Solid Wall Insulation: Best Practice and Innovation

Report for the Department of Business, Energy and Industrial Strategy

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Executive summary

This report compares the features of eight materials for solid wall insulation that are currently available on the market, and considers new methods for insulating walls that could increase take-up of wall insulation in future.

Context

Solid wall insulation (SWI) has been available as a possible energy efficiency upgrade for decades, but take-up remains very low. Around 7.7 million homes in Great Britain have un-insulated solid walls, so could in principle install internal or external wall insulation, but only around 3% have installed wall insulation so far (internal and external insulation combined).

There are barriers to installation from the cost and disruption of work, loss of internal space, changed appearance, low awareness of the options for wall insulation, and uncertainty about actual energy savings. As part of its work aimed at reducing carbon emissions, BEIS wishes to increase uptake of internal wall insulation (IWI), and to identify current and future innovations that could raise uptake.

Best Practice for SWI varies according to the building being insulated, the space available, the material(s) being used, and the budget available to carry out the work. Relatively recent concerns about moisture risks from insulating vapour-permeable traditional buildings with impermeable materials also divide opinion among experts and installers about which methods are appropriate. Some experts insist that only breathable materials should be used – either internally or externally – but the most common methods of carrying out SWI still use impermeable materials.

What materials are already on the market?

Interviews with 34 people working in the sector, and Internet and literature searches, identified eight materials currently available for SWI on the market, shown in Table 1 below. Four of these are commonly used for retrofit wall insulation in the UK: phenolic foam, polyurethane, poly-isocyanurate, and expanded polystyrene. (The first three are used mainly for internal wall insulation the fourth used mainly for external wall insulation, EWI.) The other four materials are less commonly used for retrofit wall insulation: vacuum-insulated panels and Aerogel because they remain expensive, and glass wool and wood fibre because they are not the conventional materials.

Table 1: Comparing costs and benefits of different insulation materials

Technology	Thermal conductivity (lambda, in W/mK)	Indicative cost per m^2 (materials only)	Indicative Cost for 3-bed semi-D (materials only)	Notes
Vacuum-insulated panels (VIPs)	0.007	£125	£14,375	VIPs cannot be cut on site and must be ordered to size. Gaps must be filled with other materials. Performance may suffer if they are pierced. They remain expensive because manufacture is expensive.
Aerogel	0.013	£100	£11,500	Aerogel is fragile and expensive to manufacture. It is favoured for small areas where thickness is important, like window reveals.
Phenolic foam	0.022	£17	£1,955	Rigid phenolic foam is used for internal and external insulation (e.g. in Kingspan boards). It offers better insulation than the same thickness of PUR or PIR, and good fire performance.
Polyurethane (PUR)	0.025	£16	£1,840	PUR can be sprayed or formed into boards. Untreated PUR is highly combustible, but most PUR is treated with fire retardant. How effective this is is contested.

Poly-isocyanurate (PIR)	0.025	£16	£1,840	PIR has better fire performance and lower combustibility than PUR. It is commonly used for IWI, including by Celotex, with a foil facing.
Expanded polystyrene (EPS)	0.03	£4	£460	EPS is commonly used in external wall insulation. Different specifications/thermal conductivities are available. EPS is flammable, although fire-retardant and encapsulation reduces fire hazard.
Glass wool	0.033	£5	£575	Glass wool is breathable/vapour permeable. It is less commonly used for retrofit wall insulation. It offers acoustic insulation as well as thermal. (Knauf use glass wool in their products.)
Wood fibre	0.039	£4	£460	Breathable (vapour-permeable), but needs a lime plaster and permeable paint on top to breath. (A lime plaster needs three coats, and takes longer to dry than modern plaster, so this may increase installation costs.)

Are better methods available?
There are much thinner methods of carrying out IWI using insulating paint, or Aerogel mixed with plaster (1 to 3mm thick). However, these have dramatically lower insulating performance (thermal resistance of 0.8 or 0.9 m^2K/W, or around a tenth of the improvement of 60mm of polyurethane). There are also insulating wallpapers like Sempatap (10mm thick), but this also has much lower insulating performance (thermal resistance of 0.98 m^2K/W, or about a fifth as good as PUR).

The thin insulation methods are cheaper and easier to install than conventional methods, but neither interviewees nor literature sources advocated them.

There are also volume methods of installing IWI: laser scanning to take measurements and pre-cutting insulation boards offsite. However, these have been stymied by insufficient demand.

There is also an innovative approach for applying EWI when a brick finish is needed, pioneered by Mauer UK. This also uses laser scanning, with prefabricated boards with a brick finish attached using a spacer to the outside of the wall. The cavity between boards and walls is then filled using insulating ‘thermabeads’. The big advantage of this method is that no wet trades are needed, reducing time on site and bringing costs down approximately 50%. So far, however, take-up of this method is very low.

Our interviews also uncovered a method of using pliable insulation material to cope with uneven walls – a common problem – which can be used internally or externally.

Are there pre-commercial methods that will become available soon?
Our work identified five pre-commercial methods for installing SWI. None of these can overcome the barriers facing SWI alone, or solve all of the technical challenges to provide a high-quality, low-cost solution for SWI. Development of new methods has been hit hard by low demand for wall insulation.

What can we learn from past innovation work?
Two strong messages emerged from interviews with innovators working on SWI. First, that innovations must address a commercial problem – where there is a market need that does not rely on government policy. There is evidence that many people will act to reduce energy use if the action they need to take is commensurate with the saving, like low cost/hassle/complexity of changing from incandescent to low energy light bulbs. This balance of costs against benefits does not appear to stack up for SWI at present.

Second, considerable effort and money is needed to commercialise an innovation. At present, it is hard to fund this commercialising activity in the UK.

Introduction

This project was conceived as a way to identify innovations relating to solid wall insulation - especially innovations that stand to reduce the cost of carrying out wall innovation, and/or accelerate the installation time for wall insulation, and/or to raise the quality of wall insulation. The innovation could be technical, or related to the method of delivery of the standards, and the motive for carrying out this research was to understand more about new technologies or business processes that could help to raise uptake of SWI.

Internal and external wall insulation have been available as a possible energy efficiency upgrades for decades, but take-up remains very low. Whereas around 7.7 million homes in Great Britain have un-insulated solid walls and could in principle install SWI, only around 3% have installed wall insulation so far (internal and external insulation combined). Around 144,000 homes with solid walls had either internal or external wall insulation installed from 2008 to July 2013, an average of 26,000 a year (DECC, 2013). Nearly all of these installations were funded or part-funded by Government schemes or energy companies. [1]

There are barriers to installation from the cost and disruption of work, loss of internal space (internal insulation), planning and visual impact (external insulation), low awareness of these upgrades, and uncertainty about actual energy savings. BEIS wishes to increase uptake of SWI, and to identify current and future innovations that could raise uptake.

However, there is little merit in increasing take-up if this brings the risk of poor quality or inappropriate installations that could undermine the performance of insulation and raise the risk of condensation and mould, and potentially damaging buildings. Cutting corners to reduce costs is not the answer and it is important to maintain best practice at the same time as overcoming barriers to uptake.

Current best practice sets the context for work on innovation: it defines how work should be carried out now. Innovations can build on this – improving either materials that are used or how they are applied. For the purposes of increasing uptake of SWI, useful innovations would achieve at least one of four things:

- Making it easier and/or faster to install SWI
- Making it more economical to install SWI (from savings in materials or installation)
- Allowing SWI in circumstances that would otherwise be impossible to insulate, and appropriate for the construction, current condition, local climate and building use
- Improving the in-use performance of SWI (i.e. lower heat loss, or better reduction of moisture risks).

This report starts with a description of our methods, and continues with concise responses to BEIS's research questions for the project, defined in the Invitation to Tender for this work.

Methods

We carried out interviews with 29 insulation manufacturers, installers, architects and specifiers of insulation products, asking about best practice and innovations relating to solid wall insulation – both technical innovations and new ways of providing insulation services. They were selected from CAR's existing contacts in the field of SWI, plus by carrying out online searches of SWI, IWI and EWI. We also interviewed five people working on innovation – in universities and R&D organisations, including Innovate UK, the UK Government's innovation agency. We also reviewed the literature about SWI, identifying and reading more than 50 publications referencing best practice and innovation.

[1] DECC (2013) Estimates of Home Insulation Levels in Great Britain: July 2013 (Experimental Statistics). London: DECC.

For the interviews, we developed three separate interview schedules, intended for three different types of interviewee:

1. Designers and installers (22)
2. Manufacturers (7)
3. Innovators and funding organisations (5)

These interview schedules are included as Appendices 1 to 3. Most of the interviews were conducted by telephone, and most took 20 to 40 minutes, depending how much interviewees had to say and particularly whether they had information relating to one or both types of wall insulation (internal and external). Six interviews were carried out face-to-face, where the interviewees were based in Cambridge or willing to travel to Cambridge to be interviewed, or where the interview took place at Ecobuild.

Our interviewees are listed in Appendix 4, and they included large manufacturers like BASF and YBS Insulation, national installers like Matilda's Planet and Retrofit UK, and small local installers and designers. Disappointingly, we were only able to identify and interview one innovator working at a university.

Interviewees were so heterogeneous that we would not suggest this is a 'representative' sample of innovators working on SWI. However, we carried out sufficient interviews with installers and designers (14 of the 29) to be confident that we have not omitted technologies that are in widespread use. Although there may be some low-profile innovations that have not so far gained exposure, we are also confident that we have identified all of the innovations that are already familiar to people working in the field.

For the literature review, we restricted searching to the 10-year period from 2007 to 2017. We searched Google, Google Scholar and Science Direct, using 15 search terms in different combinations, see Table 2 below.

Table 2: Search terms used for literature review

Solid wall	Insulation
Retrofit	Refurbishment
Internal wall insulation	External wall insulation
U-value	Heat loss
Innovative	New
State-of-the-art	Technologies
Materials	Processes
Evidence	

We graded each source from 1 to 5 according to the strength of evidence presented, and their potential impact on uptake of SWI. (For the strength of evidence, '5' means they described methods in full, and used rigorous methods with appropriate sample sizes, while '1' means they failed to describe methods, or the evidence presented does not support their conclusions. For potential impact, '5' means the innovation could result in 100,000s of additional insulation installs, while '1' means no impact on take-up.) In each case, we also summarised their findings and how they stand to increase uptake of SWI, in a searchable spreadsheet available here.

There was only a small number of sources addressing innovation and/or best practice in solid wall insulation. (We found more work addressing in-situ measurements of U-values, and work on insulation for new buildings which, although related, does not help to answer the questions of interest to the Department.) So we looked internationally for work – particularly in continental Europe and the US, where we found more evidence, but it was still mainly unrelated to specific innovations.

The number of hits against different combinations of search terms is shown in Table 3 below. Readers should note that the most successful search terms at the top of the table also brought a large number of distantly related work which, on inspection, brought little value to the study.

Table 3: Search terms used against hits	Number of Hits
evidence U-value technologies process insulation wall	2390
"heat loss" new U-value retrofit insulation	2260
evidence insulation U-value innovative heat loss	1350
refurbishment “solid wall” technologies heat loss insulation	1270
"Solid wall" Insulation U-value	480
innovation insulation retrofit installation “external wall insulation”	360
insulation “solid wall” retrofit “heat loss” U-value	232
retrofit “external wall insulation” innovative evidence	218
“external wall insulation” U-values refurbishment process	212
innovative technologies “internal wall insulation”	168
innovation insulation retrofit installation “internal wall insulation”	159
refurbishment U-values "solid walls" innovation	103
U-value State-of-the-art “external wall insulation” process	96
evidence U-value technologies “external wall insulation” State-of-the-art	43
U-value State-of-the-art “internal wall insulation” process	36

What is the current state of the art for IWI and EWI?

It is difficult to describe one-size-fits-all best practice that for SWI that applies to all properties because wall construction, materials, design, space and layouts all differ between properties. (PAS 2030, the Publically Available Specification for improving the energy efficiency of existing buildings, attempted to do this and the authors encountered difficulties.[2]) There are also context-specific trade-offs. For example, installing IWI reduces the floor area of rooms, and better U-values (measuring heat loss through the walls) often come at the expense of more lost floor space. Similarly, achieving better U-values with EWI means that more space is needed externally, which is not always feasible. Experts and installers also disagree about which methods constitute best practice – with particular disagreements about addressing moisture risks introduced when buildings are insulated.

Internal wall insulation

Accepting that experts disagree, and that different situations call for different solutions, *in most cases*, best practice IWI will include:

- Insulation material attached directly to the external wall, floor to ceiling, with boards abutting tightly and joints between boards and between the boards and floor, ceiling and other walls sealed
- Window reveals insulated with thinner, high performance insulant like Aerogel (see below)
- Plasterboard attached (or bonded) to the insulant, usually with a skim on top to conceal joints and provide extra strength against knocks

[2] BSI (2017) PAS 2030: 2017 - Specification for the installation of energy efficiency measures (EEM) in existing buildings. London: BSI.

- Radiators and hot water pipework moved away from the wall to allow space for insulation
- Electricity sockets and skirting boards re-located to the new surface of the wall, with insulation behind
- Internal walls connected to external walls insulated with a 150mm return to prevent thermal bridging through the internal walls

Ideally, the wall insulation is accompanied by floor and ceiling insulation to prevent thermal bridging and condensation at the junctions. There is some consensus that additional ventilation is also needed alongside insulation to reduce moisture risks. In areas prone to wind driven rain or where damp may be an issue, some installers recommend an air gap is created between the insulation and the wall using battens lined with a vapour barrier, to protect the insulation from damp.

External wall insulation

Again, accepting that experts disagree, and that different situations call for different solutions, *in most cases*, best practice EWI for impermeable (vapour closed) walls will include[3, 4]:

- Expanded polystyrene boards attached to the outer face of all external walls with adhesive and mechanical fixings
- Acrylic or silicate render or brick slips applied over the top of the polystyrene, on suitable scrim (reinforcement material) and basecoat layers
- High performance insulation materials on window/door reveals
- Continuous insulation, with all exposed edges of the insulation protected
- Where eaves do not cover the thickness of the insulation they are extended to protect the top of the EWI
- Appropriate strengthened fixings for satellite dishes, TV aerials, washing lines or other services that need to be attached to the wall

Best practice for vapour permeable walls is disputed, and although it is very common to install EWI following the points above, some experts say that only vapour permeable materials should be used: permeable insulation made from wood fibre or mineral wool, with permeable adhesives and finishes, including lime render. Most experts agree that extra ventilation is needed in most cases after EWI has been installed, to reduce moisture risks.

[3] CJ Pearson (2009) The Complete Guide to External Wall Insulation. York: Wellgarth Publishing.
[4] Rickaby Thompson Associates (unpublished) Viridian Housing Retrofit Specifications. Milton Keynes: Rickaby Thompson Associates.

What types of material are currently available for SWI in the UK?

The main forms of insulation currently available on the market have costs from £4 to £125 per m^2, with thermal conductivities (measuring how well they prevent heat loss, where lower is better) from 0.007 to 0.039 W/mK, see Table 5 below. There is some link between cost and performance (at present the technologies with the best performance, vacuum panels and aerogel, cost significantly more than other approaches).

Table 5: Comparing costs and benefits of different insulation materials

Technology	Thermal conductivity (lambda, in W/mK)*	Indicative cost per m^2 (materials only)**	Indicative Cost for 3-bed semi-D (materials only)***	Notes
Vacuum-insulated panels	0.007	£125	£14,375	VIPs cannot be cut on site and must be ordered to size. Gaps must be filled with other materials. Performance may suffer if they are pierced. They remain expensive because manufacture is expensive.
Aerogel	0.013	£100	£11,500	Aerogel is fragile and expensive to manufacture. It is favoured for small areas where thickness is important, like window reveals.
Phenolic foam	0.022	£17	£1,955	Rigid phenolic foam is used for internal and external insulation (e.g. in Kingspan boards). It offers better insulation than the same thickness of PUR or PIR, and good fire performance.
Polyurethane (PUR)	0.025	£16	£1,840	PUR can be sprayed or formed into boards. Untreated PUR is highly combustible, but most PUR is treated with fire retardant. How effective this is is contested.
Poly-isocyanurate (PIR)	0.025	£16	£1,840	PIR has better fire performance and lower combustibility than PUR. It is commonly used for IWI, including by Celotex, with a foil facing.
Expanded polystyrene (EPS, 30kg/m^2)	0.03	£4	£460	EPS is commonly used in external wall insulation. Different specifications/ thermal conductivities are available. EPS is flammable, although fire-retardant and encapsulation reduces fire hazard.
Glass/mineral wool (48 kg/m^2)	0.033	£5	£575	Glass or mineral wool materials are breathable/vapour permeable. They are less commonly used for retrofit wall insulation. They offer acoustic insulation as well as thermal. (Knauf use glass wool in their products.)
Wood fibre	0.039	£4	£460	Breathable (vapour-permeable) and hygroscopic (absorbs water vapour), but needs a lime plaster and permeable paint on top to breath. (A lime plaster needs three coats, and takes longer to dry than modern plaster, so this may increase installation costs.)

**Manufacturers' figures, not independently verified. **Costs exclude VAT. Indicative costs for a semi-D assume the external wall area is 115m²*.

These materials may be divided into four groups. First, high-cost and high-performance materials that require greater attention to detail during installation: vacuum-insulated panels and aerogel. These offer thermal performance that is two or three times better than the next best insulant of the same thickness, but they have to be used in combination with other materials (VIPs), or are delicate (aerogel). Second, impermeable materials made from petroleum products: phenolic foam, PIR, PUR and EPS. These offer broadly similar performance, and do not breathe, which is an important consideration for moisture control, see below. Third, permeable insulation materials: glass wool and mineral wool. These offer slightly inferior insulation performance with the same thickness, but they breathe and so potentially allow moisture to escape. Fourthly, hygroscopic materials such as wood fibre that absorb water vapour as well as allowing it to pass through.

Are there better approaches to IWI and EWI that are under-exploited due to low demand?

Internal wall insulation

Internet searching revealed several approaches to IWI that are uncommon, and not mentioned by interviewees or in the papers and reports we reviewed. Some of these were very thin forms of insulation (less than 1mm thick): thermal insulating paint and aerotherm (aerogel mixed with plaster). We calculated the thermal resistance at the recommended thicknesses of just 0.8 or 0.9 m^2K/W, which would make only a very small difference to the heat loss through a solid wall: around one tenth of the improvement from insulating with 60mm of PUR.[5]

Internet searches also led to Sempatap – insulating wallpaper, originally developed for sound insulation. This is 10mm thick, and made from latex with a fibre glass face. Again, this makes a much smaller difference to heat loss through a solid wall: around one fifth of the improvement from insulating with 60mm of PUR. [6] The manufacturers claim it is an effective treatment for rooms with condensation problems.

These products are cheaper than conventional materials to install (materials costs between £1,200 and £3,900 for materials, but much simpler and faster installation[7]) but they lead to only a modest improvement in the insulation of walls. This probably explains why none of the interviewees, papers or reports we reviewed referred to them.

Interviewees also identified two volume approaches for installing IWI: Matilda's Blanket and WHISCERS (the Whole House In-Situ Carbon and Energy Reduction Solution). These both involve laser scanning of rooms, offsite panel cutting, and fast, clean installation (1 day per room). However, both of these have been stymied by insufficient demand, and the company behind Matilda's Blanket ceased trading two weeks after we interviewed them.

Several interviewees discussed the difficulties of fitting rigid insulation to uneven walls. One solution is to use a board that is soft and pliable such as UdiRECO. (The same problem and solution applies to external insulation too.)

YBS Insulation, who manufacture SuperQuilt multi-foil insulation, said there is greater scope for using multi-foils for SWI, both internally and externally. SuperQuilt consists of 19 layers of wadding, aluminium foil and plastics foil, and needs an air gap, but they said it can achieve 0.3 W/m^2K, and it is cleaner and less disruptive on site than other insulation materials. It also costs only £6/m^2, excluding plasterboard, skim or decorating costs, and they said the installation costs vary according to the situation.

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[5] Two layers of thermal insulating paint with thickness of 254 microns calculated to improve solid wall U-value from 1.3 W/m^2K to 1.29 W/m^2K. Aerotherm applied 1mm thick calculated to improve solid wall U-value from 1.3 to 1.26 W/m^2K. In contrast, 60mm of PIR with 12.5mm of plasterboard on top calculated to improve solid wall U-value from 1.3 to 0.31 W/m^2K.

[6] 10mm of Sempatap calculated to improve solid wall U-value from 1.3 W/m^2K to 1.02 W/m^2K.

[7] Estimated materials costs for a three-bedroom semi-detached home: Synavax insulating paint £1,200; Aerotherm £2,500, Sempatap £3,900. Installation cost and time likely to be around half that of conventional insulation.

The low demand for internal wall insulation makes it hard for new techniques to build market share. The reasons for this low demand relative to external wall insulation include disruption for the householder during installation, as well as the loss of usable room space. Innovations can reduce these barriers but not avoid them altogether.

External wall insulation

Mauer UK has an innovative method of applying EWI for situations where a brick finish is needed. They use laser scanning to accurately measure the dimensions of a home before it is insulated, and deliver all materials to site, pre-cut to size and drilled for installation. They use tracks to attach their system at the top and bottom of the wall, with timber battens and a patented spacer attach facade boards and brick slips to the wall. Then they inject 'thermabeads' (like cavity wall insulation) behind the boards.

This avoids the need for wet trades (render) on site, which gives much more control over the timing of work and means that bad weather is no longer such an impediment to carrying out EWI. Mauer UK claim it is also faster to install, in any weather conditions, and 20m^2 can be installed in as little as an hour. Overall, they claim their system can reduce costs by approximately 50% compared to conventional EWI with a brick-slip finish: £6,000 compared to typical costs of £12,000 with brick slips (thin bricks hung outside the insulation, usually installed on site). However, only a handful of homes have been insulated to date because of limited demand for EWI.

Breathable insulation materials

A number of different interviewees expressed concern about using non-breathable materials for EWI – even though this is commonplace. Both interviewees and some literature sources noted concerns about humidity and mould resulting from EWI – especially in situations where:

- the original wall is breathable (i.e. where a non-cementitious, lime mortar is used, which is common for homes built before 1919), and/or
- where there is inadequate ventilation after the wall is insulated.

Many traditional buildings work by allowing the wall to absorb excess humidity, which evaporates off externally (in summer) or even internally (in winter). Some interviewees and literature sources claim that 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. Several interviewees said that the answer is to use breathable insulation materials (like those manufactured by NBT, Natural Building Technologies) finished using a lime render or weatherboard. Pavatherm, a wood-fibre product, is reported to be one suitable response. This should be installed with no cavity (so moisture can be carried to and through the board), and the lime render should have a waterproof coating that is vapour-permeable.

However, using NBT products is more expensive than standard EWI approaches (estimated extra cost £1500-£2000 more for an average semi-D), and more time-consuming on site because the wood-fibre products are harder to cut.

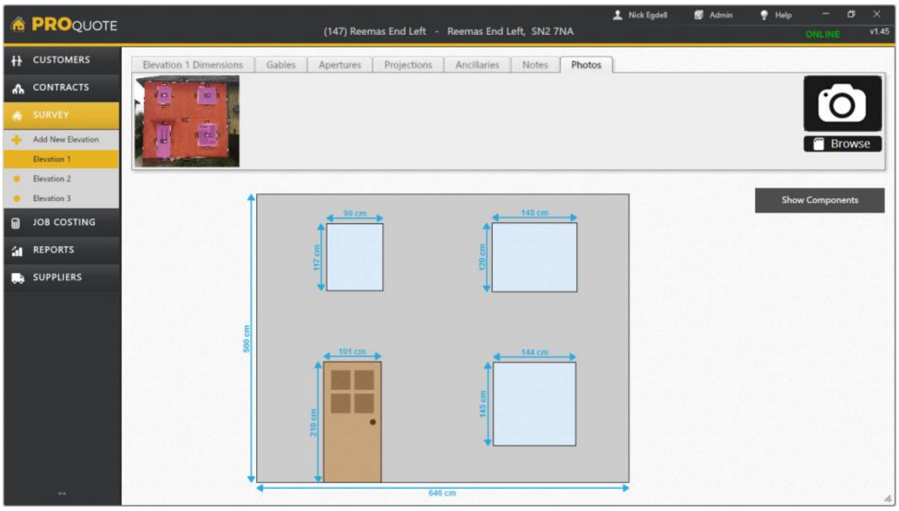
Further, the need to use breathable EWI materials is contested by conventional materials manufacturers (Kingspan, BASF, YBF Insulation and others), who claim there is no hard evidence of problems with non-breathable materials, when they are properly detailed and installed.

Aluminium verge trims

Specialist installer EWI-Pro has its own, innovative method of installing verge trims at the top of the insulation. Whereas most installers use silicon to fix verges, EWI-Pro avoid this. Over time, silicon sealant can fail and result in water collecting against back wall and seeping in behind the cladding. When this water freezes it can push cladding away from wall. Instead, EWI-Pro uses an aluminium strip fixed directly to the wall, behind the cladding. They buy in aluminium for the verge, which they fold on site to an optimum profile. That is then fixed to the aluminium strip, thus avoiding any silicon use.

New business processes for EWI

Procost Solutions have developed software to turn photographs into dimensions data for ordering EWI materials, also to track progress on a portfolio of EWI projects, and to share information and communicate between team members. (Screenshot of the online tool to turn photographs into dimensions and an order kit is shown below.) Increased demand for EWI would boost uptake and use of this software, and other similar tools to accelerate EWI work.



What materials or techniques are at the pre-commercial stage of development?

Q-bot and others received funding from Innovate UK to develop a robot arm to scan walls and apply external wall insulation. They saw this as an opportunity to help to reduce labour costs for installing EWI and at the same time improve site quality. They completed a feasibility study/proof of concept, including developing computer routines to cater for the enormous variation between existing homes, and they were able to carry out a lab-based demonstration, insulating a 1m^2 wall. However, the system was still a long way from being a commercial product, and problems linked to impermeable insulation materials surfaced while the project was underway (see 'What effect does SWI have on moisture problems in walls?' below). This led Q-bot to rethink its choice of materials (originally poly-eurethane, an impermeable material), and carry out further research of materials before doing any additional robotics development.

EnvirUp, identified by Innovate UK, is developing a composite uPVC panel, pre-filled with insulation, that can be used for EWI. This should possible to install in all weathers, by less skilled installers than are currently needed for EWI.

Innovate UK also identified the S-IMPLER (Solid Wall Innovative Insulation and Monitoring Processes using Lean Energy Efficient Retrofit), aiming at a low-cost solution for Wimpey No-Fines homes (in-situ cast concrete wall homes). However, there have been no updates on the S-IMPLER website since October 2014, suggesting development has stalled.

Foam-Build uses a nano-cellular foam to achieve low conductivity. It is halogen free and incorporates flame retardants. The thermal conductivity (lambda) is 0.02 W/mK, which is slightly better than Celotex (0.021 W/mK) but not quite as good as Kingspan K118 boards (0.018 W/mK). It is applied as mortar, using a special nozzle which reduces waste.

Foam-Build is already available in Germany, from DAW (Deutsche Amphibolin-Werke). The UK manufacturer, Smithers Rapra, is involved in the European research project to develop the material, and it should be available in the UK later this year. Smithers Rapra said it is easy to install, and can be used in cold weather – which often precludes the use of alternative insulated renders.

Foam-Build incorporates a moisture monitoring and control system to keep the external surface dry and reduce algae growth, extending the life of the façade. The control system also links with the building ventilation system to blow air through the foam system when necessary.

Very cold weather makes EWI much harder because most renders cannot be applied when the temperature is below 5°C. This creates logistical complications and can push up costs – particularly because scaffolding is usually needed, and unpredictable weather may mean multiple visits to site before going ahead with the render. InstaGroup said their All-Weather EWI rail system should mean they can install EWI even in bad weather. This uses calcium silicate board and render is currently under development and may be available soon.

What materials or techniques need early stage funding for basic research?

Our review work and interviews uncovered few materials or techniques requiring funding for basic research. Essentially there just two areas mentioned by interviewees requiring more research in relation to insulation materials: first, the long-term effect of using impermeable insulation materials on traditional, solid brick-built homes; and second, what new materials could offer good insulation values while at the same time being water permeable.

The first area was not described in detail, apart from several interviewees noting that there is no published research examining the long-term performance of internal or external wall insulation on large numbers of homes. The second area – new materials for SWI – was described in more detail by Tom Lipinski of the robotics innovations company q-bot. Mr Lipinksi explained that when evidence emerged about the unintended consequences of installing impermeable SWI on traditional buildings, q-bot put the SWI delivery system on pause. They focused instead on identifying airtight but permeable insulation materials that could be sprayed using robotics. They have completed a simple feasibility study of alternative materials, and they are seeking funding to do more comprehensive feasibility work. They will return to the delivery system if and when they find a suitable material.

Mr Lipinksi also proposed a third subject area requiring more basic research: robotic vision to carry out improved surveying of buildings. He said that ‘hyperspectral imaging’ (extending cameras to cover a wider range of the electromagnetic spectrum – not just visible light) could allow robots to identify different building materials and distinguish between glass, wood, steel, bricks, and other building materials. If this were linked to huge computing power, this type of survey could open up the possibility of expert systems that would recommend whole house retrofit upgrades – not just for wall insulation, but how to optimise different techniques for improving energy efficiency.

What are the benefits and drawbacks of the materials and techniques identified here?

Table 6, below, summarises advantages and disadvantages of each of the materials and techniques included in this report.

Table 6: Benefits and drawbacks of different insulation materials

INTERNAL OR EXTERNAL INSULATION		
Technology	Advantages	Disadvantages
Vacuum insulated panels	Thin insulation with better claimed insulation value (thermal resistance) than any other material.	Cannot be cut to size – available in a range of sizes. Expensive (more than six times the cost of conventional insulation boards).
Aerogel	Thinner insulation, good for small areas such as window reveals.	Expensive, fragile
Phenolic/PIR/PUR boards	Familiar, tried-and-tested materials available in different thicknesses.	Questionable fire performance with PUR boards.
Blown PUR foam	Good for uneven walls.	Specialist contractor needed.
Glass or mineral wool	Inexpensive, familiar product. Breathable and low flammability.	Liable to slumping, creating cold bridges. (Not commonly used for retrofit wall insulation.)
Wood fibre	Breathable, hygroscopic and more robust than other insulation products. Economical.	Somewhat lower insulation value than other materials (thermal conductivity is roughly one third higher).
Multifoil	Fast installation with low mess. Inexpensive.	Only available in one thickness (40mm plus air gap).
INTERNAL INSULATION		
Technology	Advantages	Disadvantages
WHISCERS [prefabricated panels allowing fast install]	Fast installation, cut to fit offsite so low mess.	Requires board cutter.
Matilda's Blanket [prefabricated panels and tracking allowing fast install]	Fast installation: 1 day per room.	Higher materials cost. [Company has now stopped trading.]
AeroTherm	Very thin (1mm), straightforward installation.	Makes only a small difference to heat loss through a wall and does not achieve 0.3 W/m^2K mandated for ECO support.
Insulating paint	Very thin (0.5mm), straightforward installation	Hardly any difference to heat loss through a wall and does not achieve 0.3 W/m^2K mandated for ECO support .

EXTERNAL INSULATION		
Technology	Advantages	Disadvantages
Mauer UK system	Fast installation in any weather. Matches any brick finish, at much lower cost than brick slips. No wet trades needed.	Specialist installation skills needed.
Expanded polystyrene	Inexpensive, available in different grades, and with fire retardant. Familiar product.	Even with fire retardant some fire hazard remains.
Procost Solutions software	Faster and simpler ordering of EWI materials, simpler sharing of information.	Additional cost

What effect does SWI have on moisture problems in walls?

Several interviewees and sources from the literature review mentioned unintended consequences from insulating walls – especially linked to condensation and moisture in walls. Traditional masonry wall construction relied on lime mortars in the UK until at least 1919. These lime mortars are vapour-permeable ("breathable"), allowing water vapour to pass through the wall from inside to outside. This means that many solid wall properties still have lime mortar, although some have been replaced or re-pointed with modern, cementitious mortar that is impermeable to water.

If the external walls have lime mortar joints, there is a case (disputed by some) for using only vapour-permeable insulation, such as insulation made from wood fibre. This needs a vapour-permeable adhesive and plasterboard. Any impermeable finishes also need to be removed from the inner surface of the wall before work starts. The rationale is that many traditional buildings were intended to wick and shed moisture internally as well as externally – especially in winter. If an impermeable barrier prevents moisture from passing through the wall, according to the Sustainable Traditional Buildings Alliance (2013), there is a risk of moisture and mould growth between layers of the wall construction, where the old wall meets the impermeable barrier.[8] It is held that this happens with either internal or external wall insulation, but it is worse post-insulation with IWI because the original wall is colder, so less likely to dry out. There is also a greater risk of frost damage because the colder, wetter wall is more likely to freeze in very cold periods. (Three installers we spoke to insist on always using breathable insulation. They said it costs more than using PIR (poly-isocyanurate) boards – typical total installed cost are £120-£140 per m^2.)

[8] Valentina Marincioni & Chris Sanders (2013) Internal Insulation of solid masonry walls – practical limits due to thermal bridging and moisture performance. London: Sustainable Traditional Buildings Alliance.

What gaps and opportunities might innovation address?

The biggest opportunity remains the roughly 7.7 million UK homes with un-insulated solid walls. This represents both an opportunity to reduce carbon emissions and energy use, and also a commercial opportunity. Many interviewees mentioned difficulties in justifying the cost of SWI – particularly when householders are unsure whether they will remain in their homes long enough to recoup the investment. They also mentioned problems of ensuring high quality of wall insulation – exacerbated by attempts to reduce costs on site.

There is currently no simple or single answer for how to insulate walls at low cost, with high quality, and simultaneously avoid the risk of unintended consequences (and particularly moisture risks). Nor is there a simple answer in prospect. However, interviewees identified a number of contributory innovations that would be helpful small steps.

Kingspan Insulation suggested two possible innovations for EWI. First, a way of insulating utilities boxes (gas or electricity boxes) commonly mounted on the front facade of homes. (Also suggested by Tim Acheson, Green Hat Construction, an SWI installer.) These can only be moved by Transco (gas) or the district network operator (electricity), which costs around £500 and requires two visits. A meter box could be designed with insulation behind it so that only one visit is needed. Or perhaps the box itself could be insulated on all sides so there is minimal heat loss from the box to outside.

Secondly, Kingspan said that renders used to finish EWI are messy, and installers commonly use a damp-proof membrane or similar on driveways to catch any render that does not adhere to the wall. A render could be formulated to create less mess, or that is easier to clean up. (CAR's suggestion – perhaps a more accurate method of applying render to the wall would help – so there is no excess render applied to fall to the floor.)

Andrew Champ of SWIGA, the Solid Wall Insulation Guarantee Association, suggested developing a reliable solution to extending roof lines would be a very useful innovation for EWI. In his view, using verge trims (PVC extensions to roofs to cover the increased thickness of EWI, which is a common economical way to extend roofs over insulation material, widely used under the Green Deal) is 'a claim waiting to happen'.

CAR's past work on EWI suggests that other beneficial innovations include a way to extend iron soil stacks (flues for toilets that often go out through external walls). These cannot easily be extended, so often need to be replaced with new PVC (polyvinyl chloride) soil stacks. Similarly, it is often impossible to obtain flue extensions for old boilers, so old boilers are often replaced even though they still function properly.

More economical ways to manufacture Aerogels and VIPs would also be very helpful in bringing down the cost of both internal and external wall insulation – especially if the saving allows more on-site attention and brings higher quality installation.

What can we learn from past innovation projects?

Interviewees found it hard to stand back and summarise the learning from past innovation work. However, they collectively identified four issues that make innovation for SWI more difficult.

1. Innovation must address a commercial problem

Some past innovation projects have been geared to meeting legislation (like the Code for Sustainable Homes), which can change. If the only driver for using the innovation is from legislation, the innovator is vulnerable to changing political priorities, and the intended market may disappear.

2. Standards that are too rigid can stifle innovation

The rigid requirement in the old Green Deal and the Energy Company Obligation to achieve a U-value of 0.3 W/m^2K meant that there was no incentive to go beyond this insulation value, and simultaneously that there was no financial support for improvements in insulation that do not achieve 0.3 W/m^2K. This precludes thin wall insulation, which may be appropriate in some situations (and potentially better at avoiding unintended consequences).

3. Government support emphasises technology innovations over process innovations

There is a major opportunity to carry out area-wide retrofit work that could bring cost savings and improved site quality. For example, in actively trying to recruit other households on an estate where one house signs up for improvements. (If one house in a street is suitable for wall insulation, it is likely that other houses will be too.) This could reduce inspection or assessment costs, and could also bring savings in logistics, scaffolding and travel costs for contractors. However, it is hard to get funding for this type of innovation.

4. Lost floor space can cost as much as the capital cost of IWI

In some parts of the country floor space is at a premium and this adds to the perceived cost of IWI. For example in parts of London house prices can be £6,000-£10,000 or even more per square metre.[9] This means the floor space taken up by 100mm of internal insulation on a wall 4m long is worth £2,400 to £4,000 - more than the cost of insulating one room. Thinner insulation would reduce this barrier.

Conclusions

Although there are recent innovations for SWI now commercially available on the UK market, none of them has achieved wide uptake so far. Conventional IWI using blown polymer insulation boards remains by far the most common approach, with expanded polystyrene plus render the most common approach for EWI – possibly because of conservatism in the construction supply chain. Demand for both forms of wall insulation remains weak, partly because of uncertainties about what to do, potential energy savings, and the uncertainty about continued financial support for IWI given changes to the Energy Company Obligation and the end of the Green Deal Home Improvement Fund.

There remains limited evidence about the long-term risk of humidity, condensation and mould growth behind IWI. At present it is very common to insulate with impermeable boards both internally and externally, which may be storing up problems for the future.

Approximately one third of the installers we spoke to expressed a strong preference for hygroscopic insulation boards, like Pavadry, made from wood fibre (and in some cases they insist on only using this).

[9] See https://www.findproperly.co.uk/price-per-square-foot.php#.WTVf9hPytwc

Cost is only one of a number of barriers to increased take-up of IWI. Hassle factors and uncertainty about quality and what type of insulation to use are also impediments, but even these may be less important than the simple point that people have other priorities, and many people living in solid wall homes have not thought about insulating their walls. Even those who have may have been deterred by not wishing to sacrifice space or cover up historical decorative surfaces

Easy and economical access to thinner insulation materials would probably make a difference to take-up. However, there is no simple formula to dictate whether householders or even social landlords will decide to insulate their walls. Like the decision to buy a new car or install a new kitchen, economics are only part of the equation.

Nevertheless, there are some innovations identified in this report that may help to increase uptake of SWI. These include:

- More economical ways to manufacture Aerogels
- More economical production of nano-insulated plaster
- More economical ways to manufacture VIPs
- Fast and accurate ways to measure walls and cut insulation boards to fit
- Flexible finishes that can be moulded around uneven walls (which could include pliable boards or foam/bead fill)
- More durable verge trim systems for protecting the top of walls
- A system for moving and insulating behind meter cupboards on external walls that requires only one visit by a Gas Safe engineer.

Appendix 1: Interview schedule for designers and installers

	INTERVIEW 1 (DESIGNERS & INSTALLERS)
	We are under contract to the Government's Department for Business, Energy & Industrial Strategy (which used to be called DECC). The Department is exploring how to help support new ways of providing wall insulation. They want to get a better understanding of best practice on solid wall insulation. They also want to know more about future innovations - either technical innovations or new business practices. This will go into a report, to be published on the government website, GOV.UK. You can answer anonymously if you prefer, or we can name your firm as one of the firms that helped with this. If you wish to say anything commercially sensitive that should not go in the published report, tell us, and we will record this separately. It normally takes about 20 minutes. We may not need answers to all questions, and you may be able to help us prioritise the questions so we cover the most important ones.
1	Can you tell me about your company? - size - specialisms - main sectors (housing, commercial, other) - anything unusual
2	What types of insulation do you install?
3	Do you do any other energy efficiency work?

4	**Internal Solid Wall Insulation - Current state of the art**
4.1	Let me confirm that you do internal wall insulation (IWI).
4.2	The Department is most interested in aspects of wall insulation that could increase take up, and any features of your work that could make IWI more attractive to building owners. What materials and products do you normally use? (Please consider fixings and finishings as well as the insulation itself, if you think they are important).
4.3	How do these materials perform in terms of: - installation time - reliability and durability - the range of applications where they are suitable - moisture management - reducing heat loss, or - total installation cost?
4.4	Please tell us more about this. [If cost, ideally figures on cost/building, cost/sq m, and/or cost compared to standard practice]
4.5	Do your current methods go beyond normal practice in any way?
4.6	What other factors are important in determining installation time, costs and quality?

4.7	Are there any aspects of your business processes, or the way you find buildings to insulate, or how you fund your work, that go beyond normal practice in IWI? (Please describe)
5	**Internal Solid Wall Insulation - Future practice**
5.1	Are you planning to use different materials and products in the future?
5.2	Do you have any innovative techniques for installing IWI planned for the future?
5.3	Do you have any innovative business processes for installing IWI planned for the future?
5.4	How do you expect the innovative techniques or business processes to affect installation costs?
5.5	Do you know of any such innovations planned by other organisations working on IWI? (Can you provide contact details?)

6	**External Solid Wall Insulation - Current practice**
6.1	Let me confirm that you do external wall insulation (EWI) - normally by attaching insulation to the outside of walls, and rendering over the top, right?
6.2	Again, the Department is most interested in aspects of wall insulation that could increase take up, and any features of your work that could make EWI more attractive to building owners. What products do you prefer to use? (Please tell us about fixings and products for window reveals, sills, eaves, and extensions as well as the insulation itself, if you think these are important)
6.4	How do these perform in terms of: - installation time - reliability and durability - the range of applications where it is suitable - moisture management - reducing heat loss, or - lower total installation cost?
6.5	Please tell us more about this. [If cost, ideally cost/building, cost/sq m, and/or cost compared to standard practice]
6.6	Do your current methods go beyond normal practice in any way?
6.7	What other factors are important in determining installation time, costs and quality?
6.8	Are there any aspects of your business processes, or the way you find buildings to insulate, or how you fund your work, that go beyond normal practice in IWI? (Please describe)

7	**External Solid Wall Insulation - Future practice**
7.1	Are you planning to use different materials and products in the future?
7.2	Do you have any innovative techniques for installing EWI planned for the future?
7.3	Do you have any innovative business processes for installing EWI planned for the future?
7.4	How do you expect the innovative techniques or business processes to affect installation costs?

7.5 Do you know of any innovations planned by other organisations working on EWI? (Can you provide contact details?)

8 ARE THERE ANY OTHER COMMENTS YOU WOULD LIKE TO MAKE?

Appendix 2: Interview schedule for manufacturers

	INTERVIEW 2 (MANUFACTURERS)
	Introduction: 'I'm calling from Cambridge Architectural Research to ask you about work on retrofitting solid wall insulation in buildings. This is for the Government's Department for Business, Energy & Industrial Strategy (which used to be called DECC). The Department is considering setting up an Innovation Fund to help support new ways of providing wall insulation. They want to get a better understanding of best practice on solid wall insulation. They also want to know more about future innovations on wall insulation - either technical innovations or new business practices. This will go into a report, to be published on the government website, GOV.UK. You can answer anonymously if you prefer, or we can name your firm as one of the firms that helped with this. If you wish to say anything commercially sensitive that should not go in the published report, tell us, and we will record this separately. Are you the right person to ask about this?[If not, record who is, and take a number] It normally takes about 20 minutes, and we can go through the questions now or another time if that's more convenient for you [record when]. [Record whether they want to be anonymous or named in the report]
1	Can you tell me about your company/organisation? - Size, - specialisms

	About your work
2	We are interested in projects you are involved in or have been recently related to solid wall insulation. This could be about insulation materials or products (including associated fixings and finishings), new processes or new business models. Have you done or are you doing any work that might help improve uptake of solid wall insulation? How? For example BEIS is interested in: Thinner insulation Reducing material costs Reducing installation time Other cost savings Moisture management Improving reliability or durabiity

	Will your work bring these or other benefits? (Please describe.)
3	The Department is also particularly interested in new ways of providing insulation, and new business models. (Including new technologies for surveying or designing insulation.) Does your work touch on these aspects? (Please describe.)
4	How is your research/development funded?
5	Who else is involved?
6	At what stage is this innovation at? (Concept stage, lab testing, field testing, or available on the market)
7	If you had more funding, what else would you do? How much funding would you need, roughly?

	Gap analysis
8	Do you know of other research/development going on this area? (What?, who?, how to contact).
9	What do you think are the most important issues restricting solid wall insulation take-up right now?
10	Do you know of other research that addresses these issues?
	If yes, please tell us about them (what, who, how to contact). If no, please tell us who might be interested in doing this? (Who, how to contact)

	Other comments
11	ARE THERE ANY OTHER COMMENTS YOU WOULD LIKE TO MAKE? [record]

Appendix 3: Interview schedule for innovators and academics

	INTERVIEW 3 (INNOVATORS/ACADEMICS)
	Introduction: 'I'm calling from Cambridge Architectural Research to ask you about work on retrofitting solid wall insulation in buildings. This is for the Government's Department for Business, Energy & Industrial Strategy (which used to be called DECC). The Department is considering setting up an Innovation Fund to help support new ways of providing wall insulation. They want to get a better understanding of best practice on solid wall insulation. They also want to know more about future innovations on wall insulation - either technical innovations or new business practices. This will go into a report, to be published on the government website, GOV.UK. You can answer anonymously if you prefer, or we can name your firm as one of the firms that helped with this. If you wish to say anything commercially sensitive that should not go in the published report, tell us, and we will record this separately. Are you the right person to ask about this?[If not, record who is, and take a number] It normally takes about 20 minutes, and we can go through the questions now or another time if that's more convenient for you [record when].
1	Can you tell me about your company/organisation? - Size, - specialisms

	About your work
2	We are interested in projects you are involved in or have been recently related to solid wall insulation. This could be about insulation materials or products (including associated fixings and finishings), new processes or new business models. Have you done or are you doing any work that might help improve uptake of solid wall insulation? How? For example BEIS is interested in: Thinner insulation Reducing material costs Reducing installation time Other cost savings Moisture management Improving reliability or durabiity Will your work bring these or other benefits? (Please describe.)
3	The Department is also particularly interested in new ways of providing insulation, and new business models. (Including new technologies for surveying or designing insulation.) Does your work touch on these aspects? (Please describe.)
4	How is your research/development funded?

5	Who else is involved?
6	At what stage is this innovation at? (Concept stage, lab testing, field testing, or available on the market)
7	If you had more funding, what else would you do? How much funding would you need, roughly?
	Gap analysis
8	Do you know of other research/development going on this area? (What?, who?, how to contact).
9	What do you think are the most important issues restricting solid wall insulation take-up right now?
10	Do you know of other research that addresses these issues?
	If yes, please tell us about them (what, who, how to contact). If no, please tell us who might be interested in doing this? (Who, how to contact)
	Other comments
11	ARE THERE ANY OTHER COMMENTS YOU WOULD LIKE TO MAKE? [record]

Appendix 4: List of interviewees

Name	Company	External wall insulation	Internal wall insulation
Daniel Jay	Mauer UK	Y	N
Tom Lipinski	q-bot	Y	N
Nick Egdell	ProCost Solutions	Y	N
Andrew Champ	SWIGA	Y	N
Two Anonymous interviewees	Celotex Ltd	Y	Y
Suzanne Johnston	Smithers Rapra, collaborating in Foam-build	Y	N
Sofie Pelsmakers	Sheffield University	Y	N
Matthew Evens, Matthew Ball, Jonathon Ducker	Kingspan	Y	Y
Yangang Xing	Cardiff University	Y	Y
Tim Acheson	Green Hat Construction	Y	Y
Jim Ross	Caroe Architecture	Y	Y
Anne Cooper	AC Architects	Y	Y
Nigel Gervis	Ty Mawr Lime Ltd	Y	Y
James Alcock	The Greenage	N	Y
Anonymous	Architect, AECB CarbonLite Retrofit training, Energy Assessor	Y	N
Stuart Roberts	SD Roberts Plastering, Warwickshire	N	Y
Patrick McCool	Make My Home Green	N	Y
Andrei Tartza	Pioneer Wall Cladding and Building Insulation Ltd	Y	Y
Charlotte Knott	Rockwarm	Y	Y
Peter Dunsby	ECO Matters	Y	Y
Nick Lloyd	Urbane-eco	Y	Y
Nick Miles	EWI-Pro	Y	N
Terry Evans	InstaGroup	Y	Y

Matthew McKnight	Therm-eco EWI Ltd	Y	N
Nick Stevens	Retrofit UK	Y	N
Simon Hart	Innovate UK	Y	N
Rick Holland	Innovate UK	Y	Y
Chris Boardman	Back to Earth	Y	Y