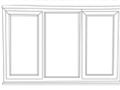


Supplementary material S1: General assumptions of the retrofit measures

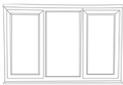
The model simulation general assumptions

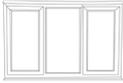
- 1- All single-family houses SFH are detached houses, low urban density oriented towards East and have an average shading rate
- 2- Top floor flats were chosen for simulation in all apartments BA and MFH
- 3- Pre 1945 dwellings are high thermal mass value whilst post 1965 are low thermal mass value
- 4- Location of all dwellings are in East Scotland specifically in Edinburgh
- 5- Dwelling pre 1944 has solid floor construction
- 6- No cavities in party walls in all dwellings
- 7- Default total thermal bridging value of 0.15 W/m²K for all existing dwelling pre1945, 0.10 W/m²K (1945-1980) and 0.05W/m²K for post 1980
- 8- All dwellings subject to system upgrade (Mechanical Ventilation without Heat Recovery)
- 9- Single-family and Terraced houses are oriented east with possibility of installing PVs at inclination angle of 45° with little or no shadings
- 10- The assessment is based on standardised assumptions for occupancy and behaviour

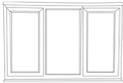
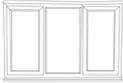
SFH Typology	Building Measures	Improvement actions
PRE 1919 TFA =198m ² Height=2.5 m 2 storey house	Existing 	<p>Windows; Double-glazed (east & west) PVCU 12mm air-filled U-value 2.1 W/m²k</p> <p>Door: Half-Double glazed 12mm PVCU U-value 1.85 W/m²k</p> <p>Floor: Solid floor 150mm concrete dense R-value 0.075 + soft plywood 20mm R-value 0.154, total U-value= 0.6 W/m²k</p> <p>External Wall: Solid brickwork double BRE (102.50mm) + inner-leaf Plaster dense 20mm + render 20mm outer-leaf Total U-value1.95 W/m²k</p> <p>Roof: tiles clay 12mm ventilated cavity 255mm + soft chipboard 15mm (U-value 2.2 W/m²k).</p> <p>System: Natural ventilation, combi-gas boiler with radiators for heating and hot water + room thermostat efficiency 75%.</p>
	Windows and doors replacement 	<p>Windows: Triple-glazed windows with argon filled U-value of 1.6W/m²K</p> <p>External door: Triple-glazed argon filled PPCU 16mm U-value 1.4</p>
	Roof & floor insulation 	<p>Floor: Mineral wool Quilt 200mm added under the soft plywood layer (R-value 4.76) + Foil-Tec Single VCL (1 mm R=0.74) Total floor U-value 0.14 W/m²K</p> <p>Roof: Felt/Bitumen Layers (1.5 mm) (R0.013) + Mineral Wool Quilt (300 m, R=7.14) + Foil-Tec Single VCL (1 mm R=0.74)</p>

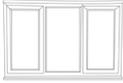
		Total U-value = 0.12 W/m²K
	EWI/CWI/IWI + Ex-door 	EWI: Extruded Polystyrene (200 mm, R=7.407) + Foil-Tec Single VCL (1 mm R=0.74).
	Systems replacement	System: Decentralised mechanical whole house extract ventilation and ASHP installed to existing radiators, electric heat pump and DHW storage 250L provided with full insulation of 100mm for pipework.
	Renewables 	4 KWp of PV added to the roof oriented south with tilted angle of 45°.
1919-1944 TFA = 153.20m ² Height=2.5 m 2 storey house	Existing 	Floor = Solid concrete dense 150mm+ soft plywood 20mm (total U-value 0.56 W/m ² K) External wall = brickwork 223mm+ 20mm plaster+ 20mm render cement (total U-value 1.81 W/m ² K) Roof: Tiles (Clay 20 mm) + Wood Wool Slab (20 mm) + Ventilated Cavity + loft insulation 100mm + Plasterboard Standard (15 mm) Total U-value = 1.61 W/m ² K Windows: PVCU Double glazed 12mm U-value = 1.85 W/m ² K System: Natural ventilation, combi-gas boiler with radiators for heating and hot water Door: PVCU double glazed 16mm U-value= 2.0 W/m ² K
	Windows + ventilation 	Windows: Triple-glazed windows with argon filled U-value of 1.6W/m ² K, System: Decentralised mechanical whole house extract ventilation and ASHP installed to existing radiators, electric heat pump and DHW storage 250L provided with full insulation of 100mm for pipework.
	Roof & floor insulation 	Floor: Solid concrete Dense (150 mm) + EPS 200mm + Foil-Tec Single VCL (1 mm) + soft plywood 15mm (U-value 0.13 W/m ² K). Roof: Tiles (Clay) (12 mm) + Wood Wool Slab (15mm) + Polyurethane Board (250 mm) + Foil-Tec Double VCL (1 mm) + Plasterboard Standard (12.5 mm) total U-value 0.10 W/m ² K.
	EWI/CWI/IWI + Ex-door 	External wall: Render - Cement and Sand (20 mm) + Breather Foil-FR (2 mm) + XPS 200mm+ Solid Brickwork (Double layer 112.5*2) Foil-Tec Double VCL (1 mm) + Plaster (Dense) (20 mm) Total U-value 0.10 W/m ² K. External door: Half triple-glazed PVCU argon filled 16mm or more U-value 1.5 W/m ² K.
	Renewables 	4 KWp of PV added to the roof oriented south with tilted angle of 45°.

1945-1964 TFA = 134.40m ² Height=2.5 m 2 storey house	Existing 	Suspended Floor: Soft Wood/Plywood/Chipboard (Softwood) (20 mm) + Polyurethane foam (50 mm) + Unventilated Cavity 650mm + ground U-value 0.24 W/m ² K. Pitched roof: Tiles (Clay) (12 mm) + Woodfibre 30mm + Plasterboard Standard (20 mm) U-value 0.6 W/m ² K. Cavity wall: Render - Gypsum and Sand (20 mm) + Brickwork Outer Leaf - BRE (102.5 mm) + Polyurethane foam (40 mm) + Brickwork Inner Leaf - BRE (102.5 mm) + Plaster (Dense) (20 mm) total U-value 0.49 W/m ² K. Windows: PVCU Double glazed 12mm U-value = 1.85 W/m ² K Door: Half-Double glazed 12mm PVCU U-value 1.85 W/m ² k System: Natural ventilation, combi-gas boiler with radiators for heating and hot water storage tank in loft 250L.
	Windows + ventilation 	Windows: Triple-glazed argon filled 16mm or more U-value of 1.4 W/m ² K, windows half opened 50%. System: Decentralised mechanical whole house extract ventilation and ASHP installed to existing radiators, electric heat pump and DHW storage 250L provided with full insulation of 100mm for pipework.
	Roof & floor insulation 	Suspended Floor: Soft Wood/Plywood/Chipboard (Softwood) (20 mm) + Foil-Tec Double VCL (1 mm) + Polyurethane foam (150 mm) + Unventilated Cavity 450mm + ground (U-value 0.13 W/m ² K). Pitched roof: Tiles (Clay) (12 mm) + Felt/Bitumen Layers (1 mm) + Mineral Wool Batt (300 mm) + Foil-Tec Double VCL (1 mm) + Plasterboard Standard (20 mm) U-value 0.12 W/m ² K.
	EWI/CWI/IWI + Ex-door 	External wall: Render - Gypsum and Sand (20 mm) + Brickwork Outer Leaf - BRE (102.5 mm) + Extruded Polystyrene (80 mm) + Brickwork Inner Leaf - BRE (102.5 mm) + Expanded Polystyrene (100 mm) + Foil-Tec Double VCL (1 mm) + Plaster standard (20 mm) Total U-value 0.15 W/m ² K. External door: Half triple-glazed PVCU argon filled 16mm or more U-value 1.5 W/m ² K.
	Renewables 	4 KWp of PV added to the roof oriented south with tilted angle of 45°.
1965-1980 TFA = 123.08m ² Height=2.5 m 2 storey house	Existing 	Suspended Floor: Soft Wood/Plywood/Chipboard (Softwood) (20 mm) + Polyurethane foam (50 mm) + Ventilated Cavity 650mm + ground U-value 0.42 W/m ² K. Pitched roof: Tiles (Clay) (12 mm) + Mineral Wool Batt (70 mm)+ Plasterboard Standard (20 mm) U-value 0.55 W/m ² K.

		<p>Cavity wall: Plasterboard High Density (20 mm) + Brickwork Outer Leaf - BRE (102.5 mm) + Polyurethane foam (40 mm) + Brickwork Inner Leaf - BRE (102.5 mm) Total U-value 0.47 W/m²K.</p> <p>Windows: PVCU Double glazed 16mm U-value = 1.8 W/m²K</p> <p>Door: Half-Double glazed 16mm PVCU U-value 1.8 W/m²k</p> <p>System: Natural ventilation, combi-gas boiler with radiators for heating and hot water storage tank in loft 300L.</p>
	<p>Windows + ventilation</p> 	<p>Windows: Triple-glazed argon filled 16mm or more U-value of 1.2 W/m²K, windows slightly open 5mm.</p> <p>Decentralised mechanical whole house extract ventilation and ASHP installed to existing radiators with minimum efficiency of 190%, electric heat pump and DHW storage 300L provided with full insulation of 100mm for pipework and water heating timed separately.</p>
	<p>Roof & floor insulation</p> 	<p>Suspended Floor: Soft Wood/Plywood/Chipboard (Softwood) (20 mm) + Foil-Tec Double VCL (1 mm) + Polyurethane foam (200 mm) + Unventilated Cavity 450mm + ground (U-value 0.12 W/m²K).</p> <p>Pitched roof: Tiles (Clay) (12 mm) + Felt/Bitumen Layers (1 mm) + Mineral Wool Batt (300 mm) + Foil-Tec Double VCL (1 mm) + Plasterboard Standard (20 mm) U-value 0.10 W/m²K.</p>
	<p>EWI/CWI/IWI + Ex-door</p> 	<p>External wall: Render - Gypsum and Sand (20 mm) + Brickwork Outer Leaf - BRE (102.5 mm) + Extruded Polystyrene (80 mm) + Brickwork Inner Leaf - BRE (102.5 mm) + Expanded Polystyrene (100 mm) + Foil-Tec Double VCL (1 mm) + Plaster standard (20 mm) Total U-value 0.15 W/m²K.</p> <p>External door: Half triple-glazed PVCU argon filled 16mm or more U-value 1.2 W/m²K.</p>
	<p>Renewables</p> 	<p>4 KWp of PV added to the roof oriented south with tilted angle of 45°.</p>
<p>Post 1980s TFA = 149.35m² Height=2.5 m 2 storey house</p>	<p>Existing</p> 	<p>Suspended Floor: Soft Wood/Plywood/Chipboard (Softwood) (20 mm) + Polyurethane foam (100 mm) + Ventilated Cavity 550mm + ground U-value 0.28 W/m²K.</p> <p>Pitched roof: Tiles (Clay) (12 mm) + Mineral Wool Batt (150 mm)+ Plasterboard Standard (20 mm) U-value 0.24 W/m²K.</p> <p>Cavity wall: Plasterboard High Density (20 mm) + Brickwork Outer Leaf - BRE (102.5 mm) + Mineral Wool Quilt (50 mm) + Brickwork Inner Leaf - BRE (102.5 mm) Total U-value 0.58 W/m²K.</p>

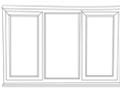
		<p>Windows: PVCU Double glazed 16mm U-value = 1.6 W/m²K</p> <p>Door: Half-Double glazed 16mm PVCU U-value 1.5 W/m²k</p> <p>System: Natural ventilation, Condensing combi-gas boiler with radiators for heating and hot water storage tank in loft 300L.</p>
	<p>Windows + ventilation</p> 	<p>Windows: Triple-glazed argon filled 16mm or more U-value of 1.2 W/m²K, windows slightly open 5mm.</p> <p>Decentralised mechanical whole house extract ventilation and ASHP installed to existing radiators with minimum efficiency of 190%, electric heat pump and DHW storage 300L provided with full insulation of 100mm for pipework and water heating timed separately.</p>
	<p>Roof & floor insulation</p> 	<p>Suspended Floor: Soft Wood/Plywood/Chipboard (Softwood) (20 mm) + Foil-Tec Double VCL (1 mm) + Polyurethane foam (200 mm) + Unventilated Cavity 450mm + ground (U-value 0.12 W/m²K).</p> <p>Pitched roof: Tiles (Clay) (12 mm) + Felt/Bitumen Layers (1 mm) + Mineral Wool Batt (300 mm) + Foil-Tec Double VCL (1 mm) + Plasterboard Standard (20 mm) U-value 0.10 W/m²K.</p>
	<p>EWI/CWI/IWI + Ex-door</p> 	<p>External wall: Render - Gypsum and Sand (20 mm) + Brickwork Outer Leaf - BRE (102.5 mm) + Extruded Polystyrene (80 mm) + Brickwork Inner Leaf - BRE (102.5 mm) + Expanded Polystyrene (100 mm) + Foil-Tec Double VCL (1 mm) + Plaster standard (20 mm) Total U-value 0.15 W/m²K.</p> <p>External door: Half triple-glazed PVCU argon filled 16mm or more U-value 1.2 W/m²K.</p>
	<p>4 KW_p of PV added to the roof oriented south with tilted angle of 45°.</p>	<p>4 KW_p of PV added to the roof oriented south with tilted angle of 45°.</p>
TH Typology	Building Measures	Improvement actions
<p>PRE 1919 TFA = 104.62m² Height=2.5 m 2 storey house</p>	<p>Existing</p> 	<p>Floor= Solid concrete dense 150mm+ soft plywood 20mm (total U-value 0.60 W/m²K)</p> <p>External wall= brickwork 223mm+ 20mm plaster+ 20mm render cement (total U-value 1.81 W/m²K)</p> <p>Roof: Tiles (Clay 12 mm) + Wood Wool Slab (20 mm) + Ventilated Cavity + loft insulation Mineral Wool Batt 50mm + Plasterboard Standard (15 mm) Total U-value = 0.55 W/m²K</p> <p>Windows: PVCU Double glazed 16mm U-value = 1.65 W/m²K</p>

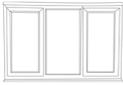
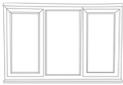
		<p>System: Natural ventilation, combi-gas boiler with radiators for heating and hot water</p> <p>Door: PVCU double glazed 16mm U-value= 1.80 W/m²K</p>
	<p>Windows + ventilation</p> 	<p>Windows: Triple-glazed argon filled 16mm or more U-value of 1.5 W/m²K, windows slightly open 5mm.</p> <p>Decentralised mechanical whole house extract ventilation and ASHP installed to existing radiators with minimum efficiency of 180%, electric heat pump and DHW storage 300L provided with full insulation of 100mm for pipework and water heating timed separately.</p>
	<p>Roof & floor insulation</p> 	<p>Floor: Solid concrete Dense (150 mm) + EPS 200mm + Foil-Tec Single VCL (1 mm) + soft plywood 20mm (U-value 0.12 W/m²K).</p> <p>Roof: Tiles (Clay) (12 mm) + Wood Wool Slab (15mm) + Mineral Wool Batt (300 mm)+ Foil-Tec Double VCL (1 mm) + Plasterboard Standard (12.5 mm) total U-value 0.10 W/m²K.</p>
	<p>EWI/CWI/IWI + Ex-door</p> 	<p>External wall: Render - Gypsum and Sand (20 mm) + brickwork - BRE (223mm) + Extruded Polystyrene (200 mm) + Foil-Tec Double VCL (1 mm) + Plaster standard (20 mm) Total U-value 0.11 W/m²K.</p> <p>External door: Half triple-glazed PVCU argon filled 16mm or more U-value 1.2 W/m²K.</p>
	<p>Renewables</p> 	<p>4 KWp of PV added to the roof oriented south with tilted angle of 45°.</p>
<p>1919-1944 TFA = 153.20m² Height=2.5 m 2 storey house</p>	<p>Existing</p> 	<p>Floor= Solid concrete dense 150mm+ soft plywood 20mm (total U-value 0.62 W/m²K)</p> <p>External wall= 20mm plaster+ brickwork 223mm+ 20mm render cement (total U-value 1.80 W/m²K)</p> <p>Roof: Tiles (Clay 20 mm) + Wood Wool Slab (20 mm) + Ventilated Cavity + Unventilated Cavity - (Roof - Low Emissivity) (300 mm) + loft insulation Mineral Wool Batt (50 mm) + Plasterboard Standard (15 mm) Total U-value = 0.51 W/m²K</p> <p>Windows: PVCU Double glazed 12mm U-value = 1.85 W/m²K</p> <p>System: Natural ventilation, combi-gas boiler with radiators for heating and hot water</p> <p>Door: PVCU double glazed 16mm U-value= 2.0 W/m²K</p>
	<p>Windows + ventilation</p> 	<p>Windows: Triple-glazed argon filled 16mm U-value of 1.4 W/m²K, windows half opened.</p> <p>Decentralised mechanical whole house extract ventilation and ASHP installed to existing radiators efficiency 180%, electric heat pump and DHW storage 300L provided with full insulation of 100mm for pipework and water heating timed separately.</p>

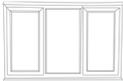
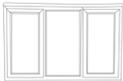
	Roof & floor insulation 	Floor: Solid concrete Dense (150 mm) + EPS 200mm + Foil-Tec Single VCL (1 mm) + soft plywood 15mm (U-value 0.12 W/m ² K). Roof: Tiles (Clay) (12 mm) + Wood Wool Slab (15mm) + Mineral Wool Batt (300 mm) + Foil-Tec Double VCL (1 mm) + Plasterboard Standard (12.5 mm) total U-value 0.10 W/m ² K.
	EWI/CWI/IWI + Ex-door 	External wall: Render - Cement and Sand (20 mm) + Breather Foil-FR (2 mm) + XPS 200mm+ Solid Brickwork (Double layer 112.5*2) + Foil-Tec Double VCL (1 mm) + Plaster (Dense) (20 mm) Total U-value 0.09 W/m ² K. External door: Half triple-glazed PVCU argon filled 16mm or more U-value 1.4 W/m ² K.
	Renewables 	4 KWp of PV added to the roof oriented south with tilted angle of 45°.
1945-1964 TFA = 87.72m ² Height=2.5 m 2 storey house	Existing 	Suspended Floor: Soft Wood/Plywood/Chipboard (Softwood) (20 mm) + Ventilated Cavity 700mm + ground U-value 0.46 W/m ² K. Pitched roof: Tiles (Clay) (12 mm) + Woodfibre 30mm + Mineral Wool Batt (50 mm) Plasterboard Standard (20 mm) U-value 0.41 W/m ² K. Cavity wall: Render - Gypsum and Sand (20 mm) + Brickwork Outer Leaf - BRE (112.5 mm) + Unventilated Cavity - (Wall - Low Emissivity) (80 mm) + Brickwork Inner Leaf - BRE (112.5 mm) + Plaster (Dense) (20 mm) total U-value 1.00 W/m ² K. Windows: PVCU Double glazed 12mm U-value = 1.80 W/m ² K Door: Half-Double glazed 12mm PVCU U-value 1.90 W/m ² k System: Natural ventilation, combi-gas boiler with radiators for heating and hot water storage tank in loft 250L.
	Windows + ventilation 	Windows: Triple-glazed argon filled 16mm or more U-value of 1.25 W/m ² K, windows half opened 50%. Decentralised mechanical whole house extract ventilation and ASHP installed to existing radiators with minimum efficiency of 190%, electric heat pump and DHW storage 300L provided with full insulation of 100mm for pipework and water heating timed separately.
	Roof & floor insulation 	Suspended Floor: Soft Wood/Plywood/Chipboard (Softwood) (20 mm) + Foil-Tec Double VCL (1 mm) + Polyurethane foam (200 mm) + Ventilated Cavity 400mm + ground (U-value 0.11 W/m ² K). Pitched roof: Tiles (Clay) (12 mm) + Felt/Bitumen Layers (1 mm) + Mineral Wool Batt (300 mm) + Foil-Tec

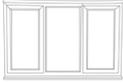
		Double VCL (1 mm) + Plasterboard Standard (20 mm) U-value 0.10 W/m ² K.
	EWI/CWI/IWI + Ex-door 	External wall: Render - Gypsum and Sand (20 mm) + Brickwork Outer Leaf - BRE (112.5 mm) + Extruded Polystyrene (80 mm) + Brickwork Inner Leaf - BRE (112.5 mm) + Expanded Polystyrene (100 mm) + Foil-Tec Double VCL (1 mm) + Plaster standard finishing (15 mm) Total U-value 0.12 W/m ² K. External door: Half triple-glazed PVCU argon filled 16mm or more U-value 1.4 W/m ² K.
	Renewables 	4 KWp of PV added to the roof oriented south with tilted angle of 45°.
1965-1980 TFA = 85.32m ² Height=2.5 m 2 storey house	Existing 	Suspended Floor: Soft Wood/Plywood/Chipboard (Softwood) (25 mm) + Polyurethane foam (40 mm) + Ventilated Cavity 650mm + ground U-value 0.29 W/m ² K. Pitched roof: Tiles (Clay) (12 mm) + Mineral Wool Batt (50 mm) + Plasterboard Standard (20 mm) U-value 0.50 W/m ² K. Cavity wall: Plasterboard High Density (20 mm) + Brickwork Outer Leaf - BRE (102.5 mm) + Polyurethane foam (40 mm) + Brickwork Inner Leaf - BRE (102.5 mm) Total U-value 0.47 W/m ² K. Windows: PVCU Double glazed 16mm U-value = 1.8 W/m ² K Door: Half-Double glazed 16mm PVCU U-value 1.9 W/m ² k System: Natural ventilation, combi-gas boiler with radiators for heating and hot water storage tank in loft 300L.
	Windows + ventilation 	Windows: Triple-glazed argon filled 16mm or more U-value of 1.3 W/m ² K, windows slightly open 50mm. Decentralised mechanical whole house extract ventilation and ASHP installed to existing radiators with minimum efficiency of 190%, electric heat pump and DHW storage 300L provided with full insulation of 100mm for pipework and water heating timed separately.
	Roof & floor insulation 	Suspended Floor: Soft Wood/Plywood/Chipboard (Softwood) (20 mm) + Foil-Tec Double VCL (1 mm) + Polyurethane foam (200 mm) + Unventilated Cavity 400mm + ground (U-value 0.13 W/m ² K). Pitched roof: Tiles (Clay) (12 mm) + Felt/Bitumen Layers (1 mm) + Mineral Wool Batt (300 mm) + Foil-Tec Double VCL (1 mm) + Plasterboard Standard (20 mm) U-value 0.11 W/m ² K.

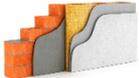
<p>Post 1980s TFA = 98.40m² Height=2.5 m 2 storey house</p>	<p>EWI/CWI/IWI + Ex-door</p> 	<p>External wall: Render - Gypsum and Sand (20 mm) + Brickwork Outer Leaf - BRE (102.5 mm) + Polyurethane foam (80 mm) + Brickwork Inner Leaf - BRE (102.5 mm) + Expanded Polystyrene (120 mm) + Foil-Tec Double VCL (1 mm) + Plaster standard (20 mm) Total U-value 0.11 W/m²K.</p> <p>External door: Half triple-glazed PVCU argon filled 16mm or more U-value 1.25 W/m²K.</p>
	<p>Renewables</p> 	<p>4 KWp of PV added to the roof oriented south with tilted angle of 45°.</p>
	<p>Existing</p> 	<p>Suspended Floor: Soft Wood/Plywood/Chipboard (Softwood) (20 mm) + Polyurethane foam (50 mm) + Ventilated Cavity 650mm + ground U-value 0.32 W/m²K.</p> <p>Pitched roof: Tiles (Clay) (12 mm) + Mineral Wool Batt (75 mm) + Plasterboard Standard (20 mm) U-value 0.40 W/m²K.</p> <p>Cavity wall: Plasterboard High Density (20 mm) + Brickwork Outer Leaf - BRE (102.5 mm) + Polyurethane foam (50 mm) + Brickwork Inner Leaf - BRE (102.5 mm) Total U-value 0.55 W/m²K.</p> <p>Windows: PVCU Double glazed 16mm U-value = 1.55 W/m²K</p> <p>Door: Half-Double glazed 16mm PVCU U-value 1.65 W/m²k</p> <p>System: Natural ventilation, Condensing combi-gas boiler with radiators for heating and hot water storage tank in loft 300L.</p>
<p>Windows + ventilation</p> 	<p>Windows: Triple-glazed argon filled 16mm or more U-value of 1.0 W/m²K, windows slightly open 50mm.</p> <p>Decentralised mechanical whole house extract ventilation and ASHP installed to existing radiators with minimum efficiency of 190%, electric heat pump and DHW storage 300L provided with full insulation of 100mm for pipework and water heating timed separately.</p>	
<p>Roof & floor insulation</p> 	<p>Suspended Floor: Soft Wood/Plywood/Chipboard (Softwood) (20 mm) + Foil-Tec Double VCL (1 mm) + Polyurethane foam (200 mm) + Ventilated Cavity 450mm + ground (U-value 0.13 W/m²K).</p> <p>Pitched roof: Tiles (Clay) (12 mm) + Felt/Bitumen Layers (1 mm) + Mineral Wool Batt (300 mm) + Foil-Tec Double VCL (1 mm) + Plasterboard Standard (20 mm) U-value 0.09 W/m²K.</p>	

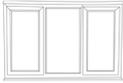
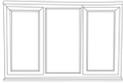
	EWI/CWI/IWI + Ex-door 	External wall: Render - Gypsum and Sand (20 mm) + Brickwork Outer Leaf - BRE (102.5 mm) + Polyurethane foam (80 mm) + Brickwork Inner Leaf - BRE (102.5 mm) + Expanded Polystyrene (120 mm) + Foil-Tec Double VCL (1 mm) + Plaster standard (20 mm) Total U-value 0.12 W/m ² K. External door: Half triple-glazed PVCU argon filled 16mm or more U-value 1.2 W/m ² K.
	Renewables 	4 KWp of PV added to the roof oriented south with tilted angle of 45°.
MFH Typology	Building Measures	Improvement actions
PRE 1919 TFA = 425 m ² Height=2.5 m 2 storey house	Existing 	Floor = Solid concrete dense 150mm+ soft plywood 20mm (total U-value 0.55 W/m ² K) External wall = Render - Gypsum and Sand (20 mm) + brickwork 205mm+ 20mm plaster+ 20mm render cement (total U-value 1.9 W/m ² K) Roof: Tiles (Clay 12 mm) + Wood Wool Slab (20 mm) + Ventilated Cavity + Mineral Wool Batt (75 mm)+ Plasterboard Standard (15 mm) Total U-value = 0.38 W/m ² K Windows: PVCU Double glazed 12mm U-value = 2.1 W/m ² K System: Natural ventilation, combi-gas boiler with radiators for heating and hot water mains Door: PVCU double glazed 16mm U-value= 1.90 W/m ² K
	Windows + ventilation 	Windows: Triple-glazed argon filled 16mm or more U-value of 1.6 W/m ² K, half-way opened. Decentralised mechanical whole house extract ventilation and new condensing boiler >90% Efficiency Rate installed to existing radiators.
	EWI/CWI/IWI + Ex-door 	External wall: Render - Gypsum and Sand (20 mm) + brickwork - BRE (205mm) + Extruded Polystyrene (200 mm) + Foil-Tec Double VCL (1 mm) + Plaster standard (20 mm) Total U-value 0.15 W/m ² K. External door: Half triple-glazed PVCU argon filled 16mm or more U-value 1.4 W/m ² K.
1919-1944 TFA = 480.81m ² Height=2.5 m 2 storey house	Existing 	Floor = Solid concrete dense 150mm+ soft plywood 20mm (total U-value 0.44 W/m ² K) External wall = 20mm plaster+ brickwork 205mm+ 20mm render cement (total U-value 1.90 W/m ² K) Roof: Tiles (Clay 20 mm) + Wood Wool Slab (20 mm) + Unventilated Cavity - (Roof - Low Emissivity) (250 mm) + loft insulation Mineral Wool Batt (50 mm) + Plasterboard Standard (15 mm) Total U-value = 0.58 W/m ² K Windows: PVCU Double glazed 12mm U-value = 1.95 W/m ² K

		<p>System: Natural ventilation, combi-gas boiler with radiators for heating and hot water</p> <p>Door: PVCU double glazed 16mm U-value= 2.1 W/m²K</p>
	<p>Windows + ventilation</p> 	<p>Windows: Triple-glazed argon filled 16mm U-value of 1.25 W/m²K, windows half opened.</p> <p>Decentralised mechanical whole house extract ventilation and new condensing boiler >90% Efficiency Rate installed to existing radiators.</p>
	<p>EWI/CWI/IWI + Ex-door</p> 	<p>External wall: Render - Cement and Sand (20 mm) + Breather Foil-FR (2 mm) + XPS 200mm+ Solid Brickwork (Double layer 102.5*2) + Foil-Tec Double VCL (1 mm) + Plaster (Dense) (20 mm) Total U-value 0.12 W/m²K.</p> <p>External door: Half triple-glazed PVCU argon filled 16mm or more U-value 1.5 W/m²K.</p>
<p>1945-1964 TFA = 447.09m² Height=2.5 m 2 storey house</p>	<p>Existing</p> 	<p>Suspended Floor: Soft Wood/Plywood/Chipboard (Softwood) (20 mm) + Ventilated Cavity 700mm + ground U-value 0.42W/m²K.</p> <p>Pitched roof: Tiles (Clay) (12 mm) + Woodfibre 30mm + Mineral Wool Batt (50 mm) Plasterboard Standard (20 mm) U-value 0.53 W/m²K.</p> <p>Cavity wall: Render - Gypsum and Sand (20 mm) + Brickwork Outer Leaf - BRE (102.5 mm) + Unventilated Cavity - (Wall - Low Emissivity) (80 mm) + Brickwork Inner Leaf - BRE (102.5 mm) + Plaster (Dense) (20 mm) total U-value 1.01 W/m²K.</p> <p>Windows: PVCU Double glazed 12mm U-value = 1.85 W/m²K</p> <p>Door: Half-Double glazed 12mm PVCU U-value 1.65 W/m²k</p> <p>System: Natural ventilation, combi-gas boiler with radiators for heating and hot water storage tank in loft 250L.</p>
	<p>Windows + ventilation</p> 	<p>Windows: Triple-glazed argon filled 16mm or more U-value of 1.20 W/m²K, windows half opened 50%.</p> <p>Decentralised mechanical whole house extract ventilation and new condensing boiler >90% Efficiency Rate installed to existing radiators.</p>
	<p>EWI/CWI/IWI + Ex-door</p> 	<p>External wall: Render - Gypsum and Sand (20 mm) + Brickwork Outer Leaf - BRE (102.5 mm) + Polyurethane foam (80 mm) + Brickwork Inner Leaf - BRE (102.5 mm) + Expanded Polystyrene (120 mm) + Foil-Tec Double VCL (1 mm) + Plaster standard finishing (15 mm) Total U-value 0.10 W/m²K.</p> <p>External door: Half triple-glazed PVCU argon filled 16mm or more U-value 1.2 W/m²K.</p>
<p>1965-1980 TFA = 559.42m²</p>	<p>Existing</p> 	<p>Suspended Floor: Soft Wood/Plywood/Chipboard (Softwood) (20 mm) + Polyurethane foam (50 mm) + Ventilated Cavity 650mm + ground U-value 0.31 W/m²K.</p>

Height=2.5 m 2 storey house		<p>Pitched roof: Tiles (Clay) (12 mm) + Unventilated Cavity - (Roof - Low Emissivity) (250 mm) + Mineral Wool Batt (50 mm) + Plasterboard Standard (20 mm) U-value 0.57 W/m²K.</p> <p>Cavity wall: Render - Gypsum and Sand (20 mm)) + Brickwork Outer Leaf - BRE (102.5 mm) + Polyurethane foam (40 mm) + Brickwork Inner Leaf - BRE (102.5 mm) Total U-value 0.46 W/m²K.</p> <p>Windows: PVCU Double glazed 16mm U-value = 1.85 W/m²K</p> <p>Door: Half-Double glazed 16mm PVCU U-value 1.95 W/m²k</p> <p>System: Natural ventilation, combi-gas boiler with radiators for heating and hot water storage tank in loft 300L.</p>
	Windows + ventilation 	<p>Windows: Triple-glazed argon filled 16mm or more U-value of 1.2 W/m²K, windows opened halfway.</p> <p>Decentralised mechanical whole house extract ventilation and new condensing boiler >90% Efficiency Rate installed to existing radiators.</p>
	EWI/CWI/IWI + Ex-door 	<p>External wall: Render - Gypsum and Sand (20 mm) + Brickwork Outer Leaf - BRE (102.5 mm) + Polyurethane foam (80 mm) + Brickwork Inner Leaf - BRE (102.5 mm) + Expanded Polystyrene (100 mm) + Foil-Tec Double VCL (1 mm) + Plaster standard (20 mm) Total U-value 0.12 W/m²K.</p> <p>External door: Half triple-glazed PVCU argon filled 16mm or more U-value 1.4 W/m²K.</p>
Post 1980s TFA = 994.42m ² Height=2.5 m 2 storey house	Existing 	<p>Suspended Floor: Soft Wood/Plywood/Chipboard (Softwood) (20 mm) + Polyurethane foam (50 mm) + Ventilated Cavity 650mm + ground U-value 0.25 W/m²K.</p> <p>Pitched roof: Tiles (Clay) (12 mm) + Ventilated Cavity - (Roof - Low Emissivity) (250 mm) + Mineral Wool Batt (75 mm) + Plasterboard Standard (20 mm) U-value 0.42 W/m²K.</p> <p>Cavity wall: Plasterboard High Density (20 mm) + Brickwork Outer Leaf - BRE (102.5 mm) + Polyurethane foam (40 mm) + Brickwork Inner Leaf - BRE (102.5 mm) Total U-value 0.60 W/m²K.</p> <p>Windows: PVCU Double glazed 16mm U-value = 1.55 W/m²K</p> <p>Door: Half-Double glazed 16mm PVCU U-value 1.60 W/m²k</p> <p>System: Natural ventilation, Condensing combi-gas boiler with radiators for heating and hot water storage tank in loft 300L.</p>
	Windows + ventilation 	<p>Windows: Triple-glazed argon filled 16mm or more U-value of 1.0 W/m²K, windows slightly open 50mm.</p>

		Decentralised mechanical whole house extract ventilation and new condensing boiler >90% Efficiency Rate installed to existing radiators.
	EWI/CWI/IWI + Ex-door 	External wall: Render - Gypsum and Sand (20 mm) + Brickwork Outer Leaf - BRE (102.5 mm) + Polyurethane foam (80 mm) + Brickwork Inner Leaf - BRE (102.5 mm) + Expanded Polystyrene (100 mm) + Foil-Tec Double VCL (1 mm) + Plaster standard (20 mm) Total U-value 0.14 W/m ² K. External door: Half triple-glazed PVCU argon filled 16mm or more U-value 1.25 W/m ² K.
AB Typology	Building Measures	Improvement actions
PRE 1919 TFA = 496.26m ² Height=2.5 m 2 storey house	Existing 	Floor = Solid concrete dense 150mm+ soft plywood 25mm (total U-value 0.52 W/m ² K) External wall = Render - Gypsum and Sand (20 mm) + brickwork 205mm+ 20mm render cement (total U-value 1.9 W/m ² K) Roof: Tiles (Clay 12 mm) + Wood Wool Slab (20 mm) + Ventilated Cavity + Mineral Wool Batt (75 mm) + Plasterboard Standard (15 mm) Total U-value = 0.51 W/m ² K Windows: PVCU Double glazed 12mm U-value = 1.90 W/m ² K System: Natural ventilation, combi-gas boiler with radiators for heating and hot water mains Door: PVCU double glazed 16mm U-value= 1.85 W/m ² K
	Windows + ventilation 	Windows: Triple-glazed argon filled 16mm or more U-value of 1.45 W/m ² K, slightly opened 50mm. Decentralised mechanical whole house extract ventilation and new condensing boiler >90% Efficiency Rate installed to existing radiators.
	EWI/CWI/IWI + Ex-door 	External wall: Render - Gypsum and Sand (20 mm) + brickwork - BRE (205mm) + Extruded Polystyrene (200 mm) + Foil-Tec Double VCL (1 mm) + Plaster standard (20 mm) Total U-value 0.12 W/m ² K. External door: Half triple-glazed PVCU argon filled 16mm or more U-value 1.4 W/m ² K.
1919-1944 TFA =886.78m ² Height=2.5 m 2 storey house	Existing 	Floor = Solid concrete dense 150mm+ soft plywood 25mm (total U-value 0.55 W/m ² K) External wall = 20mm plaster+ brickwork 225mm+ 20mm render cement (total U-value 1.80 W/m ² K) Roof: Tiles (Clay 20 mm) + Wood Wool Slab (20 mm) + Ventilated Cavity - (Roof - Low Emissivity) (250 mm) + loft insulation Mineral Wool Batt (50 mm) + Plasterboard Standard (15 mm) Total U-value = 0.50 W/m ² K Windows: PVCU Double glazed 12mm U-value = 1.85 W/m ² K System: Natural ventilation, combi-gas boiler with radiators for heating and hot water

		Door: PVCU double glazed 16mm U-value= 2.0 W/m ² K
	Windows + ventilation 	Windows: Triple-glazed argon filled 16mm U-value of 1.20 W/m ² K, windows half opened. Decentralised mechanical whole house extract ventilation and new condensing boiler >90% Efficiency Rate installed to existing radiators.
	EWI/CWI/IWI + Ex-door 	External wall: Render - Cement and Sand (20 mm) + Breather Foil-FR (2 mm) + XPS 200mm+ Solid Brickwork (Double layer 112.5*2) + Foil-Tec Double VCL (1 mm) + Plaster (Dense) (20 mm) Total U-value 0.10 W/m ² K. External door: Half triple-glazed PVCU argon filled 16mm or more U-value 1.4 W/m ² K.
1945-1964 TFA =3362.70m ² Height=2.5 m 2 storey house	Existing 	Floor= Solid concrete dense150mm+ soft plywood 20mm (total U-value 0.57 W/m ² K) External wall= 20mm Gypsum render + brickwork 225mm+ 20mm render cement (total U-value 1.85 W/m ² K) Roof: Tiles (Clay 20 mm) + Wood Wool Slab (20 mm) + Ventilated Cavity - (Roof - Low Emissivity) (250 mm) + loft insulation Mineral Wool Batt (50 mm) + Plasterboard Standard (15 mm) Total U-value = 0.52 W/m ² K Windows: PVCU Double glazed 12mm U-value = 1.90 W/m ² K System: Natural ventilation, combi-gas boiler with radiators for heating and hot water Door: PVCU double glazed 12mm U-value= 2.3 W/m ² K
	Windows + ventilation 	Windows: Triple-glazed argon filled 16mm or more U-value of 1.25 W/m ² K, windows half opened 50%. Decentralised mechanical whole house extract ventilation and new condensing boiler >90% Efficiency Rate installed to existing radiators.
	EWI/CWI/IWI + Ex-door 	External wall: Render - Gypsum (20 mm) + Breather Foil-FR (2 mm) + XPS 200mm+ Solid Brickwork (225mm) + Foil-Tec Double VCL (1 mm) + Plaster (Dense) (20 mm) Total U-value 0.11 W/m ² K. External door: Half triple-glazed PVCU argon filled 16mm or more U-value 1.10 W/m ² K.
	Existing 	Floor= Solid concrete dense150mm+ soft plywood 20mm (total U-value 0.55 W/m ² K) Pitched roof: Tiles (Clay) (12 mm) + Ventilated Cavity - (Roof - Low Emissivity) (250 mm) + Mineral Wool Batt (100 mm) + Plasterboard Standard (20 mm) U-value 0.28 W/m ² K. Cavity wall: Render - Gypsum and Sand (20 mm)) + Brickwork Outer Leaf - BRE (102.5 mm) + Polyurethane foam (50 mm) + Brickwork Inner Leaf - BRE (102.5 mm) Total U-value 0.38 W/m ² K. Windows: PVCU Double glazed 16mm U-value = 1.80 W/m ² K

		<p>Door: Half-Double glazed 16mm PVCU U-value 1.85 W/m²k</p> <p>System: Natural ventilation, combi-gas boiler with radiators for heating and hot water storage tank in loft 300L.</p>
	<p>Windows + ventilation</p> 	<p>Windows: Triple-glazed argon filled 16mm or more U-value of 1.1 W/m²K, windows opened halfway.</p> <p>Decentralised mechanical whole house extract ventilation and new condensing boiler >90% Efficiency Rate installed to existing radiators.</p>
	<p>EWI/CWI/IWI + Ex-door</p> 	<p>External wall: Render - Gypsum and Sand (20 mm) + Brickwork Outer Leaf - BRE (102.5 mm) + Polyurethane foam (80 mm) + Brickwork Inner Leaf - BRE (102.5 mm) + Expanded Polystyrene (150 mm) + Foil-Tec Double VCL (1 mm) + Plaster standard (20 mm) Total U-value 0.10 W/m²K.</p> <p>External door: Half triple-glazed PVCU argon filled 16mm or more U-value 1.2 W/m²K.</p>
<p>Post 1980s TFA = 4045.10m² Height=2.5 m 2 storey house</p>	<p>Existing</p> 	<p>Suspended Floor: Soft Wood/Plywood/Chipboard (Softwood) (20 mm) + Polyurethane foam (50 mm) + Ventilated Cavity 650mm + ground U-value 0.28 W/m²K.</p> <p>Pitched roof: Tiles (Clay) (12 mm) + Ventilated Cavity - (Roof - Low Emissivity) (250 mm) + Mineral Wool Batt (75 mm) + Plasterboard Standard (20 mm) U-value 0.41 W/m²K.</p> <p>Cavity wall: Plasterboard High Density (20 mm) + Brickwork Outer Leaf - BRE (102.5 mm) + Polyurethane foam (40 mm) + Brickwork Inner Leaf - BRE (102.5 mm) Total U-value 0.58 W/m²K.</p> <p>Windows: PVCU Double glazed 16mm U-value = 1.50 W/m²K</p> <p>Door: Half-Double glazed 16mm PVCU U-value 1.55 W/m²k</p> <p>System: Natural ventilation, Condensing combi-gas boiler with radiators for heating and hot water storage tank in loft 300L.</p>
	<p>Windows + ventilation</p> 	<p>Windows: Triple-glazed argon filled 16mm or more U-value of 1.1 W/m²K, windows slightly open 50mm.</p> <p>Decentralised mechanical whole house extract ventilation and new condensing boiler >90% Efficiency Rate installed to existing radiators.</p>
	<p>EWI/CWI/IWI + Ex-door</p> 	<p>External wall: Render - Gypsum and Sand (20 mm) + Brickwork Outer Leaf - BRE (102.5 mm) + Polyurethane foam (80 mm) + Brickwork Inner Leaf - BRE (102.5 mm) + Expanded Polystyrene (100 mm) + Foil-Tec Double VCL (1 mm) + Plaster standard (20 mm) Total U-value 0.12 W/m²K.</p> <p>External door: Half triple-glazed PVCU argon filled 16mm or more U-value 1.20 W/m²K.</p>