building opportunities for business

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6

LOW CARBON DOMESTIC RETROFIT

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Institute for Sustainability

Technology Strategy Board
Driving Innovation

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6.1 Introduction

This guide focuses on upgrading the performance of the fabric of existing homes – walls, floors, roofs, windows and doors. Inadequate thermal insulation and excessive air leakage are the main causes of heat loss in older domestic properties. We summarise the strategies required on an elemental basis, identify appropriate materials and highlight areas where particular care is required in order to prevent unintended consequences. The key message is the need to adopt an integrated approach to the treatment of all fabric elements to achieve improved thermal performance and optimum comfort conditions internally.

Figure 6.1 Whole-house retrofit solutions require detailed understanding of building construction and may require a range of fabric solutions to be integrated with a complementary services strategy to realise low carbon ambitions.

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Business Opportunity

Provide strategic pre-installation advice on the selection, specification and detailing of insulation.

6.2 Understanding how thermal insulation works

There are many types of insulation, derived from natural, mineral or petrochemical sources. Thermal insulation acts as an inhibitor to heat transfer either by conduction, convection, radiation or a combination of these, reducing heat loss in winter to keep the house warm or reducing heat gain in summer to keep the house cool.

Insulation products work by trapping dry gas, such as air or a blowing agent, in lightweight, bulky but cellular materials or sometimes by using reflective materials to reflect heat back into the building. All are processed to a greater or lesser extent to provide a structure that will trap gas or air and minimise conduction. Still air is a poor conductor of heat, so bulky materials that can trap large amounts of air can reduce the ability for heat to be transferred by conduction. If a material consists of many tiny pockets of trapped air rather than a large, contiguous volume of air, the ability to transfer heat by air movement is also reduced.

Understanding that the basis of insulation is to trap either air or gas is fundamental when designing or installing insulation into a retrofit scheme – reducing air movement between, around or across the surface of the insulation (referred to as thermal bypass) is crucial if insulation materials are to perform to their optimum.

Depending on the construction of the fabric, insulation products are retrofitted outside, between or inside the existing wall, floor and roof elements. For walls, these are designated as cavity insulation, external wall insulation (EWI) and internal wall insulation (IWI). Where they are located will depend on a number of external factors necessitating a pre-installation assessment by the specifier or the installer. For more information on surveying dwellings, see Guide 2.

Business Opportunity

Provide planning consultancy services to negotiate with planning departments and submit applications on behalf of householders or contractors.

6.3 Common barriers and constraints for thermal upgrades

Upgrading a building's thermal fabric will require considered decisions to be made about the most appropriate and practical solutions. Many factors will affect the selection, such as:

- planning status – the property may be Listed or lie within a Conservation Area, which will greatly restrict which fabric measures can be applied
- architectural considerations – regardless of its planning status, the property may form part of a wider architectural ensemble such as a terrace where the likelihood of being able to realise planning consent for a change in appearance or ridge height is diminished
- structural considerations – can the building fabric support the additional loadings imposed by the thermal insulation systems proposed?
- occupation – will the works have to be carried out with residents living in the property during the retrofit works?

Figure 6.2 Installing internal linings and floor insulation is a very disruptive process and difficult to carry out with residents living in the property. (Source: ECD Architects)

Figure 6.3 External wall insulation has to be restrained mechanically and/or adhesively back to the wall substrate so it must be structurally sound enough to carry the additional load imposed. (Source: ECD Architects)

Figure 6.4 In smaller rooms, can the fixtures and fittings still be accommodated once IWI has been installed? (Source: ECD Architects)

Figure 6.5 Narrow side access with complex external services such as this may restrict options for EWI. (Source: ECD Architects)

- room layouts – can rooms still function for their intended purpose if internal wall insulation is added, for example fitted bathrooms?
- boundary conditions – is there physically sufficient access to install external insulation systems and maintain the original thoroughfare? Will the insulation oversail the legal boundary?

These and other considerations will greatly affect the strategy for retrofitting a particular property – the impact of different solutions for each element will be examined more closely in the following sections. For further information see Guide 3.

Business Opportunities

Provide consultancy in the calculation, or avoidance, of thermal bridging in retrofit design.

Import, manufacture or supply components associated with advanced retrofit.

Provide consultancy in the Passive House design techniques, particularly for Certified Passive House Designers.

6.4 Thermal bridging in retrofit

A comprehensive thermal insulation retrofit should create a continuous insulated envelope around the living accommodation and, ideally, avoid any residual thermal bridging of the structure. The extent of residual thermal bridging will vary depending on the insulation strategy selected and is generally the result of structural elements breaching the insulation zone.

Thermal bridges occur where localised building fabric elements are less well insulated than the surrounding areas and therefore allow a greater rate of heat loss. This can lead to lowered temperatures either on the internal surface or within the structure, with the subsequent risk of condensation and mould growth as well as the penalty on energy efficiency. When working with existing buildings, the total elimination of thermal bridging is not always practical or even possible without extreme intervention.

Even with externally applied insulation, thermal bridges typically remain where existing load-bearing structures meet the ground below, for example, at external walls, party walls and chimney breasts or at load-bearing internal partitions.

Figure 6.6 Apron insulation extends the heat loss path at the junction of the external walls with the foundations. (Source: ECD Architects)

With internally applied insulation, thermal bridges at the external wall junctions can be avoided but the party wall, chimney and internal partition bridges are comparable. In addition, further thermal continuity complications often occur where extensions meet the main external wall structures, both horizontally and vertically. Party wall and internal partition abutments are more difficult to treat with internal wall insulation installations, particularly around entrance hallways, for example, where corridor widths are narrow. Finally, internal floor structures typically bear onto the external load-bearing walls and thus penetrate the thermal layer – this is arguably the area of most concern with internal wall insulation because of potential moisture build-up in the joist ends.

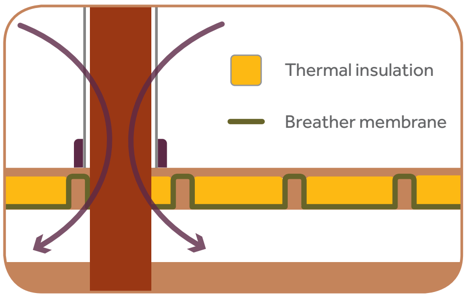

Figure 6.7 External load-bearing walls are likely to remain as residual thermal bridges.

At roof level, a typical problem area is the transition between loft insulation and external insulation at the wall plate. This can be addressed by a limited amount of internal insulation at ceiling level or, preferably, by replacing the roof covering and insulating over the top of the existing roof structure. Other difficult areas include abutments between solid-walled properties and extension roofs, and roof struts and chimney breasts, which penetrate the insulation plane.

Further information on thermal bridging can be found in Construction Products Association (CPA) (2010), Chapter 5, and in WARD & SANDERS (2007).

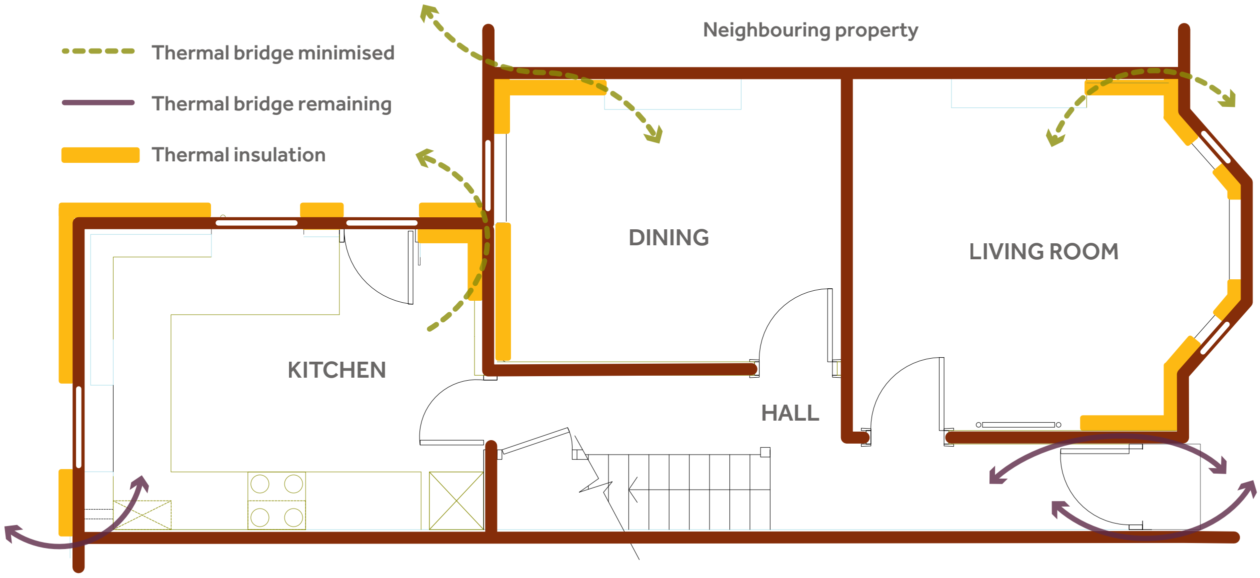

Figure 6.8 Identifying residual thermal bridges in a practical yet typical hybrid insulation retrofit plan.

Business Opportunities

Development of proprietary airtight barriers, membranes, tapes, grommets and seals and training the workforce to install them correctly.

Air tightness testing at intermediate and final stages of low carbon retrofit.

6.5 Reducing air leakage in retrofit

In construction, the term "air tightness" refers to a building's capacity to prevent air leaking from its fabric (ie walls, floors, ceilings, doors and windows) through unintended paths. All inhabited spaces need to be ventilated with fresh air in order to maintain good air quality. However, poorly sealed building fabric can be a major source of heat loss and occupant discomfort.

Air leakage occurs through a significant number of routes, as illustrated in Figure 6.9. Those highlighted in orange are unintended leakage paths, as distinct from intended ventilation paths, which might include permanent wall vents, window trickle vents, mechanical extract fans and passive vent ducts. Airtight construction therefore aims to eliminate unwanted air leakage so that the ventilation design strategy is optimised. This is summed up by the phrase "Build Tight, Ventilate Right".

It is very important in low energy retrofits to retain the heat contained within the internal air as any escaping warmed air is replaced by cold from outside, causing draughts and discomfort. As this replacement air then needs to be heated, it compromises the efficiency of the heating system and wastes energy. At the same time, it is essential to refresh the indoor air to remove pollutants (such as water vapour from cooking), supply fresh air for the occupants and provide a means of cooling in summer. The most advanced energy efficiency solutions are even able to recover the heat from this extracted air, but for such systems to work effectively the building envelope needs to be very airtight. For further information on domestic ventilation systems see Guide 7.

Airtight construction methods are also important in retrofit to avoid thermal bypass (where air is able to circulate around joints in the insulation due to poor installation) and mitigate the risk of interstitial condensation. Techniques might include the use of taped membranes or sheet materials, parging coats and proprietary grommets and seals around service penetrations. Further information on airtight construction methods can be found in EST (2010), Chapter 4, and CPA (2010a), Chapter 8. For advanced EWI standards and methodologies refer to HAZUCHA (2009).

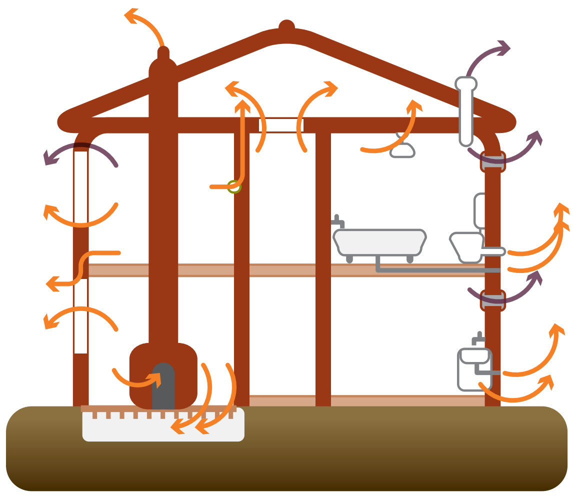

Figure 6.9 Typical unintended air leakage paths (orange) and intended ventilation (purple).

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Figure 6.10 Blower door tests involve connecting a fan to a suitable aperture in the building envelope and pressurising it over a range of pressure differences. (Source: ECD Architects)

The air tightness of a building is tested through the blower door method in accordance with industry standard methodologies (ATTMA Test Standard 1) and is measured either as air permeability in $m^3/hr/m^2$ at 50 Pa pressure or in air changes per hour at 50 Pa pressure (h–1) depending on the assessment procedure selected. The result should be taken as the average of the pressurised and depressurised results to reflect real pressure conditions. Good practice air permeability is considered to be around 5 $m^3/hr/m^2$ at 50 Pa (compared with the 2010 Building Regulations minimum for new buildings of 10 $m^3/hr/m^2$ at 50 Pa) while heat recovery ventilation is only considered effective below an air permeability of 3.0 $m^3/hr/m^2$ at 50 Pa.

Figure 6.11 Localised testing can be carried out using a smoke pencil to determine the sources of air leakage. (Source: ECD Architects)

Air tightness tests should be carried out at key intermediate moments in the retrofit strategy, not just left until practical completion as it will not be possible to carry out remedial work without major disruption to the completed installations. The programme of the retrofit works should take account of the need for air tightness testing, for example, upon completion of the air barrier including all service penetrations and fenestration installations but prior to internal finishes being applied. Further information on air tightness testing is available from the Airtightness Testing and Measurement Association.

Business Opportunities

- Consultancy services providing condensation risk analysis using dynamic analysis such as WUFI.
- Importing, manufacturing or supplying silicate coatings for masonry walls.

6.6 Controlling building fabric moisture in retrofit

The air inside buildings is generally warmer and more humid than external air with the result that any air leaking through the fabric carries a lot of moisture with it. There is a considerable risk that this moisture will then condense on colder surfaces towards the outside of the building envelope.

This is known as interstitial condensation. In retrofit scenarios, it is therefore usually a better solution to place the insulation on the outside of the existing fabric. Provided a vapour permeable weatherproof finish is applied externally, there should be very little risk of interstitial condensation. However, for heritage reasons, there will inevitably be many occasions where external solutions are simply not going to be permissible. In those circumstances, airtight linings are crucial as the internal surface of the external masonry will now be cold, providing ideal conditions for interstitial condensation and potential mould growth.

A further concern when internally insulating solid masonry walls is the potential build-up of moisture levels within the element from external conditions ie precipitation. Masonry walls are prone to absorb rainfall falling on exposed facades but this is usually mitigated by the drying effect of heat loss and the vapour permeable nature of lime-mortar masonry. However, when this drying capability is removed by insulation and vapour/air barriers, a potential risk exists whereby moisture continues to build in the exposed wall over time until reaching the point where the inside surface of the masonry can be permanently saturated. The risk to the structures lies not only in mould growth on the inside surface or rot in timbers located in this position but also in causing a sheer split in the masonry due to freeze/thaw actions. Solutions to address this in exposed regions or where absorbent materials are prevalent include the use of vapour permeable silicate coatings externally to reduce the absorption of rainwater and the use of "intelligent" membranes, which allow moisture diffusion in both directions as conditions demand.

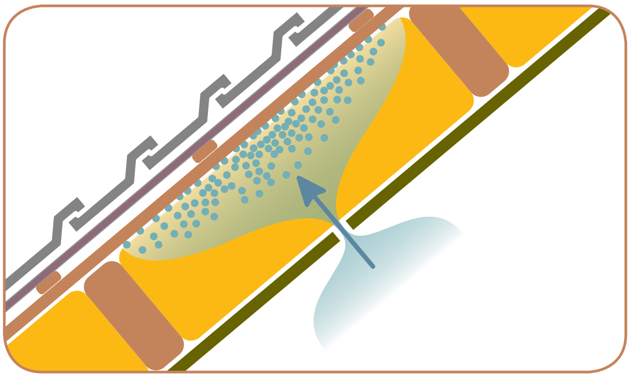

Figure 6.12 As much as 800 g of water per square metre per day can enter a structure through a 1 mm x 1 m gap.

6.7 Floor insulation

Insulating the ground floor is one of the most disruptive of all retrofit measures, often requiring removal of all internal fittings, furniture and finishes from the area being insulated. Floor structures are referred to as being suspended or solid. Suspended floors are typically very poor thermally, constructed of timber joists spanning between load-bearing walls (or bearing on secondary dwarf walls) supporting timber floorboards, which might be tongued and grooved or simply butted together.

The sub-floor void should be cross-ventilated via vents in the external walls and thus cold air can readily circulate through gaps in the construction. Solid floors are typically constructed of concrete, which might bear directly onto the ground or be supported via concrete beams with infill blocks. It is common practice to top the structural layer with a screed of 50–75 mm thickness.

Timber floors should be checked for structural soundness and the presence of wet or dry rot before proceeding to retrofit any insulation. Insulation can be fitted between and above the existing joists, using rigid insulation boards, mineral wool batts or even loosely laid cellulose but care should be taken not to block cross-ventilation through the sub-floor void. Non-rigid insulations will require some form of support between joists such as wire netting stapled over and between joists or lapped breather membrane laid to form trays between joists. The latter helps to reduce air movement around the insulation from the sub-floor void and is essential for poured insulations. Rigid boards, such as polyurethane, can be supported on battens fixed beneath or at the base of each joist. These boards should ideally be slightly undersized so that foamed polyurethane can be applied around each junction. In all cases, care should be taken to insulate between all perimeter joists and the external walls, if necessary moving the last joist inboard to allow sufficient room.

Business Opportunity

Facilitating the process of residents moving out temporarily to allow retrofit works to proceed, including resident liaison and removals logistics.

Figure 6.13 Breather membranes can be lapped tightly over and between floor joists to support loose or quilt insulation. (Source: ECD Architects)

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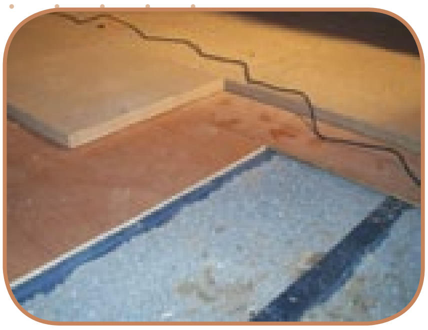

Figure 6.14 Structural support layers and insulation layers can be laid above the joist to eliminate thermal bridges. (Source: ECD Architects)

Thermal performance can be enhanced by the addition of a further layer of rigid insulation across the timbers to reduce the thermal bridging effect of the joists – a structural layer of 12 mm plywood may be required as extra support with some forms of rigid insulation. The insulation will have to be protected by a chipboard or plywood deck, which, if taped appropriately, can also form the airtight barrier (in this case, the tapes may need the additional protection of a layer of hardboard). Alternatively, a continuous airtight membrane system could be applied beneath the deck layer.

Solid floors, where sound, should be insulated with high-performance rigid insulation above the existing concrete or screed in the form of a "floating" floor. Laying a continuous damp-proof membrane beneath the insulation is advisable, taking care to overlap with any damp-proof course (DPC) in the external walls. The insulation may be supplied pre-bonded to a chipboard deck or may require a separate deck to be laid. Considerations for the airtight barrier are consistent with those for suspended floors.

Whether in an existing solid or a suspended floor situation, the impact of additional layers of insulation on other existing features should be thoroughly considered before proceeding with this measure. Examples would include the reduction in room, cill, door opening and switch heights, the need to undercut door leafs and the decrease in riser height at the bottom step of any stair, which will need the prior consent of the Building Control Body.

Further information on floor insulation solutions can be found in EST (2010), Chapter 3, and CPA (2010a), Chapter 4.

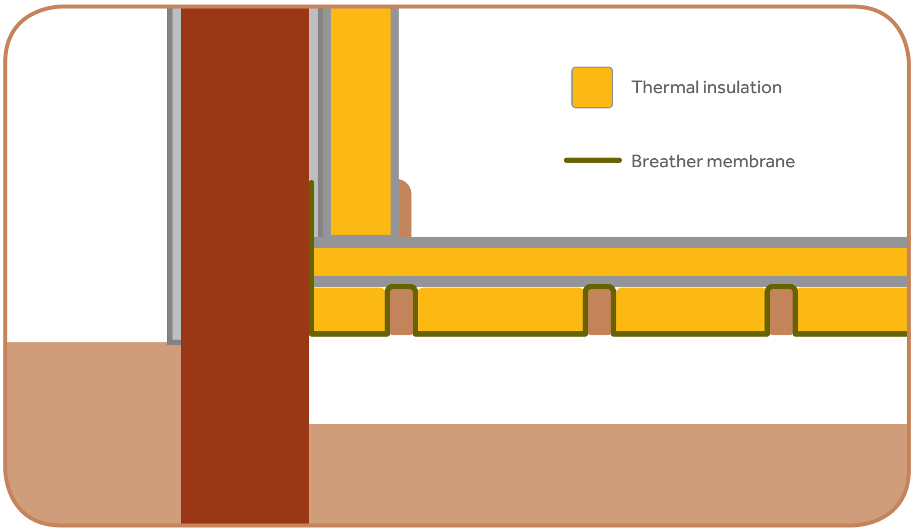

Figure 6.15 Diagram showing the build-up of layers for a suspended floor solution.

6.8 Cavity wall insulation

Cavity wall insulation (CWI) is a common form of retrofit whereby insulation is injected into the void between inner and outer leafs of masonry walls, a form of construction typical since 1920. The Government estimates that around 18.6 million homes in Great Britain have cavity walls of which only 10.3 million have been insulated. When improving cavity insulation the main considerations are:

- avoiding gaps between injection points where thermal bypass can occur
- avoiding moisture ingress across leafs in regions with high exposure
- avoiding damage to any materials within the cavity through inappropriate specification.

Materials suitable for insulating cavities include the following:

- polystyrene beads
- mineral wool (glass or rock wool fibres)
- urea formaldehyde foam
- urethane foam.

Most systems can be used throughout the UK – mineral fibre and expanded polystyrene bead CWI have British Board of Agrément (BBA) certificates for use in all areas but urea formaldehyde foam has a British Standards Institution (BSI) certificate with certain restrictions in severe weather zones, including coastal areas. Problems with rain penetration are rare, especially if walls are rendered, and warranties are available for most systems from the Cavity Insulation Guarantee Agency (CIGA). For information on the use of urea formaldehyde in cavity wall insulation see 2010 Building Regulations Approved Document Part D.

Cavity wall insulation alone is not considered to provide sufficient thermal improvement to meet the Government's targets on carbon reduction and should be used in conjunction with EWI or IWI to meet minimum energy efficiency targets. Where EWI is installed onto a cavity wall, it is essential that the cavity is filled in order to prevent thermal bypass effects created by the existence of a ventilated cavity behind the insulation. Further information on the various approved systems available, a directory of registered installers and details of their 25-year guaranteed installers can be found from the Cavity Insulation Guarantee Agency. Information on cavity wall insulation solutions can be found in EST (2007) and CPA (2010a), Chapter 5.

Business Opportunity

Cavity wall insulation surveys, specification and installation.

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Business Opportunities

Providing strategic pre-installation advice on the selection, specification and detailing of external wall insulation.

Installing external wall insulation – a National Occupational Standard, together with retraining and apprenticeship schemes are being established to meet expected demand.

Carrying out preparatory groundworks work in advance of the above ground installation of EWI.

Preparing roofs in advance of EWI installation by extending eaves, verges and soffits or re-engineering roof void ventilation.

Importing, manufacturing or supplying components associated with EWI as the EWI industry expands and specifications focus on ever higher performance.

6.9 External wall insulation

External wall insulation (EWI) comprises an insulation layer fixed to the outside of an external wall, using a combination of mechanical fixings and adhesive depending on the material used, with a protective render or cladding finish. It is suitable for solid wall, non-traditional and cavity wall properties and offers several advantages, as well as the improvement of energy efficiency standards:

- The work is done externally so there is very little disruption and no loss of living space.
- The system will protect the property and the results can improve the appearance of the building through a range of external finishes.
- Condensation risk is managed to the outside of the home and there should be little thermal bridging if the insulation layer is continuous.
- It needs little maintenance while, internally, no redecoration is needed.

Proprietary insulation systems use a variety of rigid insulation types depending on the characteristics needed, such as mineral wool batts, expanded or extruded polystyrene and phenolic foam boards. Key selection considerations are: fire resistance; thermal performance (ie thickness); weight and cost. Adhesive is applied to the back of boards to create a continuous combed surface suitable for bedding and adjusting the boards – it is important that due care is given to the avoidance of any gaps behind the boards which could lead to thermal bypass. A parging coat may be applied prior to fixing the insulation to smooth out any surface irregularities and act as the air tightness barrier. Proprietary insulation anchors, sleeved in plastic, are then used to mechanically secure the boards.

Finishes fall into two categories: wet render systems (either thicker cement mineral renders or thinner synthetic renders); or rainscreen systems (comprising panels or boards on a carrier system of either timber battens or aluminium rails). Wet render systems are typically built up using mesh and base coats, before the final through-coloured top coat. Where a brick appearance is required, 20 mm thick brick slips may be adhered directly onto the insulation or, alternatively, a two-coat render build-up is used to achieve the same appearance. Rainscreen carrier systems may reduce the thermal performance of the insulation, particularly where metal brackets are used.

Figure 6.16 Insulated render system build-up: parge coat as air barrier; mechanically and adhesively fixed insulation batts; mesh and base coat render; silicone render top coat.
(Source: ECD Architects)

While EWI may at first appear to be the least disruptive solid wall insulation solution, there are a number of constraints to overcome. Typical cases include:

- eaves, soffits and verges, particularly where the proposed insulation thickness exceeds the existing projection. Care must be taken to achieve thermal continuity with the roof insulation
- junctions with windows where, if possible, consideration should be given to overlapping the window frame to further improve energy efficiency of these elements. Window cills will most likely need to be extended also. If at all feasible, window replacement should take place concurrently with EWI as the replacement windows can then be integrated into the plane of the insulation to reduce thermal bridging at the edges

- architectural features such as balconies, canopies, bay windows and side alleys will have to be addressed sympathetically and carefully to maintain the continuity of the insulation
- building services such as waste pipework, drainage, flues, vents and telecommunications equipment will all have to be removed and relocated on the face of the insulation. Typically, a timber pattress is used in the UK to carry the loads to the wall substrate.

To avoid thermal bridging at the threshold between ground floor and the external ground and, where it is practical to do so, apron insulation should be installed below DPC level. Closed cell insulation should be used for this purpose, such as extruded polystyrene, fixed in a similar fashion to above-ground EWI. This process will often require the repositioning of below-ground drainage where gulleys and waste outlets would break the continuity of the EWI system.

Further information on the various approved systems available, the code of professional practice and a directory of contractors can be obtained from the Insulated Render and Cladding Association. Information on external wall insulation solutions can be found in EST (2010), and CPA (2010a), Chapter 5. For advanced EWI standards and methodologies refer to HAZUCHA (2009).

Figure 6.17 Insulated rainscreen system build-up: parge coat as air barrier; mechanically fixed insulation boards; ventilated batten zone; cement fibreboard carrier or decorative rainscreen panel. (Source: ECD Architects)

Figure 6.18 Eaves and verge roof structures will need to be extended where EWI thickness exceeds existing overhang dimensions. (Source: ECD Architects)

Figure 6.19 Extruded polystyrene insulation installed below ground to insulate floor junctions will require underground drainage systems to be repositioned. (Source: ECD Architects)

Figure 6.20 Proprietary eaves gutter and verge extensions may avoid the need to extend roof structures. (Source: Prewett Bizley Architects)

6.10 Internal wall insulation

Internal wall insulation (IWI) comprises an insulation layer fixed to the inside of an external wall, using a combination of mechanical fixings and adhesive depending on the material used, with a decorative plasterboard finish. It is suitable for solid wall, non-traditional and cavity wall properties and might be selected over EWI for a number of key reasons, as well as in the improvement of energy efficiency standards:

- The work is done internally so there is no impact on planning policy, although Listed Buildings may need specific permission.
- It can be installed in one room at a time so disruption is minimised.
- Installers will not need to use scaffolding.

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Figure 6.21 Foil-backed polyurethane insulation pinned and foamed to an internal wall. The battens form a service zone ready to receive a plasterboard finish. (Source: ECD Architects)

Figure 6.22 Phenolic thermal laminate boards line the inside of a bay window. (Source: ECD Architects)

Business Opportunities

Providing strategic pre-installation advice on the selection, specification and detailing of IWI.

Fitting IWI behind kitchen and bathroom fittings in advance of the main IWI installations.

Installing IWI – a National Occupational Standard together with retraining and apprenticeship schemes are being established to meet expected demand.

IWI systems use a variety of insulation types depending on the characteristics needed:

- EPS-backed thermal laminate boards
- phenolic foam-backed thermal laminate boards
- foil-backed polyisocyanurate boards plus dry-lined service zone
- aerogel lining boards
- insulated stud mineral wool systems
- wood fibre lining boards
- rigid "wool" boards
- anti-mould growth linings.

IWI can be disruptive and there are often a considerable number of constraints to overcome, typically at the junctions of the building fabric, for example:

- Intermediate floors, where floor joists are built into external walls: not only is it difficult to insulate this zone, addressing air tightness continuity is particularly tricky with the risk of failure quite high if moist internal air is permitted to condense on cold joist ends, potentially leading to rot and structural failure.
- Internal partitions and party walls, where they are tied in to the external solid wall: returning the insulation back into the room may help to alleviate cold bridging in these locations.
- Junctions with windows: where possible, consideration should be given to overlapping the window frame to further improve energy efficiency of these elements. Window boards will most likely need to be extended or replaced also. If at all feasible, window replacement should take place concurrently with IWI as the replacement windows can then be located closer to the plane of the insulation to reduce thermal bridging at the edges.
- Fixtures and fittings such as bathroom fittings, kitchens, cupboards and radiators all have to be removed and relocated. It is important to take advantage of this opportunity when these elements are being replaced anyway.
- Internal building services such as waste pipework, wall-mounted boilers, flues, vents and telecommunications equipment will all have to be removed and relocated on the face of the dry lining.

Figure 6.23 Timber stud lining with infill mineral wool or wood fibre insulation. (Source: ECD Architects)

Figure 6.24 Proprietary wood fibre IWI insulation boards being mechanically fixed to an external wall. (Source: ECD Architects)

The greatest concern with internal wall insulation is the control of moisture. Water vapour can pass through the wall build-up by both diffusion through the insulation layer but far more significantly by air movement through gaps in the system between insulation boards. It is therefore vital to introduce a continuous vapour barrier to prevent moisture meeting the cold inner surfaces. By separating the insulation, vapour control layer and plasterboard, greater control over continuity can be achieved compared with a thermal laminate board solution and electrical services need not penetrate the vapour control barrier.

Further information on trigger points is available in EST (2011). Information on internal wall insulation solutions can be found in the EST (2010) and CPA (2010a), Chapter 5.

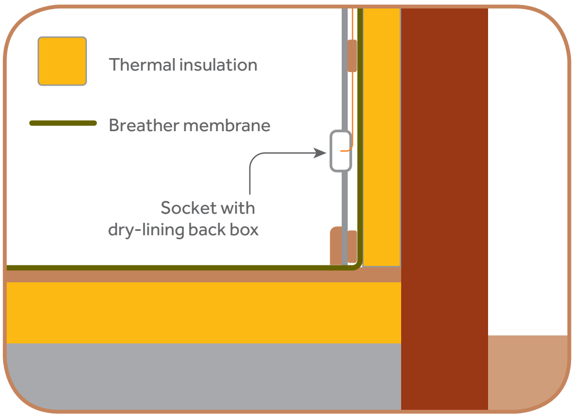

Figure 6.25 Details of the junction between IWI and floor.

6.11 Loft (ceiling) insulation

Ventilated loft spaces are a common feature in the UK housing stock. A significant proportion of a building's heat loss is through the roof, yet this is relatively easy to address through insulation laid between and above the ceiling joists. The Government estimates that only around 12.9 million homes in Great Britain, or around 55% of the total homes with lofts, have been insulated with more than 125 mm of insulation. When improving loft insulation the main considerations are:

- avoiding thermal bypass and crushing of the insulation
- maintaining cross-ventilation
- reducing air leakage from the rooms below.

Thermal bypass can occur at the eaves, where air circulates under the perimeter of the insulation, or between layers of quilt where they are lifted by obstructions such as services or roof structures. Furthermore, the effectiveness of loft insulation is greatly reduced if heavy items are placed on top, crushing the air pockets between fibres. This can be avoided by constructing a decked platform above the proposed insulation level. Measures to address these concerns might include the use of eaves trays, careful cutting of mineral wool around obstructions or relocating services inside the thermal envelope. For trussed rafter roofs or other complex structures, blown loft insulation should be considered as this could more readily fill inaccessible pockets.

Figure 6.26 Loft spaces are often used for storage of household items and this greatly reduces their thermal performance. (Source: ECD Architects)

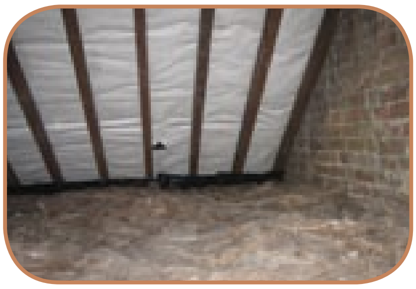

Figure 6.27 Illustration of a cleared, well insulated loft space showing both retrofitted eaves ventilation trays and a vent tile above well fitted mineral wool batts. (Source: ECD Architects)

Business Opportunities

Surveys, specification and installation of higher performance loft insulation solutions, for example, blown loft insulation as an alternative to conventional loft insulation.

Loft conversion as a retrofit strategy, or simply adapting loft spaces by re-engineering roof void ventilation and constructing storage platforms in advance of insulation works.

Importing, manufacturing or supplying high performance loft hatches for the UK market as insulation and air tightness standards are raised.

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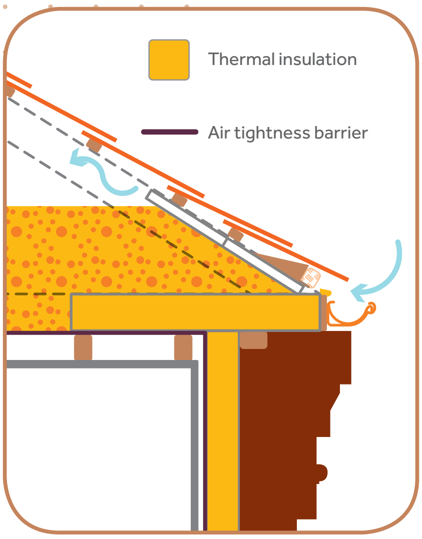

Figure 6.28 IWI solution at the junction of wall and ceiling to ensure continuity of the insulation and air barrier while providing adequate loft ventilation at the eaves.

To avoid condensation on the underside of roofing felts, ventilation must be maintained across the roof space, typically from eaves to eaves. It can be avoided by carefully fixing insulated boards or proprietary retrofit eaves vents between the rafters above the wall plate to contain any insulation and maintain a clear air passage of minimum 50 mm. The wall plate may require chamfering to assist this operation. Alternatively, new tile vent terminals can introduce cross-ventilation above the level of the proposed top-up insulation.

Finally consideration should be given to reducing air leakage from ceiling penetrations such as light fittings, cabling and loft hatches as part of an overall air tightness improvement strategy for any retrofit. If ceilings cannot be replaced, all cable penetrations should be sealed with proprietary tapes or grommets on the warm side – over-boarding with another layer of plasterboard will then be required to conceal these measures. If head heights permit and the level of disruption is acceptable, consideration should be given to replacing plasterboard ceilings with a taped 18 mm oriented strand board (OSB) lining to create an airtight barrier and a void for all service runs, which can be then faced with a second plasterboard layer. Conventional loft hatches are poor both in terms of thermal continuity and air tightness. Consideration should be given to replace them with more robust, higher performance proprietary types or even relocating access to a gable end outside of the thermal and airtight envelopes.

Figure 6.29 Replacement OSB ceiling lining provides an airtight barrier when taped and sealed, as well as providing better support for loft insulation. (Source: ECD Architects)

Further information on external wall insulation solutions can be found in EST (2010), Chapter 3 and CPA (2010a) Chapter 6.

Business Opportunities

Integrate insulation upgrades into roof replacement and maintenance work.

Loft conversion works as a retrofit strategy, or simply re-engineering roof structures and ventilation or re-roofing.

6.12 Pitched roof insulation

In roof configurations where the internal ceiling line follows the pitch of a roof, thermal insulation upgrades have to be added at rafter level. Such a "room-in-the-roof" arrangement may already exist or arise as a result of a loft conversion to create additional habitable space. When improving pitched roof insulation the main considerations are:

- adding insulation in a practical manner while eliminating any thermal bridging of the roof structure
- maintaining cross-ventilation behind the roof finish, where the construction cannot be made vapour permeable
- achieving an improvement in air tightness while working around existing framing members.

Pitched roofs can be upgraded by adding rigid insulation boards or batts between the existing rafters but it is unlikely that this will be sufficient to meet best practice standards. Insulation will therefore need to be added either above or below the rafter zone as a continuous layer. Decisions to be made include:

- whether the existing roof finish layer is to be replaced or retained, ie the slates, tiles or metal

- whether it is more practical to insulate above or below the roof structure
- how to overlap the insulation (and air barrier) with any EWI or IWI and maintain thermal continuity.

If the roof finish is being replaced, and there are no planning constraints on doing so, the best practice approach is to insulate above the existing rafters. Consideration should be given to using vapour permeable rigid insulation boards, such as wood fibre, to allow the release of any moisture present in the roof structure. Battens and counter battens can be fixed through the insulation to ventilate the space under the roof finish. A continuous vapour check will be required on the inside surface, which also forms the air tightness barrier. Mineral wool quilt can be used in the same situation in conjunction with a secondary roof structure, for example, engineered timber I-beams.

Insulating internally is also possible to allow retention of existing roof finishes. In this case, a vapour permeable membrane can be installed wrapping under and between existing rafters, ensuring that sufficient ventilation is maintained behind the tiles or slates. Insulation can then be installed between and behind the rafters, and lined with a vapour check membrane, which also forms the air barrier. This is more disruptive internally but presents no planning constraints.

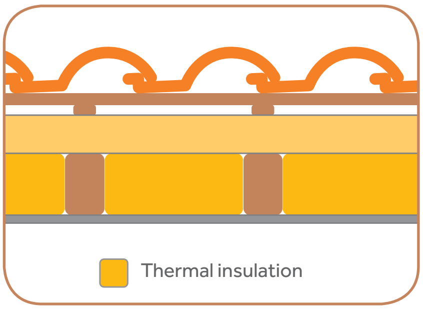

Figure 6.30 Diagram showing the preferred arrangement for thermal upgrade where roof finishes are being replaced.

Figure 6.31 I-beam structure over an existing roof ready to receive mineral wool insulation, breather membrane and battens. (Source: Simmonds Mills Architects)

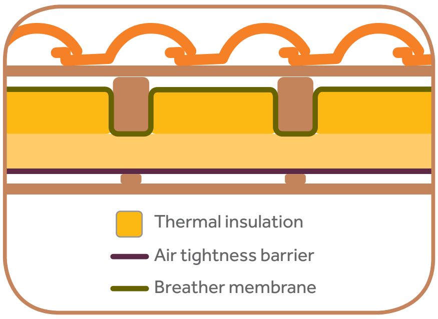

Figure 6.32 Diagram showing a possible arrangement for thermal upgrade where roof finishes are being retained.

Figure 6.33 An internal roof retrofit showing the breather membrane between and under the retained rafters, ready to receive insulation between and behind them, before the vapour check and dry-lining complete the upgrade. (Source: ECD Architects)

Further information on pitched roof insulation solutions can be found in EST (2010), Chapter 3 and CPA (2010), Chapter 6. Further information on loft conversions can be found in the CPA (2010b).

6.13 Flat roof insulation

Upgrading flat roofs can be relatively straightforward to achieve. The main considerations are:

- increasing the thermal performance, or U-value, of the roof build-up
- maintaining the waterproof membrane
- avoiding thermal bridging at the junction with the wall insulation.

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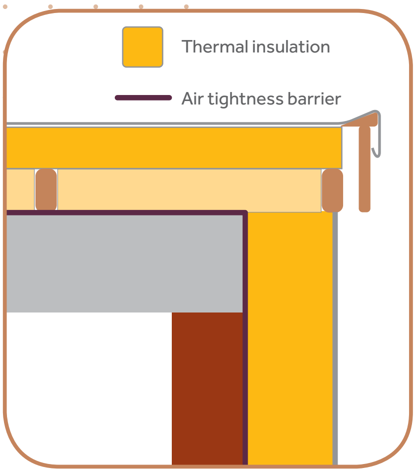

Figure 6.34 Flat roof upgrades need to consider use of existing membranes, continuity of insulation with the EWI and continuity of the air tightness barrier.

Figure 6.35 Higher performance insulation often means a deeper fascia, which requires aesthetic consideration. In this example, Thermowood cladding has been used. (Source: ECD Architects)

Flat roofs are insulated by adding rigid insulation boards above the existing structure. Decisions to be made include:

- whether to remove or retain the existing waterproof layer
- whether to choose a warm or inverted roof solution
- how to overlap with any EWI and maintain continuity.

Warm roofs are preferred. As with inverted roofs, there is a tendency for cold rainwater to percolate between the insulation to the waterproof layer. However, inverted roofs have the advantage that the roof membrane is protected. Typically, additional roof timbers are required to carry an extended eaves and fascia to accommodate the EWI.

Further information on flat roof insulation solutions can be found in EST (2010), Chapter 3, and CPA (2010a), Chapter 6.

Business Opportunities

Supply and installation of secondary glazing and applied films as an alternative to full window replacement; the need for quality control inspections of such work may also create business opportunities.

Surveying, installing and project managing window replacement where integration with other retrofit measures will need additional care and attention.

6.14 Windows

Upgrading poorly performing windows is an important part of improving the building fabric. They can be a major source of heat loss from both conduction and air leakage, while the cold surface they present to the interior of a room is a contributor to downdraughts and prone to condensation. When improving windows, the main considerations are:

- increasing the thermal performance, or U-value, of the glazing and/or the frame
- reducing unwanted air infiltration around the frames and opening lights
- reducing thermal bridging at the window reveals
- supporting the ventilation strategy, whether that be maintaining an existing approach or accommodating a new one.

There are three retrofit strategies for windows, the selection of which may depend on planning or financial constraints:

- upgrading the existing window system or adding secondary glazing
- independently replacing the windows
- replacing the windows concurrently with IWI or EWI measures.

Where windows are to be retained, it is possible to achieve energy efficiency improvements by installing higher specification glass and draught-stripping around opening lights and frames. It is important to establish whether any frames to be retained can accommodate thicker glazing units, for example, when improving from single to double or even triple-glazing. In Listed Buildings or within Conservation Areas, there may be restrictions on alterations to the appearance of existing windows. It will be necessary to consult with the local authority conservation officer to establish which measures would be acceptable eg the replacement of single-glazing with slimline double-glazing or vacuum glass. Such replacement work, where the frames are retained, does not constitute work to a "controlled fitting" according to Approved Document Part L1B and is therefore not covered by Building Regulations.

As an alternative to changing the existing glazing it may be possible to apply an additional low emissivity film layer to the inside face, or to supplement the retained windows with secondary glazing. Further information on replacement glass, secondary glazing and applied films is available from the Glass and Glazing Federation.

Around 2 million windows are replaced in the UK each year. Windows are classified as a "controlled fitting" under Approved Document Part L1B and must meet a minimum performance standard based on either a "C" Window Energy Rating (WER) or a minimum whole window U-value of 1.6 W/m²K. The best performing windows can now achieve exceptional U-values of around 0.75 W/m²K through the use of triple-glazing, gas fill, low-emissivity coatings and insulated frames, while also achieving Passive House air tightness requirements and high solar transmittance (g) values.

When replacing windows in cavity walls, it is a requirement of 2010 Building Regulations Approved Document L1B to introduce insulated cavity closers. Certification schemes that meet minimum quality assurance standards, such as the Fenestration Self-Assessment Scheme (FENSA), can alternatively provide evidence of compliance with building regulations. Replacement windows also need to take into consideration the minimum requirement of Approved Document F where trickle vents and opening lights form part of the building ventilation solution for background and purge ventilation. Alternatively, this requirement may be met by a mechanical ventilation system, in which case windows do not require trickle vents. For further information on building services in retrofit see Guide 7.

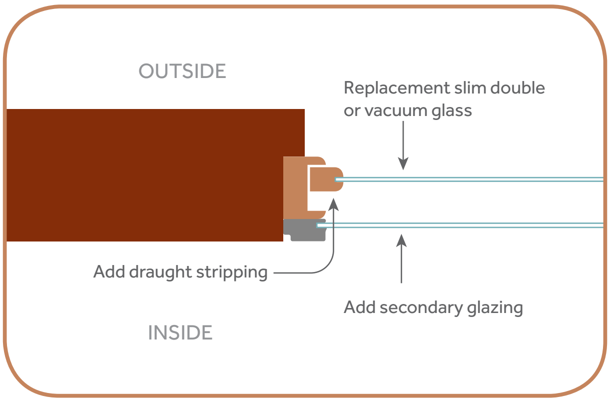

Figure 6.36 Diagram showing options for upgrade of retained window (eg sash type) with secondary glazing.

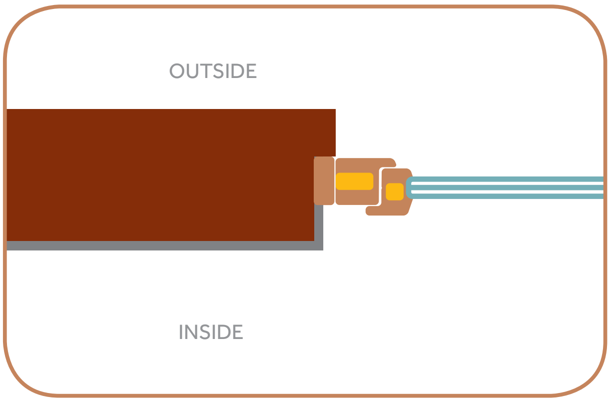

Figure 6.37 Diagram showing options for the independent replacement of windows (allowing for future IWI).

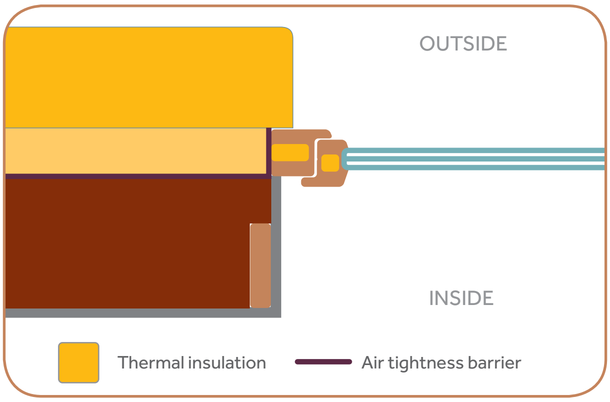

Figure 6.38 Diagram showing options for the replacement of windows in conjunction with EWI.

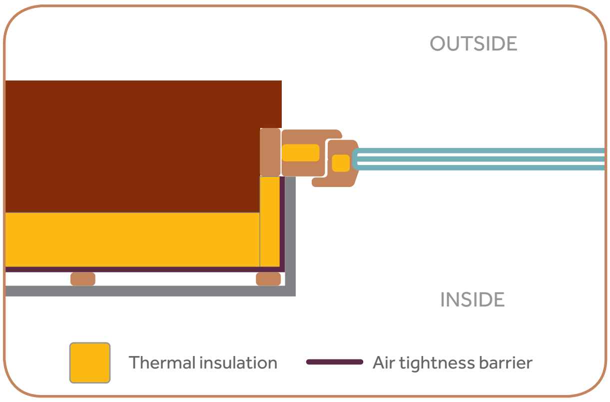

Figure 6.39 Diagram showing options for the replacement of windows in conjunction with IWI.

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Figure 6.40 Externally insulated frames awaiting EWI to be overlapped. (Source: ECD Architects)

When replacing the windows in conjunction with external or internal wall insulation, consideration should be given to the repositioning of the window to reduce perimeter thermal bridging. If employing an IWI approach, for example, it may be necessary to specify wider frames to accommodate insulated internal reveals. When insulating externally, windows can be planted on the outside of the wall on a support batten such that air tightness tapes can be used to seal between frame and parge coat and the insulation can be lapped round and over the frames to eliminate thermal bridging at the interface.

Further information on windows can be found in EST (2010), Chapter 3, and CPA (2010a). For information about advanced window standards and installations refer to HAZUCHA (2009).

Figure 6.41 Planted high performance window taped to masonry ready for parge coat to be applied and lapped. (Source: ECD Architects)

Business Opportunities

Surveying, installing and project managing door replacement where integration with other retrofit measures will need additional care and attention.

Manufacture, supply or import of insulated threshold components associated with high performance entrance doors as the retrofit industry expands and specifications focus on the elimination of thermal bridging.

6.15 External doors

As with windows, upgrading doors to improve thermal performance and air tightness should form part of any comprehensive retrofit strategy. Doors are also defined as controlled fittings in the 2010 Building Regulations, but only where door and frame are being replaced simultaneously. The limiting factor for replacement is defined by the maximum permitted U-value of 1.8 W/m²K for the whole door. Therefore, when improving entrance doors, the main considerations are:

- increasing the thermal performance, or U-value, of the door and the frame
- reducing unwanted air infiltration around the frames and the door leaf
- reducing thermal bridging at the door reveals
- accounting for functional aspects such as security and post delivery.

There are three retrofit strategies for doors, the selection of which may depend on planning constraints, budget or opportunity:

- upgrading the existing door leaf
- independently replacing the door and frame
- replacing the door concurrently with IWI or EWI measures.

If the door structure allows, it may be possible to refurbish panels in an existing door leaf to introduce insulation in the form of polystyrene, polyurethane or even vacuum-insulated panel (VIP) cores. New panelling could be retrofitted outside the existing stiles, mullions and rails to create a new appearance. Draught stripping should be applied at the same time to reduce unwanted air leakage.

New doors can be obtained that achieve as high a thermal performance as windows at a U-value of 0.8 W/m²K, incorporating triple-glazed lights, pre-insulated cores and double seals. Unlike windows, doors should usually be fitted by screw-fixing directly into the adjacent opening jambs in order to be able to cope with the additional stresses created when opening heavy doors.

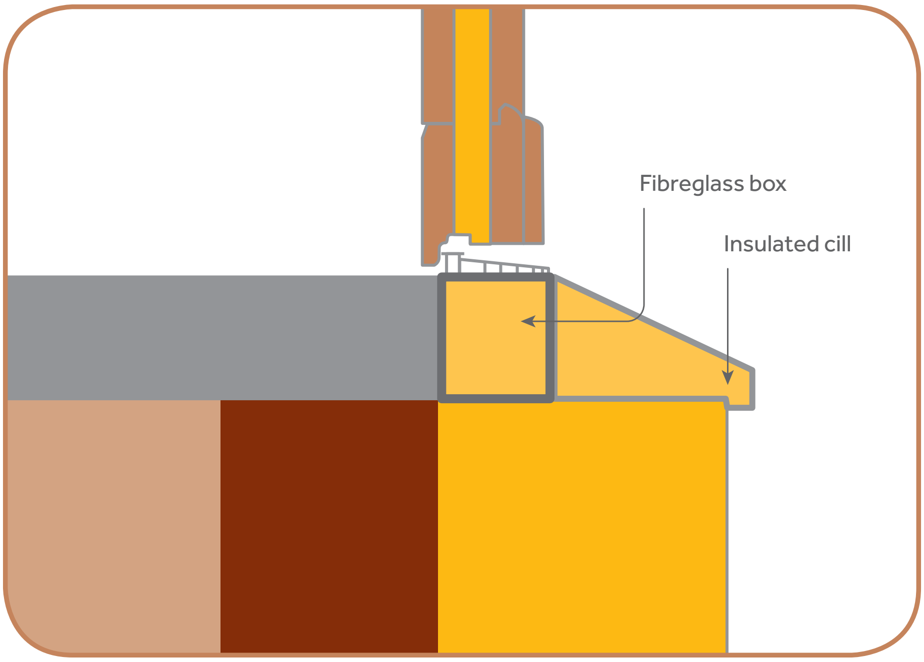

Figure 6.42 Addressing cold bridging at door thresholds can be very difficult to achieve. Proprietary solutions need to be made available for the retrofit market.

Figure 6.43 Bespoke dimensions for high performance entrance doors may not be available and make-up panels may be required above the door. (Source: ECD Architects)

Figure 6.44 Vacuum insulated panels being incorporated into a new entrance door for a retrofit project. (Source: ECD Architects)

There are often conflicts between Approved Document Part M and the need to achieve better air tightness at threshold upstands – a relaxation may need to be negotiated with the Building Control Body. Carrying the weight of the entrance door and cill while maintaining continuous insulation is another area of conflict.

Further information on doors can be found in EST (2010), Chapter 3, and CPA (2010a), Chapter 7.

6.16 Fittings

As well as the controlled fittings, additional measures may be considered to further reduce heat loss or reduce solar gains. Thermally insulating window hangings are available to retain additional heat within the room at night, for example.

Shutters can work in a similar fashion, or can be employed to reflect heat back out from a building, particularly when installed on the outside of the building. With increasing concern about adapting our existing buildings to cope with higher temperatures in the future, keeping heat out of the building in summer will form an equally important aspect of retrofit. Solar control measures might include the following:

- external blinds
- retractable louvres
- external shutters
- brise-soleil.

Business Opportunity

Manufacture, supply and installation of thermally insulating internal blinds and external solar control devices. Further opportunities exist in providing consultancy on overheating risk analysis.

6.17 Summary of business opportunities

The supply chain for components associated with advanced retrofit, for structural insulation etc is currently under-developed in this country. Opportunities exist to import, manufacture or supply such items as the demand for advanced retrofit expands and specifications focus on ever higher performance with the complete elimination of thermal bridges.

Resident liaison and logistics

Facilitating a temporary decant

Retrofit works may, in some cases, be highly disruptive to a property requiring residents to undertake a temporary decant to allow the works to proceed. Opportunities exist in facilitating this process through resident liaison and removals logistics roles.

Statutory approvals

Planning consultant services

Planning consent may be required in many retrofit scenarios. Opportunities exist to provide planning consultant services to negotiate with planning departments, provide "before and after" visualisation and submit applications on behalf of householders or contractors.

Design and modelling

Strategic pre-installation advice

There are a wide range of insulation types and solutions available for retrofit projects. Opportunities exist to provide strategic pre-installation advice on the selection, specification and detailing of insulation.

Consultancy in the calculation, or avoidance, of thermal bridging

Modelling of linear and point thermal bridges requires specialised 2D or 3D software analysis. Opportunities exist to provide consultancy in the calculation, or avoidance, of thermal bridging in retrofit design.

Consultancy in the Passive House design techniques

Meeting the Passive House or EnerPHit standards in retrofit requires a good understanding of the Passive House principles and the verification software used in assessing compliance. Opportunities exist to provide consultancy in the Passive House design techniques, particularly for Certified Passive House Designers.

Consultancy services providing condensation risk analysis

It is possible to accurately calculate vapour diffusion patterns in construction build-ups using specialist software, although this is rarely undertaken in the UK where the steady-state Glaser method prevails. Opportunities exist for consultancy services providing condensation risk analysis using non-stationary analysis such as WUFI. Further opportunities exist to import, manufacture or supply silicate coatings for masonry walls.

Air tightness

Development, application and training

Airtight retrofit techniques are poorly understood within the UK construction industry and specialist skills in this area will need to be improved. Opportunities exist in the development and application of proprietary airtight barriers, membranes, tapes, grommets and seals and in training the workforce to install them correctly. Further opportunities may arise as the need to fulfil the role of air tightness champion is increasingly recognised within the industry.

Air tightness testers

Air tightness testing at intermediate and final stages is recommended for all retrofits and is a necessity for advanced retrofits. Opportunities exist for air tightness testers meeting the competent person criteria of the Building Regulations to carry out the growing workload associated with low carbon retrofit.

Cavity wall insulation

Meeting the demand for surveys, specification and installation

There are over 8 million cavities still to be insulated in Great Britain. Opportunities exist in meeting the demand for surveys, specification and installation, particularly in the private rented sector where cavity insulation will be one of the most cost-effective measures in improving dwellings to the proposed minimum EPC Band E rating.

External wall insulation

Strategic pre-installation advice

Assessing a building's suitability for EWI will be necessary in advance of the actual measure being carried out. Opportunities exist to provide strategic pre-installation advice on the selection, specification and detailing of external wall insulation.

With the proposed launch of the Government's energy efficiency incentive scheme next year, it is estimated that related jobs would have to increase from the current 27,000 to over 100,000 over the next five years if the required number of households take up the scheme. It is expected that a large proportion of that number would be engaged in installing external wall insulation – a National Occupational Standard together with retraining and apprenticeship schemes are being established to meet this demand.

Ground workers to carry out preparation work

Where EWI is proposed below DPC level, alterations will be required to below-ground services. Opportunities exist for ground workers to carry out preparation work in advance of the above-ground EWI – cross-training in EWI installation should be undertaken.

Carpenters and roof workers to prepare roof construction

Where EWI interfaces with roof components, alterations may be required. Opportunities exist for carpenters and roof workers to prepare roof construction in advance of the EWI by extending eaves, verges and soffits or re-engineering roof void ventilation.

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Import, manufacture or supply such items as the EWI industry expands

The supply chain for components associated with EWI, for example, window cill extensions, proprietary eaves extensions, thermally broken bracketry etc, is currently underdeveloped in this country. Opportunities exist to import, manufacture or supply such items as the EWI industry expands and specifications focus on ever higher performance.

Internal wall insulation

Strategic pre-installation advice on selection, specification and detailing

Assessing a building's suitability for IWI will be necessary in advance of the actual measures being carried out. Opportunities exist to provide strategic pre-installation advice on selection, specification and detailing.

Kitchen and bathroom fitters to internally insulate

IWI should be considered at every available trigger point. Opportunities exist, if appropriate cross-training is undertaken, for kitchen and bathroom fitters to internally insulate in advance of such installations.

With the proposed launch of the Government's energy efficiency incentive scheme next year, it is estimated that related jobs would have to increase from the current 27,000 to over 100,000 over the next five years if the required number of households take up the scheme. It is expected that a good proportion of that number would be engaged in installing internal wall insulation – a National Occupational Standard together with retraining and apprenticeship schemes are being established to meet this demand.

Loft and roof improvements

Meeting the demand for surveys, specification and installation of higher performance loft insulation solutions

There are around 10 million lofts still to be insulated in Great Britain. Opportunities exist in meeting the demand for surveys, specification and installation of higher performance loft insulation solutions, for example, blown loft insulation as an alternative to conventional loft insulation.

Loft conversion works as a retrofit strategy

Adapting loft spaces can add value to a property as part of the retrofit works. Opportunities exist for loft conversion works as a retrofit strategy or in simply re-engineering roof void ventilation and constructing storage platforms in advance of insulation works.

Import, manufacture or supply of advanced performance loft hatches

Advanced performance loft hatches currently have to be imported from continental suppliers. Opportunities exist in the import, manufacture or supply of such products for the UK market as insulation and air tightness standards are raised.

Roofers to integrate insulation upgrades

Replacement of roof finishes is a key trigger point for carrying out thermal upgrades simultaneously. Opportunities exist for roofers to integrate insulation upgrades into their work.

Glazing and doors

Suppliers and installers of secondary glazing

Opportunities exist for more suppliers and installers of secondary glazing and applied films as an alternative to full window replacement. The need for quality control inspections of such work may also create business opportunities.

Surveying, installing and project-managing window replacement

The current rate of window replacement may increase as a result of Green Deal funding becoming available. Opportunities exist in surveying, installing and project-managing window replacement where integration with other retrofit measures will need additional care and attention.

Surveying, installing and project-managing door replacement

The current rate of door replacement may increase as a result of Green Deal funding becoming available. Opportunities exist in surveying, installing and project-managing door replacement where integration with other retrofit measures will need additional care and attention.

Manufacture, supply or import windows and doors as the retrofit industry expands

The supply chain for insulated threshold components associated with high performance entrance doors is currently underdeveloped in this country, although pultruded fibreglass components with insulated cores exist. Opportunities exist to manufacture, supply or import such items as the retrofit industry expands and specifications focus on the elimination of thermal bridging.

Climate change adaptation

Manufacture, supply and installation of thermally insulating blinds

Most adaptation solutions currently have to be imported from continental suppliers. Opportunities exist for more manufacturers, suppliers and installers of thermally insulating internal blinds and external solar control devices. Further opportunities exist in providing consultancy on overheating risk analysis.

6.18 Next steps

Key references

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Key Links

For Building Regulations information: **www.communities.gov.uk/planningandbuilding/buildingregulations**

For information about the Green Deal from the Department of Energy and Climate Change (DECC): **www.decc.gov.uk**

For information about Retrofit for the Future projects: **www.retrofitforthefuture.org** and **www.innovateuk.org/retrofit**

For information about other exemplar projects: **www.superhomes.org.uk** and **www.energysavingtrust.org.uk**

For information on Passive House: **www.passivhaustrust.org.uk** and **www.passiv.de**

For information on air tightness testing refer to the Airtightness Testing and Measurement Association: **www.attma.org**

For information about WUFI: **www.wufi.de/index_e.html**

For information about cavity wall insulation, refer to the Cavity Insulation Guarantee Agency: **www.ciga.co.uk**

For information about external wall insulation, refer to the Insulated Render and Cladding Association: **www.inca-ltd.org.uk**

For further information about glazing and applied films, refer to the Glass and Glazing Federation: **www.ggf.org.uk**

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