

Supplementary material S2: Moisture evaluation of each retrofit solution and the information displayed for the user.

Retrofit measure	Risk of moisture	
Solid floor with insulation beneath the floor	When insulation is placed beneath the concrete floor, there is a risk of surface condensation forming (water build-up at surfaces), particularly at the junction with external walls and at external corners. This risk may be eliminated by providing adequate heating and ventilation of the occupied space. In order to avoid cold spots that may cause surface condensation, thermal insulation should be provided to the edges of the slab (as indicated in the picture above)	
Solid floor with insulation above the floor	If the insulation is placed above the floor slab, there is a risk of water build-up at the interface between the insulation and the floor slab (interstitial condensation). An Air Vapour Control Layer (AVLC) should be installed on the warm side of the insulation. Critical connections between the floor and the rest of the building elements should be carefully designed. To minimise the risk of clod surfaces and condensation, the insulation and the AVCL shouldn't be interrupted.	
Suspended timber floor with insulation between the joists	As timber joists will be at near external temperatures after the insulation, there is a risk of condensation at the surface and at joists level, particularly at the junction with external walls and at outer corners. The risk might be minimised by providing adequate heating and ventilation in the conditioned space. To allow the drying of any moisture trapped within the joists, the insulation shouldn't be supported on a material that offers a higher vapour resistance (vapour resistance is a measure of the material's reluctance to let water vapour pass through). Furthermore, to prevent joists from being exposed to high levels of humidity which could lead to rot, the void between the underside of the floor and the ground should be adequately ventilated to avoid moisture problems. It shouldn't be less than 150 mm. To ensure a good level of ventilation, air bricks should never be blocked and if necessary other airbricks can be added. Sleeper walls should also allow the passage of air.	

	<p>The AVCL of the floor should be taped with the walls. Penetration of building services should be sealed. For suspended floors tongue and groove floorboards with all joints sealed in a good option to reduce air movement from the subfloor.</p>	
Internal wall insulation	<p>Most solid walls were built to be 'vapour-open' meaning that moisture can pass through the wall. If we insulate with 'vapour-closed' materials (such as foil-faced insulation foam), we risk trapping moisture inside the wall, which could lead to dampness, mould and damage to the building. If the existing wall is vapour-open, you should always use vapour-open insulation materials, plasters and paints. Suitable insulation materials include woodfibre, mineral boards and cork. These should always be plastered with a vapour open finish and painted with vapour-open paints.</p> <p>Applying internal wall insulation to open vapour wall assemblies (e.g. traditional masonry) can reduce their capacity to dry out and cause mould growth at the interface between the insulation and the wall, and this even with an open vapour insulation strategy. In these situations, some studies suggest applying a hydrophobic cream to external walls to reduce the amount of water ingress. On the other hand, applying closed cell insulation on a traditional wall would protect the wall from inside moisture; however, this strategy is extremely risky in the event of moisture coming from the outside (driven rain, rising damp, etc.) or through a failure in the air barrier (interstitial condensation) this strategy is likely to impede the wall from drying out to the inside. Accordingly, the last version of the British standard BS5250 recommended careful consideration for IWI of masonry buildings.</p> <p>Moreover, insulating a wall from the inside exposes the wall to extreme temperatures in the winter. If the wall can't dry out, there is a high risk of frost, which would cause external damage to the wall. Finally, insulating the wall from the inside also exposes the joist ends, which are generally built into the walls, to a high level of water that accumulates through interstitial condensation or driven rain. If the water content of joist ends exceeds 20 % there is a risk of rot and decay.</p>	

Cavity wall insulation	<p>Insulating cavity walls doesn't lead to damp bridging. Water damage is usually due to defects in the construction of the property and not due to the faulty or inappropriate installation of CWI. Most cavity walls in the UK that experienced moisture issues are cavity walls that shouldn't have been filled.</p> <p>There are some situations where CWI is not appropriate:</p> <ul style="list-style-type: none"> • Poor maintenance or structural issues like cracks in the walls. • Non-traditional construction. • Cavity widths of less than 50mm. These are often categorised as 'hard-to-treat' cavities for which insulation systems do exist. • Dirty cavities, dirty wall-ties or builder's rubble in the cavity. • Exposed locations, particularly those that experience persistent wind-driven rain. • Overflowing or blocked guttering. 	
External wall insulation	<p>Many existing buildings work by allowing the wall to absorb excess humidity, which evaporates off externally or internally.</p> <p>Putting an impermeable layer (like EPS or PUR) outside the wall prevents the normal passage of water vapour through the wall, which creates long-term problems allowing moisture to build up.</p> <p>It is argued that the answer is to use breathable insulation materials (like those manufactured by Natural Building Technologies) finished using lime render or weatherboard.</p> <p>A clear consensus is that extra ventilation is needed after EWI has been installed to reduce moisture risks.</p>	
Warm pitched roof (Insulation between rafters)	<p>Pitched roof insulation also presents a risk of water build-up within the roof structure. To prevent condensation, there must be a ventilated space of at least 50mm above the insulation. In addition, an effective vapour control layer should be positioned just above the plasterboard.</p> <p>This will allow any moisture trapped in the insulation to dry out.</p>	
Cold pitched roof (Insulation at ceiling level)	<p>In this situation, there is a minimal risk of surface condensation on the warm side of the insulation, provided that the insulation and AVCL are continuous and evenly across the ceiling, including an insulated and stripped hatch.</p>	

	<p>To avoid cold surfaces, particular attention should be paid to the junction between the ceiling and the walls. A possible solution could be to add some insulation on the inner face of the junction between the ceiling and wall. A strategy for continuous insulation is to cross-layer the insulation (one layer placed between the joist and the second layer across the joists).</p> <p>Loft insulation presents a high risk of condensation on the roof structure. Insulating at the ceiling level makes the loft space cooler than it has been previously. Hence, any hot, humid air that makes its way into the loft (due to the interruption of the Air vapour control layer at ceiling level) is going to come into contact with cooler air in the loft itself, which means the moisture which would be in a gaseous form in the rising warm air reverts back to a liquid. This liquid can easily condensate on the roof structure (see image below), leading to the development of damp, and potentially rot. Possible options to reduce this risk are to ensure good ventilation levels in the loft space and install a low vapour resistance underlay (provided that the external roof covering is permeable) on the roof structure.</p>	
Replacement of windows + doors + mechanical ventilation	<p>Condensation occurs when moist air comes into contact with a colder surface like a wall, window, mirror etc. The air can't hold the moisture and tiny drops of water appear. It also occurs in places the air is still, like the corners of rooms, behind furniture or inside wardrobes.</p> <p>The surfaces of high-efficiency windows and doors are warmer as they lose less heat to the outside. Hence, installing high-efficiency windows and doors will reduce the build-up of condensation and mould growth by increasing the surface temperature. It will also improve comfort by reducing draughts and cold spots.</p> <p>Often existing houses are leaky, and ventilation is ensured by air infiltration through services, windows and doors. When the insulation is improved, the airtightness of the building is also improved by sealing up uncontrolled ventilation pathways. Therefore, it is vital that, alongside insulation measures, an adequate ventilation strategy should be designed. Mechanical ventilation is needed to provide fresh external air,</p>	

	<p>keep moisture and internal temperature at desirable levels, and remove pollutants.</p> <p>Insulation without ventilation would likely lead to poor indoor air quality, condensation, and mould. The best way to control condensation is by installing mechanical ventilation to ensure desired humidity levels and good indoor air quality.</p>	
Mains gas combi- condensing boiler	<p>One of the solutions to condensation is to heat up the house. Central heating is a perfect way to heat a house and stop fluctuating temperatures that cause condensation. During cold weather, heating needs to be kept on – at a constant lower temperature if the house is empty – to prevent windows, walls, and pipes from becoming especially cold surfaces.</p>	
Air Source Heat Pump	<p>Heat pumps keep the home at an even, low temperature for prolonged periods of time, which is a good way to avoid condensation. This prevents areas of cold, which is where the condensation is most likely to occur. In cold weather, the central heating should be set to provide a constant background heat throughout the day, even when there is nobody home and in rooms which are not used.</p>	