carried out by the University of Manchester which show an increase in the temperature around the bottom of the window, a common area for condensation to form. This increase in temperature corresponds to a 92% increase in vapour pressure which increases the evaporation rate of the water directly reducing the likelihood of condensation.

3.4. Claim 4: Energy Savings

Claim: Customers could reduce their total space heating demand by up to 8% per year by adding Thermocill to their existing radiators/windows

Caveat: These savings are based on modelling carried out using the EnergyPlus software for a typical 3-bedroom semi-detached property with double glazed windows and an annual gas usage of 12,500 kWh before Thermocill is installed. Thermocill is installed in the 3 bedrooms and the living room, all of which are assumed to have radiators beneath the window. This reduces the space heating energy by 14% in each of these rooms, based on experimental work carried out at Salford Energy House on the original Thermocill design. A heating set point of 21°C and a setback temperature of 16°C are assumed for the modelling. Other temperatures may result in different savings values.

Explanation: These were calculated using EnergyPlus modelling software. Occupancy profiles, equipment use, and heating schedules use the default methodology in the software which are derived from the UK National Calculation Methodology. All heating sources were included in the calculation (i.e. heating from people, lighting and appliances were included alongside the heating system). Average efficiencies of 85% for space heating and 70% for domestic hot water were used to convert the raw heating demand for the property into actual kWh of gas used.

3.5. Claim 5: CO_2 Savings

Claim: Customers could save up to 150 kg CO_2e per year by adding Thermocill to their existing radiators/windows

Caveat: These savings are based on modelling carried out using the EnergyPlus software for a typical 3-bedroom semi-detached property with double glazed windows and an annual gas usage of 12,500 kWh before Thermocill is installed. Thermocill is installed in the 3 bedrooms and the living room, all of which are assumed to have radiators beneath the window. This reduces the space heating energy by 14% in each of these rooms, based on experimental work carried out at Salford Energy House on the original Thermocill design. A heating set point of 21°C and a setback temperature of 16°C are assumed for the modelling. Other temperatures may result in different savings values. An average GB gas CO_2 factor of 0.208 kgCO_2e/kWh is used for the savings.

Explanation: These were calculated using EnergyPlus modelling software. Occupancy profiles, equipment use, and heating schedules use the default methodology in the software which are derived from the UK National Calculation Methodology. All heating sources were included in the calculation (i.e. heating from people, lighting and appliances were included alongside the heating system). Average efficiencies of 85% for space heating and 70% for domestic hot water were used to convert the raw heating demand for the property into actual kWh of gas used.