Liverpool John Moores University and Zenova Group Ltd. AKT Project 2022-2023

Exploring the performance of **thermal barrier coatings** in a retrofit environment

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Project Overview



Aim:

To evaluate the performance a low profile, **novel thermal barrier coating** for use in retrofit applications

Objectives:

- **Collect and compare** pre and post installation data for surface and ambient temperatures, humidity, U-value and air quality.
- Install Thermal material coating in 1920's exemplar house.
- Evaluate any change in **energy performance** of the room.
- **Produce report** on findings

Basic Methodology



Steps:

- **1. Record** Baseline Data: Room response to heating and cooling, U-Value, thermal imaging
- 2. Apply Zenova thermal coating
- 3. Record post installation performance
- 4. Compare Findings



Pre-Installation Data Collection

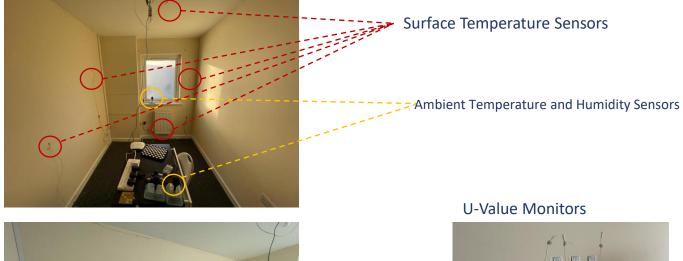
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Baseline Room





Sensor and Monitoring Installation



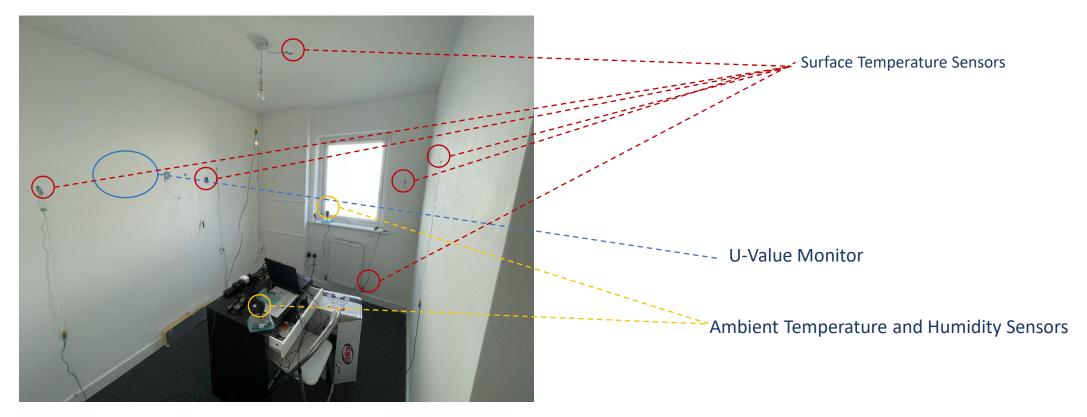




Post-Installation Data Collection



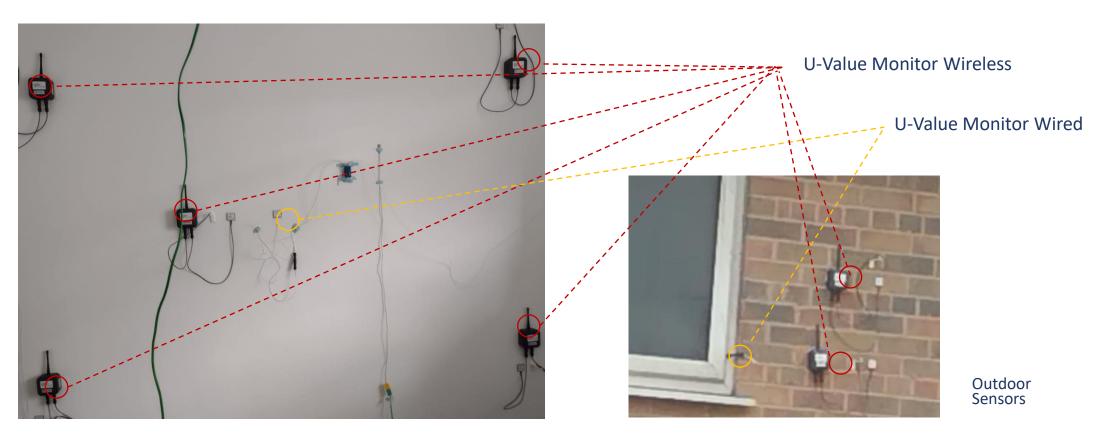
Post Installation Room



U-value Final Test (multi probe)



Post Installation Room



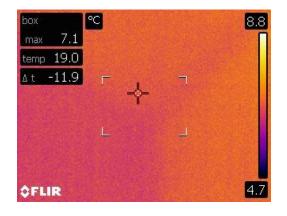
Thermal Camera Imaging

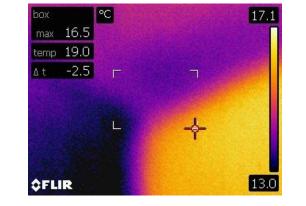




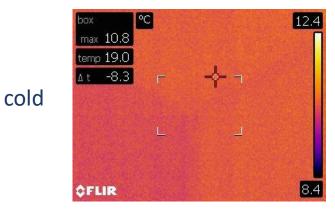


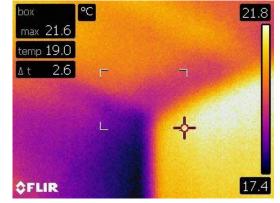
Pre-Installation





Post-Installation

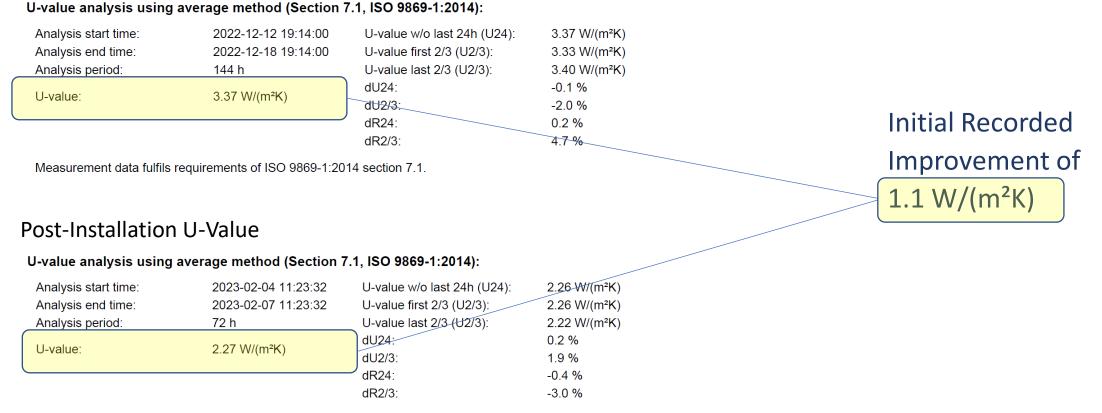




hot

U-Value Comparison

Pre-Installation U-Value



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Measurement data fulfils requirements of ISO 9869-1:2014 section 7.1.

U-Value Validation

Average values: Heat Flux (HF):

Inner Ambient Temp. (Ti) Inner Surface Temp. (Tsi)

Outer Ambient Temp. (Te)

Outer Surface Temp. (Tse)

Post-Installation U-Value

U-Value analysis:

0.279 (m²K)/W	
2.041 W/(m²K)	
-4.89 %	Outer Surface Temp. (Tse)
2.20 %	Outer Ambient Temp. (Te)
72 h	Inner Surface Temp. (Tsi)
2023-03-15 21:10:00	Inner Ambient Temp. (Ti)
2023-03-12 21:10:00	Heat Flux (HF):
ation 120.00 h	Average values:
	2023-03-12 21:10:00 2023-03-15 21:10:00 72 h 2.20 % -4.89 % 2.041 W/(m²K)

U-Value analysis:

Total measurement dura	ition 120.00 h
Analysis start time:	2023-03-12 21:10:00
Analysis end time:	2023-03-15 21:10:00
Analysis period:	72 h
dR2/3:	2.64 %
dR24:	-4.77 %
U-Value (U):	1.862 W/(m²K)
R-Value (R):	0.268 (m ² K)/W

U-Value analysis:

Total measurement dura	ation 120.00 h	Average values:	
Analysis start time:	2023-03-12 21:50:00	Heat Flux (HF):	17.73 W/m ²
Analysis end time:	2023-03-15 21:50:00	Inner Ambient Temp. (Ti)	14.12 °C
Analysis period:	72 h	Inner Surface Temp. (Tsi)	12.48 °C
dR2/3:	2.41 %	Outer Ambient Temp. (Te)	7.58 °C
dR24:	-4.83 %	Outer Surface Temp. (Tse)	8.38 °C
U-Value (U):	2.255 W/(m²K)		
R-Value (R):	0.286 (m²K)/W		



U-Value analysis:

19.10 W/m²

15.44 °C

12.79 °C

7.58 °C

8.38 °C

19.39 W/m² 16.44 °C

12.65 °C

7.58 °C

8.38 °C

Total measurement duration	120.00 h	Average values:	
Analysis start time:	2023-03-12 21:30:00	Heat Flux (HF):	23.51 W/m ²
Analysis end time:	2023-03-15 21:30:00	Inner Ambient Temp. (Ti)	16.55 °C
Analysis period:	72 h	Inner Surface Temp. (Tsi)	13.26 °C
dR2/3:	2.67 %	Outer Ambient Temp. (Te)	7.58 °C
dR24:	-4.91 %	Outer Surface Temp. (Tse)	8.38 °C
U-Value (U):	2.217 W/(m²K)		
R-Value (R):	0.251 (m²K)/W		

U-Value analysis:

t Flux (HF):
er Ambient Temp. (
r Surface Temp. (
er Ambient Temp.
er Surface Temp. (

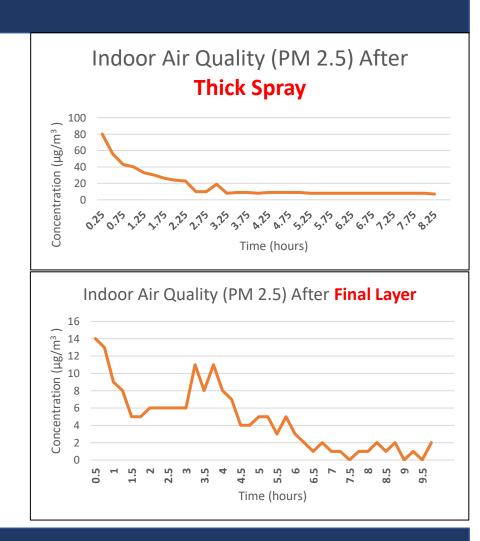
age values:	
Flux (HF):	18.58 W/m ²
r Ambient Temp. (Ti)	14.72 °C
r Surface Temp. (Tsi)	12.40 °C
er Ambient Temp. (Te)	7.58 °C
er Surface Temp. (Tse)	8.38 °C

U-value average: 2.1022 W/m²K



Air Quality Test Result

- 1. Before Painting: PM 2.5 = 2 μ g/m³; VOCs = 0 mg/m³
- 2. After the base coat: PM 2.5 = 9 μ g/m³; VOCs = 0 mg/m³
- 3. During the spray: PM 2.5 = 80 μ g/m³; VOCs = 43.72 mg/m³

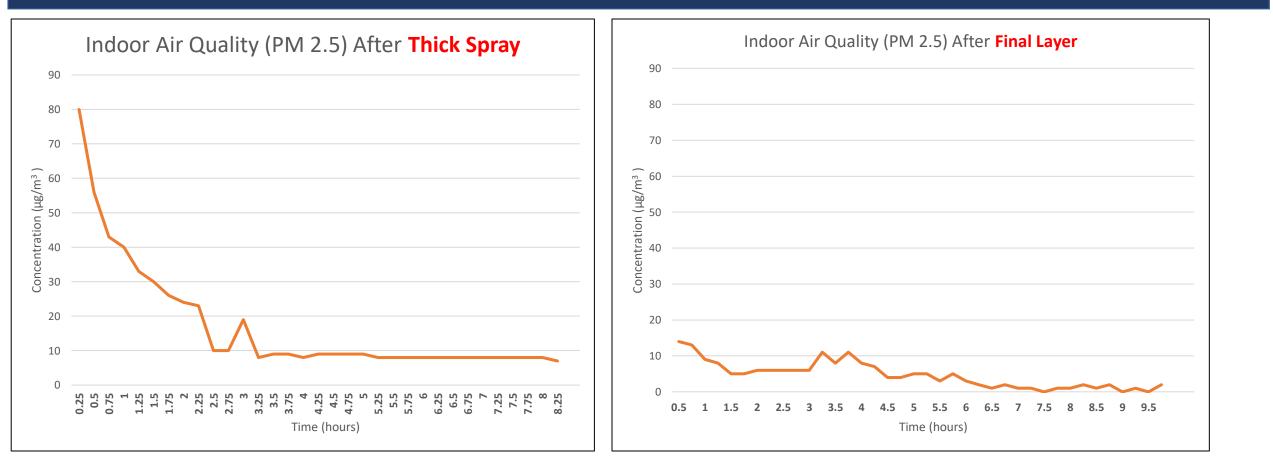


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Air Quality Test Result



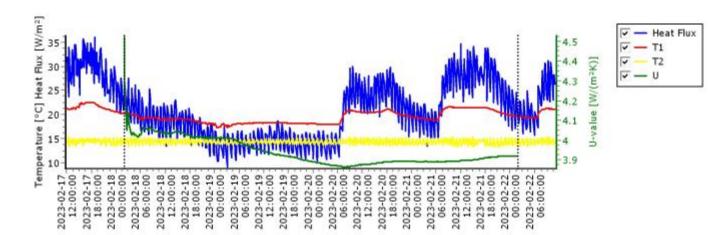


Material test Value



- The material test was done in the thermal chamber to simulate indoor and outdoor condition and was done with Uvalue test kit for at least 72 hours
- 1 mm thickness material: Uvalue of 3.92 W/(m²K); thermal conductivity = 0.00392 W/mK

Measurement overview over t=118.83 h



U-value analysis using average method (Section 7.1, ISO 9869-1:2014):

Analysis start time:	2023-02-18 01:57:32	U-value w/o last 24h (U24):	3.89 W/(m ² K)
Analysis end time:	2023-02-22 01:57:32	U-value first 2/3 (U2/3):	3.88 W/(m ² K)
Analysis period:	96 h	U-value last 2/3 (U2/3):	3.94 W/(m ² K)
U-value:	3.92 W/(m ² K)	dU24:	0.7 %
 U-Value.	3.92 W/(III K)	dU2/3:	-1.6 %
		dR24:	-2.2 %
		dR2/3:	4.7 %

Measurement data fulfils requirements of ISO 9869-1:2014 section 7.1.

Uncertainties due to improper installation or environmental influences must be estimated by user (see section 6.1).

Thermal Conductivity

Background

Different measurement results of thermal conductivity to be verified. The variety of results were due to the uneven sample composition, the dryness of the sample, and the sensor imprecision.

Methods

The value was fed to the IES VE Software to obtain the software calculated results from the digital twin.

Parameters for the digital twin:

- U-value test for pre-refurbishment: 3.37W/(m²K) → in the digital twin, the materials composition generated U-value of 3.2159 W/(m²K)
- Average U-value test for post-refurbishment: 2.1022 W/(m²K);
- Specific Heat Capacity: 966 J/kg. °C
- Density 0.75 g/cm³ = 750 kg/m³
- Vapour Resistivity: 50 GNs/kg m

The Digital Twin:

Description:	External Wall								ID: WALL	External	Inte
Performance:	EN-ISO V										
					_						
$\boldsymbol{\mathcal{C}}$	U-value: 3.2159 W/m²·K	Thickne			Therm	nal mass Cn		kJ/(m²•K)			
Tota	al R-value: 0.1410 m²K/W	Ma	iss: 193.5000 kg	g/m²			Very lightwe	ght			
Surfaces F	Functional Settings Regulations	RadianceIES									
Outside	renegational becange integrations i	to dia neceso			Inside						
	Emissivity: 0.900	Resistance (m²K/V	v): 0.0400 🖓	Default		Emissivity:	0.900	Re	esistance (m²K/M	(): 0.1300 VD	efault
Solar /	Absorptance: 0.700					sorptance:	0.550				
						orpeance.	0.000				
Constructio	on Layers (Outside To Inside)							5	System Materials	Project Mate	erials
				Thickness	Conductivity	Density	Specific Heat	Resistance	Vapour		
	Mater	181		mm	W/(m K)	kg/m³	Capacity J/(kg·K)	m²K/W	Resistivity GN·s/(kg·m)	Category	
[BRO1] SIM	NGLE BRICKWORK (OUTER LEAF)			110.0	0.8400	1700.0	800.0	0.1310	58.000	Brick & Blockwork	
[PLD] PLAS	STER (DENSE)			5.0	0.5000	1300.0	1000.0	0.0100	50.000	Plaster	
escription:	External Wall								ID: WALL	External	Int
									ID: WALL	External	Int
escription: erformance:	External Wall EN-ISO								ID: WALL	External	Int
		Thicknes	ss: 116.000 mr	m	Therm	al mass Cr	n: 0.0000	kJ/(m²·K)	ID: WALL	External	Int
erformance:	EN-ISO ~	Thicknes Ma		m]/m²	Therm	ial mass Cri	n: 0.0000 Very lightwei		ID: WALL	External	Int
erformance:	EN-ISO V U-value: 2.1022 W/m ² ·K				Therm	ial mass Cri			ID: WALL	External	Int
erformance:	EN-ISO V U-value: 2.1022 W/m ² ·K	Ма				al mass Cr			ID: WALL	External	Int
erformance:	EN-ISO V U-value: 2.1022 W/m ^{2-K} LR-value: 0.4743 m ² K/W	Ма			Therm	ial mass Cri			ID: WALL	External	Int
erformance:	EN-ISO V U-value: 2.1022 W/m ^{2-K} LR-value: 0.4743 m ² K/W	Ма	ss: 194.2500 kg		Inside	al mass Cr		ght	ID: WALL		Int
Surfaces Fi Outside	EN-ISO U-value: 2.1022 W/m ² -K LR-value: 0.4743 m ² K/W iunctional Settings Regulations R Emissivity: 0.900	Ma	ss: 194.2500 kg]/m²	Inside	Emissivity:	Very lightwei	ght			
Surfaces Fi Outside	EN-ISO U-value: 2.1022 W/m ² -K LR-value: 0.4743 m ² K/W iunctional Settings Regulations R Emissivity: 0.900	Ma	ss: 194.2500 kg]/m²	Inside		Very lightwei	ght			
Surfaces Fi Outside Solar Al	EN-ISO U-value: 2.1022 W/m ² -K LR-value: 0.4743 m ² K/W iunctional Settings Regulations R Emissivity: 0.900	Ma	ss: 194.2500 kg]/m²	Inside	Emissivity:	Very lightwei	ght Re		Ŋ: [0.1300] ☑D	efault
Surfaces Fi Outside Solar Al	EN-ISO U-value: 2.1022 W/m ² -K IR-value: 0.4743 m ² K/W iunctional Settings Regulations R Emissivity: 0.900 bsorptance: 0.700	Ma tadianceIES Resistance (m %/M	ss: 194.2500 kg]/m²] Default Thickness	Inside t Solar Abs Conductivity	Emissivity: corptance: Density	Very lightwei 0.900 0.550 Specific Heat Capacity	ght Resistance	Esistance (m²K/M System Materials Vapour Resistivity	Ŋ: [0.1300] ☑D	efault
Surfaces Fr Outside Solar Al	EN-ISO U-value: 2.1022 W/m ² +K LR_value: 0.4743 m ² KW unctional Settings Regulations R Emissivity: 0.900 bsorptance: 0.700 n Layers (Outside To Inside) Materi	Ma tadianceIES Resistance (m %/M	ss: 194.2500 kg	g/m² Default Thickness mm	Inside Solar Abs Conductivity W/(m K)	Emissivity: corptance: Density kg/m ³	Very lightwei 0.900 0.550 Specific Heat Capacity J/(kg+K)	ght Resistance m ³ K/W	esistance (m³K/M System Materials Vapour Resistivity GN°s/(kg°m)	/): 0.1300 ☑ ☑ Project Mate Category	efault
Surfaces Fr Outside Solar Al Constructor	EN-ISO U-value: 2.1022 W/m ² -K LR-value: 0.4743 m ² KW unctional Settings Regulations R Emissivity: 0.900 bsorptance: 0.700 h Layers (Outside To Inside)	Ma tadianceIES Resistance (m %/M	ss: 194.2500 kg]/m²] Default Thickness	Inside t Solar Abs Conductivity	Emissivity: corptance: Density	Very lightwei 0.900 0.550 Specific Heat Capacity	ght Resistance	Esistance (m²K/M System Materials Vapour Resistivity	/): 0.1300 V D	efault

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Result: the thermal conductivity value of **0.0061** W/(m. K)

Similar Performing Materials (1)

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Methods: Using the IES VE Software for the digital twin.

1. FELT & MEMBRANE - FELT - HF-E3 (31.3 mm thickness)

cription: External Wall						ID: WALL	External Inte
formance: EN-ISO V							
U-value: 2.1022 W/m²-K Thickness:	225.000 mm	Therma	al mass Cr	n: 187.6554	kJ/(m²∙K)		
Total R-value: 0.7199 m²K/W Mass:	316.8100 kg/m²			Mediumweigl	nt		
urfaces Functional Settings Regulations RadianceIES							
Outside		Inside					
Emissivity: 0.900 Resistance (m ² K/W):	0.0400 Default		missivity:	0.900		sistance (m²K/W	/): 0.1300 🗹 Default
	O.0400		missivity:	0.900	Re	sistance (m-k/w	Default
Solar Absorptance: 0.700		Solar Abs	orptance:	0.550			
Construction Layers (Outside To Inside)					S	ystem Materials.	Project Materials
Material	Thickness mm	Conductivity W/(m·K)	Density kg/m³	Specific Heat Capacity J/(kg·K)	Resistance m²K/W	Vapour Resistivity GN:s/(kg:m)	Category
[BRCK0000] Single Brickwork (Outer Leaf)	110.0	0.8400	1700.0	800.0	0.1310	0.000	Brick & Blockwork
	5.0	0,5000	1300.0	1000.0	0.0100	50.000	Plaster
[PLD] PLASTER (DENSE)	0.0						

2. FELT & MEMBRANE - FINISH - HF-A6 (68.4 mm thickness)

Project Cor	nstruction (Opaque: External Wall)								-	
escription:	External Wall							ID: WALL	External	Interna
erformance:	EN-ISO ~									
	U-value: 2.1022 W/m ² ·K	Thickness: 120.000 mm	n	Therm	al mass Cm	n: 81.2946	kJ/(m²∙K)			
Total	R-value: 0.1530 m²K/W	Mass: 199.7450 kg	/m ²			Very lightwei	ight			
Surfaces Fu	unctional Settings Regulations Radian	ceIES								
Outside				Inside						
	Emissivity: 0.900 Re	esistance (m²K/W): 0.0400	Default	E	Emissivity:	0.900	Re	sistance (m²K/W): 0.1300	Default
Solar Al	bsorptance: 0.700			Solar Abs	· · · ·					berdare
				30101 A03	orprance.	0.550				
Construction	Layers (Outside To Inside)						S	ystem Materials.	Project Ma	terials
	Material		Thickness mm	Conductivity W/(m·K)	Density kg/m³	Specific Heat Capacity J/(kg·K)	Resistance m²K/W	Vapour Resistivity GN·s/(kg·m)	Categor	,
[BRCK0000]	Material Single Brickwork (Outer Leaf)				Density kg/m³ 1700.0	Capacity		Resistivity	Categor Brick & Blockwork	, ~
			mm	W/(m•K) ́	kg/m³	Capacity J/(kg·K)	m²K/W	Resistivity GN·s/(kg·m)		

3. Expanded polystyrene (CIBSE) (5.8 mm thickness)

escription: External Wall						ID: WALL	External	Inter
	0.000 mm 3.6250 kg/m²	Therr	nal mass Cr	n: 0.0000 Very lightwe	kJ/(m²·K)			
Surfaces Functional Settings Regulations RadianceIES	Ng/m			very lightene	grit			
Outside		Inside						
	400 🗹 Defau		Emissivity:		Re	sistance (m²K/M	V): 0.1300 🗹 Def	ault
Solar Absorptance: 0.700		Solar Ab	sorptance:	0.550				
Construction Layers (Outside To Inside)					S	ystem Materials	Project Mater	als
Material	Thick		Density kg/m³	Specific Heat Capacity J/(kg·K)	Resistance m²K/W	Vapour Resistivity GN*s/(kg·m)	Category	
[BRCK0000] Single Brickwork (Outer Leaf)	110	.0 0.8400	1700.0	800.0	0.1310	0.000	Brick & Blockwork	
	5.0	0.5000	1300.0	1000.0	0.0100	50.000	Diacter	
[PLD] PLASTER (DENSE)	5.	0.0000	200010	2000.0				

4. INSULATION BOARD - HF-B5 (7.2 mm thickness)

Project Co	nstruction (Opaque: External Wall	0							-	
scription:	External Wall							ID: WALL	External	Interr
Total	EN-ISO U-value: 2.1022 W/m²·K R-value: 0.2546 m²K/W		mm kg/m²	Therm	al mass Cn	n: 0.0000 Very lightwe	kJ/(m²·K) ight			
Outside	unctional Settings Regulations Rai Emissivity: 0.900 bsorptance: 0.700		🗹 Default		Emissivity: orptance:	0.900	Re	sistance (m²K/W): 0.1300 🗸 De	efault
Construction	n Layers (Outside To Inside)						S	ystem Materials	Project Mate	erials
	Material		Thickness mm	Conductivity W/(m·K)	Density kg/m³	Specific Heat Capacity J/(kg·K)	Resistance m²K/W	Vapour Resistivity GN:s/(kg:m)	Category	
[BRCK0000]	Single Brickwork (Outer Leaf)		110.0	0.8400	1700.0	800.0	0.1310	0.000	Brick & Blockwork	
tori of or a cr	TER (DENSE)		5.0	0.5000	1300.0	1000.0	0.0100	50.000	Plaster	
[PLD] PLAST										

Similar Performing Materials (2)



Methods: Using the IES VE Software for the digital twin.

5. POLYURETHANE BOARD (3.6 mm thickness)

escription: Ex	xternal Wall							ID: WALL	External Inte
U-va	V-ISO ~ / /////////////////////////////////	Thickness: 120.000 Mass: 193.6500	mm	Therm	al mass Cn	n: 0.0000 Very lightwei	kJ/(m²-K)		
			1				-		
Surfaces Functi	tional Settings Regulations Radiand	eIES							
Outside				Inside					
Em	nissivity: 0.900 Re	sistance (m²K/W): 0.0400	Default		Emissivity:	0.900	Re	esistance (m²K/M	/): 0.1300 Default
Solar Absor	ptance: 0.700			Solar Abs	orptance:	0.550			
	yers (Outside To Inside)						:	System Materials	Project Materials
Construction Lay				Conductivity	Density	Specific Heat	Resistance	Vapour Resistivity	Category
Construction Lay	Material		Thickness mm	W/(m·K)	kg/m ³	Capacity J/(kg·K)	m²K/W	GN*s/(kg*m)	
	Material gle Brickwork (Outer Leaf)					J/(kg·K)	m ² K/W	GN*s/(kg*m) 0.000	Brick & Blockwork
	gle Brickwork (Outer Leaf)		mm	W/(m-K)	kg/m³	J/(kg-K)			Brick & Blockwork Plaster

6. GLASSWOOL (6.6 mm thickness)

🖗 Project Co	nstruction (Opaque: External	Wall)								-		×
Description:	External Wall ID: WALL External Internal e: EN-ISO Internal Internal Internal Internal Internal Internal Internal </td											
Performance:	EN-ISO ~	ID: WALL External Internal 22 W/m²+K Thickness: 120.000 mm Thermal mass Cm: 0.0000 kJ/(m²+K) 0 m³K/W Mass: 194.5000 kg/m² Very lightweight Regulations RadianceIES 00 Resistance (m³K/W): 0.0400 ✓ Default Emissivity: 0.900 Resistance (m³K/W): 0.1300 ✓ Default 00 Resistance (m³K/W): 0.0400 ✓ Default Solar Absorptance: 0.550 To Inside System Materials Project Materials										
	U-value: 2.1022 W/m²·K	Th	ickness: 120.000 mn	n	Therm	ial mass Cr	n: 0.0000	kJ/(m²•K)				
Total	R-value: 0.2660 m²K/W		Mass: 194.5000 kg	/m²			Very lightwei	ight				
Surfaces Fi	unctional Settings Regulations	RadianceIES										
Outside					Inside							
	Entertaitus 0.000	Desistance (0 0 1000		
	Emissivity: 0.900	Resistance (n	n-k/w): 0.0400	Default		Emissivity:	0.900	Re	sistance (m4K/V)	/): 0.1300	Default	
Solar Al	bsorptance: 0.700				Solar Abs	orptance:	0.550					
Construction	Layers (Outside To Inside)							S	System Materials	Project M	aterials	
	Mat	terial		Thickness mm	Conductivity W/(m+K)	Density kg/m³	Specific Heat Capacity J/(kg·K)	Resistance m²K/W	Vapour Resistivity GN*s/(kg·m)	Categor	у	
[BRCK0000]	Single Brickwork (Outer Leaf)			110.0	0.8400	1700.0	800.0	0.1310	0.000	Brick & Blockwork		\sim
[PLD] PLAST	TER (DENSE)			5.0	0.5000	1300.0	1000.0	0.0100	50.000	Plaster		\sim
[GW] GLASS	SWOOL			6.6	0.0400	200.0	670.0	0.1647	6.000	Insulating Materials	5	\geqslant

7. THERMALITE "SHIELD"/"SMOOTH FACE" (28 mm thickness)

scription: External Wall						TD: WALL	External	Inte	
Total R-value: 0.1704 m ¾/W Mass: 196.7500 kg/m² Very light Surfaces Functional Settings Regulations RadianceIES Outside Emissivity: 0.900 Resistance (m¾/W): 0.0400 ☑ Default Inside Solar Absorptance: 0.700 Construction Layers (Outside To Inside) Inside Inside			ID. WALL	Externa	Inte	e			
formance: EN-ISO ~									
U-value: 2.1022 W/m²·K Thickness:	120.000 mm	Therr	nal mass Cr	n: 77.9125	kJ/(m²∙K)				
Total R-value: 0.1704 m²K/W Mass:	ID: WALL External Internal W/m³-K Thidkness: 120.000 mm Thermal mass Cm: 77.9125 kJ/(m²-K) m %/W Mass: 196.7500 kg/m² Very lightweight m %/W Mass: 196.7500 kg/m² Very lightweight Regulations RadianceIES Inside Emissivity: 0.900 Resistance (m %/W); 0.1300 ✓ Default Inside Solar Absorptance: 0.550 System Materials Project Materials Material Thickness mm Conductivity W/(m %) Density kg/m³ Specific Heat Capacity J/(kg rk) Resistance Resistivity Gapacity J/(kg rk) Vapour Gapacity Gapacity Gapacity Category								
urfaces Functional Settings Regulations RadianceIES									
Outside		Inside							
	EN-ISO Control Thickness: 120.000 mm Thermal mass Cm: 77.9125 kJ/(m²+K) U-value: 2.1022 W/m³+K Thickness: 120.000 mm Thermal mass Cm: 77.9125 kJ/(m²+K) IR-value: 0.1704 m¥/W Mass: 196.7500 kg/m² Very lightweight functional Settings Regulations RadianceIES Inside Inside Emissivity: 0.900 Resistance (m³K/W): 0.0400 ☑ Default bisorptance: 0.700 Resistance (m³K/W): 0.0400 ☑ Default Emissivity: 0.900 Resistance (m³K/W): 0.1300 ☑ Default n Layers (Outside To Inside) System Materials Project Materials Project Materials Project Materials Material Thickness Conductivity Bensity Resistance Vapour Resistovity Givs:/(kg m) Category J Single Brickwork (Outer Leaf) 110.0 0.8400 1700.0 800.0 0.1310 0.000 Bick& Blockwork IS.0 0.00000<								
Emissivity: 0.900 Resistance (m ² K/W): 0	ID: WALL External Internal Thickness: 120.000 mm Thermal mass Cm: 77.9125 kJ/(m²+K) Mass: 196.7500 kg/m² Very lightweight Very lightweight RadianceIES Inside Emissivity: 0.900 Resistance (m³K/W): 0.1300 ✓ Default Solar Absorptance: 0.550 System Materials Project Materials Project Materials ial Thickness Conductivity Density Specific Heat Resistance Vapour ial Thickness Conductivity Density Specific Heat Resistance Vapour 110.0 0.8400 1700.0 0.01310 0.000 Brick & Blockwork ✓ 5.0 0.5000 1000.0 0.0100 Brick & Blockwork ✓								
	0.0400 🗹 Default				Re	sistance (m²K/W	/): 0.1300	∠ Default	
	0.0400 🔽 Default				Re	sistance <mark>(</mark> m²K/W	/): 0.1300	⊿ Default	
Solar Absorptance: 0.700	0.0400 🔽 Default								
Solar Absorptance: 0.700		Solar Ab	sorptance:	0.550	S	ystem Materials.			
Solar Absorptance: 0.700 Construction Layers (Outside To Inside)	Thickne	Solar Ab	sorptance: Density	0.550 Specific Heat Capacity	S	vstem Materials Vapour Resistivity	Project I	Materials	
Solar Absorptance: 0.700 Construction Layers (Outside To Inside) Material	Thickne	Solar Ab	Density kg/m ³	0.550 Specific Heat Capacity J/(kg·K)	S Resistance m²K/W	vstem Materials. Vapour Resistivity GN's/(kg'm)	Project I	Materials	
Solar Absorptance: 0.700 Construction Layers (Outside To Inside)	Thickne mm 110.	ss Conductivity W/(m+K) 0.8400	Density kg/m ³ 1700.0	0.550 Specific Heat Capacity J/(kg·K) 800.0	S Resistance m ² K/W 0.1310	Vapour Resistivity GN's/(kg·m) 0.000	Project I Catego Brick & Blockwork	Materials	

8. SIPOREX (19.8 mm thickness)

Project Con	nstruction (Opaque: External Wall)	1							- 0]
escription:	External Wall							ID: WALL	External	Intern
rformance:	EN-ISO ~									
U	J-value: 2.1022 W/m²·K	Thickness: 120.000 mr	m	Therm	nal mass Cn	m: 77.2610	kJ/(m²·K)			
Total R	R-value: 0.1826 m²K/W	Mass: 196.2500 kg	g/m²			Very lightwe	ight			
	nctional Settings Regulations Rad	fianceIES								
Outside				Inside						
1	Emissivity: 0.900	Resistance (m²K/W): 0.0400	∠ Default	E	Emissivity:	0.900	Re	sistance (m²K/W	/): 0.1300 🗸 Defa	ault
Solar Abs	sorptance: 0.700			Solar Abs	sorptance:	0.550				
Construction L	Layers (Outside To Inside)						s	ystem Materials.	Project Materia	als
	Material		Thickness mm	Conductivity W/(m·K)	Density kg/m³	Specific Heat Capacity J/(kg·K)	Resistance m²K/W	Vapour Resistivity GN*s/(kg·m)	Category	
[BRCK0000] 5	Single Brickwork (Outer Leaf)		110.0	0.8400	1700.0	800.0	0.1310	0.000	Brick & Blockwork	~
[PLD] PLASTE	ER (DENSE)		5.0	0.5000	1300.0	1000.0	0.0100	50.000	Plaster	~
10										

Similar Performing Materials (3)



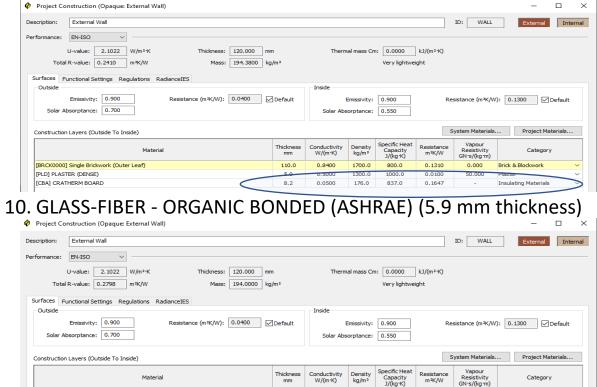
Methods: Using the IES VE Software for the digital twin.

9. CRATHERM BOARD (8.2 mm thickness)

[BRCK0000] Single Brickwork (Outer Leaf)

[USGF0000] GLASS-FIBER - ORGANIC BONDED (ASHRAE)

[PLD] PLASTER (DENSE)



110.0

5.9

0.8400

0.0360

1700.0

100.0

800.0

1000.0

0.1310

0.1647

0.000

50.00

10.000

Brick & Blockwork

Insulating Materials

Summary:

Zenova material has the advantage of the thickness against other insulation materials.

No	Materials	Thickness (in mm)
1	Zenova	1
2	FELT & MEMBRANE - FELT - HF-E3	31.3
3	FELT & MEMBRANE - FINISH - HF-A6	68.4
4	Expanded polystyrene (CIBSE)	5.8
5	INSULATION BOARD - HF-B5	7.2
6	POLYURETHANE BOARD	3.6
7	GLASSWOOL	6.6
8	THERMALITE "SHIELD"/"SMOOTH FACE"	28
9	SIPOREX	19.8
10	CRATHERM BOARD	8.2
11	GLASS-FIBER - ORGANIC BONDED (ASHRAE)	5.9

Thermal Modeling & Simulation of Exemplar 1920 House with Zenova Product

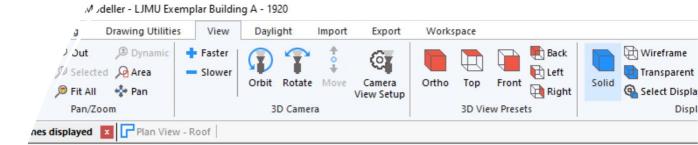
EDSL TAS software

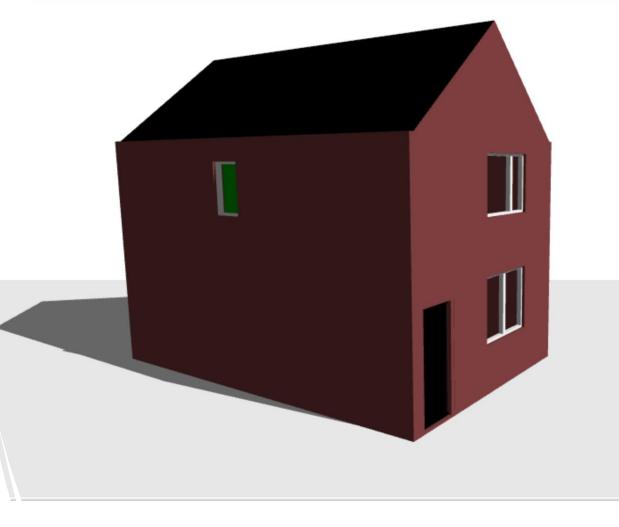
Modeling & Simulation Assumptions

- Whole house modelled as detached
- Various Scenarios Part L (SBEM Method)
- GHG Conversion Factors (Electricity – 0.519, Natural Gas – 0.216)
- Internal Condition NCM v5.2.7

RESULTS – (BRUKL Output Document/EPC)

- U values
- Energy Performance Certificate (EPC Rating)
- Energy Consumption (Heating)
- CO₂ Emission Rate





Q Search

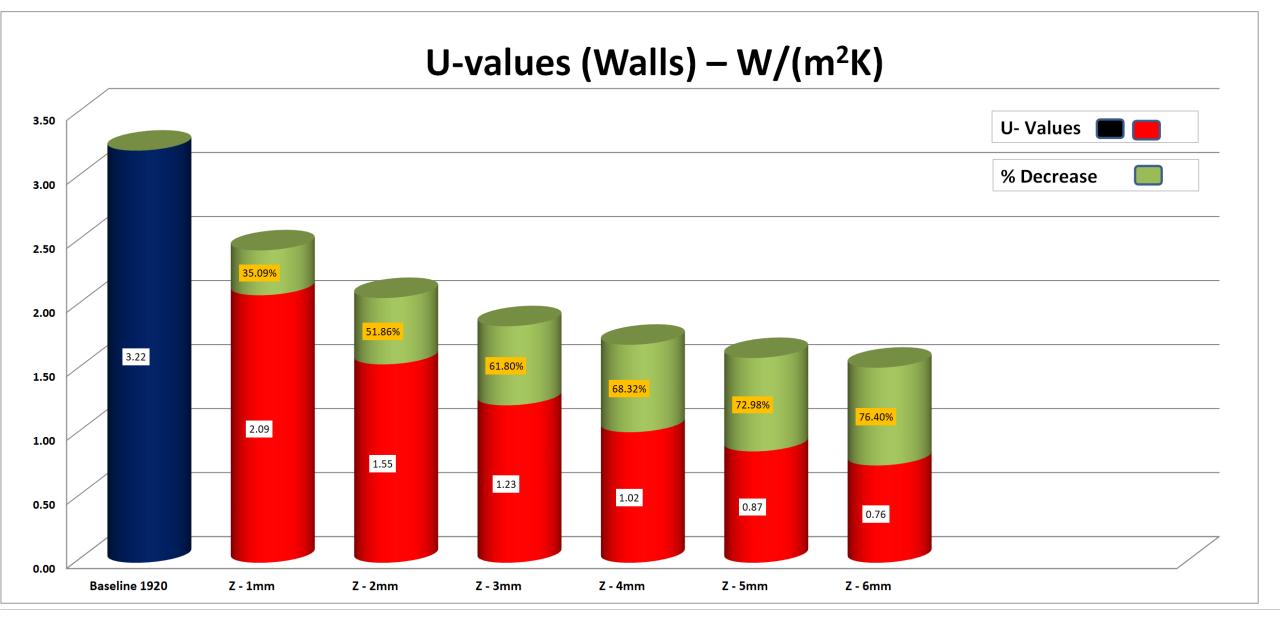
Building Elements

1920 Existing External Wall

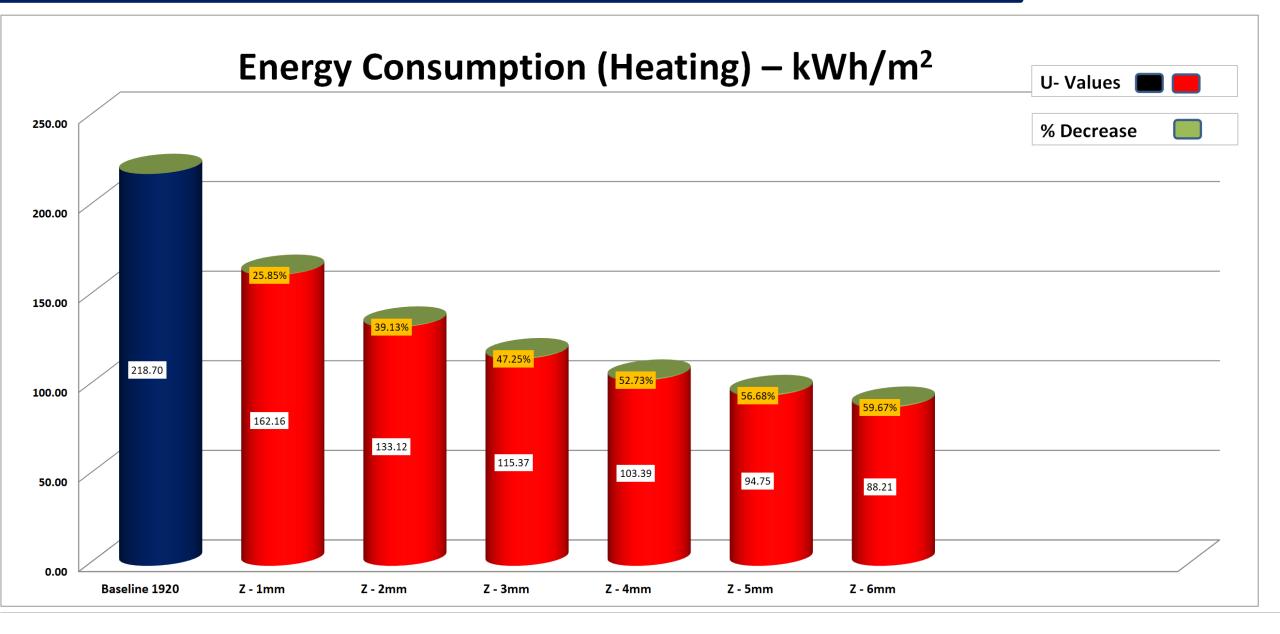
1920 Existing External Wall + 1mm Zenova Paint

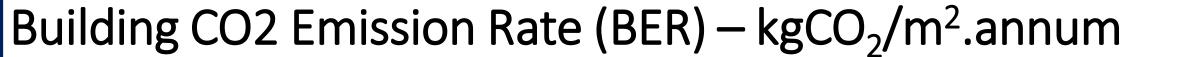
																						_
🕤 🤆 🕐 🔻 🗧 LJMU Exemplar B	Building A - 1920 - Tas B	Building Simulator								- 0 X	📔 🗂 Ċ 🕐 🔻 🛛 LJMU Exemplar	Building A - 1920 - Zer	nova (1mm) - Tas Buil	lding Simulator								-
Model Apertures Simu	lation Navigation	3D Visualisatio	on Import / E	Export Add-Ins							File Model Apertures Sim	ulation Navigation	n 3D Visualisatio	n Import,	/Export Ad	d-Ins						
e to Weather Calendar Schedule ny Database Database Building	Navigate Constructi to Element Databas	Substitute E	ement Fea Element Element		avigate Inter Zones	rnal Condition Database	IZAM Zone Col HVAC Gri Zone	-	Generation Tool ghting Control Tool Visualisation 3D	, Heating Design Day , Cooling Design Day gn Vizard Design Day	Navigate to Weather Calendar Schedule Summary Database Database Building	Navigate Construct to Element Databa	tions	lement 📑 Su	eature Shade urface Output Sp	Navigate to Zones	e Internal Condi s Database	₹ IZAM Zone C tions IVAC G Zone	ollection 🎴 L Groups	C Generation Tool Lighting Control Tool JD Visualisa 3D	Design D Sizing Wizard	
GF W04 (1)-frame GF W04 (1)-pane	Opaque Construction	in v N	lame Solid br	ick wall, 115 Desc	ription	Existing solid	d wall, with no	insulation add	led, as commonly found in pre-1919	1	— 🗿 GF W04 (2)-pane — 🗿 GF W12 (1)-frame	Opaque Constructio	on v N	ame 1920 E	xternal Wall -	Description						
GF W04 (2)-frame	Solar Abso	orptance	En	nissivity	Conduc	tance	-					Solar Abs	orptance	[missivity		onductance	-				
GF W04 (2)-pane GF W12 (1)-frame	Ext. Surf.	Int. Surf.	External	Internal	(W/m	n ^{2,v} () Tim	ne Constant				— 🦸 GF W12 (2)-frame — 🗗 GF W12 (2)-pane	Ext. Surf.	Int. Surf.	External	Inter	nal	(W/m²·°C)	Time Constant				
GF W12 (1)-pane	0.700	0.700	0.900	0.900	7.0)95	0.638					0.700	0.166	0.900	0.88	0	3.251	1.546	-			
GF W12 (2)-frame GF W12 (2)-pane											- 🖉 Internal Floor/Internal Ceiling - 🖉 Internal Wall											
Ground Floor	Layer	M-Code	Thickness (.	Conductivi Co	vectio	Vapour Dif	Density (k	Specific H	Description		🗍 Null	Layer	M-Code	Thickness	(Conductivi	i Convectio	Vapour Dif	f Density (k	Specific H.	Description		
Internal Floor/Internal Ceili Internal Wall		Brick, 110 mm	110.0	0.84 0.0		9999.000	1700.0	800.0	110 mm layer of brick (ou		Zone Groups		Zenova Paint, 1m		0.006	0.001	50.000	750.0	966.0	in beschption		
Null	2	Plaster, dense	5.0	0.5 0.0		9999.000	1300.0	1000.0	Dense plasterwork, 5 mm		Zone Groups Zones	2	Plaster, dense	5.0	0.5	0.001	9999.000	1300.0	1000.0	Dense plasterwork, 5 mm		
Roof											Internal Conditions	3	Brick, 110 mm	110.0	0.84	0.001	9999.000	1700.0	800.0	110 mm layer of brick (ou		
ne Groups											Schedules	-								, , , , , , , , , , , , , , , , , , , ,		
ines											Constructions											
ernal Conditions redules											e-16 f mm single glazing (clear glass											
Istructions											1920 Ceiling - Zenova											
δ mm single glazing (clear											1920 External Wall - Zenova 1920 Heavy partition wall - Zenova											
Heavy partition wall																						
Internal concrete floor (wit											Internal concrete floor (with cor											
Pitched roof, insul at rafter	* layer ignored in U-V	/alue/R-Value Calcula	ation								Pitched roof, insul at rafters, un	* laver innored in U-	Value/R-Value Calcula	tion								
Pitched roof, no insulation, Plastic frame, 2 hollow cha											Pitched roof, no insulation, U=2	a for ignored in 0	tarac concon									
Solid brick wall, 115 mm, u	U/R Values (ISO 694	6) (Homogenous)									Plastic frame, 2 hollow chambe	U/R Values (ISO 694	46) (Homogenous) —						_			
Solid ground floor (E&W) 1 Uninsulated personnel doo	Flow Direct		ernal U Value (W/m².ºC)	External U V (W/m ^{2,e} C			v U Values		Condensation		 Bolid brick wall, 215 mm, uninst Bolid ground floor (E&W) 1990 I Muninsulated personnel door 	Flow Direc	tion Inte	ernal U Value W/m².ºC)		nal U Value V/m².ºC)		now U Values	J	Condensation		
Nood frame, metal spacer	Horizonta	al	2.494	3.216							Wood frame, metal spacer	Horizont	tal	1.762		2.094	- 3	how R Values				
erture Types	Upward	1	2.933	3.559		Additional	Heat 0.0	1%	F-Factor 0.0 W/m.°C		Aperture Types	Upward	d	1.97		2.234	Additio	nal Heat	00/	F-Factor 0.0 W/m.°C		
stitute Elements ure Shades	Downwar	rd	2.079	2.849		Transfer					Substitute Elements	Downwa	ırd	1.544		1.932	Transfer		.0%	0.0 W/m.*C		
face Output Specifications											Feature Shades				1							
r Zone Air Movement											Surface Output Specifications											
-											Inter Zone Air Movement											
										1.1												

Results – U-values (Walls) – W/(m²K)

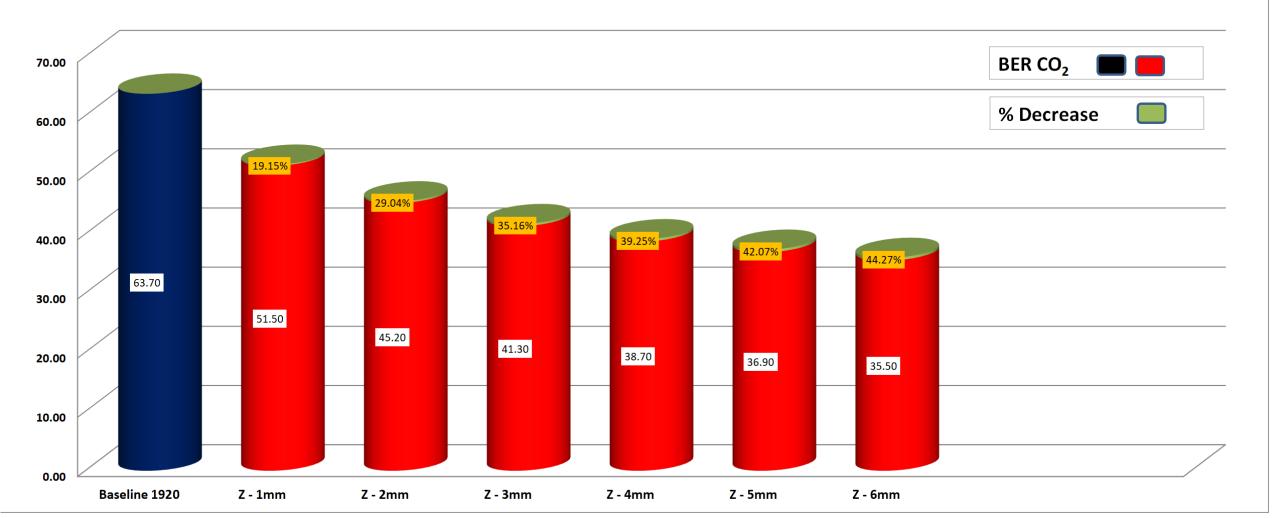


Energy Consumption (Heating) – kWh/m²





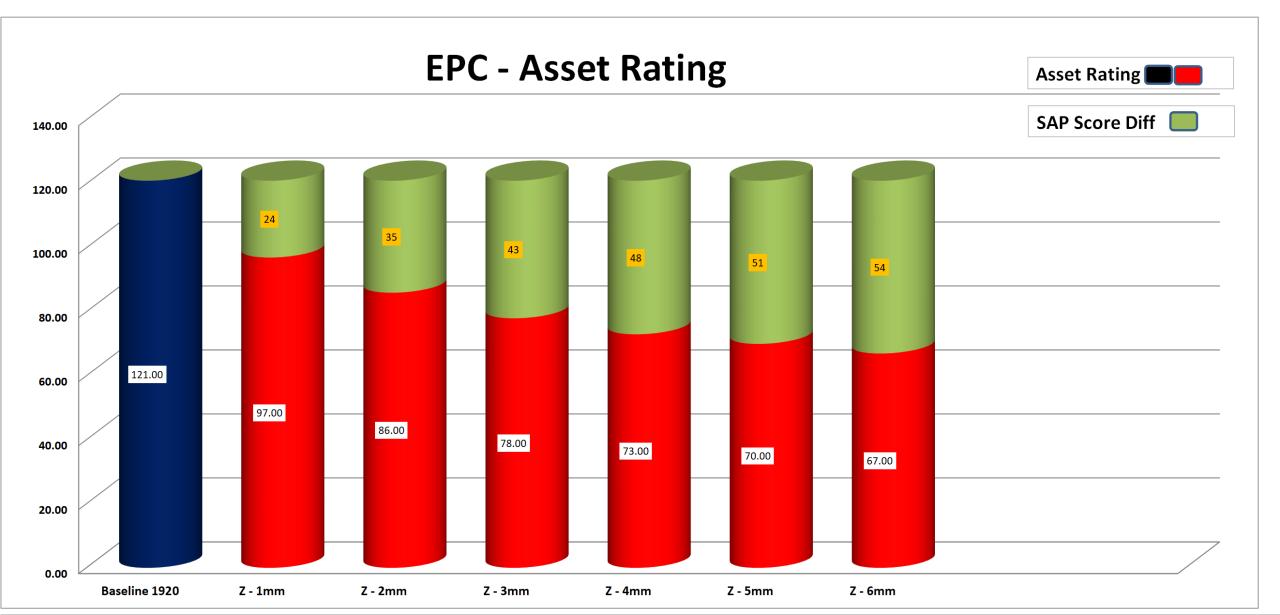
Building CO_2 Emission Rate (kg CO_2/m^2 .annum)



Energy Performance Asset Rating



Energy Performance Asset Rating





Conclusion

- **1.** The promising result shown by the U-value Improvement which is 1.2678 W/(m²K).
- 2. Zenova material has the **advantage of the thickness** against other insulation materials.
- 3. Modeling and simulation of whole building results show evidence of **significant reduction** in U-values, Energy Consumption (Heating), Building Emission Rate and Asset Rating with progressive increase in thickness application of Zenova material.

Future Works/ Considerations



- 1. Performance with **Varying** coating thickness.
- 2. Run the test and measure the **heating energy (KWh)** before and after refurbishment with dedicated heater.
- 3. Testing other buildings (1950, 2010) and **2021 New Building regulation**
- 4. Future over heating analysis using **CIBSETM59 for 2050-2080**