





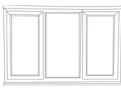











## Supplementary material S1: General assumptions of the retrofit measures

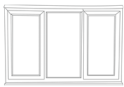




### The model simulation general assumptions





- 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/m<sup>2</sup>K for all existing dwelling pre1945, 0.10 W/m<sup>2</sup>K (1945-1980) and 0.05W/m<sup>2</sup>K 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






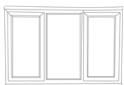
SFH Typology	Building Measures	Improvement actions
PRE 1919 TFA =198m <sup>2</sup> Height=2.5 m 2 storey house	Existing 	<b>Windows;</b> Double-glazed (east & west) PVCU 12mm air-filled U-value 2.1 W/m <sup>2</sup> k <b>Door:</b> Half-Double glazed 12mm PVCU U-value 1.85 W/m <sup>2</sup> k <b>Floor:</b> Solid floor 150mm concrete dense R-value 0.075 + soft plywood 20mm R-value 0.154, total U-value= 0.6 W/m <sup>2</sup> k <b>External Wall:</b> Solid brickwork double BRE (102.50mm) + inner-leaf Plaster dense 20mm + render 20mm outer-leaf Total U-value1.95 W/m <sup>2</sup> k <b>Roof:</b> tiles clay 12mm ventilated cavity 255mm + soft chipboard 15mm (U-value 2.2 W/m <sup>2</sup> k). <b>System:</b> Natural ventilation, combi-gas boiler with radiators for heating and hot water + room thermostat efficiency 75%.
	Windows and doors replacement 	<b>Windows:</b> Triple-glazed windows with argon filled U-value of 1.6W/m <sup>2</sup> K <b>External door:</b> Triple-glazed argon filled PPCU 16mm U-value 1.4
	Roof & floor insulation 	<b>Floor:</b> 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/m <sup>2</sup> K <b>Roof:</b> 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)

		<b>Total U-value = 0.12 W/m<sup>2</sup>K</b>
	EWI/CWI/IWI + Ex-door 	<b>EWI:</b> Extruded Polystyrene (200 mm, R=7.407) + Foil-Tec Single VCL (1 mm R=0.74).
	Systems replacement	<b>System:</b> 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.
1919-1944 TFA = 153.20m <sup>2</sup> Height=2.5 m 2 storey house	Renewables 	4 KWp of PV added to the roof oriented south with tilted angle of 45°.
	Existing 	<b>Floor</b> = Solid concrete dense 150mm+ soft plywood 20mm (total U-value 0.56 W/m <sup>2</sup> K) <b>External wall</b> = brickwork 223mm+ 20mm plaster+ 20mm render cement (total U-value 1.81 W/m <sup>2</sup> K) <b>Roof:</b> 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 <sup>2</sup> K <b>Windows:</b> PVCU Double glazed 12mm U-value = 1.85 W/m <sup>2</sup> K <b>System:</b> Natural ventilation, combi-gas boiler with radiators for heating and hot water <b>Door:</b> PVCU double glazed 16mm U-value= 2.0 W/m <sup>2</sup> K
	Windows + ventilation 	<b>Windows:</b> Triple-glazed windows with argon filled U-value of 1.6W/m <sup>2</sup> K, <b>System:</b> 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 	<b>Floor:</b> Solid concrete Dense (150 mm) + EPS 200mm + Foil-Tec Single VCL (1 mm) + soft plywood 15mm (U-value 0.13 W/m <sup>2</sup> K). <b>Roof:</b> 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 <sup>2</sup> K.
	EWI/CWI/IWI + Ex-door 	<b>External wall:</b> 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 <sup>2</sup> K. <b>External door:</b> Half triple-glazed PVCU argon filled 16mm or more U-value 1.5 W/m <sup>2</sup> K.
	Renewables 	4 KWp of PV added to the roof oriented south with tilted angle of 45°.







1945-1964 TFA = 134.40m <sup>2</sup> Height=2.5 m 2 storey house	Existing 	<p><b>Suspended Floor:</b> Soft Wood/Plywood/Chipboard (Softwood) (20 mm) + Polyurethane foam (50 mm) + Unventilated Cavity 650mm + ground U-value 0.24 W/m<sup>2</sup>K.</p> <p><b>Pitched roof:</b> Tiles (Clay) (12 mm) + Woodfibre 30mm + Plasterboard Standard (20 mm) U-value 0.6 W/m<sup>2</sup>K.</p> <p><b>Cavity wall:</b> 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<sup>2</sup>K.</p> <p><b>Windows:</b> PVCU Double glazed 12mm U-value = 1.85 W/m<sup>2</sup>K</p> <p><b>Door:</b> Half-Double glazed 12mm PVCU U-value 1.85 W/m<sup>2</sup>k</p> <p><b>System:</b> Natural ventilation, combi-gas boiler with radiators for heating and hot water storage tank in loft 250L.</p>
	Windows + ventilation 	<p><b>Windows:</b> Triple-glazed argon filled 16mm or more U-value of 1.4 W/m<sup>2</sup>K, windows half opened 50%.</p> <p><b>System:</b> 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.</p>
	Roof & floor insulation 	<p><b>Suspended Floor:</b> 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<sup>2</sup>K).</p> <p><b>Pitched roof:</b> 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<sup>2</sup>K.</p>
	EWI/CWI/IWI + Ex-door 	<p><b>External wall:</b> 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<sup>2</sup>K.</p> <p><b>External door:</b> Half triple-glazed PVCU argon filled 16mm or more U-value 1.5 W/m<sup>2</sup>K.</p>
	Renewables 	4 KWp of PV added to the roof oriented south with tilted angle of 45°.
1965-1980 TFA = 123.08m <sup>2</sup> Height=2.5 m 2 storey house	Existing 	<p><b>Suspended Floor:</b> Soft Wood/Plywood/Chipboard (Softwood) (20 mm) + Polyurethane foam (50 mm) + Ventilated Cavity 650mm + ground U-value 0.42 W/m<sup>2</sup>K.</p> <p><b>Pitched roof:</b> Tiles (Clay) (12 mm) + Mineral Wool Batt (70 mm)+ Plasterboard Standard (20 mm) U-value 0.55 W/m<sup>2</sup>K.</p>






		<p><b>Cavity wall:</b> 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<sup>2</sup>K.</p> <p><b>Windows:</b> PVCU Double glazed 16mm U-value = 1.8 W/m<sup>2</sup>K</p> <p><b>Door:</b> Half-Double glazed 16mm PVCU U-value 1.8 W/m<sup>2</sup>k</p> <p><b>System:</b> Natural ventilation, combi-gas boiler with radiators for heating and hot water storage tank in loft 300L.</p>
	<p>Windows + ventilation</p> 	<p><b>Windows:</b> Triple-glazed argon filled 16mm or more U-value of 1.2 W/m<sup>2</sup>K, windows slightly open 5mm.</p> <p><b>Decentralised mechanical whole house extract ventilation</b> 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 &amp; floor insulation</p> 	<p><b>Suspended Floor:</b> 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/m<sup>2</sup>K).</p> <p><b>Pitched roof:</b> 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<sup>2</sup>K.</p>
	<p>EWI/CWI/IWI + Ex-door</p> 	<p><b>External wall:</b> 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<sup>2</sup>K.</p> <p><b>External door:</b> Half triple-glazed PVCU argon filled 16mm or more U-value 1.2 W/m<sup>2</sup>K.</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 = 149.35m<sup>2</sup> Height=2.5 m 2 storey house</p>	<p>Existing</p> 	<p><b>Suspended Floor:</b> Soft Wood/Plywood/Chipboard (Softwood) (20 mm) + Polyurethane foam (100 mm) + Ventilated Cavity 550mm + ground U-value 0.28 W/m<sup>2</sup>K.</p> <p><b>Pitched roof:</b> Tiles (Clay) (12 mm) + Mineral Wool Batt (150 mm)+ Plasterboard Standard (20 mm) U-value 0.24 W/m<sup>2</sup>K.</p> <p><b>Cavity wall:</b> 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/m<sup>2</sup>K.</p>

		<p><b>Windows:</b> PVCU Double glazed 16mm U-value = 1.6 W/m<sup>2</sup>K</p> <p><b>Door:</b> Half-Double glazed 16mm PVCU U-value 1.5 W/m<sup>2</sup>k</p> <p><b>System:</b> Natural ventilation, Condensing combi-gas boiler with radiators for heating and hot water storage tank in loft 300L.</p>
	<p>Windows + ventilation</p> 	<p><b>Windows:</b> Triple-glazed argon filled 16mm or more U-value of 1.2 W/m<sup>2</sup>K, windows slightly open 5mm.</p> <p><b>Decentralised mechanical whole house extract ventilation</b> 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 &amp; floor insulation</p> 	<p><b>Suspended Floor:</b> 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/m<sup>2</sup>K).</p> <p><b>Pitched roof:</b> 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<sup>2</sup>K.</p>
	<p>EWI/CWI/IWI + Ex-door</p> 	<p><b>External wall:</b> 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<sup>2</sup>K.</p> <p><b>External door:</b> Half triple-glazed PVCU argon filled 16mm or more U-value 1.2 W/m<sup>2</sup>K.</p>
	<p>4 KWp of PV added to the roof oriented south with tilted angle of 45°.</p>	<p>4 KWp of PV added to the roof oriented south with tilted angle of 45°.</p>
TH Typology	Building Measures	Improvement actions
<p>PRE 1919</p> <p>TFA = 104.62m<sup>2</sup></p> <p>Height=2.5 m 2 storey house</p>	<p>Existing</p> 	<p><b>Floor=</b> Solid concrete dense 150mm+ soft plywood 20mm (total U-value 0.60 W/m<sup>2</sup>K)</p> <p><b>External wall=</b> brickwork 223mm+ 20mm plaster+ 20mm render cement (total U-value 1.81 W/m<sup>2</sup>K)</p> <p><b>Roof:</b> 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/m<sup>2</sup>K</p> <p><b>Windows:</b> PVCU Double glazed 16mm U-value = 1.65 W/m<sup>2</sup>K</p>






		<p><b>System:</b> Natural ventilation, combi-gas boiler with radiators for heating and hot water</p> <p><b>Door:</b> PVCU double glazed 16mm U-value= 1.80 W/m<sup>2</sup>K</p>
	<p>Windows + ventilation</p> 	<p><b>Windows:</b> Triple-glazed argon filled 16mm or more U-value of 1.5 W/m<sup>2</sup>K, windows slightly open 5mm.</p> <p><b>Decentralised mechanical whole house extract ventilation</b> 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 &amp; floor insulation</p> 	<p><b>Floor:</b> Solid concrete Dense (150 mm) + EPS 200mm + Foil-Tec Single VCL (1 mm) + soft plywood 20mm (U-value 0.12 W/m<sup>2</sup>K).</p> <p><b>Roof:</b> 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<sup>2</sup>K.</p>
	<p>EWI/CWI/IWI + Ex-door</p> 	<p><b>External wall:</b> 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/m<sup>2</sup>K.</p> <p><b>External door:</b> Half triple-glazed PVCU argon filled 16mm or more U-value 1.2 W/m<sup>2</sup>K.</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 = 153.20m<sup>2</sup> Height=2.5 m 2 storey house</p>	<p>Existing</p> 	<p><b>Floor</b>= Solid concrete dense 150mm+ soft plywood 20mm (total U-value 0.62 W/m<sup>2</sup>K)</p> <p><b>External wall</b>= 20mm plaster+ brickwork 223mm+ 20mm render cement (total U-value 1.80 W/m<sup>2</sup>K)</p> <p><b>Roof:</b> 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/m<sup>2</sup>K</p> <p><b>Windows:</b> PVCU Double glazed 12mm U-value = 1.85 W/m<sup>2</sup>K</p> <p><b>System:</b> Natural ventilation, combi-gas boiler with radiators for heating and hot water</p> <p><b>Door:</b> PVCU double glazed 16mm U-value= 2.0 W/m<sup>2</sup>K</p>
	<p>Windows + ventilation</p> 	<p><b>Windows:</b> Triple-glazed argon filled 16mm U-value of 1.4 W/m<sup>2</sup>K, windows half opened.</p> <p><b>Decentralised mechanical whole house extract ventilation</b> 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>




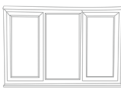







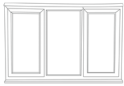


	Roof & floor insulation 	<b>Floor:</b> Solid concrete Dense (150 mm) + EPS 200mm + Foil-Tec Single VCL (1 mm) + soft plywood 15mm (U-value 0.12 W/m <sup>2</sup> K). <b>Roof:</b> Tiles (Clay) (12 mm) + Wood Wool Slab (15mm) + Mineral Wool Batt (300 mm) + Foil-Tec Double VCL (1 mm) + Plasterboard Standard (12.5 mm) total U-value 0.10 W/m <sup>2</sup> K.
	EWI/CWI/IWI + Ex-door 	<b>External wall:</b> 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 <sup>2</sup> K. <b>External door:</b> Half triple-glazed PVCU argon filled 16mm or more U-value 1.4 W/m <sup>2</sup> K.
	Renewables 	4 KWp of PV added to the roof oriented south with tilted angle of 45°.
1945-1964 TFA = 87.72m <sup>2</sup> Height=2.5 m 2 storey house	Existing 	<b>Suspended Floor:</b> Soft Wood/Plywood/Chipboard (Softwood) (20 mm) + Ventilated Cavity 700mm + ground U-value 0.46 W/m <sup>2</sup> K. <b>Pitched roof:</b> Tiles (Clay) (12 mm) + Woodfibre 30mm + Mineral Wool Batt (50 mm) Plasterboard Standard (20 mm) U-value 0.41 W/m <sup>2</sup> K. <b>Cavity wall:</b> 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 <sup>2</sup> K. <b>Windows:</b> PVCU Double glazed 12mm U-value = 1.80 W/m <sup>2</sup> K <b>Door:</b> Half-Double glazed 12mm PVCU U-value 1.90 W/m <sup>2</sup> k <b>System:</b> Natural ventilation, combi-gas boiler with radiators for heating and hot water storage tank in loft 250L.
	Windows + ventilation 	<b>Windows:</b> Triple-glazed argon filled 16mm or more U-value of 1.25 W/m <sup>2</sup> K, windows half opened 50%. <b>Decentralised mechanical whole house extract ventilation</b> 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 	<b>Suspended Floor:</b> 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 <sup>2</sup> K). <b>Pitched roof:</b> 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 <sup>2</sup> K.
	EWI/CWI/IWI + Ex-door 	<b>External wall:</b> 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 <sup>2</sup> K. <b>External door:</b> Half triple-glazed PVCU argon filled 16mm or more U-value 1.4 W/m <sup>2</sup> K.
	Renewables 	4 KWp of PV added to the roof oriented south with tilted angle of 45°.
1965-1980 TFA = 85.32m <sup>2</sup> Height=2.5 m 2 storey house	Existing 	<b>Suspended Floor:</b> Soft Wood/Plywood/Chipboard (Softwood) (25 mm) + Polyurethane foam (40 mm) + Ventilated Cavity 650mm + ground U-value 0.29 W/m <sup>2</sup> K. <b>Pitched roof:</b> Tiles (Clay) (12 mm) + Mineral Wool Batt (50 mm) + Plasterboard Standard (20 mm) U-value 0.50 W/m <sup>2</sup> K. <b>Cavity wall:</b> 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 <sup>2</sup> K. <b>Windows:</b> PVCU Double glazed 16mm U-value = 1.8 W/m <sup>2</sup> K <b>Door:</b> Half-Double glazed 16mm PVCU U-value 1.9 W/m <sup>2</sup> k <b>System:</b> Natural ventilation, combi-gas boiler with radiators for heating and hot water storage tank in loft 300L.
	Windows + ventilation 	<b>Windows:</b> Triple-glazed argon filled 16mm or more U-value of 1.3 W/m <sup>2</sup> K, windows slightly open 50mm. <b>Decentralised mechanical whole house extract ventilation</b> 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 	<b>Suspended Floor:</b> 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 <sup>2</sup> K). <b>Pitched roof:</b> 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 <sup>2</sup> K.








Post 1980s TFA = 98.40m <sup>2</sup> Height=2.5 m 2 storey house	EWI/CWI/IWI + Ex-door 	<b>External wall:</b> 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/m <sup>2</sup> K. <b>External door:</b> Half triple-glazed PVCU argon filled 16mm or more U-value 1.25 W/m <sup>2</sup> K.
	Renewables 	4 KWp of PV added to the roof oriented south with tilted angle of 45°.
	Existing 	<b>Suspended Floor:</b> Soft Wood/Plywood/Chipboard (Softwood) (20 mm) + Polyurethane foam (50 mm) + Ventilated Cavity 650mm + ground U-value 0.32 W/m <sup>2</sup> K. <b>Pitched roof:</b> Tiles (Clay) (12 mm) + Mineral Wool Batt (75 mm) + Plasterboard Standard (20 mm) U-value 0.40 W/m <sup>2</sup> K. <b>Cavity wall:</b> 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/m <sup>2</sup> K. <b>Windows:</b> PVCU Double glazed 16mm U-value = 1.55 W/m <sup>2</sup> K <b>Door:</b> Half-Double glazed 16mm PVCU U-value 1.65 W/m <sup>2</sup> k <b>System:</b> Natural ventilation, Condensing combi-gas boiler with radiators for heating and hot water storage tank in loft 300L.
	Windows + ventilation 	<b>Windows:</b> Triple-glazed argon filled 16mm or more U-value of 1.0 W/m <sup>2</sup> K, windows slightly open 50mm. <b>Decentralised mechanical whole house extract ventilation</b> 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 	<b>Suspended Floor:</b> 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/m <sup>2</sup> K). <b>Pitched roof:</b> 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/m <sup>2</sup> K.

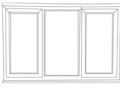





	EWI/CWI/IWI + Ex-door 	<b>External wall:</b> Render - Gypsum and Sand (20 mm) + Brickwork Outer Leaf - BRE (102.5 mm) + Polyurethane foam (80 mm) + Brickwork Inner Leaf - BRE (102.5 mm) + Expanded Polystyrene (120 mm) + Foil-Tec Double VCL (1 mm) + Plaster standard (20 mm) Total U-value 0.12 W/m <sup>2</sup> K. <b>External door:</b> Half triple-glazed PVCU argon filled 16mm or more U-value 1.2 W/m <sup>2</sup> 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 <sup>2</sup> Height=2.5 m 2 storey house	Existing 	<b>Floor=</b> Solid concrete dense 150mm+ soft plywood 20mm (total U-value 0.55 W/m <sup>2</sup> K) <b>External wall=</b> Render - Gypsum and Sand (20 mm) + brickwork 205mm+ 20mm plaster+ 20mm render cement (total U-value 1.9 W/m <sup>2</sup> K) <b>Roof:</b> 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 <sup>2</sup> K <b>Windows:</b> PVCU Double glazed 12mm U-value = 2.1 W/m <sup>2</sup> K <b>System:</b> Natural ventilation, combi-gas boiler with radiators for heating and hot water mains <b>Door:</b> PVCU double glazed 16mm U-value= 1.90 W/m <sup>2</sup> K
	Windows + ventilation 	<b>Windows:</b> Triple-glazed argon filled 16mm or more U-value of 1.6 W/m <sup>2</sup> K, half-way opened. <b>Decentralised mechanical whole house extract ventilation</b> and new condensing boiler >90% Efficiency Rate installed to existing radiators.
	EWI/CWI/IWI + Ex-door 	<b>External wall:</b> 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 <sup>2</sup> K. <b>External door:</b> Half triple-glazed PVCU argon filled 16mm or more U-value 1.4 W/m <sup>2</sup> K.
1919-1944 TFA = 480.81m <sup>2</sup> Height=2.5 m 2 storey house	Existing 	<b>Floor=</b> Solid concrete dense 150mm+ soft plywood 20mm (total U-value 0.44 W/m <sup>2</sup> K) <b>External wall=</b> 20mm plaster+ brickwork 205mm+ 20mm render cement (total U-value 1.90 W/m <sup>2</sup> K) <b>Roof:</b> 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 <sup>2</sup> K <b>Windows:</b> PVCU Double glazed 12mm U-value = 1.95 W/m <sup>2</sup> K

		<p><b>System:</b> Natural ventilation, combi-gas boiler with radiators for heating and hot water</p> <p><b>Door:</b> PVCU double glazed 16mm U-value= 2.1 W/m<sup>2</sup>K</p>
	<p>Windows + ventilation</p> 	<p><b>Windows:</b> Triple-glazed argon filled 16mm U-value of 1.25 W/m<sup>2</sup>K, windows half opened.</p> <p><b>Decentralised mechanical whole house extract ventilation</b> and new condensing boiler &gt;90% Efficiency Rate installed to existing radiators.</p>
	<p>EWI/CWI/IWI + Ex-door</p> 	<p><b>External wall:</b> 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/m<sup>2</sup>K.</p> <p><b>External door:</b> Half triple-glazed PVCU argon filled 16mm or more U-value 1.5 W/m<sup>2</sup>K.</p>
<p>1945-1964 TFA = 447.09m<sup>2</sup> Height=2.5 m 2 storey house</p>	<p>Existing</p> 	<p><b>Suspended Floor:</b> Soft Wood/Plywood/Chipboard (Softwood) (20 mm) + Ventilated Cavity 700mm + ground U-value 0.42W/m<sup>2</sup>K.</p> <p><b>Pitched roof:</b> Tiles (Clay) (12 mm) + Woodfibre 30mm + Mineral Wool Batt (50 mm) Plasterboard Standard (20 mm) U-value 0.53 W/m<sup>2</sup>K.</p> <p><b>Cavity wall:</b> 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/m<sup>2</sup>K.</p> <p><b>Windows:</b> PVCU Double glazed 12mm U-value = 1.85 W/m<sup>2</sup>K</p> <p><b>Door:</b> Half-Double glazed 12mm PVCU U-value 1.65 W/m<sup>2</sup>k</p> <p><b>System:</b> Natural ventilation, combi-gas boiler with radiators for heating and hot water storage tank in loft 250L.</p>
	<p>Windows + ventilation</p> 	<p><b>Windows:</b> Triple-glazed argon filled 16mm or more U-value of 1.20 W/m<sup>2</sup>K, windows half opened 50%.</p> <p><b>Decentralised mechanical whole house extract ventilation</b> and new condensing boiler &gt;90% Efficiency Rate installed to existing radiators.</p>
	<p>EWI/CWI/IWI + Ex-door</p> 	<p><b>External wall:</b> 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/m<sup>2</sup>K.</p> <p><b>External door:</b> Half triple-glazed PVCU argon filled 16mm or more U-value 1.2 W/m<sup>2</sup>K.</p>
<p>1965-1980 TFA = 559.42m<sup>2</sup></p>	<p>Existing</p> 	<p><b>Suspended Floor:</b> Soft Wood/Plywood/Chipboard (Softwood) (20 mm) + Polyurethane foam (50 mm) + Ventilated Cavity 650mm + ground U-value 0.31 W/m<sup>2</sup>K.</p>






Height=2.5 m 2 storey house		<p><b>Pitched roof:</b> 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/m<sup>2</sup>K.</p> <p><b>Cavity wall:</b> 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/m<sup>2</sup>K.</p> <p><b>Windows:</b> PVCU Double glazed 16mm U-value = 1.85 W/m<sup>2</sup>K</p> <p><b>Door:</b> Half-Double glazed 16mm PVCU U-value 1.95 W/m<sup>2</sup>k</p> <p><b>System:</b> Natural ventilation, combi-gas boiler with radiators for heating and hot water storage tank in loft 300L.</p>
	Windows + ventilation 	<p><b>Windows:</b> Triple-glazed argon filled 16mm or more U-value of 1.2 W/m<sup>2</sup>K, windows opened halfway.</p> <p><b>Decentralised mechanical whole house extract ventilation</b> and new condensing boiler &gt;90% Efficiency Rate installed to existing radiators.</p>
	EWI/CWI/TWI + Ex-door 	<p><b>External wall:</b> 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/m<sup>2</sup>K.</p> <p><b>External door:</b> Half triple-glazed PVCU argon filled 16mm or more U-value 1.4 W/m<sup>2</sup>K.</p>
Post 1980s TFA = 994.42m <sup>2</sup> Height=2.5 m 2 storey house	Existing 	<p><b>Suspended Floor:</b> Soft Wood/Plywood/Chipboard (Softwood) (20 mm) + Polyurethane foam (50 mm) + Ventilated Cavity 650mm + ground U-value 0.25 W/m<sup>2</sup>K.</p> <p><b>Pitched roof:</b> 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/m<sup>2</sup>K.</p> <p><b>Cavity wall:</b> 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/m<sup>2</sup>K.</p> <p><b>Windows:</b> PVCU Double glazed 16mm U-value = 1.55 W/m<sup>2</sup>K</p> <p><b>Door:</b> Half-Double glazed 16mm PVCU U-value 1.60 W/m<sup>2</sup>k</p> <p><b>System:</b> Natural ventilation, Condensing combi-gas boiler with radiators for heating and hot water storage tank in loft 300L.</p>
	Windows + ventilation 	<p><b>Windows:</b> Triple-glazed argon filled 16mm or more U-value of 1.0 W/m<sup>2</sup>K, windows slightly open 50mm.</p>

		<b>Decentralised mechanical whole house extract ventilation</b> and new condensing boiler >90% Efficiency Rate installed to existing radiators.
	EWI/CWI/IWI + Ex-door 	<b>External wall:</b> 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 <sup>2</sup> K. <b>External door:</b> Half triple-glazed PVCU argon filled 16mm or more U-value 1.25 W/m <sup>2</sup> K.
AB Typology	Building Measures	Improvement actions
PRE 1919 TFA = 496.26m <sup>2</sup> Height=2.5 m 2 storey house	Existing 	<b>Floor=</b> Solid concrete dense 150mm+ soft plywood 25mm (total U-value 0.52 W/m <sup>2</sup> K) <b>External wall=</b> Render - Gypsum and Sand (20 mm) + brickwork 205mm+ 20mm render cement (total U-value 1.9 W/m <sup>2</sup> K) <b>Roof:</b> 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 <sup>2</sup> K <b>Windows:</b> PVCU Double glazed 12mm U-value = 1.90 W/m <sup>2</sup> K <b>System:</b> Natural ventilation, combi-gas boiler with radiators for heating and hot water mains <b>Door:</b> PVCU double glazed 16mm U-value= 1.85 W/m <sup>2</sup> K
	Windows + ventilation 	<b>Windows:</b> Triple-glazed argon filled 16mm or more U-value of 1.45 W/m <sup>2</sup> K, slightly opened 50mm. <b>Decentralised mechanical whole house extract ventilation</b> and new condensing boiler >90% Efficiency Rate installed to existing radiators.
	EWI/CWI/IWI + Ex-door 	<b>External wall:</b> 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 <sup>2</sup> K. <b>External door:</b> Half triple-glazed PVCU argon filled 16mm or more U-value 1.4 W/m <sup>2</sup> K.
1919-1944 TFA =886.78m <sup>2</sup> Height=2.5 m 2 storey house	Existing 	<b>Floor=</b> Solid concrete dense 150mm+ soft plywood 25mm (total U-value 0.55 W/m <sup>2</sup> K) <b>External wall=</b> 20mm plaster+ brickwork 225mm+ 20mm render cement (total U-value 1.80 W/m <sup>2</sup> K) <b>Roof:</b> 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 <sup>2</sup> K <b>Windows:</b> PVCU Double glazed 12mm U-value = 1.85 W/m <sup>2</sup> K <b>System:</b> Natural ventilation, combi-gas boiler with radiators for heating and hot water



		<b>Door:</b> PVCU double glazed 16mm U-value= 2.0 W/m <sup>2</sup> K
	<b>Windows + ventilation</b> 	<b>Windows:</b> Triple-glazed argon filled 16mm U-value of 1.20 W/m <sup>2</sup> K, windows half opened. <b>Decentralised mechanical whole house extract ventilation</b> and new condensing boiler >90% Efficiency Rate installed to existing radiators.
	<b>EWI/CWI/IWI + Ex-door</b> 	<b>External wall:</b> 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 <sup>2</sup> K. <b>External door:</b> Half triple-glazed PVCU argon filled 16mm or more U-value 1.4 W/m <sup>2</sup> K.
1945-1964 TFA =3362.70m <sup>2</sup> Height=2.5 m 2 storey house	<b>Existing</b> 	<b>Floor=</b> Solid concrete dense 150mm+ soft plywood 20mm (total U-value 0.57 W/m <sup>2</sup> K) <b>External wall=</b> 20mm Gypsum render + brickwork 225mm+ 20mm render cement (total U-value 1.85 W/m <sup>2</sup> K) <b>Roof:</b> 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 <sup>2</sup> K <b>Windows:</b> PVCU Double glazed 12mm U-value = 1.90 W/m <sup>2</sup> K <b>System:</b> Natural ventilation, combi-gas boiler with radiators for heating and hot water <b>Door:</b> PVCU double glazed 12mm U-value= 2.3 W/m <sup>2</sup> K
	<b>Windows + ventilation</b> 	<b>Windows:</b> Triple-glazed argon filled 16mm or more U-value of 1.25 W/m <sup>2</sup> K, windows half opened 50%. <b>Decentralised mechanical whole house extract ventilation</b> and new condensing boiler >90% Efficiency Rate installed to existing radiators.
	<b>EWI/CWI/IWI + Ex-door</b> 	<b>External wall:</b> 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 <sup>2</sup> K. <b>External door:</b> Half triple-glazed PVCU argon filled 16mm or more U-value 1.10 W/m <sup>2</sup> K.
1965-1980 TFA =4357.12m <sup>2</sup> Height=2.5 m 2 storey house	<b>Existing</b> 	<b>Floor=</b> Solid concrete dense 150mm+ soft plywood 20mm (total U-value 0.55 W/m <sup>2</sup> K) <b>Pitched roof:</b> 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 <sup>2</sup> K. <b>Cavity wall:</b> 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 <sup>2</sup> K. <b>Windows:</b> PVCU Double glazed 16mm U-value = 1.80 W/m <sup>2</sup> K



		<p><b>Door:</b> Half-Double glazed 16mm PVCU U-value 1.85 W/m<sup>2</sup>k</p> <p><b>System:</b> Natural ventilation, combi-gas boiler with radiators for heating and hot water storage tank in loft 300L.</p>
	<p>Windows + ventilation</p> 	<p><b>Windows:</b> Triple-glazed argon filled 16mm or more U-value of 1.1 W/m<sup>2</sup>K, windows opened halfway.</p> <p><b>Decentralised mechanical whole house extract ventilation</b> and new condensing boiler &gt;90% Efficiency Rate installed to existing radiators.</p>
	<p>EWI/CWI/IWI + Ex-door</p> 	<p><b>External wall:</b> 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/m<sup>2</sup>K.</p> <p><b>External door:</b> Half triple-glazed PVCU argon filled 16mm or more U-value 1.2 W/m<sup>2</sup>K.</p>
<p>Post 1980s TFA = 4045.10m<sup>2</sup> Height=2.5 m 2 storey house</p>	<p>Existing</p> 	<p><b>Suspended Floor:</b> Soft Wood/Plywood/Chipboard (Softwood) (20 mm) + Polyurethane foam (50 mm) + Ventilated Cavity 650mm + ground U-value 0.28 W/m<sup>2</sup>K.</p> <p><b>Pitched roof:</b> 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/m<sup>2</sup>K.</p> <p><b>Cavity wall:</b> 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/m<sup>2</sup>K.</p> <p><b>Windows:</b> PVCU Double glazed 16mm U-value = 1.50 W/m<sup>2</sup>K</p> <p><b>Door:</b> Half-Double glazed 16mm PVCU U-value 1.55 W/m<sup>2</sup>k</p> <p><b>System:</b> Natural ventilation, Condensing combi-gas boiler with radiators for heating and hot water storage tank in loft 300L.</p>
	<p>Windows + ventilation</p> 	<p><b>Windows:</b> Triple-glazed argon filled 16mm or more U-value of 1.1 W/m<sup>2</sup>K, windows slightly open 50mm.</p> <p><b>Decentralised mechanical whole house extract ventilation</b> and new condensing boiler &gt;90% Efficiency Rate installed to existing radiators.</p>
	<p>EWI/CWI/IWI + Ex-door</p> 	<p><b>External wall:</b> 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/m<sup>2</sup>K.</p> <p><b>External door:</b> Half triple-glazed PVCU argon filled 16mm or more U-value 1.20 W/m<sup>2</sup>K.</p>