NSAI

Standard Recommendation S.R. 54:2014

Code of practice for the energy efficient retrofit of dwellings

S.R.54:2014

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Foreword & Introduction

Foreword

This Standard Recommendation (S.R.) has been developed by the Department of the Environment, Community and Local Government (DECLG), Department of Communications Energy and Natural Resources (DCENR), Sustainable Energy Authority of Ireland (SEAI) and the National Standards Authority of Ireland (NSAI) in conjunction with the Building Research Establishment (BRE) to provide guidance for the energy retrofit of dwellings.

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The energy upgrade or retrofit of a dwelling will reduce energy consumption and costs, increase occupant comfort and reduce harmful greenhouse gas emissions. It also makes an important contribution to meeting climate change targets as 25 % of energy use occurs in dwellings. EU Directives and National Regulations promote energy efficiency in existing buildings. These include:

— The Recast Energy Performance of Buildings Directive;

— The Energy Efficiency Directive; and

— Part L of the Building Regulations.

In line with international standards practice the decimal point is shown as a comma (,) throughout this document.

For clarity where 2D diagrams are used they are colour coded to differentiate between new and existing materials i.e. existing construction in black and white, retrofit measures are in colour.

Introduction

The intended users for this S.R. are designers, specifiers, installers and property managers working on energy efficient retrofit projects for dwellings. The technical detail provided assumes that those using this S.R. have appropriate qualifications and experience of working on retrofit projects.

This S.R. provides technical guidance on the energy efficient retrofit of the building fabric and services, the application of retrofit measures on a whole dwelling basis, general building science and the management of retrofit projects.

The building fabric and services clauses have the following structure:

— typical existing construction and installations;

— appropriate retrofit measures;

— detailed design issues for each retrofit measure to be considered;

— detailed installation measures for each retrofit measure.

It is intended that the designer and/or installer should be able to refer to the relevant technical section of this S.R. associated with the building fabric or services being retrofitted. This S.R. takes a holistic approach to dwelling retrofit, the guidance considers the effects of the various measures on the existing construction and overall energy use.

The 'Planning a Retrofit' section describes the improvement in energy performance when these measures are applied on a whole dwelling basis to typical dwellings. Example case studies of improvements to typical dwellings are also provided.

The 'Building Science' section provides general information on the principles of building physics. This is intended to refresh/inform the reader on basic principles of building physics applicable to retrofit where they may not have had need to use them in the recent past or where they are not specific to the user's own discipline.

The materials, methods of construction, standards and other specifications (including technical specifications) that are referred to in this S.R. are those which are likely to be suitable for the purposes of an energy efficient retrofit.

However, the adoption of an approach other than that outlined in this S.R. is not precluded provided that equivalent performance is demonstrated and approved in all aspects.

The development of this S.R. is based on the most recent Standards and technical guidance.

The management of retrofit works will take many forms, from single tasks to a complete upgrade by a main contractor under a single contract. This S.R. also provides guidance on managing retrofit projects.

Supporting Technical Guidance Documents may also be found on DECLG website in the Building Standards section. Further guidance can also be found on the SEAI website and NSAI Agrément website.

1. Scope

1. Scope

The scope of this Standard Recommendation addresses the energy retrofit of the building fabric and services of detached, semi-detached and terraced dwellings of not more than three stories. The main purpose of this S.R. is to provide technical guidance on the design and installation of retrofit measures to improve energy efficiency while: -

- maintaining the fire safety performance of dwellings;
- ensuring structural integrity and acoustic performance;
- maintaining healthy internal environments;
- controlling the movement of moisture.

The S.R. addresses the following points:

- retrofit measures that are suitable for typical forms of construction in Irish dwellings;
- an explanation of building science relevant to retrofit;
- good practice for building fabric measures;
- good practice for building services measures.

Whilst the scope of this S.R. is intended for dwellings some aspects of this S.R. may be applied to other buildings as appropriate.

This S.R. does not apply to works to an existing building which is a “protected structure” or a “proposed protected structure” within the meaning of the Planning and Development Act 2000 (No. 30 of 2000) and traditional buildings.

The guidance in this S.R. may not be appropriate for dwellings which, although not protected structures or proposed protected structures, may be of architectural or historical interest.

Some traditional buildings perform and respond to the outside/inside environment differently from more modern/mid-to-late 20th Century buildings.

In general this S.R. does not provide guidance on the use of renewable energy sources in retrofit projects.

NOTE Further guidance on suitable energy efficient retrofit measures for traditional and historic buildings is contained in ‘Energy Efficiency in Traditional Buildings’, DEHLG.

2. Normative references

2. Normative References

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

2.1 Standards

I.S. 813:2014, *Domestic gas installations*

ETCI ET 101:2008 *National Rules for Electrical Installations 4th Edition*

BS 5250:2011, *Code of practice for control of condensation in buildings*

BS 5410-1:1997, *Code of Practice for oil firing - Part 1. Installations up to 45kW output capacity for space heating and hot water supply purposes*

BRE 443, 2007, *U-value calculator*

BRE 228, 1979, *Estimation of thermal and moisture movements and stresses: part 3*

BRE 262, 2002, *Thermal insulation: avoiding risks*

BRE IP 21/92, 1992, *Spillage of flue gases from open-flued combustion appliances*

BRE IP 7/94, 1994, *Spillage of flue gases from solid-fuel combustion appliances*

CIBSE, 2010, *Domestic heating design guide*

Energy Saving Trust (EST) CE 54: 2010, *Whole house boiler sizing method for houses and flats*

SEAI, 2009, *Domestic Energy Assessment Procedure* (DEAP), (www.seai.ie)

SEI, 2011, *Heating and domestic hot water systems for dwellings – Achieving compliance with Part L*

2.2 Building Regulations / Technical Guidance Documents

Technical Guidance Document B, *Fire Safety*, DECLG

Technical Guidance Document F, *Ventilation*, DECLG

Technical Guidance Document G, *Hygiene*, DECLG

Technical Guidance Document J, *Heat Producing Appliances*, DECLG

Technical Guidance Document L, *Conservation of Fuel and Energy*, DECLG

3. Terms & definitions

3. Terms and definitions

For the purposes of this S.R., the following definitions apply:

air permeability
physical property used to measure the airtightness of the building fabric. It is defined as air leakage in metres cubed per hour per square metre of envelope area ($m^3/hr/m^2$) at a test reference pressure difference across the building envelope of 50 Pascals (Pa). The envelope area of the building, or measured part of the building, is the total area of all floors, walls and ceilings bordering the internal volume subject to the test. This includes walls and floors below external ground level

automatic bypass valve
valve that controls water flow in accordance with the water pressure across it and is used to maintain a minimum flow rate through the boiler and to limit circulation pressure when alternative water paths are closed

balanced flue
room sealed appliance which draws its combustion air from a point adjacent to the point at which the combustion products are discharged, the inlet and outlet being so disposed that wind effects are substantially balanced

back boiler unit (BBU)
boiler designed to fit directly into a fireplace or stove

boiler compartment
enclosure specifically designed or adapted to house one or more boilers and which is not a habitable space

boiler interlock
arrangement of the system controls (room thermostats, programmable room thermostats, cylinder thermostats, programmers and time switches) so as to ensure that the boiler does not fire when there is no demand for heat

Note 1 to entry: It is not a physical device.

closed appliance
appliance in which the combustion is not open to the room air and therefore air supply can be controlled

colour appearance
metric used to characterise the colour appearance of the light emitted by a light source is the colour temperature, expressed in Kelvin (K)

colour rendering
ability of different light sources to render colours accurately, expressed by the colour rendering index (Ra) with values from 0 to 100 with an Ra of 100 being ideal

combi boiler
boiler designed to provide central heating and domestic hot water without the need for additional secondary (hot water) storage

communicating thermostatic radiator valve
thermostatic radiator valve (TRV) with the capability to respond to commands from a central controller

condensing appliance
boiler designed to make use of the latent heat released by the condensation of water vapour in the combustion flue products. The boiler should allow the condensate to leave the heat exchanger in liquid form by way of a condensate drain

control gear
equipment required in operating fluorescent lamps and LED lamps, where ballasts start and control the current through fluorescent lamps and drivers convert mains power into the current and voltage required by LED lamps maintaining the required intensity and colour of light during operation

cylinder thermostat
thermostat that measures the temperature of the hot water cylinder and switches the water heating supply on and off

decorative fuel-effect fire (DFE)
appliance whose function is primarily aesthetic, being designed to simulate an open solid fuel fire and which is intended to be installed within an open fireplace, so that the products of combustion pass unrestricted to the chimney or flue

direct hot water system
hot water system in which the water supply to the draw-off points is heated directly by a boiler without the use of a calorifier or heat exchanger

directional indoor lighting
lighting of particular zones or objects within a larger indoor area, by the use of directional lamps which incorporate reflectors that direct and control the light

dual fuel link-up
solid fuel boiler system linked to a gas or oil boiler system

fixed room heater
heater which is permanently installed in one position within a room and not designed to be portable e.g. a gas fire, an open fire, a solid fuel stove, a storage or fixed direct acting electric heaters

flue
passage for conveying the products of combustion from the outlet of the appliance to the outside atmosphere

flueless appliance
appliance designed for use without connection to a flue system, the products of combustion being allowed to mix with the air in a room or space in which the appliance is situated

full programmer
allows the time settings for space heating and hot water to be fully independent

gas fire
appliance constructed in a single cabinet incorporating a definite air path, a flue spigot for controlled discharge of combustion products either directly into an existing flue or by passing through a purpose made closure plate. The radiant elements may be made to simulate burning solid fuel and/or may be partially enclosed by a heat resistant glass front plate

general indoor lighting
lighting of a whole indoor area

glare
condition of vision in which there is discomfort or a reduction in the ability to see details or objects, caused by light that is too bright or extreme light contrasts in the field of view

HARP
Home-heating Appliance Register of Performance database is a product efficiency database for home-heating appliances that are used in Ireland

indirect hot water system
hot water system in which stored domestic hot water is heated by a primary heater without mixing of the primary (heating) water and the stored domestic hot water

lamp life
average rating for a lamp that indicates the time after which 50 % of a large group of lamps of the same type fail, when operated at nominal lamp voltage and current expressed in hours

light emitting diode (LED)
semiconductor diodes that emit coloured light when a low-voltage DC current is applied

liquefied petroleum gas (LPG)
generic term used to describe gases having the characteristic of being easily liquefied by the application of pressure. It is provided as commercial butane and commercial propane or mixtures thereof

lumen
unit of luminous flux, it is a measure of the total amount of visible light emitted by a source expressed in (lm)

luminaire
apparatus which distributes light from a lamp or lamps, and includes all components for fixings, protecting the lamps and connecting them to the electricity supply

luminous efficacy
measure of the effectiveness of a lighting system in converting electrical power to light, expressed in lumens/Watt (lm/W)

multi-fuel appliance
appliance that is able to burn a range of different fuels e.g. mineral fuel and wood

no fines concrete
concrete composed of cement and coarse aggregate only, fine aggregate being omitted so as to leave uniformly distributed voids throughout its mass

non-repeating thermal bridge
non-repeating thermal bridging also known as linear thermal bridging occurs where dense, structural part of a dwelling intersect e.g. a window lintel, or the join between a floor and a wall

outdoor lighting
lighting of outdoor areas, typically porches, entry ways, paths, outbuildings and sometimes gardens

open-flued appliance
appliance designed to be connected to an open-flue system, its combustion air being drawn from the room or space in which it is installed

open-flued fan assisted appliance
appliance incorporating a fan upstream or downstream of the burner taking combustion air from a room

open-flue system
flue system that is open to a room or internal space at each appliance position

open system
heating system which is open to the atmosphere and incorporates a feed and expansion cistern

plume management kit
flue component designed to manage the discharge of the products of combustion such that any plume will not cause a nuisance

pluming
visible cloud formed when products of combustion exit from a chimney and are cooled below the dew point by mixing with external air

portable room heater
heater which can readily and easily be transferred and relocated from one room to another, in the case of an electric heater having a lead and a plug. Completely free standing and self supporting on feet, legs or base on the floor

programmable room thermostat
combined time switch and room thermostat that allows the user to set different periods with different target temperatures for space heating, usually in a weekly cycle. Some models also allow time control of hot water, so it can replace a full programmer

psi value (Ψ)
property of a thermal bridge and is the rate of heat flow per degree per unit length of the bridge, that is not accounted for in the U-values of the plane building elements containing the thermal bridge (W/mK)

repeating thermal bridging
repeating thermal bridges (e.g. timber joists or rafters, mortar joints, wall ties or mullions in curtain walling) where the additional heat flow due to the bridging is to be included in the determination of the U-value of the building element containing these bridges

regular boiler
boiler providing space heating directly with domestic hot water heated in a separate hot water storage vessel. Some units are designed to fit directly in the fireplace and are referred to as back boiler units (BBU)

Note 1 to entry: Regular boiler sometimes called ‘conventional’ or ‘heat only’ boiler.

room-sealed boiler
boiler whose combustion system is sealed from the room in which the boiler is located and which obtains air for combustion from a ventilated uninhabited space within the premises, or from the open air outside the premises and which vents the products of combustion directly to open air outside the premises

room thermostat
thermostat that measures the air temperature within the building and switches the space heating on and off. A single target temperature may be set by the user

sealed system
central heating system incorporating a water circuit that is not open to the atmosphere

semi-gravity system
boiler primary water circuit which uses gravity circulation (thermosyphon) to heat a hot water vessel and pumped circulation to heat emitters

solid fuel
natural or manufactured solid mineral fuels, natural or manufactured wood chips, pellets, logs and peat briquettes

solid mineral fuel
coal, lignite, coke and fuels derived from these

specific fan power (SFP)
power consumption of the fan and all other components divided by the air flow through the system, units are in W/(l/s)

time switch
electrical switch operated by a clock to control either space heating or hot water, or both together but not independently

thermal bridge
part of the building envelope where the otherwise uniform thermal resistance is significantly changed by full or partial penetration of the building envelope by materials with a different thermal conductivity, and/or a change in thickness of the fabric, and/or a difference between internal and external areas, such as those occurring at wall/floor/ceiling junctions

thermal conductivity (λ or k-value)
quantity of heat transmitted through a unit thickness in a direction normal to a surface of unit area due to a unit temperature gradient under steady state conditions and when the heat transfer is dependent only on the temperature gradient W/mK

thermal resistance (R-value)
measure of a body's ability to prevent heat from flowing through it, equal to the difference between the temperatures of opposite faces of the body divided by the rate of heat flow (m^2K/W)

thermal transmittance (U-value)
Thermal transmittance (U-value) relates to a building component or structure, and is a measure of the rate at which heat passes through that component or structure when unit temperature difference is maintained between the ambient air temperatures on each side. It is expressed in units of Watts per square metre per degree of air temperature difference (W/m^2K)

thermostatic radiator valve (TRV)
radiator valve which includes an air temperature sensor which is used to control the heat output from the radiator by adjusting water flow

total solar energy transmittance (solar factor) $g_\perp$
fraction of the incident solar radiation that is totally transmitted by the glass

traditional buildings
traditional buildings include those built with solid masonry walls of brick, stone or mud (often with a render finish)

Note 1 to entry: These were the dominant forms of construction in Ireland from medieval times until the second quarter of the twentieth century. This form of construction performs differently from modern construction in being moisture permeable and reliant on higher levels of ventilation to ensure the wellbeing of the building fabric.

tungsten halogen lamp
gas-filled lamp containing halogens or halogen compounds, the filament being of tungsten

Terms and definitions

underlay, HR
membrane with water vapour resistance greater than 0.25 MN•s/g

underlay, LR
membrane with water vapour resistance not exceeding 0.25 MN•s/g

vapour control layer (VCL)
continuous layer of impermeable material

wet rooms
rooms where moisture is created through cooking, showering, drying clothes etc., e.g. kitchens, utility rooms, bathrooms

4. Building science

4. Building Science

4.1 General

This clause of the S.R. describes some of the basics of building physics/science. It supports the technical aspects of the S.R. and provides a reference section for the reader.

The focus is on the transfer/movement of heat, moisture and air through the dwelling and their relationship with the occupants. The control and management of these is essential in order to achieve adequate occupant comfort, good overall energy performance and to prevent building problems.

Central to building science is human comfort as any retrofit solution (e.g. increasing insulation or limiting uncontrolled air infiltration) will improve thermal comfort as well as reducing carbon emissions and minimising heating costs. Human comfort is concerned with occupants' physical and physiological needs. Internal temperature and relative humidity are core to this, and so these are key elements of building science.

The person responsible for implementing an energy retrofit solution that improves a dwelling's overall performance should have a good appreciation of building science to ensure that no new problem or risks are created.

4.2 The dwelling as a system

A dwelling should be considered as an integrated set of systems rather than a set of separate components. For example, a floor can consist of a ventilated subfloor space, timber joists, insulation, floor boards, underlay and carpet with each element playing a role. Similarly, the roof and walls are each a system as are the heating and the indoor environment and even the occupants are to be considered as part of that system.

A system may be constructed of different materials such as brick, concrete, wood, glass, steel etc., and each material has its own characteristics and how this performs affects the performance of the system and this, in turn, impacts on the performance of the whole dwelling.

Building science is concerned with how a dwelling's systems (and the elements that they consist of) interact with both the external climate (i.e. temperature, sunlight, rain, wind etc.) and internal environment which invariably relates to how a building is used.

The flow of heat, moisture and air in a dwelling has a profound effect on a dwelling's overall performance as these flows affect the materials in each of the systems that make up the building envelope. These movements are driven by gradients, i.e. differences in:

- Energy — heat moves from warm to cold (high to low temperature);
- Concentration — water moves from wet to dry (high to low concentration);
- Pressure — air moves from high to low pressure.

The dwelling envelope, ventilation and heating systems are expected to resist or control the movement of these and so create a comfortable indoor environment for the occupants.

The overall energy performance of the dwelling consists of a combination of all the energy using aspects which includes the energy needed to provide adequate comfort levels, domestic hot water and fixed building services. This is normally expressed in terms of kWh per m^2 of floor area per year (kWh/m^2/yr). The heat loss discussed in this clause is expressed in Watts (W) and is calculated on the basis of the fabric U-values, exposed surface area and the air changes per hour due to ventilation and infiltration.

Each of these flows is described in more detail in the following subclauses.

4.3 Heat flow

4.3.1 General

Heat always flows from warmer spaces to colder spaces i.e. cold does not flow into a dwelling in winter, heat flows out. Temperature is normally used to indicate the amount of heat energy as heat will flow where there is a temperature difference.

Heat moves in any one of three ways: conduction, convection and radiation, and each have a varying effect on the dwelling's heat loss or gain and on the occupants' comfort. Heat flow has a profound impact on thermal comfort (i.e. whether a person feels warm or cold in an environment) and so this subclause describes the three modes of heat transfer and how they can influence comfort levels.

4.3.2 Conduction

Conduction is the flow of heat through solid materials due to a temperature difference across the material. Heat is transferred from one molecule to another molecule in the same or other material that it comes into contact with. The greater the temperature difference the greater the heat flow.

In a dwelling, conductive heat flow occurs through the whole envelope: the exterior walls, floor, roof, windows and doors. Each material in the envelope will allow heat to pass to some degree, and those that are good at resisting the flow of heat are known as insulators. The heat flow through a material is known as the thermal conductivity (also known as lambda, λ, or k-value) and has units W/mK. Better performing insulation materials have lower thermal conductivities. Insulation materials therefore have a lower thermal conductivity than building materials such as brick, concrete, wood, etc.

Table 1 lists the thermal conductivity values of common insulation materials.

The thermal resistance (or R-value) is a measure of the ability of a material of a given thickness to resist the flow of heat. It is calculated from the thickness of the material divided by its thermal conductivity and has units m^2K/W. The higher the R-value the greater the resistance to the flow of heat.

The lambda value of an insulation material is not the sole determinant in its selection; there may be other factors such as fire resistance, moisture resistance, durability, cost, ease of use, availability and environmental impact.

4.3.3 Convection

Gases and liquids, unlike solids where molecules are at rest, are able to move freely and can carry heat with them. This movement is driven by pressure differences which can be natural in origin such as wind or differences in density/temperature, but it can also be a mechanically induced pressure from, for example, fans in a warm air central heating system or from a MVHR (Mechanical Ventilation with Heat Recovery) system.

4.3.4 Radiation

Radiation is the transfer of heat from one surface to another without contact (conduction) or air movement (convection). An object that is hot, radiates this heat through space to an object that is colder. Examples of this are the warmth radiated by a hot oven or the sun – the heat is radiated without the need for any contact.

4.3.5 Effect on occupants

Thermal comfort is whether a person feels comfortable with the thermal environment. It is assessed by a subjective evaluation and is influenced by the effects of conduction, convection and radiation. Thermal comfort is not just affected by the ambient room temperature; it also depends on the temperature of the room's walls, windows, floor and ceiling, the air circulation in the space and the local relative humidity.

Significant heat loss occurs through the dwelling envelope and so adequate levels of insulation are required to ensure a reasonable indoor ambient temperature is achieved.

Radiation is also relevant to thermal comfort. For example, if a person stands close to a cold window or wall then heat is radiated from the body to the window or wall so that the person feels cold. The sensation often feels like a draught, without air movement.

Occupants may also feel uncomfortable due to contact with floor surfaces (conduction) that are too cold or too warm. Thermal stratification (convection) that results in the air temperature at the head level being higher than at the ankle level can also cause thermal discomfort.

These impacts highlight the need to consider the occupants when planning a retrofit solution.

Table 1 - Thermal conductivity values of common insulation materials

Insulation Material		Thermal conductivity range[a, b] (W/mK)						
		0,00	0,01	0,02	0,03	0,04	0,05	0,06
Highest performance	Vacuum insulation panels	0,008						
	Aerogel		0,013					
Polyurethane	Polyurethane with pentane up to 32 kg/m³			0,027	0,030			
	Polyurethane soy based			0,026	0,038			
	Foil-faced Polyurethane with pentane up to 32 kg/m³			0,020				
	Polyurethane with CO_2				0,035			
	In-situ applied Polyurethane (sprayed or injected)			0,026				
Polyisocyanurate (PIR)	Polyisocyanurate up to 32 kg/m³			0,026				
	Foil faced Polyisocyanurate up to 32 kg/m³			0,023				
	In-situ applied Polyisocyanurate (sprayed)			0,025				
Phenolic foam	Phenolic foam			0,023				
	Foil-faced Phenolic foam			0,022				
Expanded polystyrene (EPS)	Expanded polystyrene up to 30 kg/m³				0,030	0,045		
	Expanded polystyrene with graphite (grey)				0,031			
Extruded polystyrene (XPS)	Extruded polystyrene with CO_2			0,025	0,037			
	Extruded polystyrene with HFC 35 kg/m³			0,029	0,031			
Wool and fibre	Glass wool [up to 48 kg/m³]				0,030	0,044		
	Glass wool [equal/greater then 48 kg/m³]				0,036			
	Stone wool [less than 160 kg/m³]				0,036			
	Stone wool [160 kg/m³]				0,037	0,040		
	Sheep's wool [25 kg/m³]				0,034		0,054	
	Cellulose fibre [dry blown 24 kg/m³]				0,035	0,046		
	Hemp fibre				0,039			
	Polyester fibre				0,035	0,044		
	Wood fibre (WF)				0,039			0,061

a Thermal conductivity ranges are a minimum and maximum obtained from the thermal conductivity values declared by manufacturers (or suppliers) and those given in the *Final report of the thermal values group*.

b The values in this table are indicative only. Certified values, should be used in preference, if available.

4.4 Heat loss from the dwelling

4.4.1 General

Heat is lost from buildings by transmission through the building fabric and ventilation (see clause 4.6)

4.4.2 Total heat flow through the fabric

The total heat loss through the fabric is made up of heat loss through plane elements and thermal bridges. Heat loss due to plane elements is calculated using U-values and heat loss due to thermal bridging is calculated using linear thermal transmittance. Often it is convenient to characterise the whole building by transmission heat loss coefficient, H_{TB}, i.e:

$$H_{TB} = \Sigma(A.U) + \Sigma(L.\Psi)$$

Where H_{TB} is the transmission heat loss coefficient (W/K), Σ(A.U) is the sum over all the components of the building (i.e. roof, walls, floor, windows) of the product of the area of each component and its U-value (W/m^2K) and Σ(L.Ψ) is the sum over all thermal bridges of the product of the length of each thermal bridge (m) and its linear thermal transmittance (W/mK).

4.4.3 Thermal Transmittance (U-value)

Conduction occurs in any direction and is the dominant heat loss path in a dwelling (see Figure 1). Thermal transmittance (U-value) relates to a building component or structure, and is a measure of the rate at which heat passes through that component or structure when unit temperature difference is maintained between the ambient air temperatures on each side. It is expressed in units of Watts per square metre per degree of air temperature difference (W/m^2K). It is calculated by adding the reciprocals of the R-values (i.e. 1/R-value) of each of the materials (e.g. brick, insulant etc.) and then adding convective and radiation heat losses (e.g. wall cavity or roof space). Repeating thermal bridges are also accounted for in this calculation. This is a complex calculation and is best undertaken using U-value calculation software to I.S. EN ISO 6946. The addition of insulation reduces the U-value which means an increased resistance to heat flow.

The total heat flow through the plane elements of the envelope is given by the U-value multiplied by the area of the wall, floor or roof etc. multiplied by the temperature difference across it. Dwellings with an irregular shape will generally have a greater heat loss than more regularly shaped dwellings of the same height and floor area due to greater surface area, (see Figure 2).

Insulants primarily work by trapping pockets of still air or other gases within the body of the material, and because the molecules of gases are widely spaced the conduction of heat from molecule to molecule is low which gives them their low thermal conductivity. This also means that compressing such materials (e.g. 150 mm mineral wool blanket beneath loft boarding laid on a 100 mm joist) reduces the amount of air present and so the thermal conductivity increases and the U-value decreases.

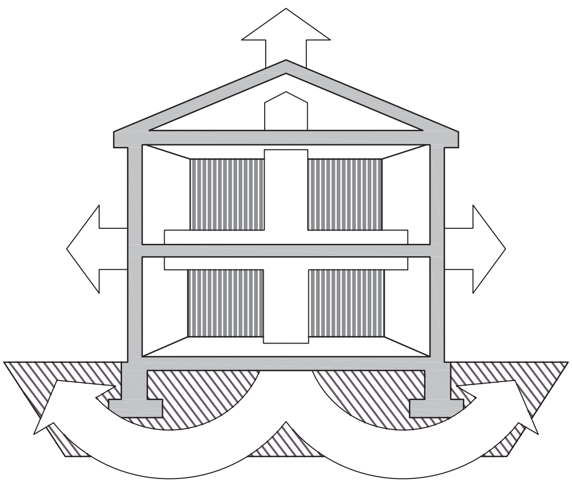

Figure 1 - Conductive flow of heat from dwelling

BUILDING SCIENCE

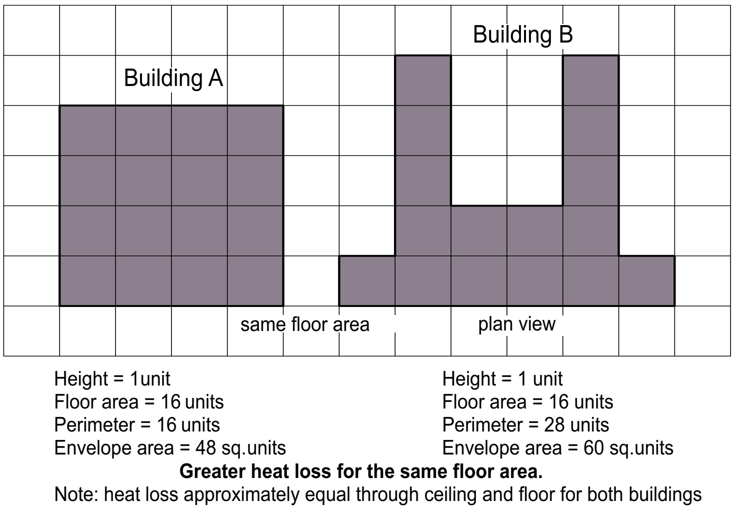

Figure 2 - Irregular shaped buildings have greater heat loss

4.4.4 Thermal bridging

Thermal bridging (also known as cold bridging) occurs where there are materials of higher thermal conductivity than the plane elements which allow heat to flow more easily out of a dwelling.

There are two types of thermal bridging:

- Repeating thermal bridges;
- Non-repeating thermal bridges.

Repeating thermal bridges occur for example, where wall ties cross the insulation in a cavity wall or where repeating studs occur in timber frame construction or joists occur in ceilings or floors. These examples have a thermal conductivity that is much greater than the insulation; hence they form a thermal bridge. These are referred to as repeating thermal bridges, because they occur at regular intervals throughout the entire element e.g. steel wall ties are at least 500 times more thermally conductive than insulation and so form a thermal bridge. U-value calculation software includes the contribution of such thermal bridging in the U-value calculation

Non-repeating thermal bridging also known as linear thermal bridging occurs where dense, structural parts of a dwelling intersect e.g. a window lintel, or the join between a floor and a wall. Non-repeating point thermal bridge can also occur where special structural members are used e.g. steel post penetrating through insulation. It is difficult to incorporate adequate insulation at these points because they need to be structurally robust, so they act as thermal bridges. Figure

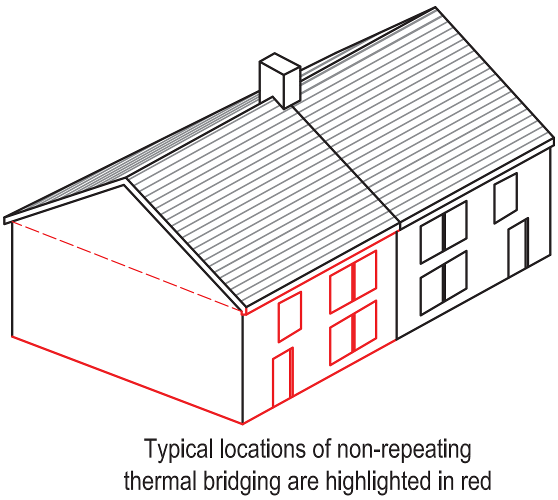

Figure 3 - Key non-repeating thermal bridging in a typical semi-detached house

3 shows key non-repeating thermal bridging in a typical semi-detached dwelling; corners, lintels and junctions between the floor/walls/roof are all affected.

Each individual thermal bridge has a psi (Ψ) value associated with it which is a measure of the linear heat loss and has units W/mK. Figure 4 shows a typical thermal bridge in a corner.

The U-value heat loss accounts for the heat loss through the plane internal surfaces of the wall and roof area above, but there is a small square in the corner that causes additional heat loss. Because the only point within the room that leads to the heat loss square is the line along the corner, it is described as a linear heat loss. Linear thermal transmittance can be calculated using the guidance in BR 497 *Conventions for calculating linear thermal transmittance and temperature factors*. Calculating a psi-value is complex and the use of specialist thermal modelling software is required.

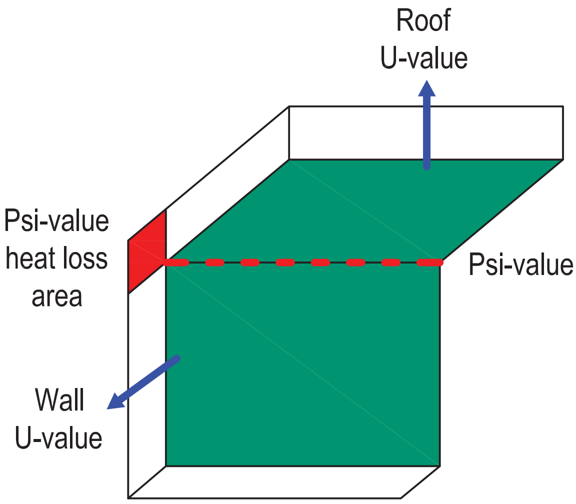

Figure 4 - Psi value linear heat loss and external heat loss area of a corner

Thermal bridging should be considered as part of both the assessment of heat loss and proposed retrofit solution. Thermal bridges become proportionately more important as the insulation of the dwelling envelope is improved, and they can also lower the temperature of the internal surface such that it becomes the site of condensation and staining e.g. A liner thermal bridge with a Psi value of 0,21 W/mK is equivalent to an extra 1m^2 section of wall with a U-value of 0,21W/m^{2}K. Thermal bridges can be accounted for using the guidance in BRE IP 1/06 *Assessing the effects of thermal bridging at junctions and around openings*.

4.4.5 Thermal bypass

Thermal bypass can occur in party walls with cavities where cold air enters and moves up the cavity, conducting heat from the dwelling through the party wall and exits the cavity at the top, as shown in Figure 5.

NOTE Further information can be obtained from "*Evidence for significant heat losses through party wall cavities in load bearing masonry construction*", RJ Lowe et al, UCL & Leeds Metropolitan University, 2007.

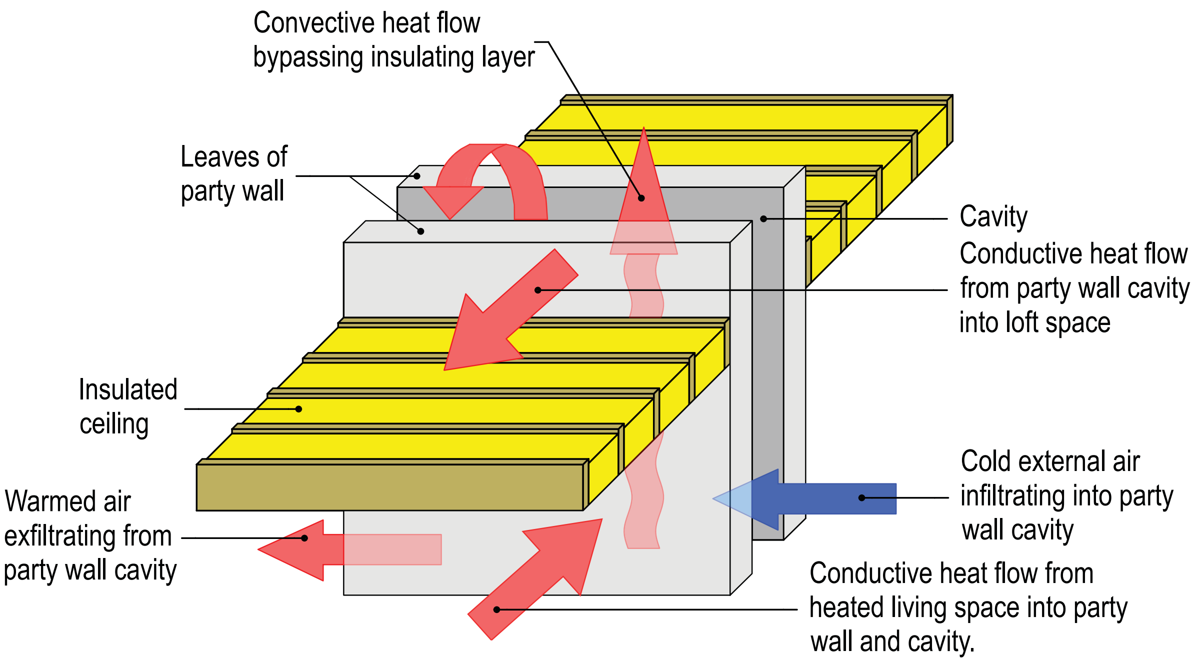

Figure 5 - Thermal bypass

4.4.6 Thermal mass

Thermal mass describes how the mass of the building provides 'inertia' against temperature fluctuations. For example, as external temperatures fluctuate throughout the day, a large thermal mass within the insulated part of a dwelling can 'flatten out' the daily temperature fluctuations, since the thermal mass will absorb thermal energy when the surroundings are higher in temperature than the mass, and give thermal energy back when the surroundings are cooler, without reaching thermal equilibrium.

Thermal mass can improve thermal comfort both in winter as well as in summer. When used and combined with passive solar design, thermal mass can help to reduce the energy used by heating and cooling systems. The terms heavy-weight and light-weight are often used to describe buildings with different thermal mass. Concrete, clay bricks and other forms of masonry are often used to provide thermal mass.

4.5 Moisture flow

4.5.1 General

Controlling and managing moisture is important in providing a durable building envelope and a healthy living space. Moisture can exist within the dwelling in any of its three states: gas, liquid or solid.

4.5.2 Water vapour

Water vapour is the gaseous form of water and is always present as part of the air inside and outside dwellings.

Relative humidity (RH), in simple terms, is the amount of water vapour in air relative to the maximum amount of water that air can hold at that temperature. At 100 % RH, air cannot hold any more water vapour and is considered saturated. The amount of water vapour that air can hold depends on temperature; warm air is able to hold more water than cold air as shown in this Table 2.

Table 2 - Mass of water held by 1 kg air

Mass of water held by 1 kg air	Air at:	
	-10 °C	25 °C
50 % RH	1,1 g	10,0 g
100 % RH	2,3 g	20,0 g

Air at 25 °C can hold nearly ten times as much water vapour compared to air at -10 °C.

When the temperature of air at 100 % RH is lowered, the water vapour begins to condense out onto cool surfaces and appear as liquid water. The air remains at 100 % RH, but because it has cooled, it is not able to hold all of the water vapour it had suspended at the warmer temperature.

The temperature where a mixture of air and water vapour reaches 100 % RH, or saturation, defines when condensation occurs. This is called the dew point temperature. If the dew point temperature occurs below the point of freezing, the water will appear as ice/frost.

Water vapour in a dwelling arises from:

- humans and animals through respiration, and plants also produce moisture;
- activities such as cooking, bathing, laundry, dish washing etc.; and
- diffusion from the soil through the floor and foundation walls.

Water vapour moves from one space to another either by diffusion through a material or is carried by moving air. With diffusion, the vapour exerts a pressure as it moves from high to low concentration through the material. This vapour pressure drives the diffusion; the greater the concentration difference the greater the driving pressure, see Figure 6.

All materials allow water vapour to pass through them to some extent. The ability of a material to resist the flow of water vapour is measured by its vapour resistivity which has units Ns/g.m, (Newton seconds/gram.metre). The greater the number, the larger the resistance to flow. The vapour resistance of a material is the vapour resistivity multiplied by the material's thickness and has units Ns/g, this may also be expressed as MNs/g, i.e. 10^6 x Ns/g.

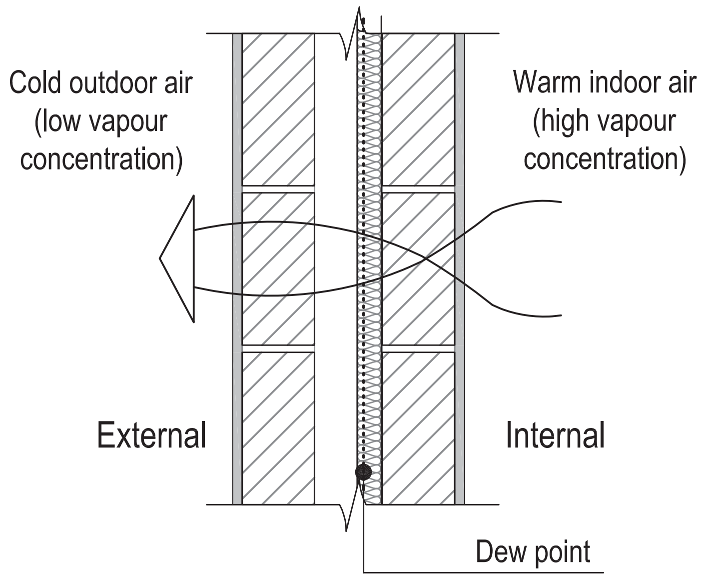

Figure 6 - Vapour diffusion through a wall

Polyethylene is commonly used as a barrier to resist the passage of vapour but a wide range of thin membranes and foils can be used. Table 3 shows the vapour resistance of these and other common building materials. To function properly, the vapour control layer (VCL) needs to be installed on the warm side of the insulation or, more specifically, on the warm side of the dew point.

A VCL may be provided by:

- materials of construction with an inherently high vapour resistance;
- an integral barrier, such as a board with an applied film or foil;
- certified proprietary membrane with appropriate vapour resistance; or
- an impermeable membrane.

Designers should determine the performance standard required in any given situation and ensure the specified VCL will meet that standard over the life of the building. It should be borne in mind that some membranes offer high resistance to the passage of water vapour and air, whilst others offer high resistance to air leakage but low resistance to the passage of water vapour.

Building owners/occupants should be made aware of the importance of maintaining VCLs throughout the life of the building, particularly when repairs, alterations and extensions are made.

Table 3 - Vapour resistance of thin membranes, foils and other common building materials

Material	Vapour resistance (MNs/g)	
	Typical	Range
Aluminium foil	1 000	200 to 4 000
Asphalt (laid)	10 000	
Breather membrane	0,5	0,1 to 0,6
Building paper (bitumen impregnated)	10	
Felt		
(a) Roofing felt laid in bitumen	1 000	
(b) Type 1F felt	450	
Glass (sheet)	10 000	
Metals and metal cladding	10 000	
Paint		
(a) Emulsion	0,5	
(b) Gloss	15	8 to 40
(c) Vapour resistant	25	
Polyethylene		
(a) 500 gauge (0,12 mm)	250	200 to 350
(b) 1,000 gauge (0,25 mm)	500	400 to 600
Roof tiling or slating	2,5	0,5 to 3,0
Vinyl wallpaper	10	

4.5.3 Liquid water

Liquid water affects buildings in the form of rain. The driving rain index which is based on wind speed and rainfall indicates the exposure of different areas. Further details are given in Annex D.

The detail design of the varying elements of the building fabric should resist moisture ingress and any resultant deterioration of fabric and structure.

Different types of external finishes provide different methods to resist moisture ingress. Methods vary depending on exposure, for example, in areas of low exposure single leaf construction may be appropriate whereas in areas of high exposure rendered cavity construction is the recommended option.

4.5.4 Solid water

Solid water takes the form of ice and snow. Moisture that expands due to freezing in cracks can further deteriorate the condition on render and lead to increased moisture ingress in dwellings. The freezing of moisture in porous bricks can also lead to spalling.

4.5.5 Effect on occupants

Water vapour plays a particularly important role in health and thermal comfort. Too much moisture can cause a damp atmosphere inside a dwelling, while too little is also undesirable.

Whilst the human body is fairly efficient in sensing heat and cold, it is not very effective in detecting relative humidity. Extremes of relative humidity create the perception of a dry or moist indoor environment, and this plays a part in thermal comfort.

For people at rest or doing light work, 30 % - 60 % RH is an acceptable range. Conditions above this may cause discomfort. Below this range the conditions are too dry and may trigger a number of health ailments in occupants.

High humidity can increase wetness on different areas of the body, leading to a perception of discomfort.

4.5.6 Inside the dwelling

Where relative humidity (RH) is above 70 % there is the risk of surface condensation and the potential for mould growth. In a room with high humidity, water condenses on any surface that is below the dew point temperature. This often means that surfaces only a few degrees cooler than the ambient air will be a site for condensation. Locations of thermal bridges such as corners, lintels and junctions are particularly vulnerable. Software, verified to I.S. EN ISO 10211, used to calculate psi-values of thermal bridges can also produce a risk estimate of surface condensation.

Windows are often among the first surfaces on which condensation becomes visible. Poor air circulation can exacerbate the risk, for example by locating wardrobes against exposed and poorly insulated external walls.

The risk of condensation can be mitigated by increasing the temperature of these surfaces with the addition of insulation, improving the thermal efficiency of windows, improving ventilation or by reducing the indoor humidity levels through extraction at source or management of sources.

4.5.7 Within the structure

Water vapour passes through the dwelling structure by diffusion (see Figure 6) or is carried by moving air through any openings that are present. The dominant route is by air flow which is discussed in clause 4.6. Resulting condensation which occurs within or between layers of a construction is known as interstitial condensation. This occurs where the temperature in a roof or wall is at or below the dew point temperature of the vapour laden air. Depending on the construction and the location of the dewpoint this, in the long term, may lead to degradation of the building envelope and may even cause structural damage.

Interstitial calculations, where required, should be carried out to EN standards (I.S. EN ISO 13788 or I.S. EN 15026). Software is available to calculate the transfer of heat, moisture and air through building structures and is used to assess the risk of interstitial condensation.

The envelope can be protected by reducing the amount of vapour in the structure or by increasing the temperature of the construction. In both ways the air and vapour mixture in the construction is prevented from reaching its dew point.

4.6 Air flow

4.6.1 General

Controlling air flow into and out of the dwelling is an important function of the building envelope. Uncontrolled air infiltration can result in excessive heat loss, draughts and moisture damage of the envelope.

As air flows out of a dwelling it carries heat with it, and incoming air from outdoors requires energy to warm it to achieve a comfortable indoor temperature for occupants.

At the same time, adequate ventilation is required to ensure reasonable indoor air quality (IAQ) and to remove excess moisture produced within the dwelling. Dwellings have predominately been ventilated by air infiltration (i.e. adventitious leakage through the building envelope), but this is uncontrolled and can lead to less effective ventilation. In recent years there has been a move to constructing an air-tight envelope and providing purpose-built and controllable ventilation. See Clause 10 for further guidance.

The two requirements to drive air flow through the building envelope are an opening and a force. The openings in a dwelling envelope include gaps and cracks around windows and doors, gaps around service entry points etc. The flow through these openings is driven by natural forces produced by the wind and temperature differences, and mechanical forces generated by fans.

4.6.2 Wind pressure

Wind blowing on a dwelling will cause a positive pressure on the windward side of the building and negative suction on the leeward side. Figure 7 shows the differential wind pressure between the windward façade and the leeward façade acts to drive air flow through the dwelling. Moisture problems can occur on the leeward side of the building when warm, moist air is drawn out of the dwelling.

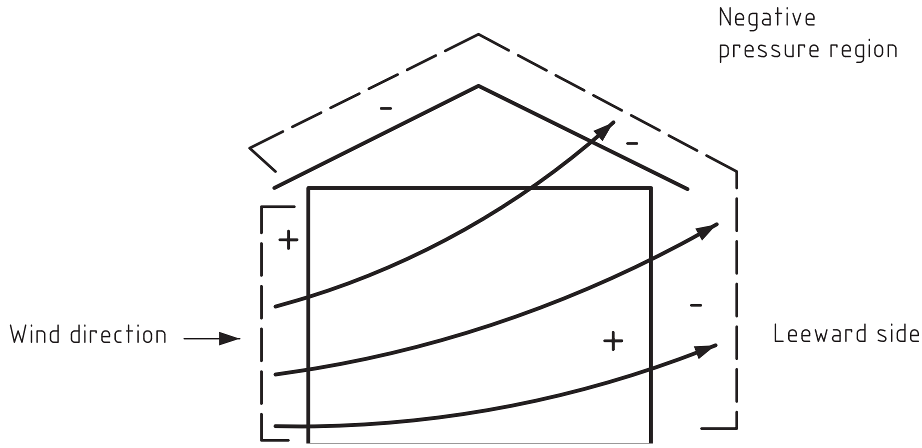

Figure 7 - **Wind driven air flow**

4.6.3 Stack pressure

The stack effect is the flow of warm air in the dwelling due to natural buoyancy when there is a temperature difference between the indoor and outdoor air and the fact that warm air within the dwelling rises due to natural buoyancy. The pressure generated can drive air out of the dwelling at the upper levels and draw replacement air in at the lower levels. See Figure 8.

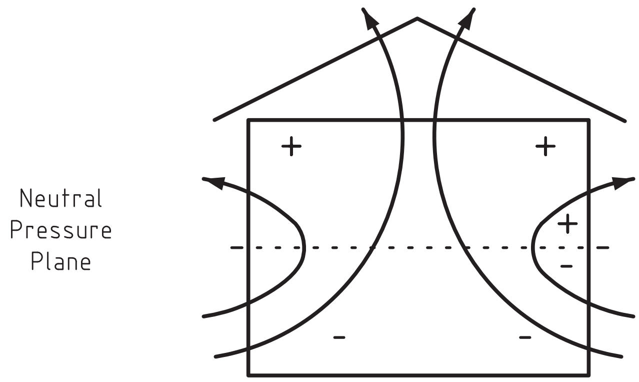

Figure 8 - **Stack driven air flow**

This pattern can be reversed on hot summer days. The more storeys a dwelling has the more pronounced the stack effect becomes and opening upstairs windows can further enhance the effect. In dwellings natural convection of this form can be a significant heat transfer mechanism, moving heat upwards and ultimately out of the building.

Stack effect can lead to condensation problems in the upper part of a dwelling, especially in attic and roof spaces. Warm, moist air tends to be driven out of the dwelling at the upper levels and is replaced by cold, dry air entering through the lower levels. Sealing gaps and cracks in the building envelope at both high and low level can help to reduce the stack effect.

4.6.4 Effect on occupants

Draughts will cause unwanted local cooling of the body caused by air movement which depends on the air speed, air temperature, activity levels and clothing layers. Excessive draughts may mean that an occupant turns up the heating even though the ambient temperature is at a reasonable level.

4.6.5 Air barrier systems

The building envelope can be protected by installing air and vapour barriers in the wall. Both of these limit the passage of water vapour into the cavity space keeping the space dry and preventing condensation.

An effective air barrier system normally consists of a membrane, panel or other airtight components that act together to restrict the movement of air between the indoor and outdoor environments. Traditional wet plaster on a wall also provides an effective air barrier. It has to be continuous, well supported and correctly installed to function properly. Small openings in the air barrier can be responsible for significant air flow and can lead to considerable quantities of moisture in the structure compared to the amount that moves by diffusion. For example, moisture flowing in air through an opening of 5 mm^2 in the wall will produce the same volume of water (1/3 litre) as diffusion of vapour through 1 m^2 of wall.

An air-barrier system can be located anywhere within the building envelope, but any materials that have significant resistance to water vapour diffusion should not be placed on the cold side of the insulation unless the risk of condensation has been assessed.

4.6.6 Heating

In a dwelling the indoor-outdoor temperature difference determines the amount of space heating it requires.

To maintain adequate indoor comfort heating systems are normally provided in dwellings. The heating system provides the heat lost through the fabric, ventilation and infiltration in order to maintain design ambient temperatures. Recommended indoor temperatures for dwellings are 21 °C for living areas and 18 °C for bedrooms and kitchens.

Heating systems typically consist of a heat generator and a distribution system. The heating system is sized to meet the heat demand of the dwelling.

The distribution system is commonly a piped water system due to water's high thermal specific capacity (ability to carry heat). Heat emitters should be sized to meet the calculated heat loss of the room. Typically the heat generator should be sized to meet the whole dwelling heating and hot water demand. On-line tools are available to undertake these sizing calculations.

The quantity of heat required depends on the fabric insulation and the area of heat loss elements and the heat loss due to ventilation. Windows also contribute to heat loss measured by their U-value but also provides heat gains due to solar radiation measured by the glazing total solar energy transmittance $g_\perp$.

As fabric performance is improved heat demand will reduce and thermal comfort levels will improve.

4.7 Overall approach

A dwelling is a group of interconnected systems where changes to one will impact on another. When undertaking a dwelling retrofit these interactions should be considered.

For example, improving the airtightness of the dwelling envelope by draughtproofing and replacing windows will reduce excessive draughts improving thermal comfort, reduce energy consumption, lower CO_2 emissions and reduce heating costs. Improving air tightness will also reduce the damage caused by water vapour carried in the air leaking out of the building.

Conversely, a tighter building envelope reduces the overall ventilation rate in the dwelling and this may lead to increased indoor humidity levels and poor IAQ. A tighter envelope can also increase the risk of surface condensation which can lead to mould growth and damage to building materials.

To control indoor humidity levels and ensure good IAQ, controllable and energy-efficient ventilation should be provided. To further reduce the risk of surface condensation, increased insulation of the envelope may be required with particular emphasis on thermal bridges.

Each of a dwelling's systems should be reviewed when proposing a solution and this includes consideration of the flow of heat, moisture and air within the dwelling and the occupancy.

5. Planning a retrofit

5. Planning a retrofit

5.1 General

The various elements of an energy efficiency retrofit should be performed as part of a whole dwelling energy improvement plan.

Energy surveys and assessment provide occupants and landlords with a basis for identifying appropriate options for energy efficient retrofit plans. An energy improvement plan should be based on a sound understanding of how energy is used in the existing dwelling and of the level of change that is acceptable within that particular home to its owners and occupants.

It is recommended that an energy survey is performed on a dwelling prior to making any improvements.

An energy improvement plan should provide a dwelling owner or landlord with improvement recommendations that:

- are aligned with the current and future needs of the occupants;
- takes account of capital costs, future monetary savings and other benefits such as improved comfort and environmental impacts;
- includes consideration of future improvement opportunities, which should not be prevented by more immediate retrofit works;
- identifies opportunities for integrating energy measures with other building work as required;
- take account of any adverse effects as a result of incorporating retrofit measures;
- takes account of the likely level of disruption.

It is recommended that where a number of phased upgrades are planned, expert advise is sought to co-ordinate these works.

The Building Energy Rating (BER)[1] for a specific dwelling will provide the theoretical energy use and carbon dioxide emissions for the heating system and fixed buildings services based on standardised occupancy patterns and temperatures. It does not take account of energy used by appliances or of the way the building is used by the actual occupants. The BER is required by legislation for all dwellings for sale or rent and for new dwellings prior to occupation, see Figure 9. An advisory report is supplied with the BER with recommendations for improvements to the dwelling.

The energy loss and use for a typical dwelling before retrofit is shown in Figure 10 and Figure 11. Most of the energy used is normally for space heating so it is usually most effective to start with energy efficiency improvements to the fabric to reduce heat loss. Improving the efficiency of heating system will also reduce energy use.

By way of illustration, Table 4 shows typical BERs for dwellings prior to retrofit by year of construction.

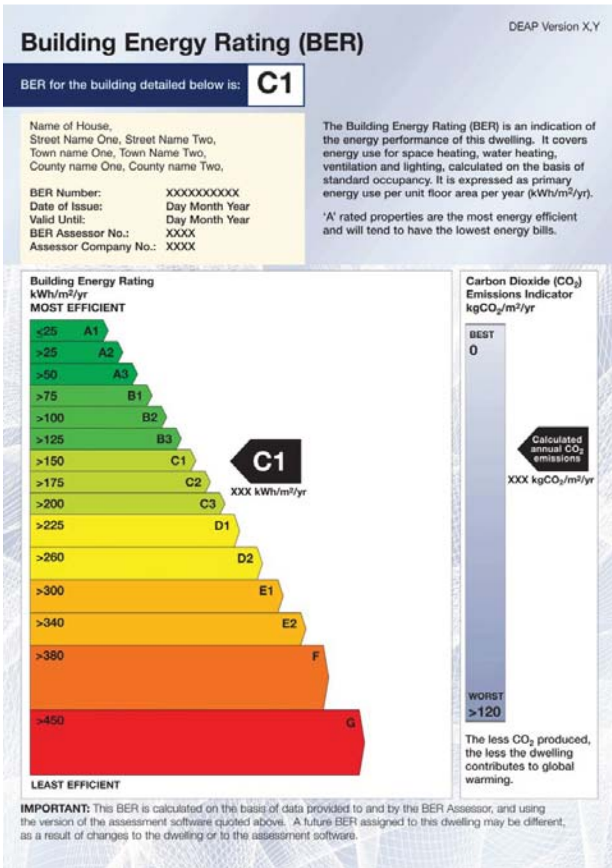

Figure 9 - BER Certificate

1) Refer to http://www.seai.ie/ for further information on BERs

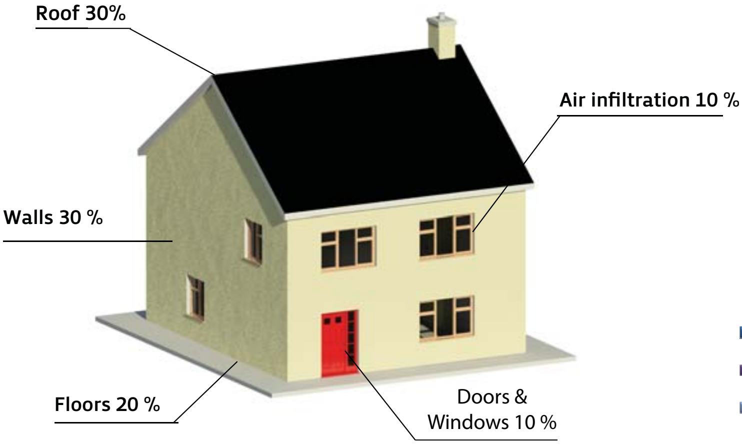

Figure 10 - Percentage heat loss through the fabric of a typical uninsulated dwelling

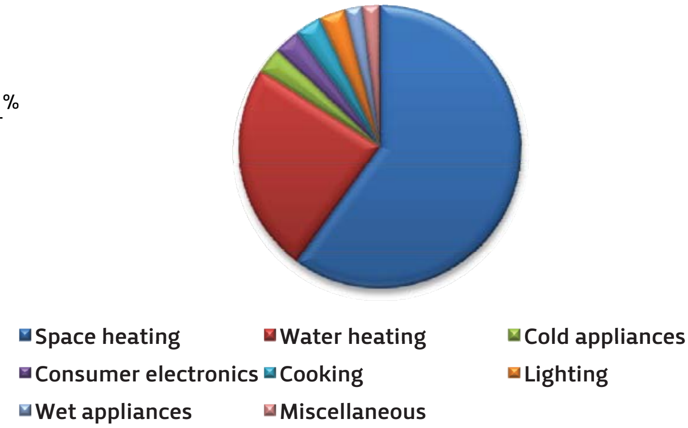

Figure 11 - Breakdown of overall energy use in a typical uninsulated dwelling

Table 4 - Typical BERs prior to retrofit for dwellings by year of construction

Year	Pre-1972	'72-'78	'79-'81	'82-'91	'92-'01	'02-'08	'09-'13
Rating	E2-G	E1-E2	D1-D2	C3-D1	C2	C1	B1

5.2 Building and Planning Regulations

Building Regulations and Planning Regulations can apply to retrofit works depending on the scope and nature of the works.

Once the scope of the works has been determined an assessment should be made to identify if Building Regulations or Planning Regulations apply.

Local authority building control and planning sections can advise whether or not proposals are subject to building or planning regulations.

5.2.1 Building Regulations

Building Regulations exist primarily to ensure the health and safety of people in and around all types of buildings (i.e. domestic, commercial and industrial). They also provide for the conservation of fuel and energy in buildings.

The current Building Regulations and Technical Guidance Documents are published by the Department of the Environment Community and Local Government and their application to works to existing buildings is available on DECLG website (www. environ.ie/en/DevelopmentHousing/BuildingStandards/).

5.2.2 Planning

Planning permission is generally required when undertaking external alterations to a dwelling, such as changes to the façade, appearance or roof height level. Planning permission is not generally required for changes to the inside of dwellings.

Works which do not materially affect the external appearance of the structure so as to render the appearance inconsistent with the character of the structure or of neighbouring structures are generally exempt from planning permission.

NOTE Further guidance is given in DECLG Planning Leaflet PL5.

5.3 Materials

All products, materials and systems referred to in this S.R. should be fit for the use for which they are intended and for the conditions in which they are to be used.

The performance of construction products, materials and systems may be demonstrated by CE Marking, by conformity with harmonized European product standards (hENs) or other European Standards (ENs). When incorporating a product, material or system into construction works, it is essential however, that the declared performances are fit for the use in which the product, material or system is intended and for the conditions in which it is to be used. The NSAI has produced additional national guidance for some hENs and ENs in the form of National Annexes or Standard Recommendations (S.R.s) which provide guidance on the appropriate minimum performance levels for specific intended uses of the products, materials and systems in Ireland. Where a construction product is covered by such guidance, compliance with the National Annex/ Standard Recommendation in so far as it relates to the product, material or system may be used to demonstrate that when incorporated into construction works the product material or system is fit for the use for which it is intended.

Where a product, material or system is not covered by a European Standard, a national technical specification may be used to demonstrate that a product is fit for its intended use and for the condition it is to be used.

For innovative products, materials and systems, not covered by Standards:

— European Technical Assessment (ETA) from a Technical Assessment Body, on the basis of a European Assessment Document (EAD), may be used to obtain a CE Marking and demonstrate performance. When incorporating such a product, material or system into construction works, it is essential however, that the declared performances are fit for the use in which the product, material or system is intended and for the conditions in which it is to be used, or

— Agrément certificate, or equivalent, may be used to confirm that new building products, materials, systems are fit for the purpose for which they are intended and the conditions of use. Such certificates may be in addition to, but not conflict with, CE Marking.

5.4 Project stages

The stages of an energy retrofit project are:

— defining the scope, budget, schedule and disruption of retrofit;

— surveying the dwelling;

— selection of interventions;

— installation works;

— commissioning;

— handover.

All the above steps should be considered at the planning stage of a project.

Retrofit projects take many forms, from a single task to a complete upgrade. Whatever form, it is important to consider procurement, construction, administration and contractual issues.

Energy efficient retrofit projects can be:

— small scale (single tasks) e.g. replacement of windows;

— multiple works (combination of measures) e.g. loft and wall insulation;

— whole dwelling retrofit upgrade (single contract); or

— multiple dwellings retrofit upgrade (e.g. terraces of houses or area based).

Where planned works are due on the dwelling to maintain a specific element such as a roof replacement, repair to wall render or replacement of windows, energy saving measures should also be considered as part of these works.

The level of management and oversight of a retrofit project depends on the scope of the project and the experience and expertise of the client. The design process for all projects should include an energy efficiency assessment.

NOTE See Annex F for further guidance on project management.

5.4.1 Scope of project

The scope of project depends on:

— the budget available;

— the thermal improvement required;

— the time available to complete the works;

— the amount of acceptable disruption to the occupant.

5.4.2 Surveying the dwelling

The scope of proposed works will determine the extent of the survey.

When assessing a dwelling for an energy retrofit, detailed surveys should be undertaken to identify:

— the condition of the existing fabric and services; and

— the existing energy performance.

In order to determine the appropriate energy improvement interventions necessary the following key characteristics of the dwelling should be obtained in a survey, where applicable, (see subclauses 5.4.2.1 to 5.4.2.24). Specific considerations for detailed surveys are provided in related design and installation sections for individual interventions.

NOTE The Dwelling Energy Assessment Procedure (DEAP) Survey Guide and Appendix I: DEAP survey form, also provides guidance and an example of the useful information which can be collected during an energy survey.

5.4.2.1 Age

The DEAP manual, Appendix S, provides indicative performance standards based on the age of the dwellings.

5.4.2.2 Wall, roof and floor type

The type of wall (cavity wall, hollow block, solid wall, timber frame, steel frame), roof (insulation at rafter or ceiling level) or floor construction (suspended or ground supported) will influence the appropriate intervention.

The placement of existing insulation or drylining, if any, in the construction build up will affect the final design.

The type and nature of construction can be determined by practical measures such as removal of existing vent covers to determine if wall construction can be verified in the vent aperture, attic inspection can verify level of insulation installed and inspection of gable wall in the attic which can assist in determining the construction type.

5.4.2.3 Existing services, fixtures and fittings

These should be identified as they may impact on the choice of intervention and may need to be included in any proposed works.

5.4.2.4 Existing ventilation provision

The existing ventilation openings in rooms, under floors and eaves should be identified as these will need to be maintained or even enhanced.

5.4.2.5 Space and access

Available space to perform works should be identified. Effects of modifications to existing paths, steps and ramps should be considered.

5.4.2.6 Adjacent boundaries and public footpaths

Boundaries should be identified and the effects of measures on the boundary or their proximity to it.

5.4.2.7 Fuel

Current fuel type and alternative fuel sources should be identified, e.g. oil, gas, biomass, electricity, district heating etc., and potential space for oil or biomass storage identified. Enquiries should be made to the supply companies where services are not currenlty on the gas network, whether it is planned to bring mains gas to the area.

5.4.2.8 Size and heights of rooms

Room size and height should be recorded as this will impact on the possible internal measures, e.g. above floor insulation.

5.4.2.9 Widths of stairs, hallways, doorways and side passageways

Widths should be recorded in order to ensure appropriate widths are maintained and not adversely affected by any intervention.

5.4.2.10 Façades or elevations

Any façades, elevations or features of architectural interest listed by the local authority should be identified in the survey and checked with local conservation officer.

5.4.2.11 Wildlife

The works or materials used should not cause any harm to the surrounding habitats or waterways, as this might have adverse impacts on wildlife.

Relevant regulations should be consulted with regards to protected species and habitats (see website for Irish Wildlife Acts and European Nature Directives: www.npws.ie/legislationandconventions).

Bat colonies are particularly vulnerable to disturbance during retrofitting.

NOTE See the National Parks & Wildlife Service's Bat Mitigation Guidelines:

www.npws.ie/publications/archive/IWM25.pdf for guidance on the legal situation regarding bats and advice on how to minimise the impact of works on bats.

5.4.2.12 Exposure

The exposure of the dwelling and the wind driven rain index for the area should be identified, (see Annex D). The exposure to the weather will limit the use of certain interventions and require additional methods to ensure the retrofit measures are not detrimental to the long term structural integrity of the dwelling. For example, full fill cavity wall insulation should not be used in an area of severe wind driven rain with non rendered masonry.

5.4.2.13 Cavity walls

For cavity wall dwellings where it is not evident as to the extent of insulation (if any) in a wall, then a boroscope survey should be carried out to determine the presence, type and the condition of any insulation.

5.4.2.14 Damp and condensation

Any signs of damp within the dwelling should be assessed as to its origin, whether it is caused by condensation, rising damp or penetrating from an external source. Rain water goods (e.g. gutter and downpipes), roof condition and soil levels should be checked. A damp meter can be used to check the humidity levels of the walls and this can identify areas of dampness in walls and floors. Further diagnosis is normally needed to determine the cause.

NOTE For further guidance see BRE DG 245 *Rising damp in walls - diagnosis and treatment*.

5.4.2.15 Radon

Where planned retrofit measures comprise of floor replacement consideration should be given to provision of radon preventative measures as detailed in Building Regulations Technical Guidance Document C.

Post retrofit radon testing is recommended where extensive energy retrofit measures have been completed.

NOTE For further guidance see www.rpii.ie/Your-Home/Publications-on-your-home.aspx and the Department of the Environment, Community and Local Government publication *Radon in Existing Buildings - Corrective options*.

5.4.2.16 Asbestos

Where the presence of asbestos is suspected during a building survey or during the course of retrofit measures, an asbestos management survey should be undertaken to determine the extent of Asbestos Containing Materials (ACMs) in the dwelling that may be disturbed by the proposed works. All ACMs identified should be removed by a competent contractor prior to the commencement of proposed works in accordance with the relevant Safety Health and Welfare at Work (Construction) Regulations.

NOTE For further guidance see Health & Safety Authority website:

www.hsa.ie/eng/Your_Industry/Chemicals/Asbestos/.

5.4.2.17 Air permeability (airtightness)

Airtightness should be checked, so that uncontrolled infiltration is assessed and remedies identified. Poorly fitting windows and doors should be noted, and seals around window frames should be assessed. An air permeability test may be carried out to give accurate figures for the leakage through the building envelope and this may be used directly in the DEAP model to calculate infiltration heat losses. The test can also be used to determine (e.g. through smoke pencil tests) the exact locations of air penetrating from outside and highlight the remedial action to be carried out. Gaps around floors, particularly suspended floors should be noted, and loft hatches and any service penetrations identified where there is a lack of a seal around these items.

5.4.2.18 Windows and doors

The condition of openings should also be checked for soundness, with measures listed for repair or replacement. Commercially available laser gauges provide a simple way to identify accurately the type of glazing installed within a window. The gauges enable the glass thickness, width of air gap and presence of any low-e coating or laminate to be identified.

5.4.2.19 Mechanical ventilation

The presence of mechanical ventilation systems, their operating controls and their condition should be noted.

5.4.2.20 Building services

The services in the dwelling should be identified such as the current heating system and controls. The heating system should be identified and the age determined along with the water heating provision.

5.4.2.21 Dwelling layout

The number of space heating zones in the dwelling should be identified and the controls (thermostats and valves) checked for correct operation. The potential for dividing dwellings into separate heating zones (e.g. bedroom and living zones) should be identified. The layout of the dwelling determines how efficiently the dwelling can be heated.

5.4.2.22 Heating controls

The controls should be identified for adequacy. The potential for improved controls with pipework configuration should be assessed.

For electrical heating the timers, thermostats and controls should be noted and the controls for immersion heater should be identified.

5.4.2.23 Electrical cabling

The type and location of electrical wiring and whether enclosed in conduit should be noted. This is important as expanded polystyrene insulation should be isolated from all existing PVC insulated electrical cables, see 6.3.1.7 and 7.3.3.3.1.1 for further guidance.

5.4.2.24 Lighting

A survey of existing lamps and light fittings should be carried out. The potential for low energy lamps and any opportunity to maximise daylight into the dwelling should be noted.

5.4.3 Selection of interventions

The selection of measures will depend on the homeowners priorities.

Influencing parameters include:

— available budget;

— lifecycle operating costs;

— thermal comfort;

— level of disruption;

— period of time over which improvements should take place; and

— desired level of energy performance improvement.

Generally it is recommended to reduce energy consumption first by improving the energy performance of the fabric and then to improve the efficiency of services and heating systems as appropriate.

Where cost is a defining parameter, Table 5 provides indication of capital costs and lifecycle costs. In general it is recommended to implement low capital cost and low lifecycle cost improvements first followed by higher capital and lifecycle costs.

Table 5 - Comparative capital cost and relative lifecycle cost of retrofit measures

	Capital Cost			Lifecycle Cost		
	Low	**Medium**	**High**	**Low**	**Medium**	**High**
Insulation						
Roof insulation	√			√		
Pumped cavity wall insulation	√			√		
Ground floor insulation (solid)		√				√
Ground floor insulation (suspended)	√			√		
Internal wall insulation		√		√		
External wall insulation			√		√	
Windows and Doors						
Replacement windows			√			√
Secondary glazing		√			√	
Replacement doors		√			√	
Heating and Hot Water						
High efficiency condensing boiler		√			√	
Upgrade cylinder insulation	√			√		
Replacement hot water cylinder with factory fitted insulation	√			√		
Upgrade of all heating controls		√		√		
Draughtproofing						
Seal disused fireplaces	√			√		
Draught-stripping and sealing	√			√		
Windows and Doors	√			√		
Lighting						
Replacement of lamps with CFLs	√			√		

NOTE The costs and savings will vary according to the size of the dwelling, its location, the combination of measures and fuel used.

Energy savings are estimated from a range of standard house types with gas central heating and standard occupancy. Actual savings depend on individual circumstances. Some of the benefit may be taken in improved comfort.

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5.4.4 Installation works

When carrying out energy retrofit measures the following should be considered and adhered to where applicable:

- relevant Health and Safety Regulations e.g. safe working at height. It may be necessary to allow and price for scaffolding, towers or mechanical lifting as appropriate;
- electrical works to ET 101;
- relevant Building Regulations, Standards, Codes of Practice and product certification;
- current validity of warranties and guarantees of the products or systems used for the particular installation/application;
- risk assessments and method statements where the occupants remain in place during the works to elimate or reduce risks; and
- schedule and programme for the works which set the timeframe and sequence.

Where works are planned to be completed over a long timeframe they should be carefully sequenced so that each stage can be carried out without detriment to the previous intervention.

5.4.5 Commissioning and handover

Project works and systems should be inspected to produce a snag list and commissioned so that on completion, all works are left in the intended working order and can perform as intended.

A list of works carried out and the associated operation and maintenance manuals, certificates and warranty information should be handed over to the homeowner and, where necessary, the operation of equipment should be explained to the homeowner. All necessary signage required to operate and maintain equipment should also be put in place.

Where new building systems are provided, a suitable set of operating and maintenance instructions that householders can understand should be provided. These operating and maintenance instructions should also provide information on health and safety and the energy efficient operation of the systems. The instructions should be directly related to the particular system(s) installed in the dwelling. These instructions should include:

- the operation of the heating system including adjusting the timing and temperature control settings; and
- routine maintenance required to enable operating efficiency to be maintained at a reasonable level through the service life (lives) of the system(s).

It is recommended that a final BER and Advisory Report are also provided to the homeowner as part of the retrofit project.

5.5 Application of retrofit measures

5.5.1 General

The following subclauses 5.5.2, 5.5.3 and 5.5.4 describe three case study dwellings intended to be representative of the most common dwelling types which are encountered and the possible challenges to achieving improved energy performance.

The example improvement measures applied to these case studies A, B and C correspond to the improvements described in the fabric and services sections of this S.R.

The improvements presented are but one option to achieving a certain performance level. Other approaches specifying different measures (systems, materials or products) may be used to achieve the same improvement in performance. It is the role of the designer or specifier to choose the optimum approach for any particular dwelling. Designers and installers should refer to the technical guidance sections of this S.R. for detailed guidance on the design and installation of measures described in Tables 7, 9 and 11.

The specification table in each section specifies the level of improvement to be achieved for four different packages of improvements. The graphs following the table show the improvement achieved by each package in terms of energy (kWh/m²/yr, coloured bars) and carbon dioxide emissions (kgCO_2/m²/yr, black line). The colour of the energy performance bars correspond to the Building Energy Rating of the dwelling.

5.5.2 Case study A

Table 6 - Typical semi-detached hollow block dwelling

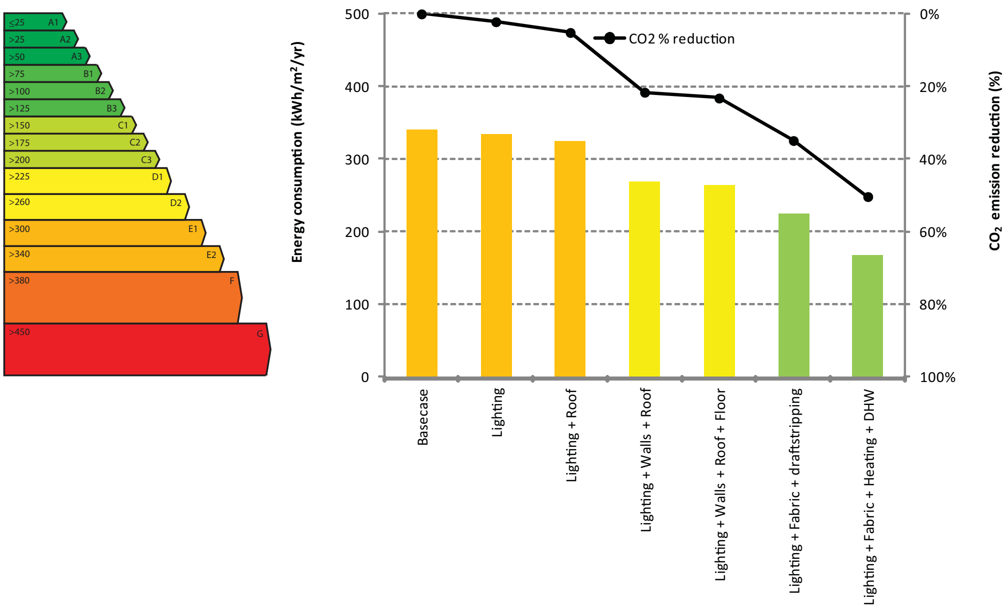
Semi-detached house, 1981			
Description			
Semi-detached or end of terrace house commonly built in Dublin with a red-brick front with a small cavity behind it on the ground floor and 225 mm hollow block walls elsewhere. Insulation first appeared in 1978 and these walls would be typically drylined with 25 mm polystyrene board or with 50 mm of insulation fibre between battens.			
Building elements		Insulation	U-value W/m²K
Walls	**Concrete hollow block, drylined**	**15 mm - 25 mm**	**1,1**
Roofs	**Pitched, insulation between joists**	**100 mm**	**0,4**
Floors	**Solid**	**10 mm - 15 mm**	**0,57**
Windows	**Double glazed, metal frame, 6 mm gap**	**n/a**	**3,7**
Doors	**Double glazed, metal frame, 6 mm gap (front)**	**n/a**	**3,7**
	Solid wood (kitchen door)	**none**	**3,0**
Heating systems characteristics:		Fuel	Efficiency
Primary	**Central heating boiler, pipework uninsulated**	**Mains gas**	**70 %**
Secondary	**Open fire in grate**	**Solid multi-fuel**	**30 %**
Hot water	**From primary heating system, Electric immersion used in summer**		
Cylinder	**Insulated with loose jacket, 35 mm thick, no thermostat**		
Controls	**Programmer**		

Table 7 - Specification for different performance levels for semi-detached dwelling (hollow block)

		Retrofit measures			
Element	Base Case	Example 1	Example 2	Example 3	Example 4
Roof – Pitched					
Insulation	**100 mm between joists**	**250 mm between and over joists**	**300 mm between and over joists**	**400 mm between and over joists**	**400 mm between and over joists**
Conductivity	**0,04 W/mK**	**0,04 W/mK**	**0,04 W/mK**	**0,04 W/mK**	**0,04 W/mK**
U-Value	**0,4 W/m²K**	**0,16 W/m²K**	**0,14 W/m²K**	**0,10 W/m²K**	**0,10 W/m²K**
Walls – Hollow block					
Internal insulation (IWI)	**15 mm - 25 mm drylined**	**60 mm IWI**	**90 mm IWI**	**120 mm IWI**	**160 mm IWI**
Conductivity		**0,025 W/mK**	**0,025 W/mK**	**0,025 W/mK**	**0,025 W/mK**
U-value	**1,1 W/m²K**	**0,35 W/m²K**	**0,27 W/m²K**	**0,21 W/m²K**	**0,15 W/m²K**
		OR	**OR**	**OR**	**OR**
External insulation (EWI)		**90 mm EWI**	**120 mm EWI**	**160 mm EWI**	**220 mm EWI**
Conductivity		**0,035 W/mK**	**0,035 W/mK**	**0,035 W/mK**	**0,035 W/mK**
U-value		**0,35 W/m2K**	**0,27 W/m²K**	**0,21 W/m²K**	**0,15 W/m²K**
Floor					
Insulation	**Solid 10 mm - 15 mm**	**Solid 20 mm**	**Solid 70 mm**	**Solid 100 mm**	**Solid 120 mm**
Conductivity		**0,035 W/mK**	**0,035 W/mK**	**0,035 W/mK**	**0,025 W/mK**
U-value	**0,57 W/m²K**	**0,45 W/m²K**	**0,25 W/m²K**	**0,21 W/m²K**	**0,15 W/m²K**
Windows					
Type	**Metal frame, double glazed**	**High performance double glazed, low-e, argon**	**High performance double glazed, low-e, argon**	**High performance triple glazed, low-e, argon**	**High performance triple glazed, low-e, argon**
U-value	**3,7 W/m²K**	**1,6 W/m²K**	**1,4 W/m²K**	**0,95 W/m²K**	**0,85 W/m²K**
Total solar energy transmittance g ⊥	**0,76**	**0,75**	**0,75**	**0,64**	**0,64**

		Retrofit measures			
Element	Base Case	Example 1	Example 2	Example 3	Example 4
Doors					
Type (Front)	Double glazed, metal frame	High performance double glazed, low-e,	High performance double glazed, low-e, argon	High performance triple glazed, low-e, argon	High performance triple glazed, low-e, argon
U-value (Front)	3,7 W/m²K	1,6 W/m²K	1,4 W/m²K	0,95 W/m²K	0,85 W/m²K
Type (Rear)	Solid wood	Solid wood	Solid wood	Solid wood	Solid wood
U-value (Rear)	3,0 W/m²K	3,0 W/m²K	3,0 W/m²K	3,0 W/m²K	3,0 W/m²K
Airtightness					
% Draught stripping	90	100	100	100	
Air permeability					0,33 ACH
Ventilation	Natural with intermittent extract	Natural with intermittent extract	Natural with intermittent extract	Natural with intermittent extract	Natural with intermittent extract
Lighting	0 % CFL	100 % CFL	100 % CFL	100 % CFL	100 % CFL
Heating systems					
Primary	70 % efficient mains gas central heating primary pipework uninsulated	90 % efficient mains gas central heating primary pipework uninsulated	90% efficient mains gas central heating primary pipework insulated	91,5 % efficient mains gas central heating primary pipework insulated	91,5 % efficient mains gas central heating primary pipework insulated
Secondary	30 % efficient, open fire in grate, manufactured smokeless fuel	30 % efficient, open fire in grate, manufactured smokeless fuel	70 % efficient stove, manufactured smokeless fuel	70 % efficient stove, manufactured smokeless fuel	75 % efficient biomass stove
Hot water	From primary heating system, electric immersion used in summer	From primary heating system, electric immersion used in summer	From primary heating system	From primary heating system	From primary heating system
Thermal mass category	Medium	Medium	Medium	Medium	Medium
Cylinder	Insulated with loose jacket, 35 mm thick, no thermostat	Insulated with loose jacket, 35 mm thick, thermostat	Factory insulated, 50 mm thick, thermostat	Factory insulated, 50 mm thick, thermostat	Factory insulated, 50 mm thick, thermostat
Controls	Programmer	Programmer and TRVs and flow switch	Programmer, two heating zones, each with time control and room thermostats, separate time control for domestic hot water, two pipe system, TRVs, boiler interlock	Programmer, two heating zones, each with time control and room thermostats, separate time control for domestic hot water, two pipe system, TRVs, boiler interlock	Programmer, two heating zones, each with time control and room thermostats, separate time control for domestic hot water, two pipe system, TRVs, boiler interlock
kWh/m²/yr	341,01	167,10	108,2	98,96	89,41
kg CO_2/m²/yr	72,17	35,85	21,68	19,82	16,50
BER	E2	C1	B2	B1	B1
NOTE Individual parameter specifications provided in these tables are indicative. Individual parameters can be varied and combined to achieve different results.					

Semi detached house (1981, Hollow blocks) - Refurbishment level 1



Semi detached house (1981, Hollow blocks) - Refurbishment level 2

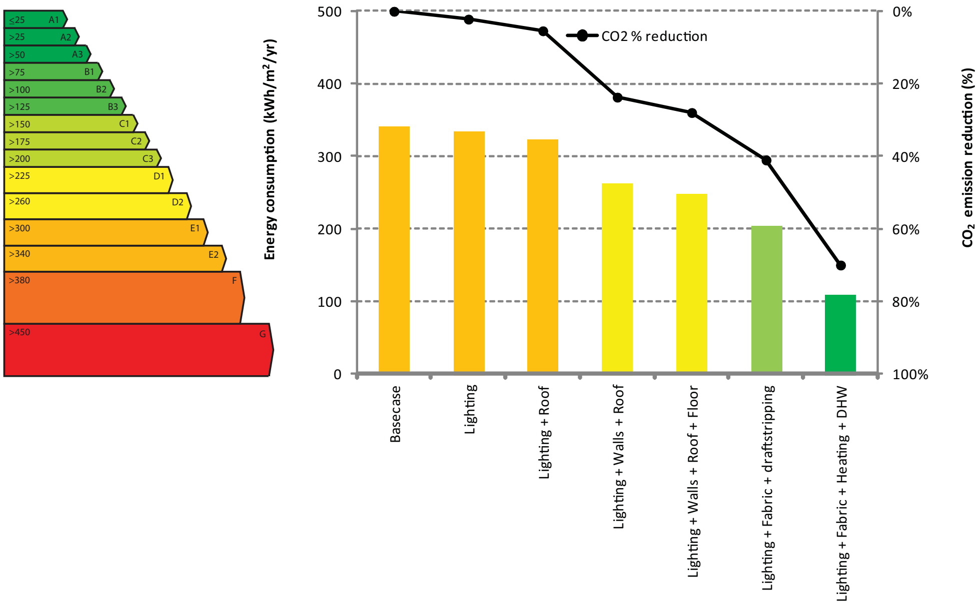
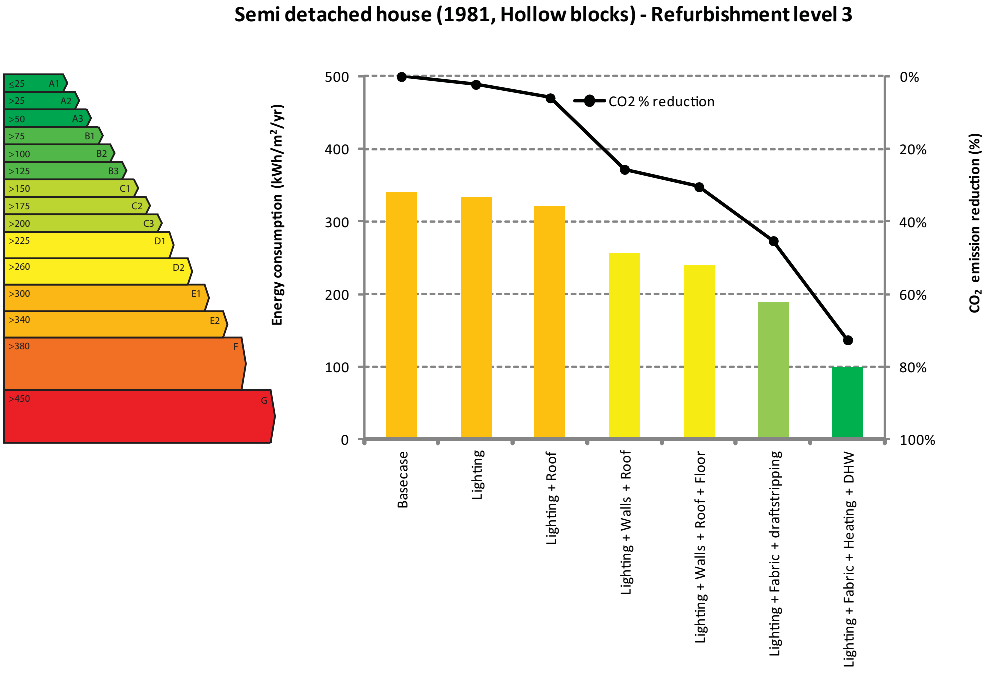


Figure 12 - A - Performance improvements for semi-detached hollow block dwellings[1)]

1) The bars on the graphs represent energy use which can be read on the left hand axis. The colour of the bar is aligned with the BER rating. The CO_2 reduction can be read from right hand axis.



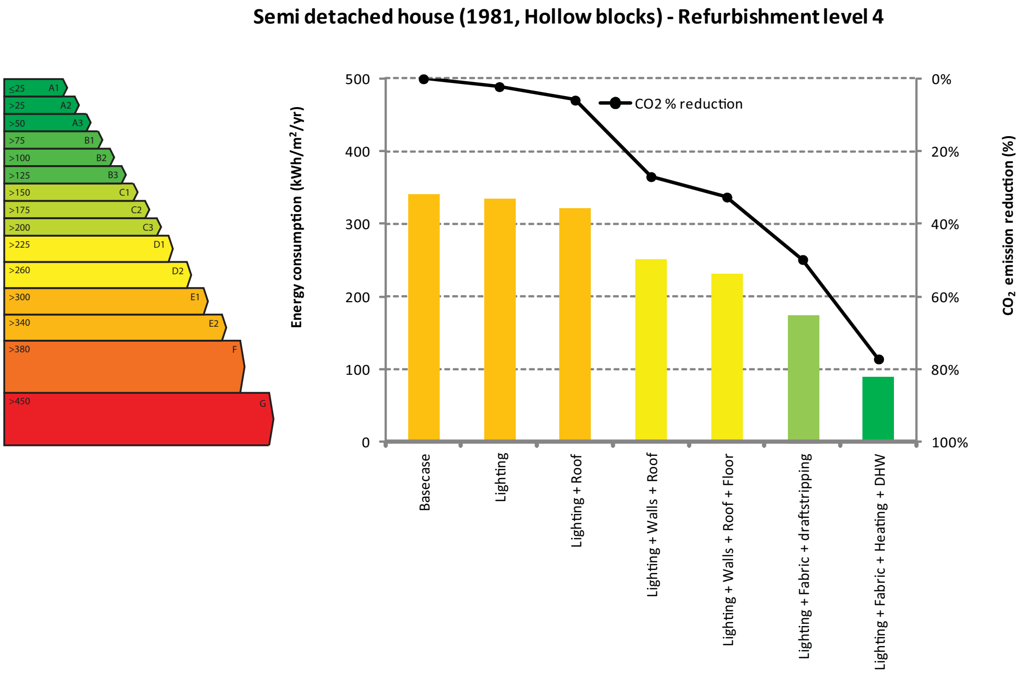


Figure 12 - B - Performance improvements for semi-detached hollow block dwellings[1]

1) The bars on the graphs represent energy use which can be read on the left hand axis. The colour of the bar is aligned with the BER rating. The CO_2 reduction can be read from right hand axis.

5.5.3 Case study B

Table 8 - Detached dwelling, cavity wall construction

Detached bungalow, cavity walls, 1989			
Description			
Typical rural bungalow from the 1980s. 50 mm of polystyrene wall insulation was normally fitted during construction. The part-filled cavity can be full-filled by pumping in additional insulation beads.			
Building elements		Insulation	U-Value
Walls	**Cavity walls, partially filled**	**25 mm - 50 mm**	**0,6**
Roofs	**Pitched, insulation between joists**	**100 mm**	**0,4**
Floors	**Solid**	**10 mm - 15 mm**	**0,57**
Windows	**Double glazed, metal frame, 6 mm gap**	**n/a**	**3,1**
Doors	**Solid wood**	**none**	**3,0**
Heating systems characteristics:		Fuel	Efficiency
Primary	**Central heating boiler, pipework uninsulated**	**Heating oil**	**75 %**
Secondary	**Open fire in grate**	**Coal**	**30 %**
Hot water	**From primary heating system. Electric immersion used in summer**		
Cylinder	**Insulated, spray foam 30 mm, no cylinder thermostat**		
Controls	Programmer		

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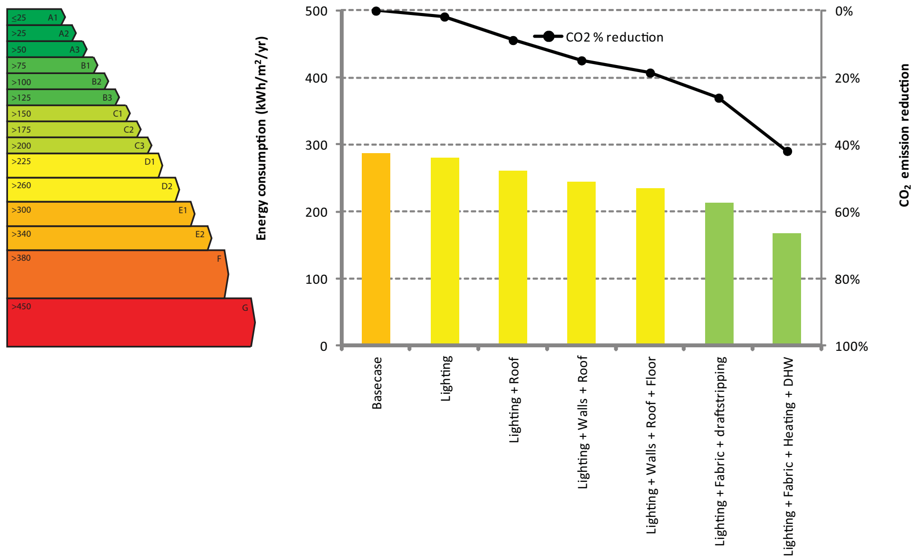
Table 9 - Specification for different performance levels for detached cavity wall construction

		Retrofit measures			
Element	**Base Case**	**Example 1**	**Example 2**	**Example 3**	**Example 4**
Roof - Pitched					
Insulation	100 mm between joists	250 mm between and over joists	300 mm between and over joists	400 mm between and over joists	400 mm between and over joists
Conductivity	0,04 W/mK	0,04 W/mK	0,04 W/mK	0,04 W/mK	0,04 W/mK
U-Value	0,4 W/m²K	0,16 W/m²K	0,14 W/m²K	0,10 W/m²K	0,10 W/m²K
Walls – Cavity					
Cavity insulation (CWI)	110 mm cavity, 25mm -50 mm partial fill	Full fill injection of residual cavity with EPS bead	Full fill injection of residual cavity with EPS bead	Full fill injection of residual cavity with EPS bead	Full fill injection of residual cavity with EPS bead
Conductivity		0,037 W/mK	0,037 W/mK	0,037 W/mK	0,037 W/mK
U-value	0,6 W/m²K	0,35 W/m²K			
			and	and	and
Internal insulation (IWI)			25 mm IWI	60 mm IWI	95 mm IWI
Conductivity			0,035 W/mK	0,035 W/mK	0,025 W/mK
U-value			0,27 W/m²K	0,21 W/m²K	0,15 W/m²K
					OR
External insulation (EWI)[1)]					135 mm EWI
Conductivity					0,035 W/mK
U-value					0,15 W/m²K
Floor					
Insulation	Solid 10-15 mm	Solid 20 mm	Solid 70 mm	Solid 100 mm	Solid 120 mm
Conductivity		0,035 W/mK	0,035 W/mK	0,035 W/mK	0,025 W/mK
U-value	0,57 W/m²K	0,45 W/m²K	0,25 W/m²K	0,21 W/m²K	0,15 W/m²K
Windows					
Type	Double glazed, wooden frame 6mm gap	High performance double glazed, low-e, argon	High performance double glazed, low-e, argon	High performance triple glazed, low-e, argon	High performance triple glazed, low-e, argon
U-value	3,1 W/m²K	1,6 W/m²K	1,4 W/m²K	0,95 W/m²K	0,85 W/m²K
Total solar energy tranmittance g ⊥	0,76	0,75	0,75	0,64	0,64

1) EWI only provided in table where thickness to be installed is greater than 80 mm

		Retrofit measures			
Element	**Base Case**	**Example 1**	**Example 2**	**Example 3**	**Example 4**
Doors					
Type (Front)	Double glazed, wooden frame 6mm gap	High performance double glazed, low-e, argon	High performance double glazed, low-e	High performance triple glazed, low-e, argon	High performance triple glazed, low-e, argon
U-value (Front)	3,1 W/m^2K	1,6 W/m^2K	1,4 W/m^2K	0,95 W/m^2K	0,85 W/m^2K
Type (Rear)	Solid wood	Solid wood	Solid wood	Solid wood	Solid wood
U-value (Rear)	3,0 W/m^2K	3,0 W/m^2K	3,0 W/m^2K	3,0 W/m^2K	3,0 W/m^2K
Airtightness					
% Draught stripping	90	100	100	100	
Air permeability					0,25 ACH
Ventilation	Natural with intermittent extract	Natural with intermittent extract	Natural with intermittent extract	Natural with intermittent extract	Natural with intermittent extract
Lighting	0 % CFL	100 % CFL	100% CFL	100% CFL	100% CFL
Heating systems					
Primary	75 % efficient oil central heating primary pipework uninsulated,	90 % efficient oil central heating primary pipework uninsulated	90 % efficient oil central heating primary pipework insulated	95% efficient oil central heating primaey pipework insulated	95 % efficient oil central heating primary pipework insulated
Secondary	30 % efficient, open fire in grate, solid multifuel	30 % efficient, open fire in grate, solid multifuel	70 % efficient stove, solid multifuel	70 % efficient stove, solid multifuel	75 % efficient biomass stove
Hot water	From primary heating system, electric immersion used in summer	From primary heating system, electric immersion used in summer	From primary heating system	From primary heating system	From primary heating system
Cylinder	Insulated spray foam, 30 mm thick no thermostat	Insulated spray foam, 30 mm thick, thermostat	Insulated spray foam, 50 mm thick, thermostat	Insulated spray foam, 50 mm thick, thermostat	Insulated spray foam, 50 mm thick, thermostat
Controls	Programmer	Programmer and TRV's and flow switch	Programmer, two heating zones each with time control and room thermostats, separate time control for domestic hot water, two pipe system, TRV's, boiler interlock	Programmer, two heating zones each with time control and room thermostats, separate time control for domestic hot water, two pipe system, TRV's, boiler interlock	Programmer, two heating zones each with time control and room thermostats, separate time control for domestic hot water, two pipe system, TRV's, boiler interlock
$kWh/m^2/yr$	286,91	167,05	111,31	98,5	88,39
kg $CO_2/m^2/yr$	73,79	42,90	27,95	24,69	20,28
BER	D2	C1	B2	B1	B1
NOTE Individual parameter specifications provided in these tables are indicative. Individual parameters can be varied and combined to achieve different results.					



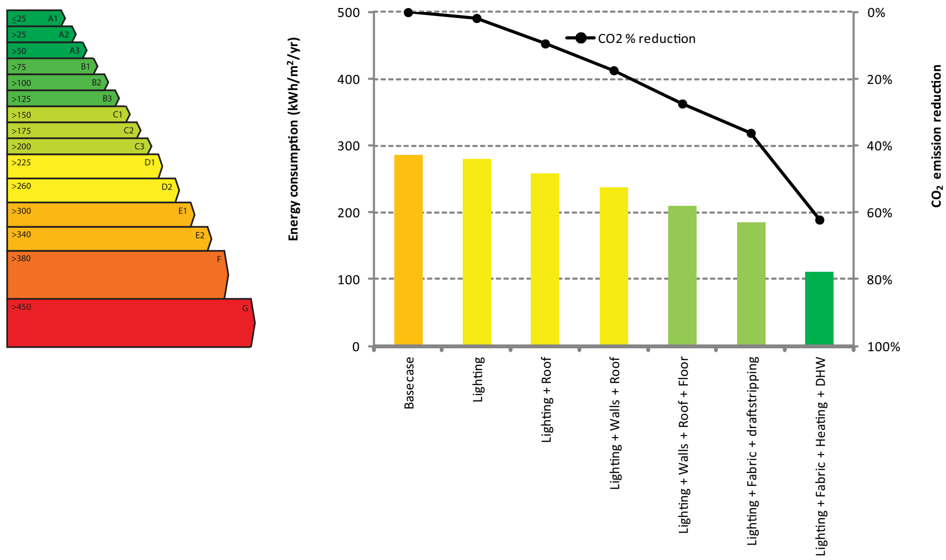
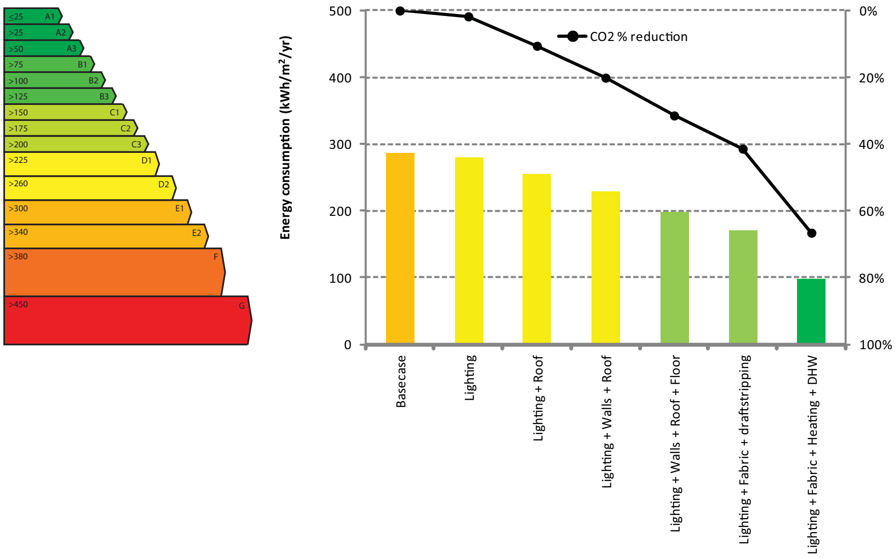


Figure 13 - A - Performance improvements for detached dwellings with cavity wall construction

Detached bunglow (1989, Cavity walls) - Refurbishment Level 3



Detached bunglow (1989, Cavity walls) - Refurbishment Level 4

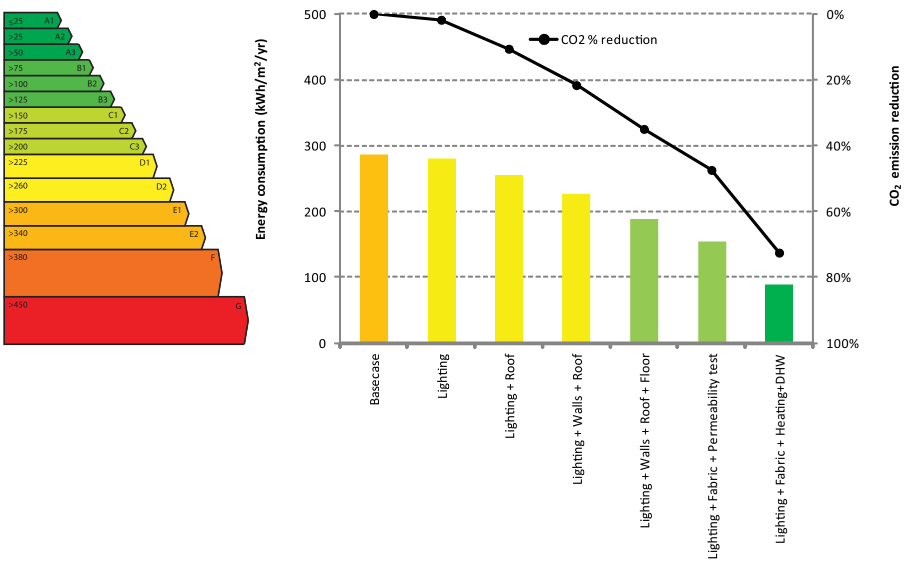


Figure 13 - B - Performance improvements for detached dwellings with cavity wall construction

5.5.4 Case study C

Table 10 - Terraced dwelling, solid masonry

Terraced house, mass concrete, 1930			
Description			
Mid terraced house, very common in Dublin in 1930s and 1940s. Originally built with mass concrete walls and solid floors.			
Building elements		Insulation	U-Value
Walls	Solid mass concrete	None	2,2
Roofs	Pitched, insulation between joists	50 mm	0,68
Floors	Solid floor	None	0,61
Windows	Single glazed, metal frame	n/a	5,7
Doors	Solid wood	none	3,0
Heating systems characteristics:		Fuel	Efficiency
Primary	Central heating boiler, pipework uninsulated	Mains gas	65 %
Secondary	Open fire in grate	Smokeless	30 %
Hot water	From primary heating system. Electric immersion heater is used in summer		
Cylinder	Insulated with loose jacket, 25 mm thick, no cylinder thermostat		
Controls	Programmer only		

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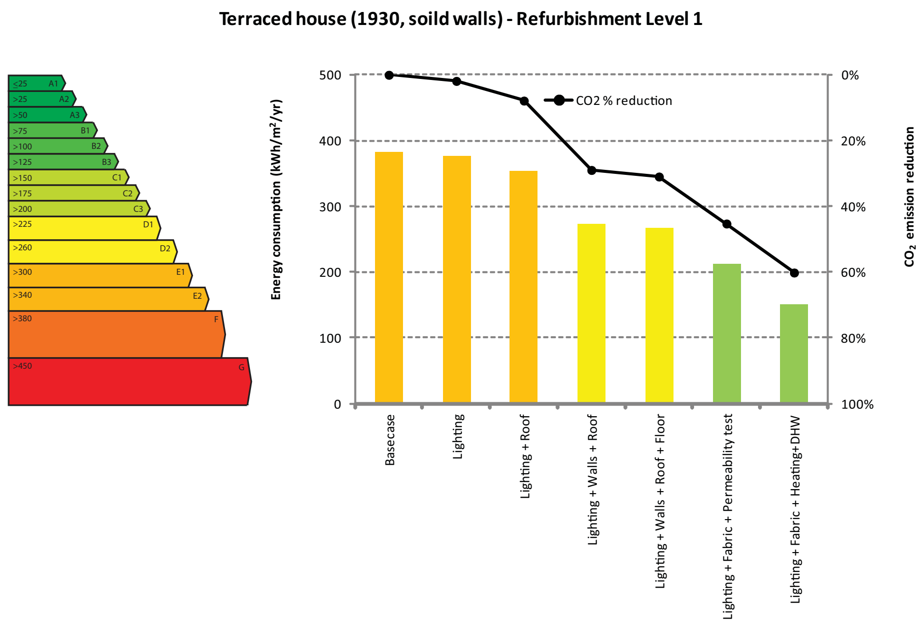
Table 11 - Specification for different performance levels for terraced dwelling with solid masonry

		Retrofit measures			
Element	Base Case	Example 1	Example 2	Example 3	Example 4
Roof – Pitched					
Insulation	**50 mm between joists**	**250 mm between and over joists**	**300 mm between and over joists**	**400 mm between and over joists**	**400 mm between and over joists**
Conductivity		**0,04 W/mK**	**0,04 W/mK**	**0,04 W/mK**	**0,04 W/mK**
U-Value	**0,68 W/m²K**	**0,16 W/m²K**	**0,14 W/m²K**	**0,10 W/m²K**	**0,10 W/m²K**
Walls – Solid mass concrete					
Internal insulation (IWI)		**65 mm IWI**	**90 mm IWI**	**120 mm IWI**	**170 mm IWI**
Conductivity		**0,025 W/mK**	**0,025 W/mK**	**0,025 W/mK**	**0,025 W/mK**
U-value	**2.20 W/m²K**	**0,35 W/m²K**	**0,27 W/m²K**	**0,21 W/m²K**	**0,15 W/m²K**
		OR	**OR**	**OR**	**OR**
External insulation (EWI)		**90 mm EWI**	**120 mm EWI**	**160 mm EWI**	**230 mm EWI**
Conductivity		**0,035 W/mK**	**0,035 W/mK**	**0,035 W/mK**	**0,035 W/mK**
U-value		**0,35 W/m²K**	**0,27 W/m²K**	**0,21 W/m²K**	**0,15 W/m²K**
Floor					
Insulation	**Solid**	**Solid 20 mm**	**Solid 70 mm**	**Solid 100 mm**	**Solid 120 mm**
Conductivity		**0,035 W/mK**	**0,035 W/mK**	**0,035 W/mK**	**0,025 W/mK**
U-value	**0,61 W/m²K**	**0,45 W/m²K**	**0,25 W/m²K**	**0,21 W/m²K**	**0,15 W/m²K**
Windows					
Type	**Single glazed, metal frame**	**High performance double glazed, low-e, argon**	**High performance double glazed, low-e, argon**	**High performance triple glazed, low-e, argon**	**High performance triple glazed, low-e, argon**
U-value	**5,7 W/m²K**	**1,6 W/m²K**	**1,4 W/m²K**	**0,95 W/m²K**	**0,85 W/m²K**
Total solar energy transmittance g ⊥	**0,76**	**0,75**	**0,75**	**0,64**	**0,64**
Doors					
Type (Front)	**Double glazed, wooden frame 6mm gap**	**High performance double glazed, low-e, argon**	**High performance triple glazed, low-e**	**High performance triple glazed, low-e, argon**	**High performance triple glazed, low-e, argon**
U-value (Front)	**3,1 W/m²K**	**1,6 W/m²K**	**1,4 W/m²K**	**0,95 W/m²K**	**0,85 W/m²K**

		Retrofit measures			
Element	Base Case	Example 1	Example 2	Example 3	Example 4
Type (Rear)	Solid wood	Solid wood	Solid wood	Solid wood	Solid wood
U-value (Rear)	3,0 W/m²K	3,0 W/m²K	3,0 W/m²K	3,0 W/m²K	3,0 W/m²K
Airtightness					
% Draught stripping	25	100	100	100	
Air permeability					0,25 ACH
Ventilation	Natural with intermittent extract	Natural with intermittent extract	Natural with intermittent extract	Natural with intermittent extract	Natural with intermittent extract
Lighting	0 % CFL	100 % CFL	100 % CFL	100 % CFL	100 % CFL
Heating systems					
Primary	65 % efficient mains gas central heating primary pipework insulated	90 % efficient mains gas central heating primary pipework uninsulated	90 % efficient mains gas central heating primary pipework insulated	91,5 % efficient mains gas central heating primary pipework insulated	91,5 % efficient mains gas central heating primary pipework insulated
Secondary	30 % efficient, open fire in grate, manufactured smokeless fuel	30 % efficient, open fire in grate, manufactured smokeless fuel	70 % efficient stove, manufactured smokeless fuel	70 % efficient stove, manufactured smokeless fuel	75 % efficient biomass stove
Hot water	From primary heating system, electric immersion used in summer	From primary heating system, electric immersion used in summer	From primary heating system	From primary heating system	From primary heating system
Thermal mass category	Medium	Medium	Medium	Medium	Medium
Cylinder	Insulated with loose jacket, 25 mm thick, no thermostat	Insulated with loose jacket, 25 mm thick, no thermostat	Factory insulated, 50 mm thick, thermostat	Factory insulated, 50 mm thick, thermostat	Factory insulated, 50 mm thick, thermostat
Controls	Programmer	Programmer and TRVs and flow switch	Programmer, two heating zones each with time control and room thermostats, separate time control for domestic hot water, two pipe system, TRV's, boiler interlock	Programmer, two heating zones each with time control and room thermostats, separate time control for domestic hot water, two pipe system, TRV's, boiler interlock	Programmer, two heating zones each with time control and room thermostats, separate time control for domestic hot water, two pipe system, TRV's, boiler interlock
kWh/m²/yr	382,28	150,20	94,47	87,42	79,65
kg CO_2/m²/yr	80,35	32,03	18,88	17,47	14,90
BER	F	C1	B1	B1	B1
NOTE Individual parameter specifications provided in these tables are indicative. Individual parameters can be varied and combined to achieve different results.					



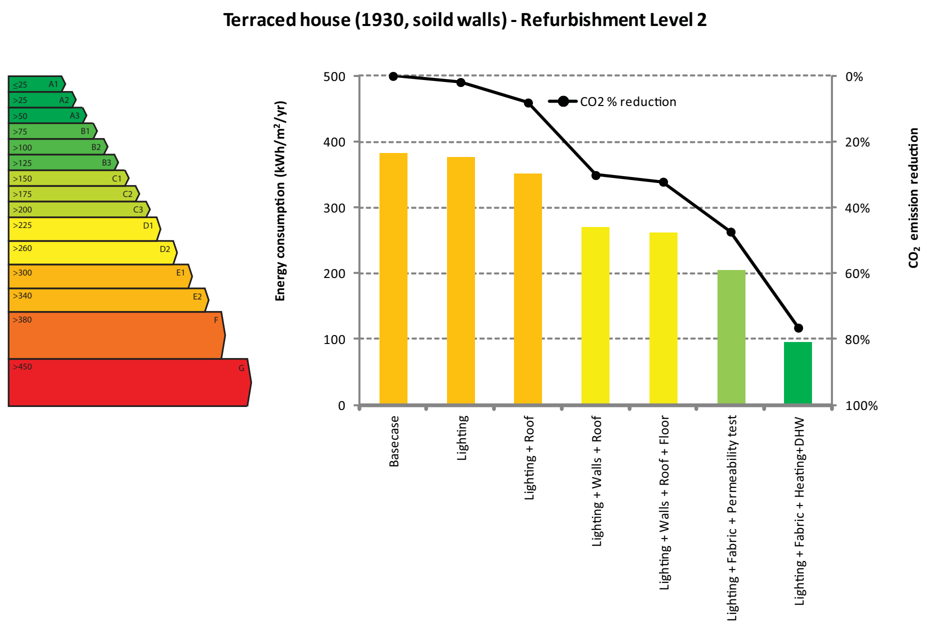
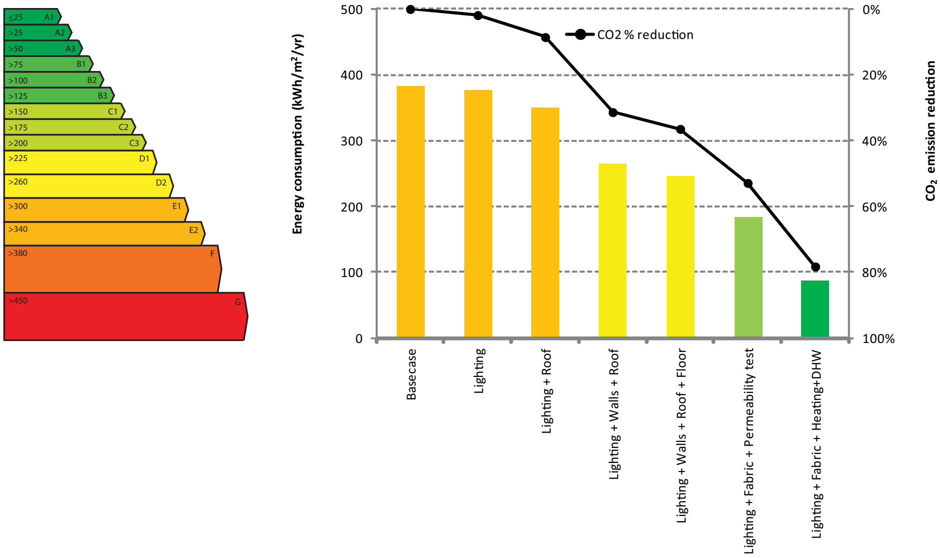


Figure 14 - A - Performance improvements for terraced dwellings, solid masonry

Terraced house (1930, soild walls) - Refurbishment Level 3



Terraced house (1930, soild walls) - Refurbishment Level 4

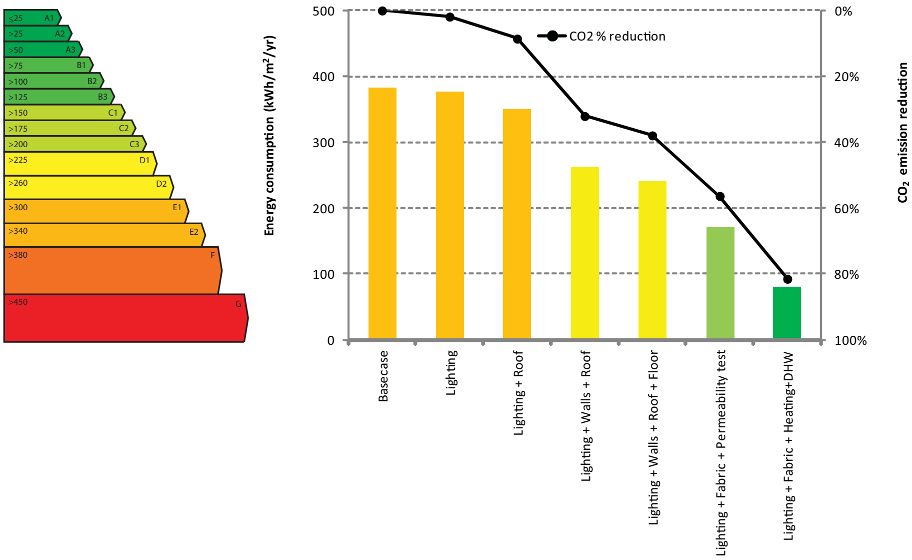


Figure 14 - B - Performance improvements for terraced dwellings, solid masonry

6. Roofs

6. Roofs

6.1 General

This clause describes the different types of roofs (both warm and cold) that exist, and the insulation methods and materials used to achieve energy savings.

A warm or cold roof is defined by which side of the roof structure the insulation is located, i.e. a cold pitched roof has the insulation at horizontal or sloping ceiling level, whereas a warm pitched roof has the insulation on top of (and sometimes between) the rafters.

U-value tables showing indicative insulation thickness needed to achieve various energy efficiency levels are given in Annex A. These values generally assume no original insulation in the existing roof, but where insulation has been assumed it is confirmed in the relevant table.

6.2 Roof types

6.2.1 Pitched roof

6.2.1.1 General

Pitched roofs are made up from structural timbers such as rafters and purlins or prefabricated roof trusses, which form the roof void, see Figure 15. The structure is then usually covered by underlay (felt/membrane) and the final outer waterproof layer is a slate or tile finish. For this type of roof, insulation of depths between 25 mm and 100 mm has typically been fitted between joists at ceiling level.

Sometimes, a room (or rooms) is located in the roof space, either because the house was originally constructed this way (dormer), or the roof space was subsequently converted to provide habitable accommodation. The insulation standards varied greatly for these constructions. Remediation may be necessary to address issues such as insufficient ventilation or sagging because of inadequate support to the rafters.

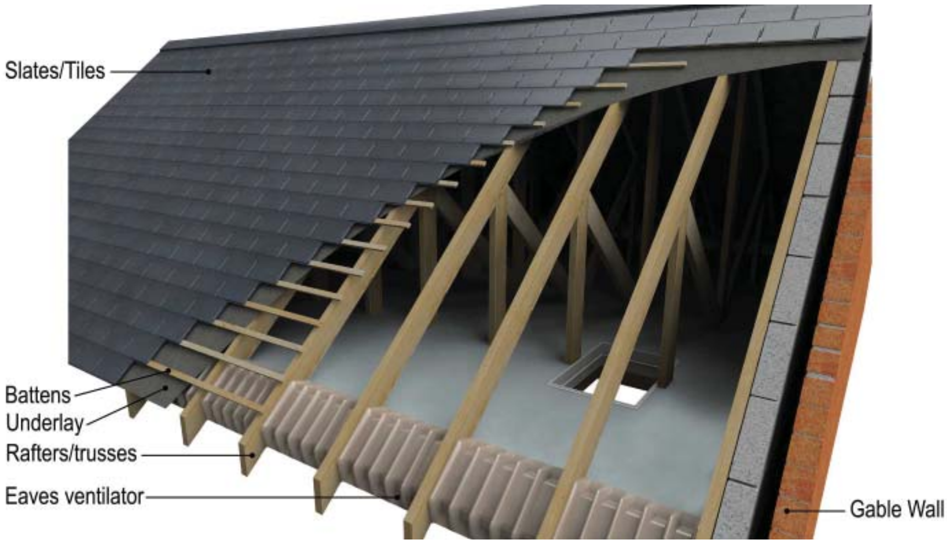


Figure 15 - Pitched Roof

6.2.1.2 Applicable retrofit methods

For a cold pitched roof with no room in the roof space, it is relatively straightforward to place sufficient insulation at ceiling level to achieve the required energy saving. It is important to cross-lay multiple layers to prevent air movement within the insulation; otherwise an increase in heat loss and a reduction in the overall performance may result, see 6.3.2.

An alternative to placing insulation at ceiling level is to insulate between and below the rafters. This is appropriate if a loft conversion is proposed in the future, or where there are already rooms present and where the surface finishes are in a poor condition and need replacing. Where the roof space already contains rooms and the finishes are in good condition and insulation already exists (or additional insulation cannot be fitted between rafters), it may be appropriate to provide a layer of insulated laminate plasterboard or insulation between battens, that includes a vapour control layer, to the inside face of the rooms. This method may also be used where the ceiling is partially sloped, see 6.3.3.

Where roof coverings are to be replaced, providing insulation above and between the rafters is an option, but only where habitable accommodation in the roof space exists or is proposed. The guidance for new build construction contained in relevant certificates is applicable in these situations. Placing insulation on top of the rafters increases the overall height of the roof. In such situations planning requirements should be checked, see 6.3.4.

6.2.2 Flat roof

6.2.2.1 Description

Figure 16 shows the typical construction of a flat timber cold roof. Roof joists span from opposing supporting walls (usually the shortest span distance), and have firrings over to allow for drainage of the roof surface. The roof is completed with suitable weatherproof membrane and coverings.

Alternatively, a flat roof can consist of a concrete slab surrounded by parapet walls, see Figure 16. Insulation may be present, either above or below the weatherproof layer.

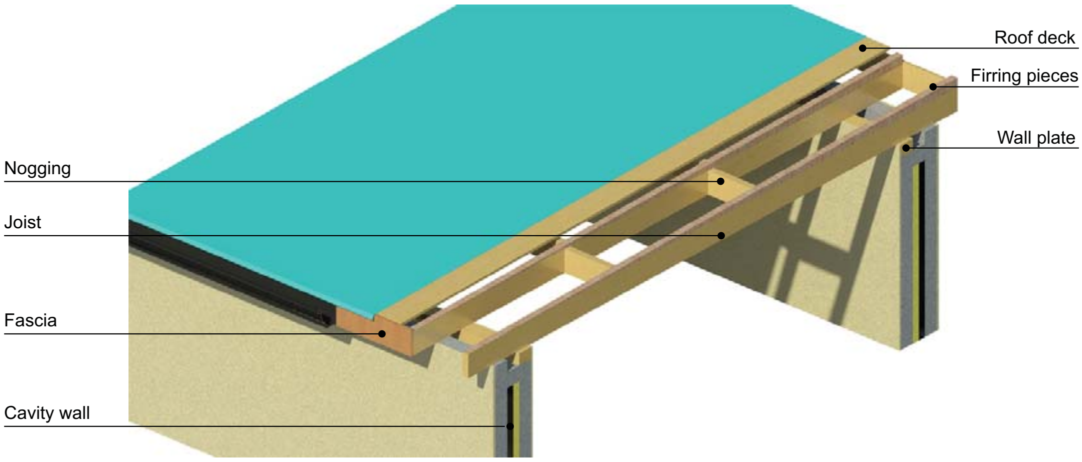


Figure 16 - Timber flat roof

6.2.2.2 Applicable retrofit methods

Where the timber flat roof covering is in good condition, insulation can be applied:

i) to the underside of the ceiling, and also between the roof joists where the ceiling is to be replaced - this is known as a cold deck roof, see 6.3.5,

ii) on top of the existing roof deck and then covered with a weatherproof membrane – this is known as a warm deck sandwich roof, see 6.3.6.2, or

iii) directly on top of the existing roof weatherproof membrane – this is known as a warm deck inverted roof, see 6.3.6.3.

Where the weatherproofing layer is in need of replacement, then it is possible to place insulation above the deck after fitting an adequate vapour control layer and then a weatherproofing layer above as in option ii).

For a concrete slab flat roof, insulation can only be applied to the upper surface, and a new weather proof membrane applied either above, see option ii), or below the insulation, see option iii). Additionally, where a parapet wall exists, the upstand may also require to be insulated.

6.3 Insulation methods

6.3.1 General

6.3.1.1 Roof condition

Where work is required on the roof due to defective weatherproof layers, missing or defective underlay, rotted timbers or structural strengthening, this provides an opportunity to insulate the roof.

Conversely, when providing insulation to the roof, a survey should be carried out and the roof strengthened where necessary. This might be to replace some of the structure, or to accommodate some form of solar technology in the future.

Where a flat roof is covered in a high quality material such as lead or copper sheeting, the addition of insulation above the existing roof surface may not be appropriate.

6.3.1.2 Services within or above roof space

Roof voids may be used to accommodate dwelling services such as:

— water tanks/cylinders and pipework (pitched roof only);

— ventilation systems (pitched roofs only); and

— electrical cabling for ring mains and lighting circuits etc. (both pitched and flat roofs).

It is therefore important to understand the consequences regarding these services with respect to overheating of cables and light fittings, freezing of pipes/tanks, access to services, airtightness sealing of penetrations etc. when proposing to insulate the roof.

Pitched and flat roof surfaces can also be used for solar technologies, with the resultant pipework and cabling passing through the roof structure to the inside of the dwelling.

Warm moist air extracted from kitchens and bathrooms cools when it passes through ducts in unheated roof spaces. If the air is cooled below its dew point, moisture will condense on the duct wall and may drip back into the fan unit. Ducts should either be insulated when passing through unheated roof spaces, or be designed to drain to outside.

6.3.1.3 Condensation

Condensation is a risk when installing insulation as described in 4.5. The installation and maintenance of vapour control layers in the correct location and providing purpose designed ventilation are necessary to prevent both interstitial and surface condensation.

6.3.1.4 Thermal bridging

The junction between the wall and eaves is a key thermal bridge. Consideration should be given to the provision of insulation at this junction to minimise surface condensation risk, see Annex G and Annex H.

Where possible the roof insulation should be continuous with the wall insulation, see Annex H.

6.3.1.5 Light shafts

The walls of light shafts passing through attic voids should be insulated to avoid heat loss. This should be considered when insulating pitched roof spaces, see Figure 17.

Figure 17 - **Insulated light shaft**

6.3.1.6 Access to flat roofs

There are two kinds of flat roofs for the purposes of designing for access:

— the roof which provides access only for repair and cleaning; and

— the roof which provides access for amenity, means of escape or for other purposes.

The essential differences to take into account include loads imposed on the roof structure (including impacts) and the provision of guarding.

Where pedestrian access is needed, the compressive strength of thermal insulation boards used over decks should have a minimum value of 175 kPa and 300 kPa for crowd loads. Care should be taken to ensure the membrane is not deformed under any of the loading criteria and that paving supports are of sufficient area to avoid crushing the insulation boards.

NOTE For further guidance see I.S. EN 1991-1-1 and I.S. EN 1991-1-3.

6.3.1.7 Cabling and insulation

The presence of insulation around a cable has the effect of reducing the current carrying capacity, this can also lead to overheating of cables. Wherever possible, electrical cables should feed over the insulation. Wiring in attic spaces should comply with the requirements of Sections 522.8.8 and 526.10 of ET 101:2008 *National Rules for Electrical Installations* to minimise the risk of mechanical damage and fire.

Cables to high load appliances, such as cookers and showers, should remain uncovered or lifted above the insulation. Where this is not possible, and to provide adequate ventilation, a minimum space of 75 mm around the cable is to be retained along its full length within the loft space.

In general, where cables are being enclosed by insulation:

— circuits run within thermal insulation should be protected with cartridge fuses or miniature circuit breakers (MCBs); and

— cables fully enclosed by insulation may need to be increased in size above the standard recommended size where they pass at right angles through an insulating layer and as much as 50 % where they are enclosed along their length for more than 500 mm, see Table 12.

Where it is not possible to raise cables over the insulation or as an alternative to providing a minimum space, cables can be increased in size to safely carry the load.

Where existing cables are retained within the insulation the derated current carrying capacity should be checked by a suitably qualified electrician to ensure they have adequate current carrying capacity.

Table 12 - De-rating of cable capacity depending upon length of insulation penetration

Length of cable within insulation mm	Derating factor
50	0,88
100	0,78
200	0,63
400	0,51
>500	0,50
NOTE The values quoted are for general guidance only. For specific insulating materials further information should be sought from the manufacturer or other reliable source.	

For example, see Table 12, if the cable is surrounded by insulation for a length of 200 mm, the current carrying capacity of the cable is reduced by a factor of 0,63. The replacement cable therefore needs to have a current carrying capacity 1/0,63 (i.e. at least 1,6) times larger.

Polystyrene insulation is commonly used in sloping roofs (as well as floors and walls) and should be isolated from existing electrical cables used for lighting and socket ring mains. The plasticizers used to make the PVC insulation on the cables flexible, reacts with the polystyrene causing it to appear to melt. More importantly, the plasticizer migrates out of the cables resulting in the cable becoming brittle and causing its insulating properties to break down. The cable will eventually fail, especially if disturbed, and increases the risk of fire or electrocution.

In all instances where polystyrene insulation is proposed, all electrical cable should be enclosed within additional trunking or isolated from the insulation by a vapour control layer or other barrier.

Whenever there is a need to replace cables within the roof void, consideration should be given to providing a suitably sized dedicated service void below the existing ceiling. This is a practical solution if the existing ceiling is to be replaced, as this will improve the airtightness of the ceiling structure as it allows the installation of an air barrier to the underside of the roof/ceiling joists. A suitable deep service void is then formed by the use of plasterboard fixed to timber battens. This is even more important where new recessed light fittings are to be installed.

6.3.1.8 Light fittings

A type of lighting installation which requires special consideration is a recessed light fitting, see Figure 18. These should be avoided where possible, especially in wet rooms.

Downlighters should be provided with sufficient space to dissipate heat so as to prevent the lights themselves from overheating.

Where the light fitting itself is airtight (to the roof) but the hood of the fitting is open to the room, then the hole for the recessed fitting should be cut into the ceiling accurately to prevent air movement from the room into the roof space. A void should be formed around the light fitting in the lowest insulation layer.

Where the light fitting itself is not airtight (to the roof), or where it is not possible to make the ceiling airtight where the fitting is provided, then an airtight enclosure should be formed or a service void provided on the warm side of the VCL.

Forming these spaces at regular intervals in the insulation layer reduces the overall effectiveness of the roof insulation. Where they are fitted, a layer of high performance insulation should be installed above the the recessed lights to compensate for the voids formed in the lowest layer to accomodate the recessed fittings.

For sloped roofs where voids cannot be provided then recessed light fittings should not be installed in the sloping roof section unless a suitably deep service void is provided.

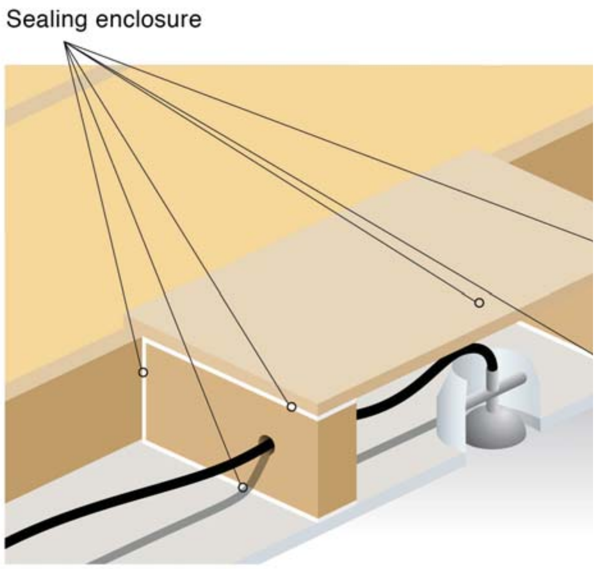


Figure 18 - Providing a sealed enclosure for a recessed down lighter

6.3.2 Cold pitched roof – insulation at ceiling

6.3.2.1 General

This is the most common form of adding insulation to a pitched roof. Insulation is placed between and over the ceiling joists and the roof void is ventilated at eaves level on opposite sides of the roof to provide cross ventilation, see Figure 19. The insulation is placed at ceiling level with minimal disruption to the dwelling's occupants.

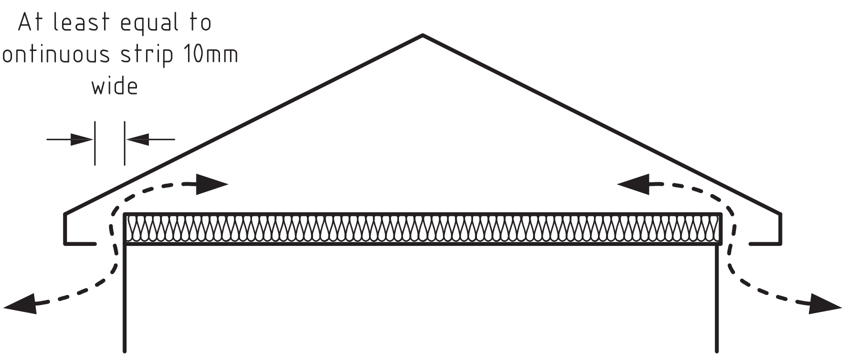


Figure 19 - Cross ventilation of roof void

6.3.2.2 Selection considerations

While rigid or semirigid insulation can be used, it is more practical to use a flexible type of insulation, i.e. mineral wool rolls, a spray foam/cellulose or a blown fibre.

Place the first layer between the ceiling joists; its thickness is determined by the depth of the existing ceiling joists and the presence of any existing insulation. Additional layers of insulation are then placed above the first, but laid across the joists.

Blown fibre, spray foam or cellulose can also be used, and this is useful where access to certain areas of the roof space is restricted (such as low pitched roof eaves) which would otherwise prevent access to lay flexible insulation from within the roof void. Precautions regarding preservation of adequate roof ventilation should be taken.

ROOFS

Blown fibre insulation is a quick installation method, but it can result in an uneven installation. The roof space should be cleared of obstructions to ensure a uniform thickness of insulation throughout.

6.3.2.3 Design considerations

6.3.2.3.1 Condensation risk

Long term exposure to interstitial condensation within the roof space can lead to the structural roof timbers rotting and, in extreme cases, failure of structural members. For a cold pitched roof, the two key design considerations are that the roof space above is adequately ventilated and that migration of moist air from the dwelling below (and potentially from within the roof space itself) into the roof void is prevented.

Only when these two considerations are dealt with together, is the risk of interstitial condensation in the roof void minimised.

Use of a vapour control layer at ceiling level, on the warm side of the insulation, will assist in limiting vapour transfer, but cannot be relied on as an alternative to ventilation. In particular, a vapour control layer should be used where the roof pitch is less than 15°, or where the shape of the roof is such that there is difficulty in ensuring adequate ventilation, e.g. habitable roof space.

6.3.2.3.2 Roof void ventilation

Roof void ventilation is generally provided in two ways through:

i) eaves ventilation; and

ii) ventilation tiles in the roof slope, positioned not more than 300 mm above the insulation.

6.3.2.3.2.1 Eaves ventilation

Eaves ventilation should be maintained. Insulation should be installed to prevent the insulation blocking the passage of air into (and out of) the roof.

Figure 20 shows how eaves ventilation (arrows) is achieved using eaves ventilators. A continuous gap of at least 10 mm or equivalent is required within the soffit or fascia below the guttering. Proprietary over fascia vent strips can also be used. The type of eaves ventilator shown here is a type that is folded to the correct pitch of the roof and placed between the rafters and then the insulation is laid into the eaves which is sufficient to hold the eaves ventilator in place.

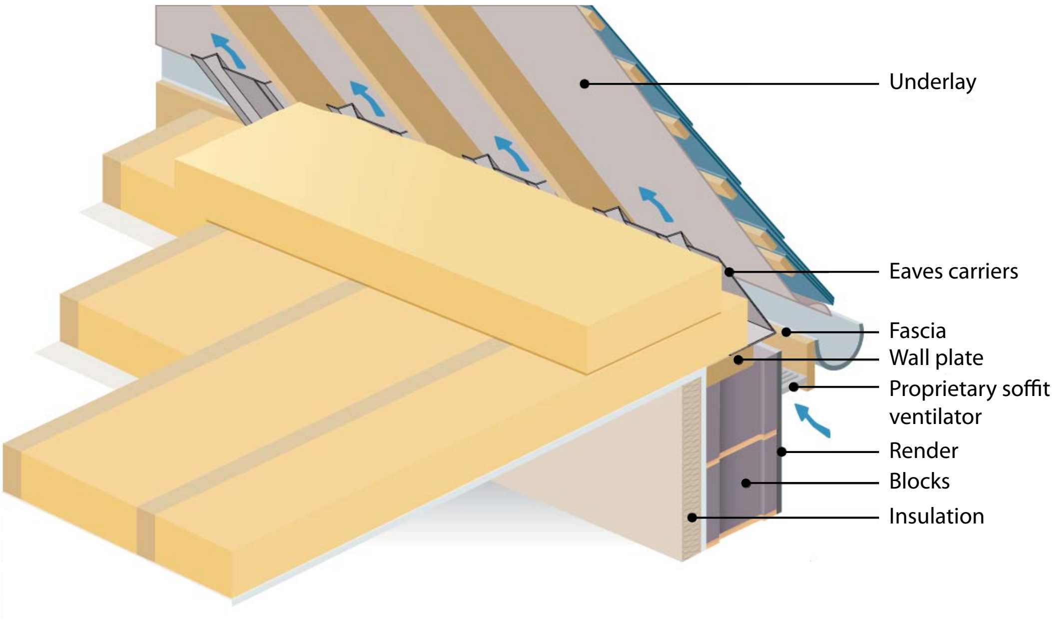


Figure 20 - **Eaves ventilation showing use of eaves ventilators**

ROOFS

6.3.2.3.2.2 Ventilation tiles

Where it is not possible to provide a gap at the soffit or fascia, the roof void can be ventilated by inserting ventilation tiles, see Figure 21. These should be positioned at low level on the roof slope (i.e. within approximately 450 mm up the slope above the top of the insulation, which is approximately 300 mm vertically above the upper most surface of the ceiling insulation for a roof with a 45° pitch). The ventilation tiles need to provide the equivalent of the 10 mm continuous gap, or 10,000 mm^2/m run of roof length net ventilation area.

Ventilation tiles may be a more practical solution where the insulation thickness or installation impedes eaves ventilation.

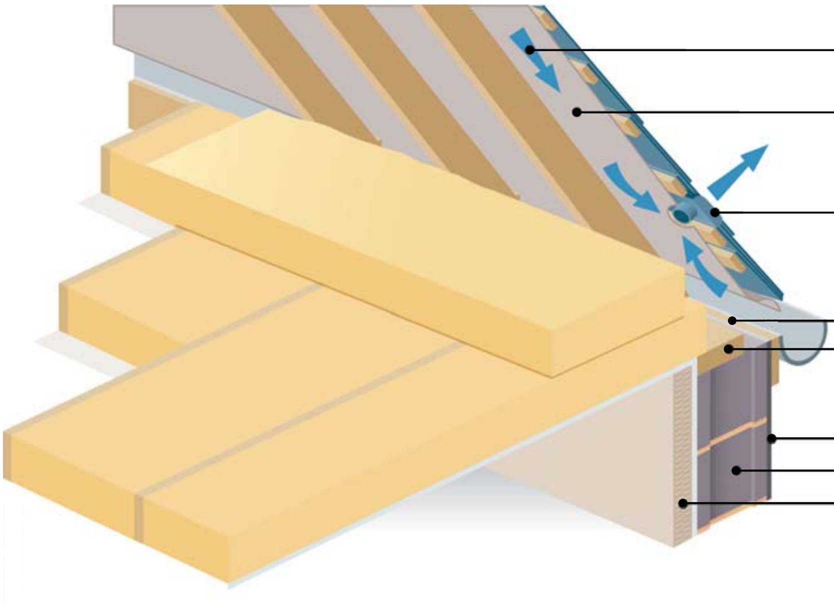


Figure 21 - Eaves ventilation showing use of vent tiles

6.3.2.3.3 Moisture prevention

6.3.2.3.3.1 Cold water tanks

A potential source of moist air from within the roof void is an open cold water tank, see Figure 22.

Insulating the roof at ceiling level will mean that the air temperature within the roof void will be close to the external temperature. To prevent the water in the tank from freezing during the winter months, the insulation should not be placed below the tank, but lapped up the sides and around it. The insulation around the tank should be closed to prevent moist air escaping into the roof void. Maintenance access to the inside of the tank should be maintained. Where raised tanks are used, to aid head pressure, the ceiling should be insulated as normal and all surfaces of the tank insulated separately. The level of thickness of insulation depends on the ambient temperature of the water and air and the exposure period, see BS 5422 and TGD G for further information. The installation should be such that future sagging or dislodgement of insulation is avoided.

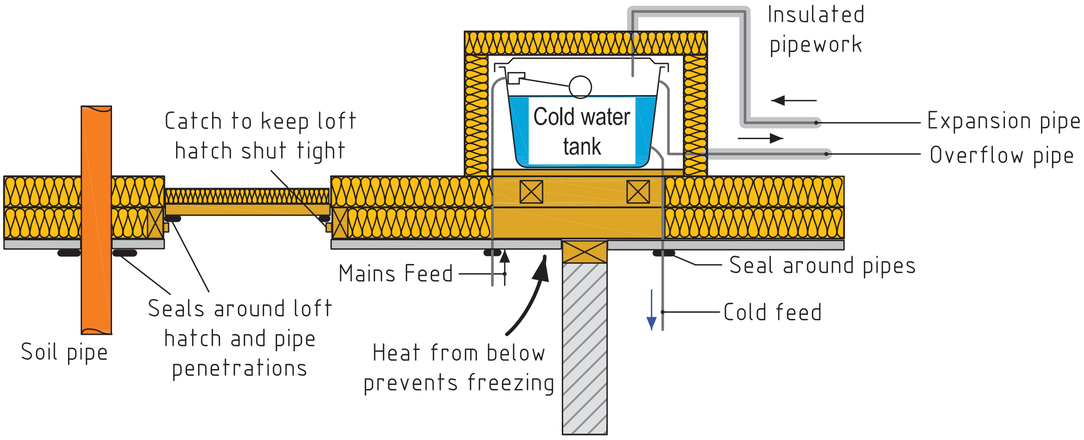


Figure 22 - Insulating water tanks and sealing penetrations to roof

6.3.2.3.3.2 Extract ventilation from wet rooms

Moist air is formed primarily in wet rooms and these should be fitted with suitable means of extract ventilation (in addition to any openable windows) to remove as much of the moist air produced at source as possible. For further details, see Clause 10.

6.3.2.4 Installation considerations

Moist air should be prevented from entering the roof void by ensuring the loft hatch is draughtproofed (and insulated) and may be closed securely. Loft hatches should be insulated. The use of a high performing insulant will reduce the thickness. Hatches with loft ladders may be difficult to insulate so proprietary solutions should be sought. Any service penetrations through the ceiling (lighting roses and pipes etc.) should be sealed. This work should be carried out before insulating the roof void, see Figure 21 and Figure 19.

Having ensured that all penetrations through the ceiling into the roof are adequately sealed, there are additional installation considerations which need to be addressed to ensure that the technical risks discussed above do not occur, and also ensure that other risks such as thermal bridging are also addressed.

Where a storage platform or access walkway is proposed, in order to achieve the same U-value, the area underneath should be provided with high performance insulation between the ceiling joists before the storage platform or walkway is provided. Additionally, high performance insulation should be placed on top of the ceiling joists, either as another layer between timber spacer battens or in the form of insulated flooring. Alternatively it may be constructed with counter joists accommodating the full depth of insulation and a deck. An access walkway should be provided where a service such as a boiler or ventilation system is provided within the roof void to allow for suitable access for repair and maintenance.

Consideration should be given to the following to avoid gaps when installing insulation at ceiling level:

— the top of the first layer of insulation laid between the ceiling joists should be no more than 25 mm either above or below the top of the ceiling joists. A gap larger than this could lead to a thermal bypass, as a continuous gap could be formed (from eaves to eaves) within the layers of insulation;

— the next layer(s) of insulation should be laid across the ceiling joists, ensuring all butted joints do not line up between the layer(s) and that each layer is tucked into the eaves as far as possible, either up to the eaves ventilators or completely into the eaves where ventilation tiles are used. This prevents excessive thermal bridging in the eaves location;

— the mineral wool insulated ceiling around the storage platform should be installed with the top layer of the mineral wool insulation overlapping into the storage decking at its edges to prevent air movement through gaps around the platform. Where a small storage area is required in the roof void, this should be located as close to the loft hatch as possible.

6.3.3 Cold pitched roof - insulation at rafters

6.3.3.1 General

This type of insulated pitched roof is most common where rooms exist in the roof space. Insulation is placed either between or below the rafters (or both) with a ventilated void between the rafters above the insulation with high level (ridge) ventilation, in addition to eaves ventilation, see Figure 23.

The insulation either completely follows the slope of the roof or the profile of the rooms. The insulation should be continuous and at no point prevent cross ventilation of the roof voids.

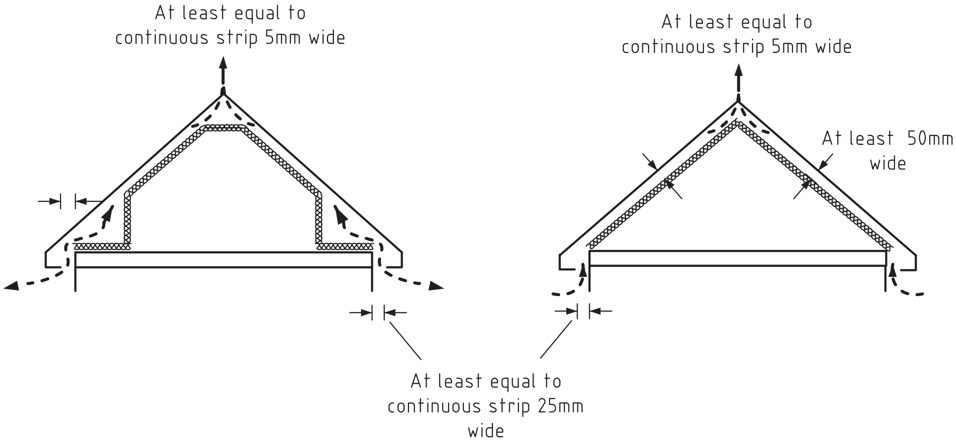


Figure 23 - Cold vented insulated roof with room in the roof space

6.3.3.2 Selection considerations

Improvements can be undertaken as part of or in preparation of a loft conversion, to provide new habitable space. Insulating the rafters of the roof instead of the ceiling increases both the heated volume of the dwelling as well as the heat loss surface area, even though the same U-value of the roof structure is achieved. Whilst increasing the potential floor area of the dwelling, this will also increase the total energy use of the dwelling.

Where loft conversions are undertaken, all structural alteration to roofs should be approved by a competent professional. This is particularly necessary where prefabricated trussed roofs are involved.

It is possible to use flexible and semi-rigid insulation to upgrade the rafter sections of a new or existing room in the roof space. A significant thickness of insulation is necessary to achieve U-value of 0,25 W/m²K or better, see Annex A. The use of a high performance rigid insulation offers a reduced overall thickness, which might be critical if existing rooms are already small, see Figure 24.

6.3.3.3 Design considerations

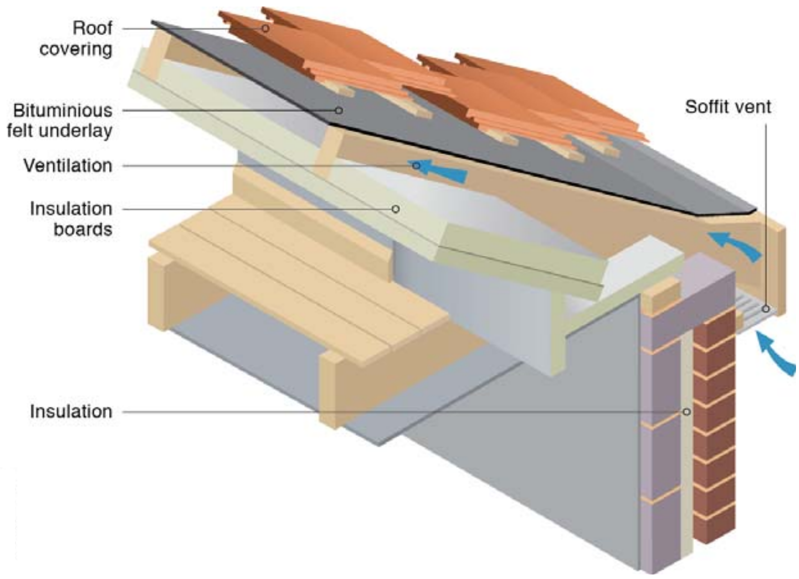


Figure 24 - The use of high performance insulation between and below rafters

6.3.3.3.1 Condensation risk

Long term exposure to interstitial condensation can lead to the structural roof timbers rotting and in extreme cases, the failure of structural members. The provision of a vapour control layer on the warm side of the insulation and ventilation above the insulation is critical to reduce the risk from condensation and any resultant damage. The vapour control layer should be continuous and all penetrations and access hatches should be sealed.

Preventative measures for interstitial condensation are as described in 6.3.2.3.1.

6.3.3.3.2 Continuity of insulation

Insulation should be continuous around the thermal envelope. Where there are habitable rooms one side of a party wall only in the attic space, then the party wall should be insulated. Access hatches to the voids or attic spaces should be draughtproofed and insulated.

6.3.3.3.3 Eaves and ridge ventilation

A gap of at least 25 mm (or equivalent) should be provided within the soffit or fascia below the guttering. Proprietary over fascia vent strips can also be used. In addition, eaves ventilators should also be installed to prevent any ceiling level insulation, blocking the passage of air into (and out of) the roof.

At ridge level, a gap of at least 5 mm (or equivalent) should be provided, see 6.3.3.3.4. To ensure that ventilation is achieved throughout the whole roof structure, there should be a vented space of at least 50 mm clear provided between each and every rafter between the top of the insulation and the underside of the roof coverings. Where underlay is present, the 50 mm space is measured from the sag in the middle of the felt between the rafters.

6.3.3.3.4 Ventilation tiles

Where it is not possible to provide a ventilation gap at the soffit, fascia or ridge, the roof void should be ventilated by inserting ventilation tiles at low level on the roof slope (i.e. within 450 mm up the slope above the top of the insulation, see Figure 21) and on both sides of the ridge, see Figure 25. The ventilation tiles at eaves level should provide the equivalent of the 25 mm continuous gap, or 25 000 mm^2/m run of roof length net ventilation area, and ventilate each and every rafter void. This is practical where attic voids exist at eaves and/or ridge.

At ridge level, ventilation tiles should provide the equivalent of a 5 mm continuous strip, i.e. 5,000 mm^2/m run, but the tiles should be located on both sides of the ridge and staggered to

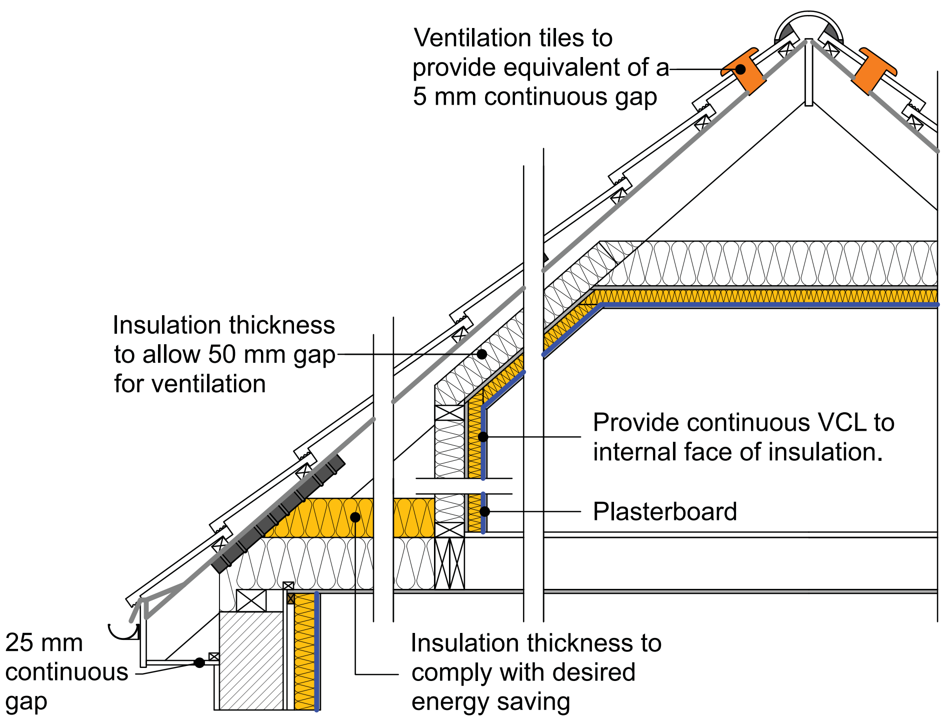


Figure 25 - Ventilation required for a room in the roof space

ensure they draw ventilation up from the eaves, instead of just providing a path to ventilate the apex of the roof, see Figure 25.

6.3.3.3.5 Re-roofing and using a breather membrane

Where roof coverings are being replaced the existing felt underlay can be replaced with a breathable roofing membrane instead of providing a 50 mm void for ventilation, in accordance with relevant certification. The membrane should be laid taut from ridge to eaves, or side to side.

Generally breather membranes should have an additional set of counter battens fixed on top of the rafters, prior to fixing the new tiling battens to allow for drainage and ventilation. The type of breathable roofing membrane should be installed in accordance with the manufacturer's instructions and any relevant certification and the void between the breather membrane created by the counter batten should be ventilated from eaves to ridge. It may then be possible to fill the majority of the depth of the rafters with insulation, as usually it is only necessary to leave a nominal space between the insulation and the breathable roofing felt.

6.3.3.3.6 Preventing moisture ingress

Moist air is formed primarily in wet rooms and these should be fitted with suitable means of extract ventilation (in addition to any openable windows) to remove as much of the moist air produced at source as possible, see Clause 10.

Any remaining moist air should be prevented entering the roof void by installing a vapour control layer on the warm side of new insulation and sealing service penetrations through the ceiling/ vapour barrier (lighting roses and pipes etc.).

A type of lighting fitting which requires special consideration is a recessed light fitting, see Figure 19. These should not be installed where they would penetrate the vapour control layer, especially in wet rooms. Where they are installed they should be positioned in a service void which should be large enough to allow for the heat of the lamp to dissipate to ensure it does not overheat.

6.3.3.4 Installation considerations

The major installation consideration is to ensure that the insulation is continuous and that the vapour barrier is contiguous with the insulation. Figure 25 shows an insulation upgrade to an existing habitable attic space. Here the vapour control layer may also serve the function of an airtightness barrier. Consideration should be given to the following when installing insulation at rafter level:

- layers of insulation should overlap those in adjacent elements to ensure no bridging of the insulation occurs at any point. Where dwarf stud walls exist, these should have insulation placed between the stud timbers (where not already existing) and across the face of the stud walls, and any residual eaves (ceiling to the rooms below) should also be insulated to at least the same standard as the sloping roof sections;
- the internal layer of insulation should be installed either as a separate layer or, where no service penetrations are required, as a laminate plasterboard (see 7.3.3.3.1);
- a vapour control layer should be installed to the warm face of the insulation;
- where foiled backed insulation is used, foil taping all joints between the insulation slabs in each layer will fulfil the requirement for a vapour control layer;
- when installing rigid insulation between the rafters, the sheets should be cut accurately so as to leave no gaps around the edges. Where gaps occur these should be filled with either insulation or insulation foam. Similarly, any service penetrations, such as a soil stack, should be sealed adequately;
- services, such as cables/pipework, can be accommodated within a battened airspace, on the inside of the finished insulation, with the depth determined by what services are provided;
- where access to eaves or ridge voids such as for maintenance is provided these should be draughtproofed, insulated and closed securely;
- where services such as mechanical ventilation systems or hot water cylinders are installed, these services should always be installed on the warm side of the insulation, i.e. in a

cupboard off a room or the landing, and should not be installed in any location beyond the plane of the insulated envelope.

6.3.4 Warm pitched roof

6.3.4.1 General

The insulation should be placed over (and in some cases between) the rafters. Ventilation of the roof void should not be provided in this form of insulated pitched roof. Ventilation through counter battening should be provided between the breather membrane and the weatherproof coverings, see Figure 26.

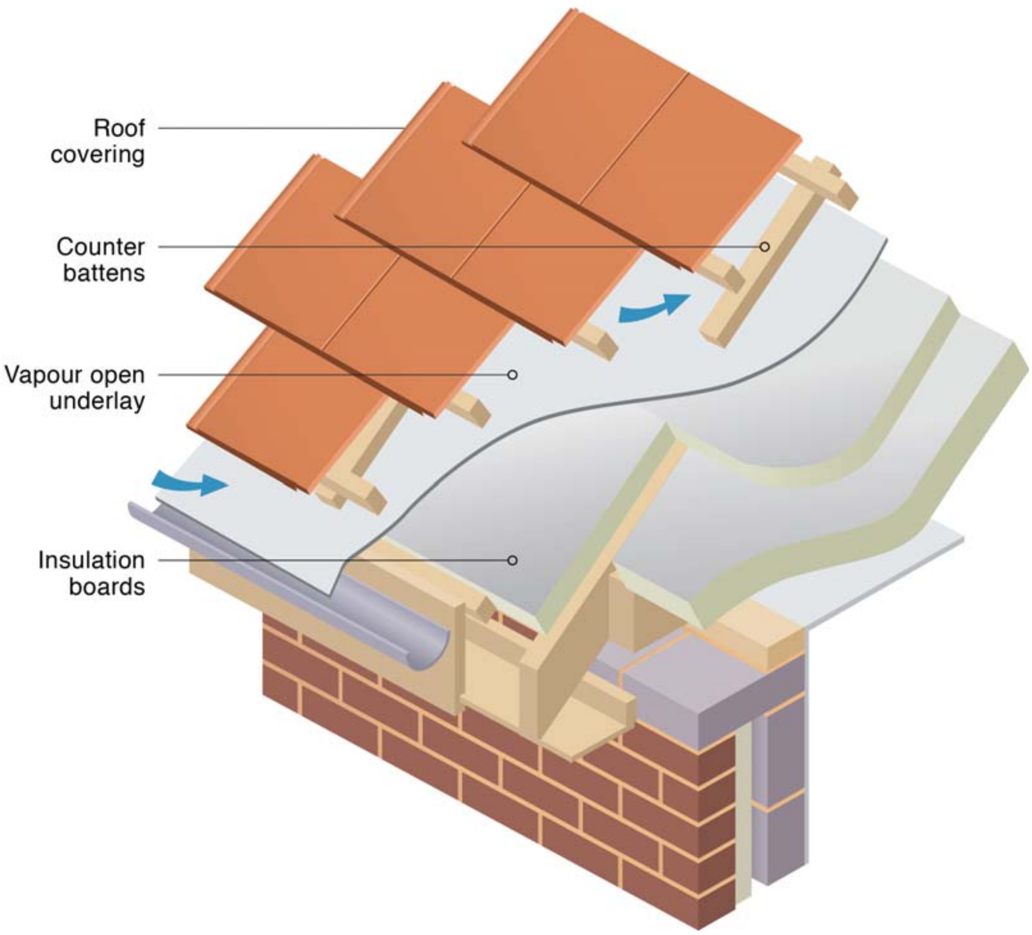


Figure 26 - **Warm pitched roof**

6.3.4.2 Selection considerations

This method of insulation is most suitable where the existing roof coverings are replaced, for instance due to nail sickness, which is where the nail heads have corroded and the tiles/slates have become loose.

Insulating the roof in this way is generally performed as part of, or in preparation for, a loft conversion to provide new habitable space. Insulating the rafters of the roof instead of the horizontal ceiling increases both the heated volume of the dwelling as well as the heat loss surface area even though the same U-value of the roof structure is achieved. Whilst increasing the potential future floor area of the dwelling, this should increase the total energy use of the dwelling compared to insulating at ceiling level.

The roof coverings (slate/tiles) etc. are fixed (by tiling battens and counter battens) through the breathable membrane and insulation layer above the rafters. To support the roof coverings, a form of rigid insulation should be used, the thickness of which is limited to the lengths/types of fixing available, generally a maximum insulation thickness of 100 mm is recommended, manufacturers' technical literature and relevant certification should be checked for clarification.

Where additional thickness of insulation is required, this can be placed between the rafters to achieve the required energy saving.

6.3.4.3 Design considerations

6.3.4.3.1 Impact on ridge line

Providing insulation to the outside of the roof structure allows for the maximum use of the space below, however it raises the ridge line which may not be acceptable in terrace or semi detached dwellings. It may also require planning approval from local authorities, see Clause 4.

6.3.4.3.2 Vapour control layer

With the insulation placed above (and possibly between) the rafters, the risk of surface condensation occurring is minimised as all internal surfaces of the roof structure are on the warm side of the insulation. However, it is still necessary to ensure a vapour control layer is provided to reduce the risk of interstitial condensation and to improve the airtightness of the construction.

6.3.4.3.3 Eaves details

Careful detailing is required to avoid thermal loss due to thermal bridging and to maintain roof ventilation at the roof-wall junction particularly where the dwelling is also provided with wall insulation. Figure 27 and Figure 28 show appropriate overlap of roof insulation at the junction with EWI and IWI respectively.

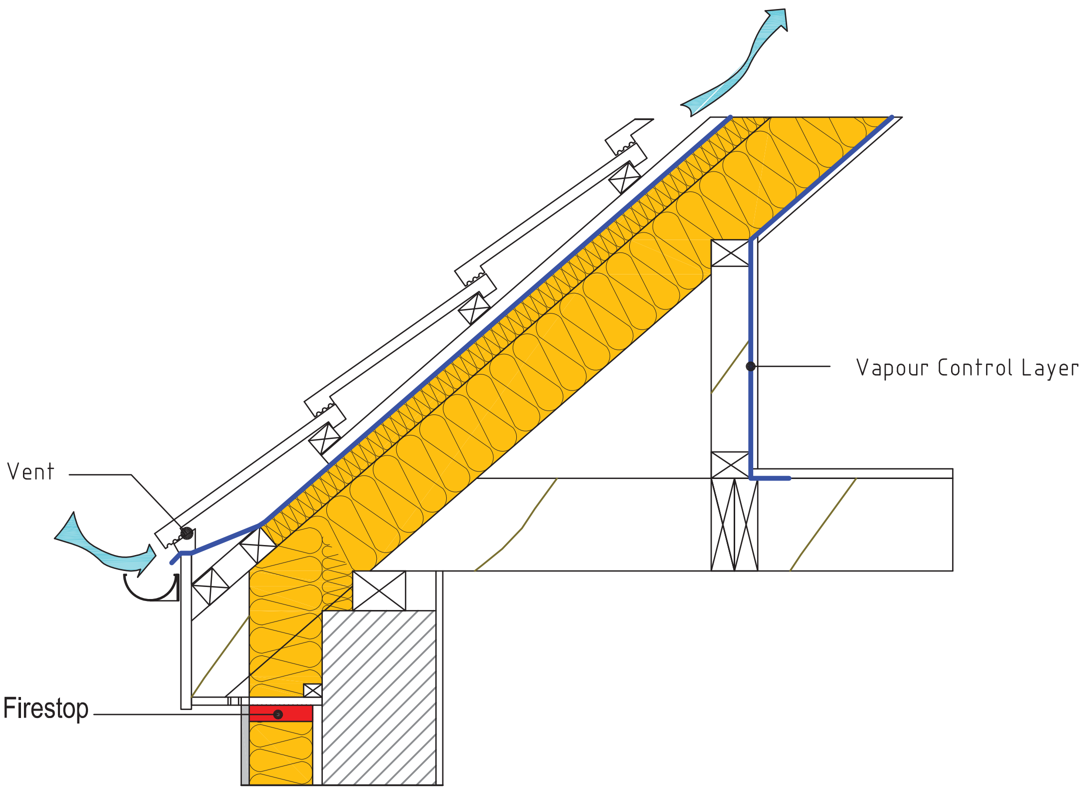


Figure 27 - Warm roof, junction with external wall insulation

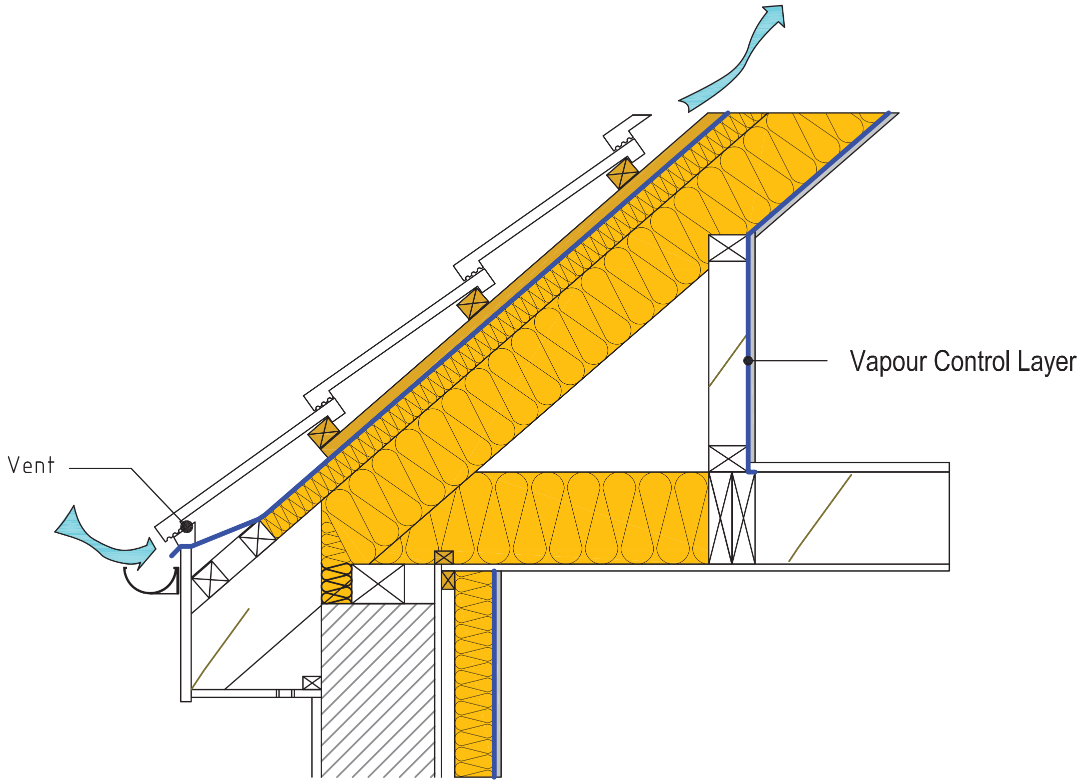


Figure 28 - **Warm roof, junction with internal wall insulation**

6.3.4.4 Installation considerations

This method of insulating an existing pitched roof should be installed in compliance with the manufacturer's instructions and relevant certification.

Consideration should be given to the following when providing a warm pitched roof:

— when installing rigid insulation between the rafters, the sheets should be cut accurately so as to leave no gaps around the edges, and all joints should be suitably taped. Where gaps occur these should be filled with either insulation or insulation foam. Similarly, any service penetrations such as a soil stack need to be sealed adequately;

— the roof insulation should be continuous with any wall insulation at eaves level;

— downlighters should be installed in accordance with the recommendations in sub-clause 6.3.1.8. In addition, where the light fitting is sealed to the plasterboard, the heat may disperse within the rafter depth over the full length of the sloping ceiling, provided the insulation does not fully fill the depth of the rafter.

6.3.5 Flat roof - cold deck

6.3.5.1 General

This is the most common form of insulated flat roof. The existing insulation (if any is present) is between the roof joists and the residual roof void above the insulation is ventilated at eaves level on opposite sides of the roof to provide cross ventilation, see Figure 29 and Figure 30.

Figure 29 and Figure 30 illustrate methods to maintain cross flow ventilation above the insulation.

This type of roof can be upgraded by adding high performance insulated laminated plasterboard to the underside of the existing ceiling. The existing ceiling can be retained if it is in good condition, or removed if it needs to be replaced.

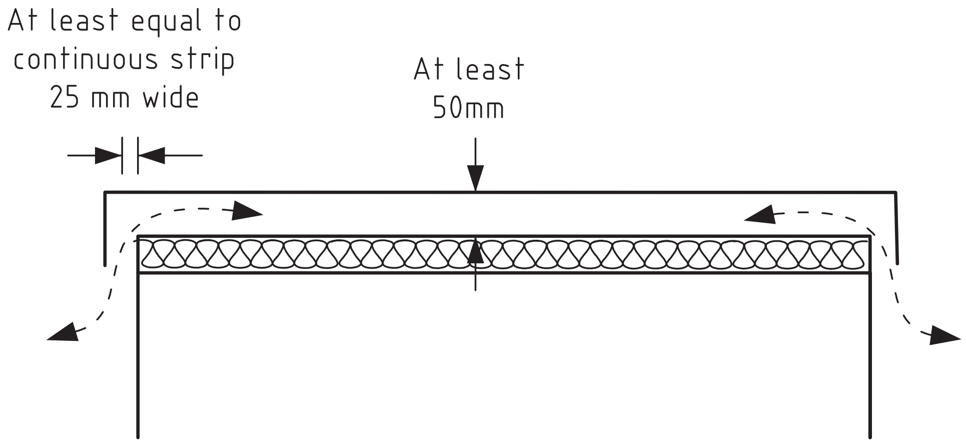


Figure 29 - Providing cross ventilation for a flat roof

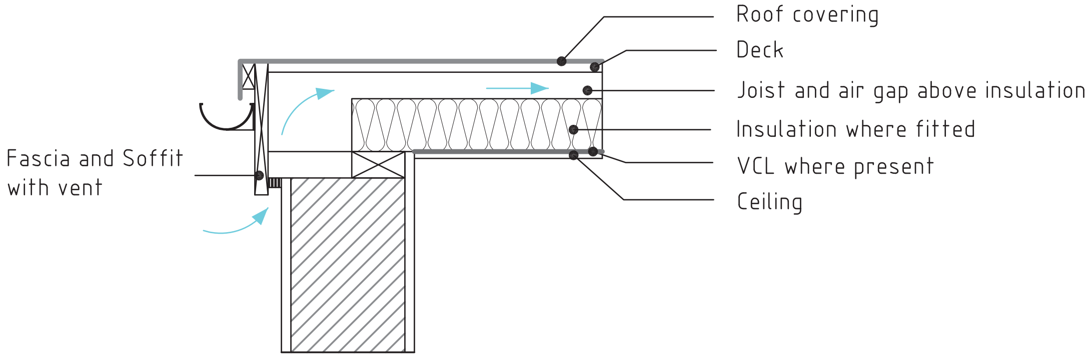


Figure 30 - Providing cross ventilation for a flat roof

6.3.5.2 Selection considerations

Where it is planned to replace the existing ceiling the insulation should be placed between (and below) the flat roof joists. Where the existing ceiling is retained, insulated laminate plasterboard should be fixed to the underside, provided the ceiling height allows.

Where the roof covering and deck is being replaced the insulation may be placed between the roof joists where the joists are deep enough to accommodate sufficient insulation.

These cold roof options should only be used where adequate cross ventilation is possible, see 6.3.5.1.

The cold deck construction should not be adopted where cross ventilation is restricted or blocked, e.g. by solid strutting. Where the structure spans between parapet or abutment walls care should be taken to ensure adequate cross ventilation is provided, which may be achieved by the use of proprietary ventilation systems, see Figure 32.

Flexible and semi-rigid insulation may be used to upgrade the flat roof. However, as the U-value table in Annex A shows, a significant thickness of insulation is required to achieve a U-value of 0,25 W/m^{2}K or better. The use of a high performance rigid insulation offers a reduced overall thickness, which may be important where existing rooms already have a low ceiling height.

6.3.5.3 Design considerations

6.3.5.3.1 Condensation risk

Long term exposure to interstitial condensation can lead to the structural roof timbers rotting and in extreme cases, the roof deck or structural members may fail. The two key design considerations are that the roof voids above the insulation are adequately ventilated and that migration of moist air from the dwelling below into the roof void is avoided.

Only when these two considerations are dealt with together can the risk of interstitial condensation in the roof void be minimised.

For a cold flat roof void ventilation is achieved by providing eaves or abutment ventilation together with a clear cross ventilation gap above the insulation, see Figure 29.

There should be a gap of at least 25 mm within the soffit or fascia below the guttering (or abutment ventilators) on two opposing sides of the roof. To ensure that cross ventilation is achieved throughout the whole roof structure where the flat roof span is less than 5 m (in the direction of the ventilation) the following apply:

- a clear 50 mm vented space is required between each and every roof joist between the top of the insulation and the underside of the roof deck; or
- 50 mm deep cross battens are provided to form a link between the vented eaves.

Where the span of the flat roof is 5 m or more, the depth of the vented space should be increased to at least 60 mm.

Where it is not possible to provide cross ventilation, a cold flat roof should not be used, and a warm deck roof should be considered instead. Where a warm deck roof is considered then no ventilation is required and any existing roof void ventilation should be sealed.

6.3.5.3.2 Preventing moisture ingress

Moist air is formed primarily in wet room, and these should be fitted with suitable means of extract ventilation (in addition to any openable windows) to remove as much of the moist air produced at source as possible.

Any remaining moist air should be prevented entering the roof void by installing a vapour control layer in the new work below the insulation and sealing service penetrations through the ceiling/vapour barrier (lighting roses and pipes etc.). Where the roof is being recovered, the sealing of service penetrations can be done from above, before the insulation is placed between the joists.

A type of lighting installation that requires special consideration is a recessed light fitting, see Figure 19. These should not be installed where they would penetrate the vapour control layer, especially in wet rooms. Where they are installed they should be positioned in a service void. This should be large enough to allow for the heat of the lamp to dissipate to ensure it does not overheat.

6.3.5.4 Installation considerations

Consideration should be given to the following when installing a cold deck roof:

- when using flexible insulation between the roof joists and installing this from below, pushing the insulation too high so as to block (or even reduce) the eaves ventilation or the cross ventilation space depth should be avoided;
- the roof insulation should be continuous with any wall insulation at eaves level;
- any service penetrations through the ceiling should be adequately sealed;
- an unrestricted air space with a depth of at least 50 mm (for spans up to 5 m) or 60 mm (for 5 m – 10 m spans) should be provided above the insulation;
- at eaves level (or at an abutment of the roof with a parapet or gable wall etc.) a ventilated strip of at least 25 mm wide, or ventilators which give the equivalent of 25 000 mm^2 ventilation area, per metre run of eaves should be provided. The entry of insects should be prevented by placing 3 mm – 4 mm mesh across ventilation apertures and the mesh should be taken into account when calculating the ventilation area.

Figure 31 shows the upgrading of an existing cold roof where internal wall insulation has also been installed.

The existing insulation should be retained where present and additional insulation should be used underneath the ceiling to achieve the required U-value. Where the existing roof is not insulated, the insulation below the ceiling needs to achieve the required U-value.

Where installing internal wall insulation, this should be fixed prior to the thermal laminate board being fitted to the underside of the ceiling.

The fascia vents should be checked to ensure there are no blockages and replaced if necessary.

Figure 32 shows a flat roof cold deck abutment where the ventilated void is maintained with a proprietary abutment ventilation system. As in Figure 31 the existing insulation is retained where present and fitted with internal wall insulation.

For a parapet wall in Figure 33, external insulation has been applied. The ventilated void is maintained with a proprietary abutment ventilation system. A thermal laminate board with integral VCL is fixed to the underside of the joists.

The internal face of the parapet wall should be insulated to reduce thermal bridging.

Thermal bridging can be further reduced by replacing the parapet wall with lightweight blocks.

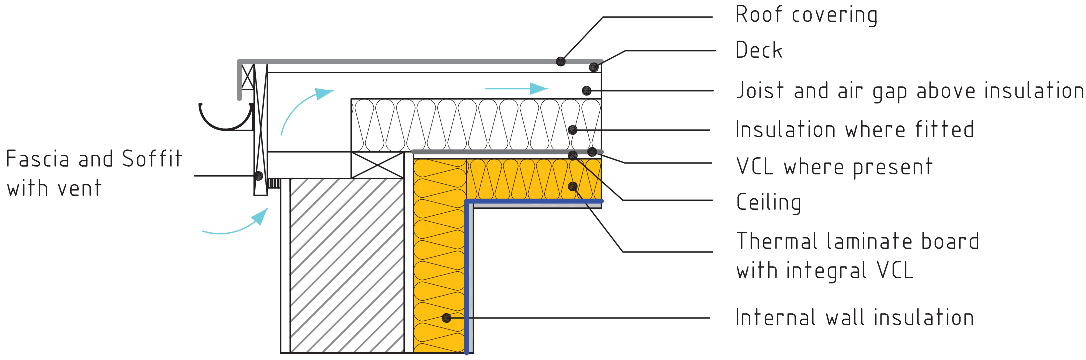


Figure 31 - Cold roof upgrade with thermal laminate board, carried out internally

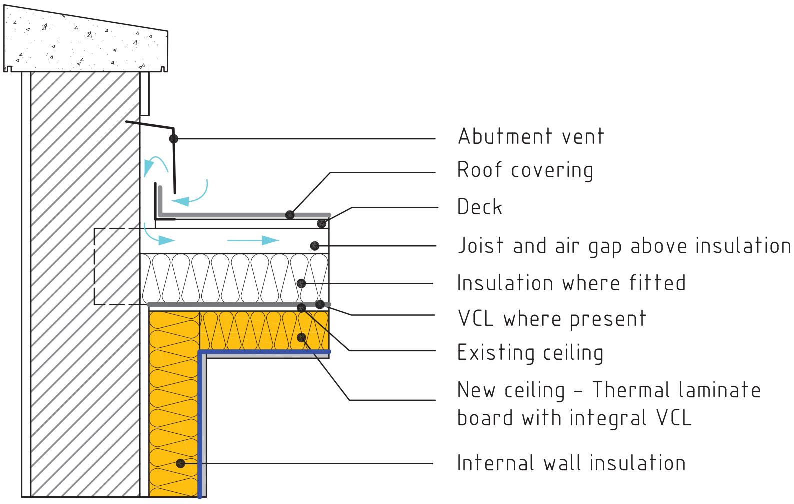


Figure 32 - Cold roof with abutment upgraded with thermal laminate board, carried out with internal insulation

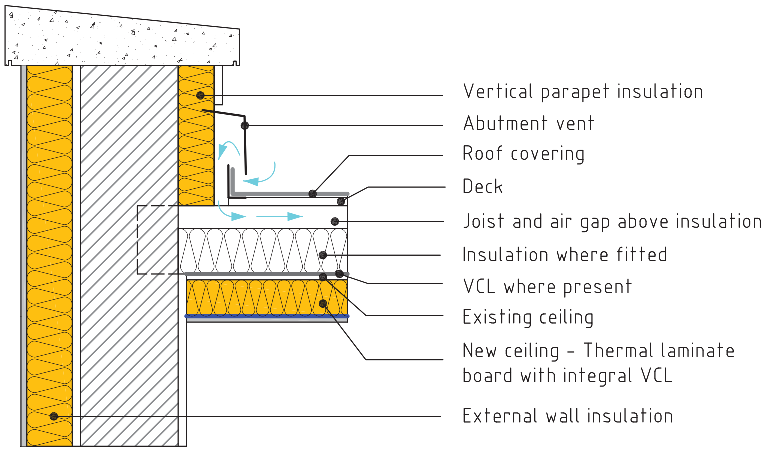


Figure 33 - Cold deck and parapet insulated with EWI and top-up thermal laminate board added underneath

ROOFS

6.3.6 Flat roof - warm deck

6.3.6.1 General

Where the insulation is on top of the flat roof structure this is known as a warm flat roof. There are two basic types of warm roof:

i) The warm deck sandwich roof;

ii) The warm deck inverted roof.

6.3.6.2 Warm deck – sandwich roof

6.3.6.2.1 Selection considerations

The provision of a warm deck roof can be an effective retrofit measure for either:

- the upgrade of an existing poorly insulated warm deck roof;
- the conversion of an existing cold deck roof to a warm deck roof, or
- un-insulated roof.

6.3.6.2.1.1 Upgrading an existing warm deck roof

There are two methods for upgrading a poorly insulated warm deck roof.

Method A – Insulating above existing, see Figure 34.

- additional roof insulation provided above together with a new weather-proof roof covering;
- the existing roof covering can be used as a VCL;
- where the existing membrane is in poor condition it should be removed.

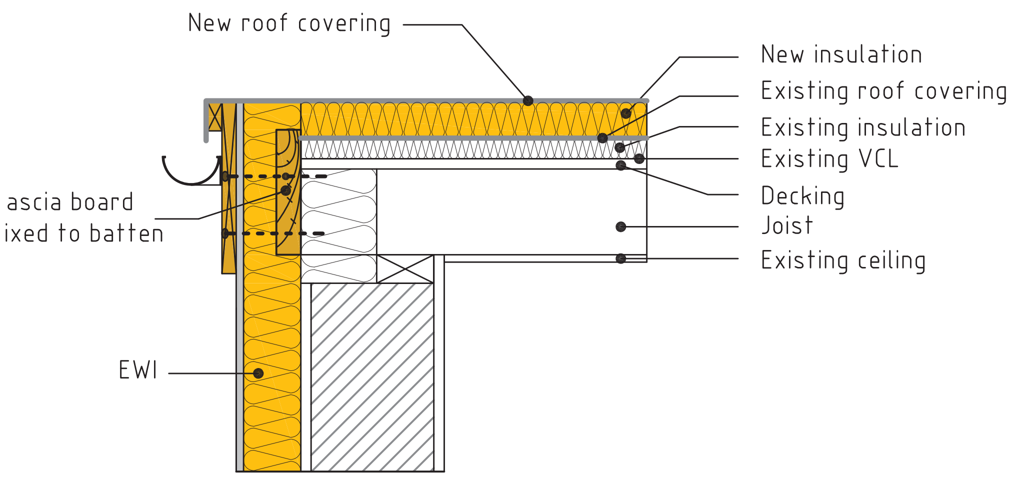


Figure 34 - with new additional insulation over existing and external wall insulation

Method B

The existing insulation is retained, provided the weather-proof roof covering is in good condition, and additional roof insulation provided below the deck, see Figure 35. When using this method a service void should be provided below the existing ceiling level to provide a new VCL. The integrity of the new VCL, which is required to prevent interstitial condensation, should be maintained. Where this is not possible Method A should be used.

ROOFS

The procedure for installation is as follows:

— the ceiling below should be removed and insulation where present removed;

— the joists should then be filled up to the full depth;

— a continuous VCL should then be fixed to the underside of the joists. Joints should be lapped at least 50 mm and sealed;

— a service void should then be formed using battens and plasterboard fixed underneath.

— NOTE Where Method B is being installed it is important to carry out an interstitial condensation risk analysis prior to performing works. Generally, the greater thermal resistance of the construction (i.e. existing insulation) should be above the deck when using this method.

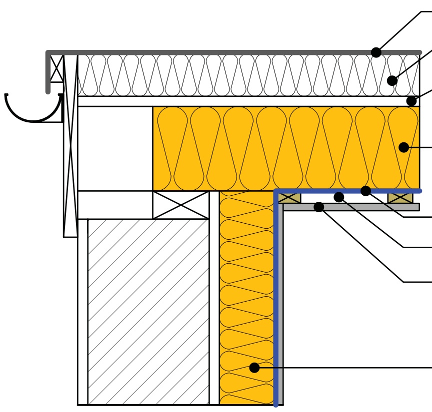


Figure 35 - Warm roof improved with insulation below, plus internal wall insulation

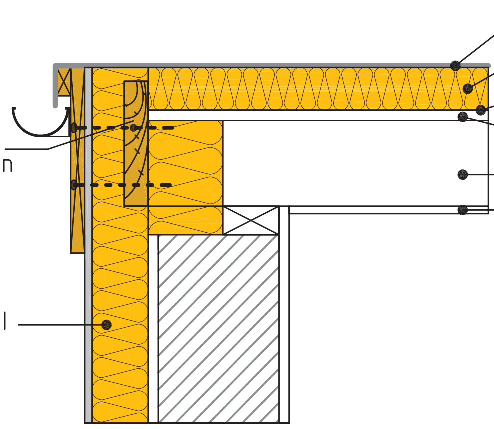


Figure 36 - Warm deck with insulation replaced and external wall insulation, or conversion of uninsulated cold deck roof to warm roof

6.3.6.2.1.2 Conversion of an existing cold deck to warm deck

Where the roof covering is in good condition, insulating above may be less disruptive to the occupants provided no insulation already exists under/between the roof structure, see 6.3.6.2.1.1 Method A. Where insulation exists, it should be removed. Where the roof covering needs replacing this can provide an opportunity to upgrade the insulation with the least disruption to the occupants, see Figure 36 and Figure 37. Where it is not possible to achieve adequate cross ventilation, then insulating above the roof joists may be the only option available.

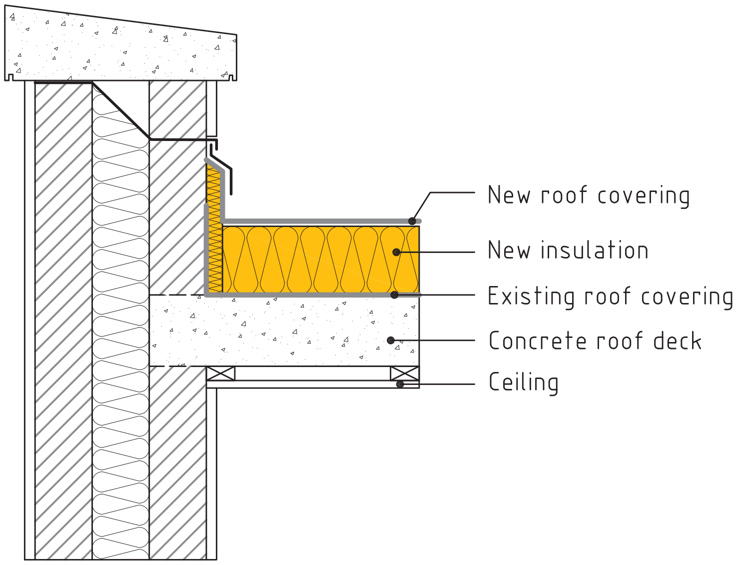


Figure 37 - Cold deck upgraded to warm deck concrete roof

6.3.6.2.2 Design considerations

6.3.6.2.2.1 General

Providing insulation on the top of the roof structure raises the finished surface, which could mean that where an abutment occurs to an existing wall, the flashing of the new roof finish may be higher than any existing stepped DPC or cavity trays present in the existing wall. Where this is the case, new stepped DPC or cavity trays are required. Similarly, parapet walls may also need to be increased in height to ensure moisture cannot migrate into the dwelling. Where the dwelling is also provided with wall insulation, internal or external, careful detailing is required to avoid thermal loss due to cold bridging at the roof-wall junction, see Figure 38 and Figure 39. Renewal of the fascia due to increased overall roof depth may allow for the provision of insulation to the soffit void to maintain a continuous thermal envelope.

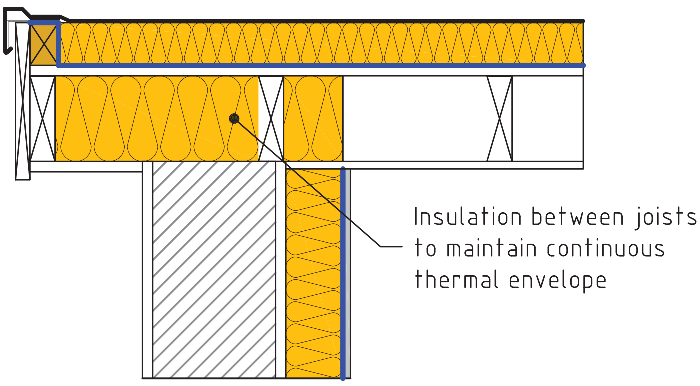


Figure 38 - Junction with internal wall insulation

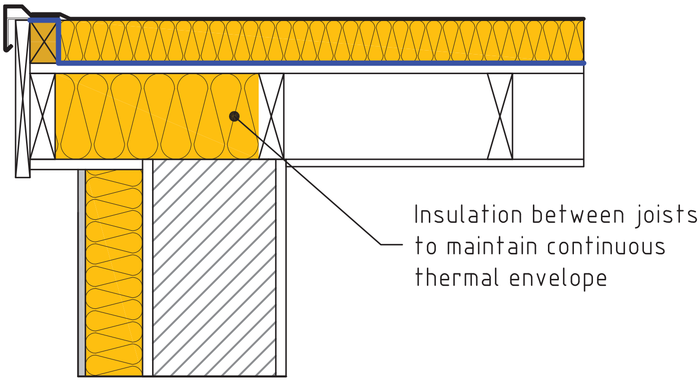


Figure 39 - Junction with external wall insulation

6.3.6.2.2.2 Materials

Only rigid or suitably dense semi rigid types of insulation should be used for this application as flexible types of insulation compress on the top of the roof decking. The uppermost weather protective layer should be suitable for bonding onto the type of insulation used without being fixed through the insulation, unless mechanical fixings have been included in the certification for the proposed membrane/insulation.

6.3.6.2.3 Installation considerations

Consideration should be given to the following when providing a warm deck roof:

- a high performance vapour control layer should be installed on top of the decking with all joints taped and turned up at the perimeter before the insulation is fitted;
- where the external walls do not continue into the roof space (whether the wall is to be insulated or not), additional insulation should still be provided to the eaves to prevent a thermal bridge in this location, see Figure 38 and Figure 39;
- where the existing roof is insulated and ventilated, see Figure 40(a), but is to be changed to a warm roof, the existing insulation should be removed, see Figure 40(b), and the eaves ventilation removed/sealed and insulation installed to prevent cold bridging;
- roof coverings of dark colour and non-reflective texture (high emissivity) absorb more solar radiant heat and develop temperatures significantly higher than the ambient temperature of the outside air, particularly in warm roof constructions. Solar reflective treatment is particularly important in warm roofs, where the differential thermal movement between the roof covering and the substrate is high and where properties of the materials are adversely affected by high temperatures;
- existing drains should be maintained on roof internal to parapet. Existing gutter locations may need to be changed;
- all insulation boards should fit tightly together preferably interlocking and in two layers with joints offset and upstand insulation should be installed to parapets etc.;

Where there is a step in the roof, see Figure 40(c), care should be taken to ensure that the insulation is continuous, see Figure 40.

In Figure 41 a step in the roof is not insulated at the upstands. Where the roof is already a warm roof any existing insulation can be retained, along with the roof covering, and a new layer of rigid board insulations applied over the existing insulation eliminating the cold bridge, with a new weatherproof membrane over it.

ROOFS

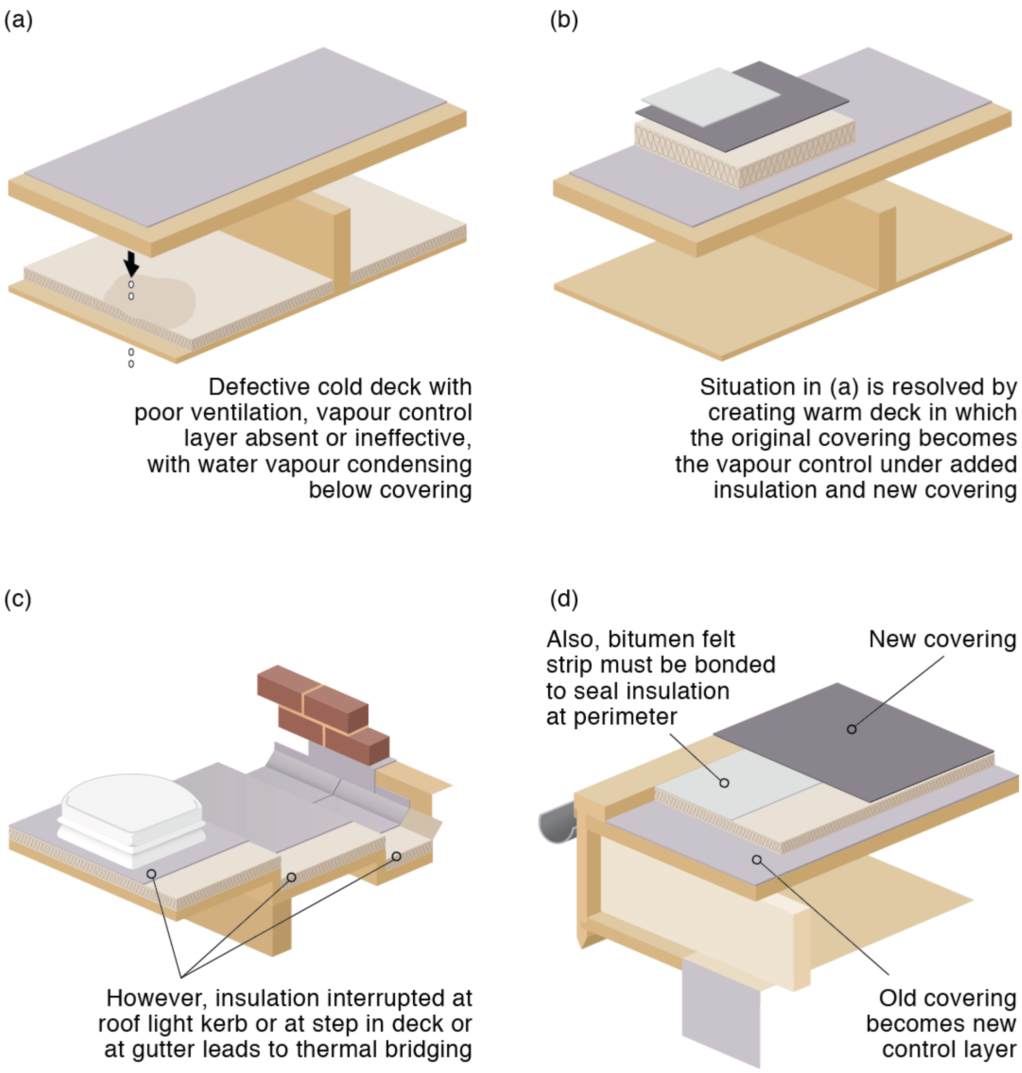


Figure 40 - Details (a) to (d) shows typical sequencing of converting a cold flat to a warm flat roof

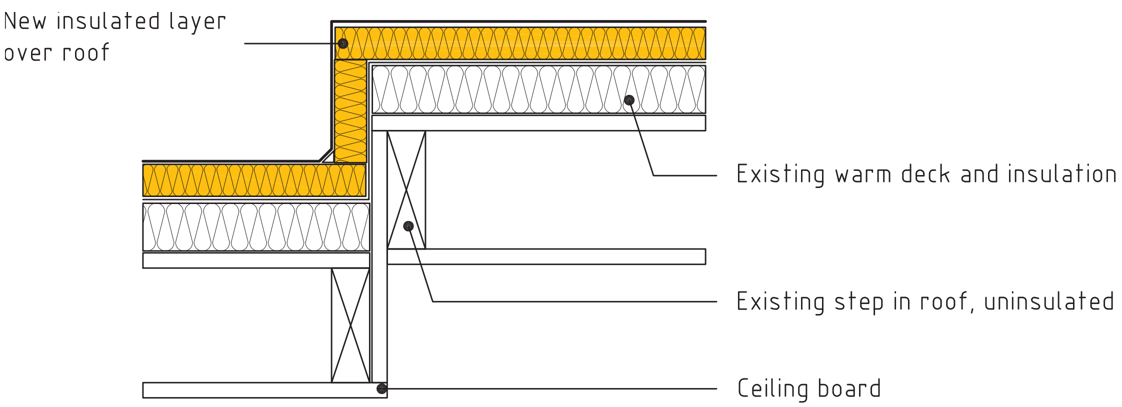


Figure 41 - Stepped warm roof with insulation improved and added to step detail

6.3.6.3 Warm deck – inverted roof

The insulation is placed directly above the weatherproof membrane, see Figure 42. It is protected from solar UV degradation and held down against wind uplift by a ballast layer and edge restraint. A filter layer is laid immediately below the ballast. The method may be used above concrete, metal and timber structural decks.

This method may be used when the existing construction is not being renewed or when it is necessary to upgrade an existing poorly insulated construction. When upgrading an existing roof, it is necessary to check:

- the condition of the existing weatherproofing membrane;
- the thermal resistance of any insulation previously installed below the weatherproof membrane; and
- the ability of the roof to support the proposed increased load.

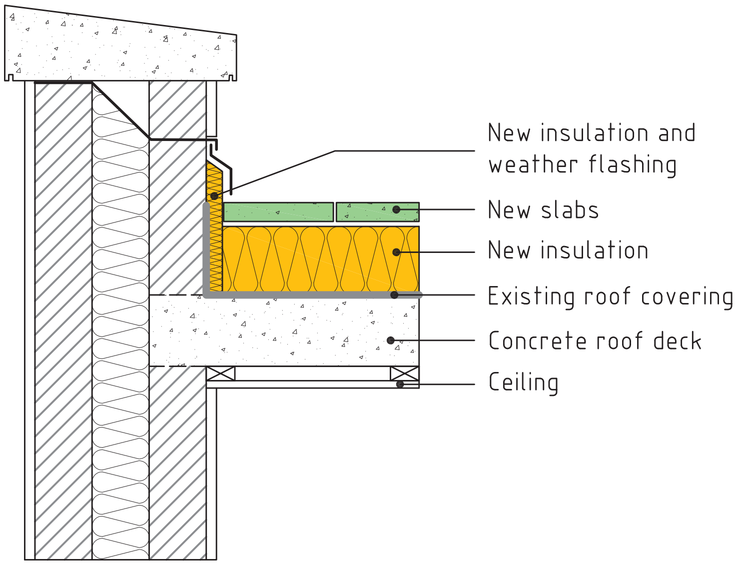


Figure 42 - **Warm inverted roof**

6.3.6.3.1 Selection considerations

Only rigid or suitably dense semirigid types of insulation should be used for this application as flexible types of insulation will compress on the top of the roof decking.

6.3.6.3.2 Design considerations

Where the dwelling is provided with wall insulation, internal or external, careful detailing is required to avoid thermal loss due to cold bridging at the roof-wall junction. Renewal of the fascia due to increased overall roof depth may allow for the provision of insulation to the soffit void to maintain a continuous thermal envelope.

Where previously installed warm roof insulation remains below the membrane ensure that the greater thermal resistance of the construction is above the weatherproof membrane. An insulant which has low water absorption, is frost resistant and certified for intended use, should be used.

6.3.6.3.3 Installation considerations

Consideration should be given to the following when providing a warm deck inverted roof:

- existing drains should be maintained on roof internal to parapet. Existing gutter locations may need to be changed;
- excess loose chippings should be removed, if any remain bonded to the existing weatherproof membrane, lay a cushioning layer to manufacturers' specification e.g.

polyethylene foam below the insulation;

- all insulation boards should fit tightly together preferably interlocking and in two layers with joints offset and upstand insulation should be installed;

- a filter membrane should be fitted above the insulation and a ballast layer placed on top. Grit washed down between the insulation boards can cause abrasion and eventually puncture weatherproof membranes, particularly single-layer membranes, or block the roof drainage system. A separating layer should be placed above single-layer weatherproof membranes to prevent this.

- for inverted roofs, the insulation and roof covering should be secured against removal or displacement by the combined effects of wind uplift and flotation in water. Where the insulation is secured by ballast the minimum aggregate size should be sufficient to prevent wind scour, see BRE Digest 311.

- where concrete slabs are used as the ballast they should be raised off the insulation to provide a nominal air gap to assist the removal of water and to help reduce rocking, see Figure 42. They may be loose laid on proprietary support pads. A 150 mm wide edge strip filled with ballast (clean rounded, nominal diameter 20 mm – 40 mm) should be provided against parapets and upstands, and around rooflights. A separation layer may be needed between certain waterproofing membranes and the insulation, in which case the manufacturer's advice should be sought.

7. Walls

7. Walls

7.1 General

This clause describes the different types of existing wall construction and the insulation methods and materials available to achieve thermal improvements.

This clause does not deal with traditional dwelling fabrics as the method of vapour transfer through these walls differ from more recent dwellings.

7.2 Wall types

7.2.1 Hollow block wall

7.2.1.1 Description

Hollow concrete blocks are a common form of wall construction particularly in the East of Ireland post 1950s and, with solid walls, represent a significant proportion of the national housing stock. The majority of heat loss through the hollow block wall is through the thermal bridge at the solid sections of the ends and spine of the block.

There are a range of internal and external finishes which can impact on the insulation solution, see Figure 43 to Figure 46 .

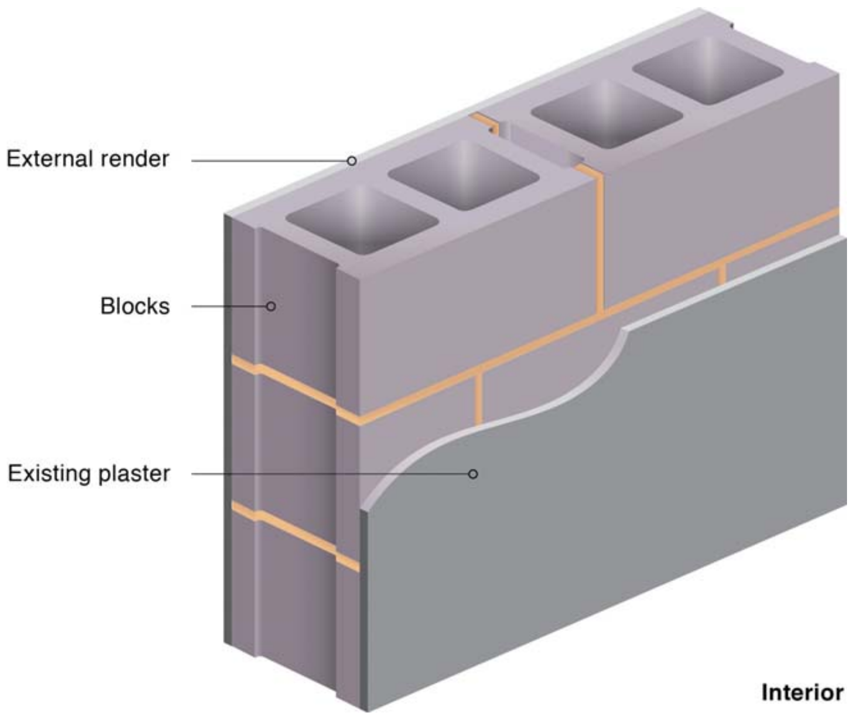


Figure 43 - Plastered internal finish

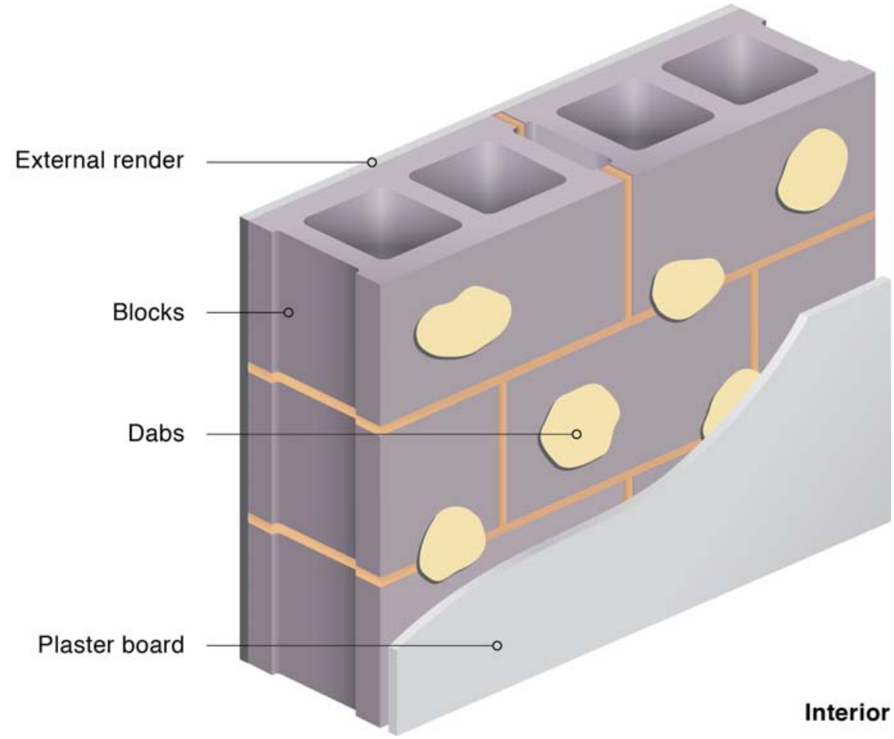


Figure 44 - Plasterboard on dabs

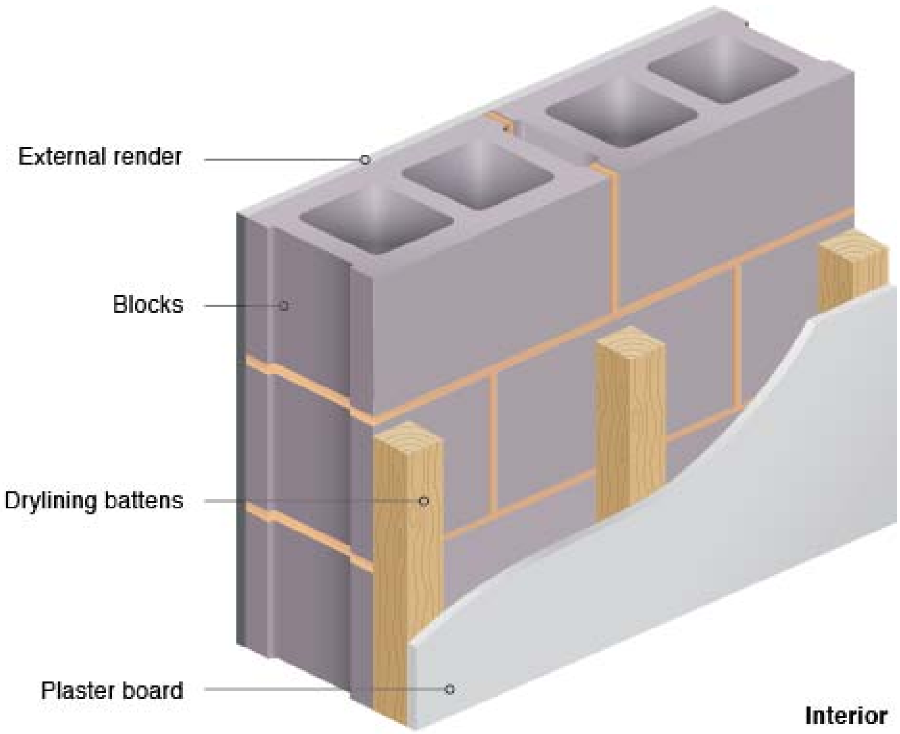


Figure 45 - Dry lined

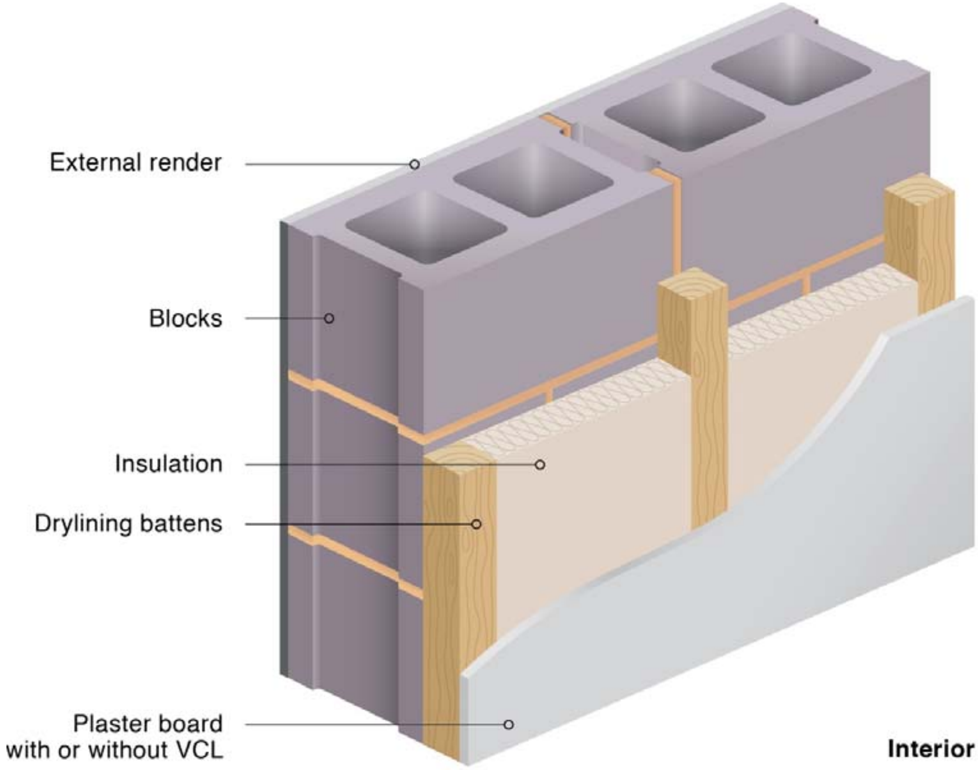


Figure 46 - Dry lined with insulation

7.2.1.2 Applicable retrofit methods

The applicable insulation methods for hollow block walls are outlined in Table 13 and the U-value tables in Annex B show the relevant insulation thicknesses.

Table 13 - Applicable insulation methods for hollow block walls

	Baseline U-value (W/m^2K)	Cavity wall insulation	External wall insulation	Internal wall insulation
Hollow block wall	2,09	N	Y	Y

For further information on selecting the retrofit method, see 7.3.1.

With an external wall insulation solution there is a need to address the issue of thermal bypassing as discussed in 7.3.2.3.8.

The cavities of hollow block walls should not be filled as a method of thermal insulation, as the cold bridging that occurs at the block spine and ends, will minimise the effectiveness.

7.2.2 Cavity wall

7.2.2.1 Description

Cavity wall construction is made up of an inner load bearing wall usually of block and an outer leaf of rendered block or brick. Cavity walls were introduced to keep the load bearing element dry and prevent ingress of moisture into the building. This method represents a significant proportion of the more recent housing stock in moderate to severe wind driven rain index areas.

The cavity typically varies from 50 mm to 110 mm and may be unfilled, see Figure 47, or partially filled, see Figure 48, depending on the building specification at the time of construction. The cavity may also have been filled through subsequent energy efficiency improvements.

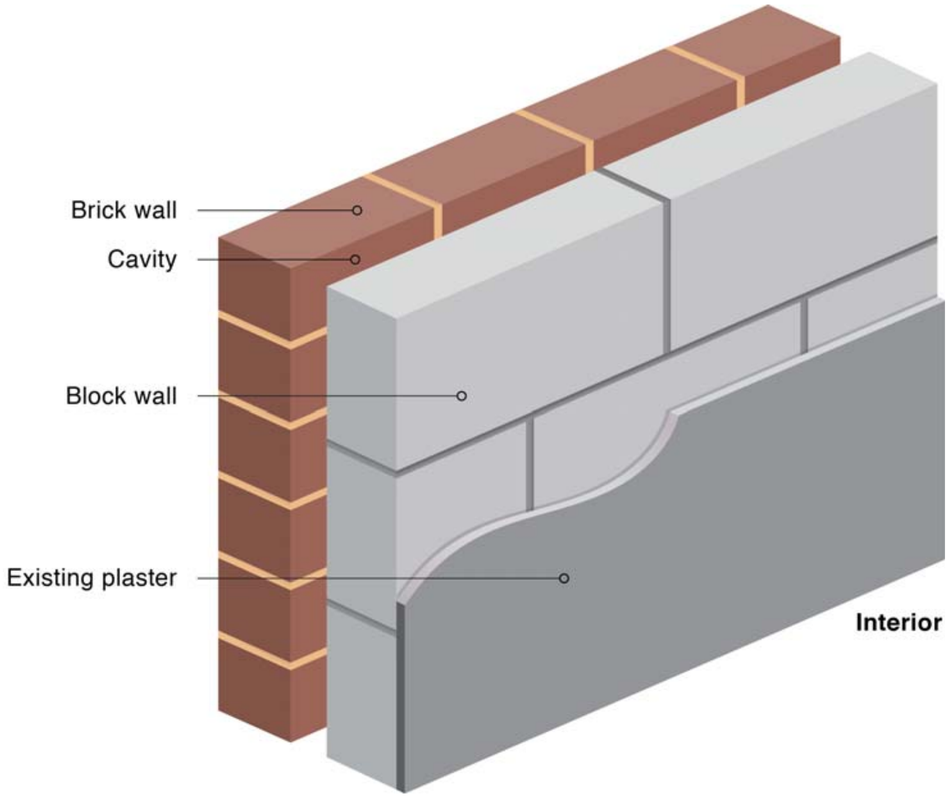


Figure 47 - Unfilled / clear cavity wall

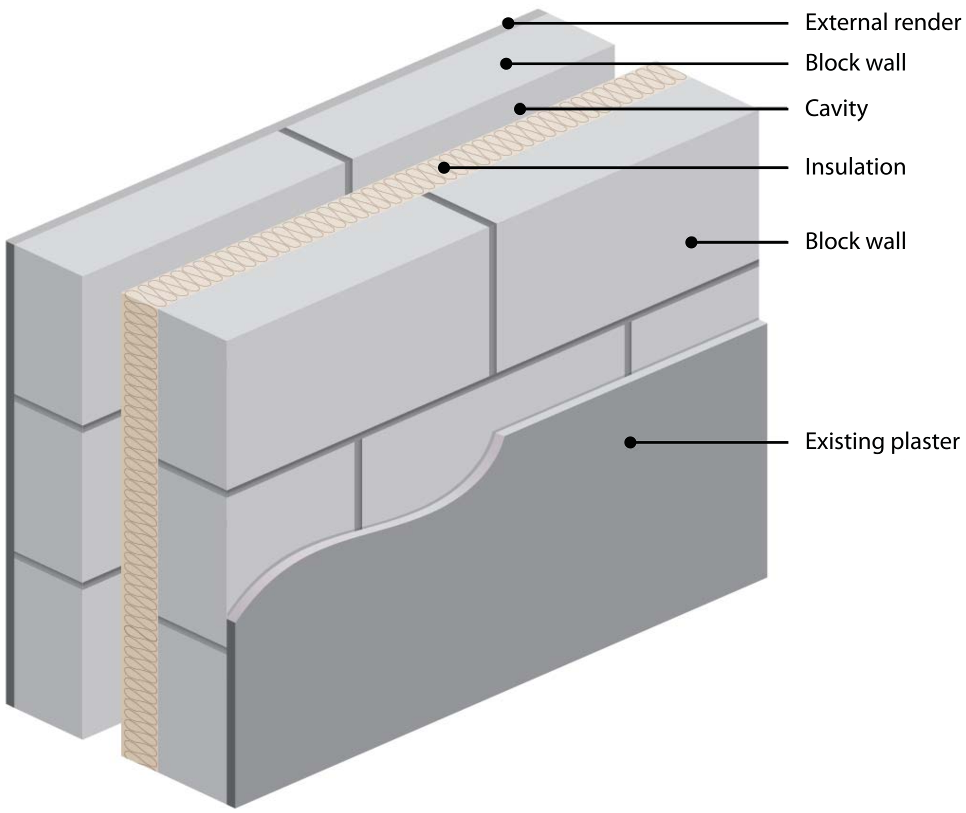


Figure 48 - Partial fill cavity wall

In order to address changes to construction practice over time and possible subsequent energy improvement work, three different cavity wall types should be considered:

- Type 1 - Cavity that cannot be filled: a cavity where no insulation is present but which cannot be filled, as it is too narrow, or there is a risk of driven rain causing moisture ingress, e.g. un-rendered brick work in a severe exposure area;
- Type 2 - Clear cavity: originally a 50 mm, 75 mm or 110 mm wide cavity which has the potential to be full-filled or has been full-filled as a result of previous energy efficiency improvements;
- Type 3 - Partial fill cavity: a partial filled cavity wall which retains a residual cavity of approximately 50 mm width or a width as specified by the product certification.

These can be further separated into:

- type 3a cavities which cannot be filled and;
- type 3b cavities which can be filled using a certified system.

7.2.2.2 Applicable retrofit methods

Table 14 shows the insulation methods that can be applied to each of the cavity wall types, and the U-value tables in Annex B show the insulation requirements for these.

Table 14 - Applicable retrofit methods for Type 1 to 3 cavity walls

	Baseline U-value (W/m².K)	Cavity wall insulation	External wall insulation	Internal wall insulation
Type 1	1,55	N	N	Y
Type 2	1,55	Y[a]	Y[b]	Y
Type 3a	0,70	N	N	Y
Type 3b		Y	Y[b]	Y
a Where cavity not filled previously.				
b Provided cavity has been filled.				

For further information on selecting the retrofit method, see 7.3.1.

Driven rain and exposure dictates the suitability of filling the cavity.

External insulation should not be used with unfilled cavities due to the possibility of thermal bypass and thermal looping within the cavity. The cavity should be fully filled either as part of the original construction or as part of the retrofit measures where external insulation is used.

Where a cavity is retained in a wall, internal wall insulation should be used.

7.2.3 Solid wall

7.2.3.1 General

Solid walls are constructed of no-fines concrete, mass concrete, solid block or pre-cast concrete panels. The majority of these constructions were built between 1940 and the late 1960s. No-fines and mass concrete walls are the most common form of solid wall. The thermal performance of these types of construction is similar, and so the insulation solutions are similar.

7.2.3.1.1 No-fines and mass concrete

These dwellings were constructed using re-usable formwork. No-fines concrete consisted of a concrete mix with no-fines aggregates. Some steel reinforcement was used at key areas, as well as joining external to internal walls.

As the technique was developed, thinner walls, and therefore less raw materials were required.

Three typical wall types with their corresponding baseline U-values are shown in Figure 49.

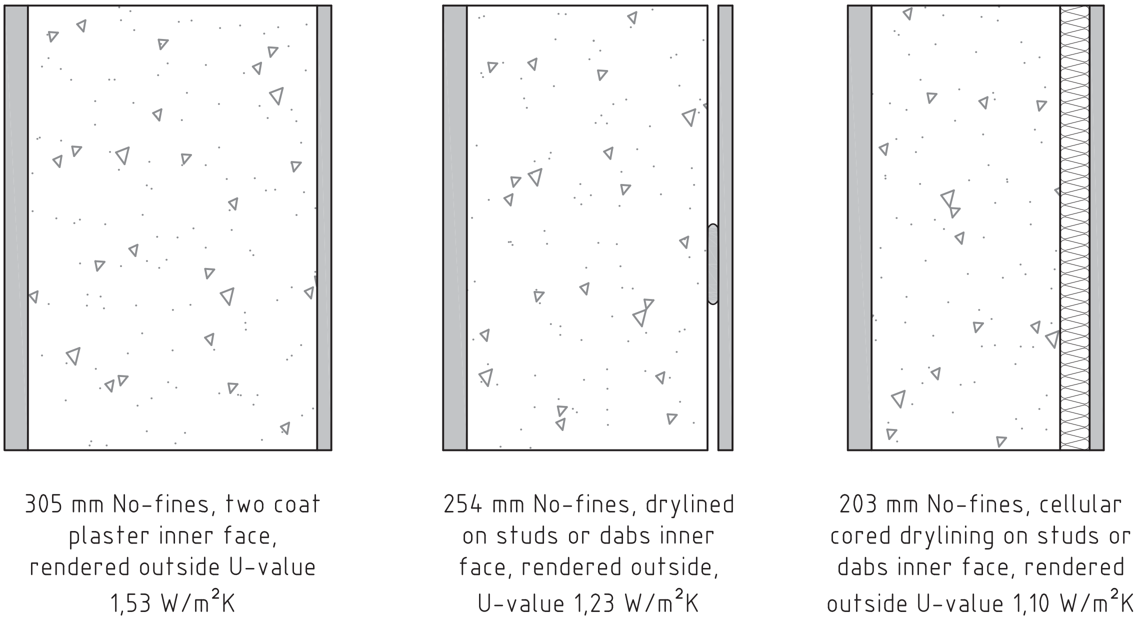


Figure 49 - Three typical no-fines concrete constructions

Mass concrete walls although uncommon, are still constructed and are treated in the same way for retrofit as no-fines walls. A typical construction consists of external render with a 275 mm mass concrete wall and internal lightweight plaster with an average baseline U-value of 2.20 W/m²K.

7.2.3.1.2 Pre-cast concrete panels

These are designed, factory produced, preformed concrete panels which are assembled together on site. The average baseline U-value is 2,09 W/m²K. These were used in 1960's and 1970's in some one off dwellings.

7.2.3.2 Applicable retrofit methods

Table 15 provides applicable retrofit methods for solid walls, and the U-value tables in Annex B show the insulation requirements for these.

Table 15 - Applicable retrofit methods for solid walls

	Baseline U-value (W/m².K)	**Cavity wall insulation**	**External wall insulation**	**Internal wall insulation**
Solid walls	1,10 - 1,53 (No-fines) 2,20 (mass concrete) 2,09 (Pre-cast concrete)	n/a	Y	Y

For further information on selecting the retrofit method, see 7.3.1.

There are likely to be a range of external and internal finishes that can impact on the insulation solution, see 7.3.2 and 7.3.3 respectively.

7.2.4 Timber frame

7.2.4.1 General

A timber frame dwelling is one in which the loads from the upper floors and roof are carried by and transmitted to the foundations by a timber frame. The construction typically consists of a rendered block or brick outer leaf, a ventilated cavity and a timber structural inner leaf. The external leaf provides weather protection, see Figure 50 .

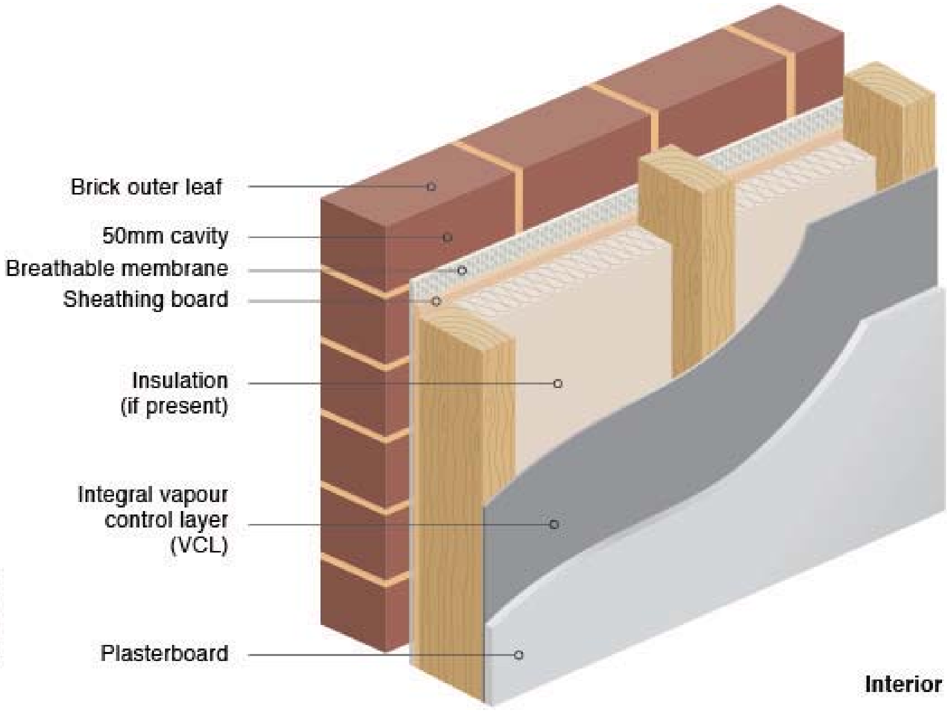


Figure 50 - Timber frame

Over the past 25 years, timber frame homes are likely to have been constructed with insulation of varying thicknesses within the studwork frames. Those built before this time may have little or no insulation.

7.2.4.2 Applicable retrofit methods

Table 16 provides applicable retrofit methods for timber frame constructions, and the U-value tables in Annex B show the insulation requirements for these.

Table 16 - Applicable retrofit methods for timber frame walls

	Baseline U-value (W/m².K)	Cavity wall insulation	External wall insulation	Internal wall insulation
Timber frame	1,17	N	N	Y

For further information on selecting the retrofit method, see 7.3.1.

7.2.5 Steel frame

7.2.5.1 Description

A steel frame dwelling is one in which the loads from the upper floors and roof are carried by and transmitted to the foundations by a lightweight steel frame. The construction typically consists of a rendered block or brick outer leaf, a cavity and a steel structural inner leaf. The external leaf provides weather protection, see Figure 51.

Steel frame dwellings are constructed of mild steel sections forming wall panels and floor sections. The insulation is usually closed cell such as EPS and does not generally feature a vapour control layer.

Typically, steel frame constructions for Ireland may be:

- Warm frame - This is where the frame is fully on the inside of the insulation and avoids the steel frame causing a cold bridge, see Figure 52;
- Hybrid light steel frame - This is an amalgamation of a warm frame and a cold frame system (insulation only between studs) where the insulation is placed on the outside of the frame and partially or wholly filling the stud void, see Figure 53.

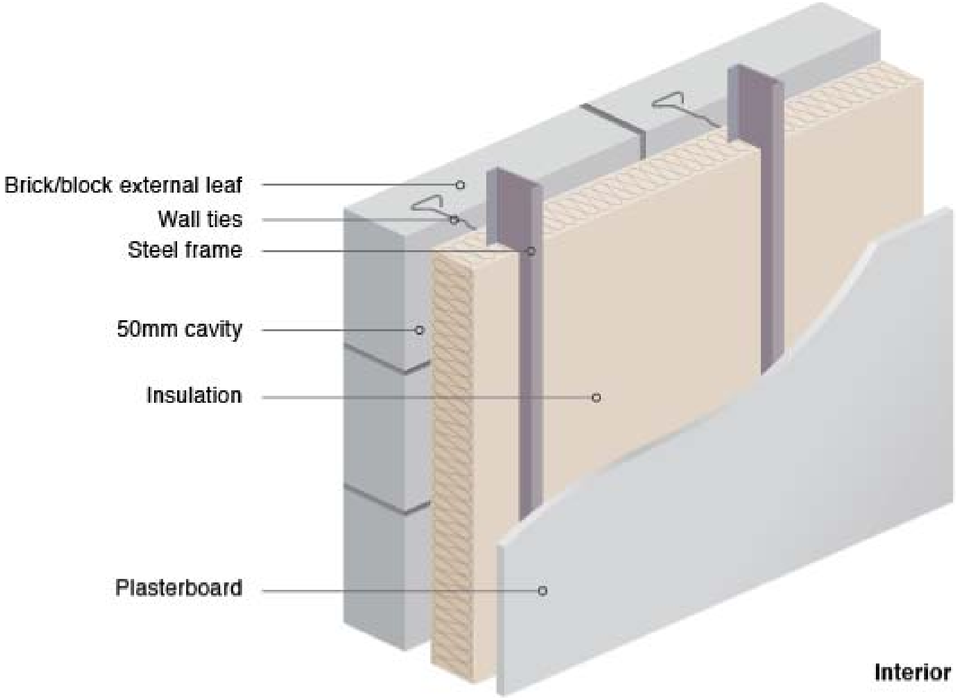


Figure 51 - Steel frame

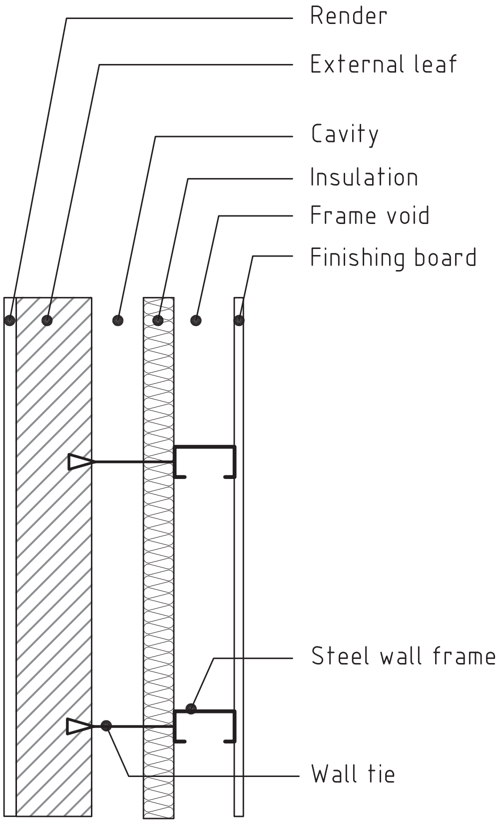


Figure 52 - Warm light steel frame wall (plan view)

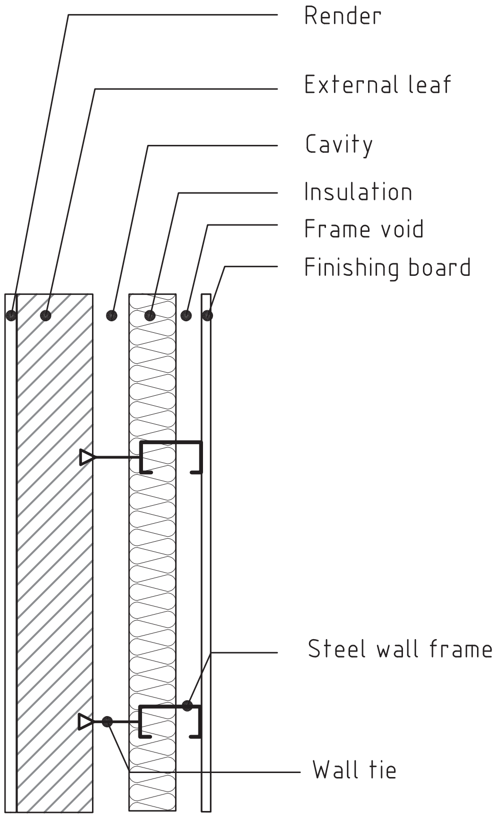


Figure 53 - Hybrid light steel frame wall (plan view)

7.2.5.2 Applicable retrofit methods

Applicable retrofit methods are shown in Table 17, and the U-value tables in Annex B, show the relevant insulation thicknesses.

Table 17 - Applicable retrofit methods for steel frame walls

	Baseline U-value ($W/m^2.K$)	Cavity wall insulation	External wall insulation	Internal wall insulation
Steel frame	0,45 (Warm frame) 0,35 (Hybrid)	N	N	Y

For further information on selecting the retrofit method, see 7.3.1.

The outer cavity should not be filled. Internal insulation can be in the form of a thermal laminate board or insulation and a finishing board. Some older non-traditional steel panel construction systems exist. These need to be treated according to their construction type.

NOTE Further information on these types is provided in BRE *Report on non-traditional houses – identifying non-traditional houses in the UK 1918-1975*.

7.3 Insulation methods

7.3.1 General

7.3.1.1 Wall type

The correct wall type should be identified by a survey before any interventions are carried out as different walls have specific characteristics that determine whether cavity, internal or external insulation is used. It should be also noted that extensions to properties may be of a different construction from the main body of the dwelling. For further information on how to identify wall type see Clause 5.

7.3.1.2 Wall structure

All walls should be of good structural condition and any modifications/repairs necessary should be carried out prior to application of insulation methods. Where there is evidence of potential structural defects appropriate professional advice should be sought.

7.3.1.3 Fire

The fire resistance of the structure and resistance to the surface spread of flame should not be adversely effected by any retrofit measures. Care should be taken when retrofitting framed buildings as the internal lining provides the fire resistance to the structure.

7.3.1.4 Dampness

High moisture levels in the wall can result in damage to the fabric, and potential failure of the structure. Excessive moisture penetration can cause rust, rot or decay to timber or steel structures. Moisture in block, brick or stone walls, can be susceptible to frost damage that will fracture the materials, and weaken the structure. Consideration should be given to the following prior to commencing works:

— the external walls, roof and openings should be inspected to check that there are no defects to the fabric that would allow water to penetrate into the structure;

— roof flashings should be checked and repaired as necessary;

— all seals around windows and doors should be checked;

— the DPC to the walls should be checked to see that it is not being bridged by soil, paths or driveways that have been constructed above the DPC. Any breaches should be rectified;

— plaster that has been subject to dampness should be removed where affected and replaced;

— ventilation bricks below DPC level where fitted should be clear in order to maintain ventilation to timber joists. Where existing ventilation is inadequate, additional ventilation should be fitted.

7.3.1.5 Airtightness

When retrofitting dwellings an appropriate ventilation and airtightness strategy should be considered.

All gaps in any insulation method should be sealed, as any air passing through joints or junctions with floors, ceilings and window frames may diminish the thermal efficiency of the insulation.

Air gaps should be sealed to prevent the spread of fire and smoke, and reduce noise transmission.

Any services which pass through the insulation should be sealed.

Sealing can be achieved with plaster, appropriate sealants, tapes or proprietary membranes that adhere to the walls and seal around the services. For further information see Clause 10.

7.3.1.6 Interstitial condensation

Interstitial condensation refers to the point at which moisture in the air passes into the fabric and condenses as it reaches a cooler part of the fabric.

Moisture in the form of water vapour is capable of passing through the walls and ceilings of a dwelling. When the temperature within the fabric, drops below the level that the air can carry that moisture, (dewpoint temperature) it then condenses. Where this occurs in the centre of the wall, the wall subsequently becomes damp and will conduct more heat out of the dwelling, and may damage the structure of the wall.

The options are to ensure the dew point temperature does not occur within the wall construction or prevent water vapour entering the wall in the first place.

By fitting external wall insulation, the wall temperature remains above the dew point temperature thus ensuring the wall is never cold enough to allow water vapour to condense.

Where internal insulation is used, the wall will remain cooler than the room, so water vapour should be prevented from entering it by installing a VCL fitted to the inner face of the new finishing board. All penetrations and joints should be sealed or overlapped. For further deatil regarding the VCL position and installation, see 7.3.3.

NOTE Where it is required to perform interstitial condensation calculations, see 4.5.7.

7.3.1.7 Wind driven rain exposure

The exposure of the property to wind driven rain will determine the interventions possible depending on the original wall type. Annex D shows the driven rain exposure map of Ireland.

In severe and moderate exposure areas with a driving rain index of greater than 5 $m^2/s/yr$, the use of external insulation particularly on solid and hollow block walls gives added protection against rain penetration, see Annex D.

Where factors do not allow external insulation on solid or hollow block walls e.g. planning or space restrictions, then internal insulation should be used where the wall condition and render prevents driving rain penetrating the fabric.

In areas of severe exposure, cavity walls with open jointed external leaf should not be filled, as the insulation may act as a bridge for moisture to pass to the inner leaf and cause dampness and decay. Internal insulation should be used in this instance.

Insulating materials should be approved for the particular application in the given exposure area.

7.3.1.8 Flood risk

Where the dwelling lies within a flood risk area, materials for wall, both internal and external, should be able to resist deterioration if exposed to flood waters. Closed cell products, e.g. EPS and XPS, perform better than fibrous products in these conditions.

7.3.1.9 Acoustics

Sound is transmitted through fabric as either airborne or impact noise, therefore when installing thermal insulation the sound insulation may be improved at the same time. Products that have good acoustic properties include glass and mineral wool and loose fill products such as cellulose fibre. While these materials may take up more space internally, they are worth considering in order to achieve additional acoustic benefits.

Where cavity party walls exist, see 4.4.4, insulating of these walls improves the thermal insulation, reduces the possibility of a thermal bypass and improves airborne acoustic insulation.

7.3.1.10 Thermal mass

Thermal mass as described in 4.4.5 should be considered when choosing an insulation method. Factors to be considered when retaining existing thermal mass include:

- orientation;
- occupancy patterns; and
- areas with high heat gains.

Properties with high thermal mass (heat storage capacity) can help prevent overheating in the summer.

7.3.1.11 Ventilation

7.3.1.11.1 Permanent air supply for heat producing appliances

A permanent air supply should be provided for efficient and safe combustion of open flued heating appliances including open fires. Existing provisions for combustion air should be maintained in order to ensure safe operation of appliances. Where permanent air supply does not exist the provisions recommended in Table 35 Clause 11 should be followed.

7.3.1.11.2 Background ventilation with extract

The installation of wall insulation may reduce air infiltration and so lead to poor indoor air quality. Where existing ventilation is provided this should be maintained and the sleeve extended to the surface of new insulation. Where sufficient ventilation does not exist adequate ventilation provisions should be installed, see Clause 10.

Where condensation occurs on walls, this can cause deterioration in the fabric and mould to appear. Therefore, any insulation measures should be installed in conjunction with the provision of adequate ventilation, particularly to wet areas, see Clause 10.

7.3.1.12 Selection criteria for insulation methods

Table 18 summarises the design and installation impacts of different insulation methods. These should be considered when selecting the appropriate intervention for a specific wall type and dwelling.

Table 18 - Selection criteria for insulation methods

	Criterion	EWI	IWI	CWI
1.	Internal disruption to occupants	No	Yes	No
2.	Reduces thermal bridging	Yes	Yes	No
3.	Retains thermal mass of building	Yes	No	Yes
4.	Reduces dwelling floor space	No	Yes	No
5.	Installation affected by external weather conditions	Yes	No	No
6.	Scaffolding required	Yes	No	Yes[a]
7.	External services (e.g. downpipes, gullies, cables, gas meter box, electricity meter box, flues, etc.) may require relocation	Yes	No	No
8.	Requires planning approval for works which materially alter exterior appearance of the dwelling	Yes	No	No
9.	Internal pipes, radiators, electrics etc. require relocation	No	Yes	No
10.	Internal skirting, architrave, fitted kitchens, wardrobes etc. require relocation	No	Yes	No
11.	Internal vapour control layer required	No	Yes	No
12.	Practical to achieve advanced U-value without combining with another system	Yes	Yes	No[b]
13.	Specification subject to wind driven rain exposure	No	Yes	Yes
14.	Impact on access provision to side of dwelling	Yes	No	No
15.	Impact on external accessibility requirements to dwelling	Yes	No	No
16.	Impact on corridor/stair widths adjacent to external walls	No	Yes	No
17.	Requires modification of eaves/gable roof line	Yes	No	No
18.	Improves external weatherproofing and appearance of building	Yes	No	No
19.	Local Authority consulted where encroaching on public footpath	Yes	No	No
a	Subject to installer's safety assessment.			
b	Advanced U-values requires a combination of methods.			

7.3.1.13 Selection criteria for insulation materials

Tables showing insulation thickness to achieve improved U-values are given in Annex B. These are indicative values and will vary depending on the exact build-up of the wall.

Table 19 provides typical thermal conductivity of various insulation materials and their applications.

Table 19 - Typical materials applicable to insulating walls

Insulation type	Thermal conductivity (λ) W/mK
Mineral fibre	0,035
Closed cell foam, PIR, PUR, phenolic	0,021 - 0,025
EPS	0,031 - 0,040
XPS	0,035
NOTE 1 Only materials certified at time of publication are included in this table.	
NOTE 2 Thermal conductivity values are indicative, values determined in accordance with the appropriate harmonised European standard should be used.	

7.3.2 External wall insulation (EWI)

7.3.2.1 Description

External wall insulation is an insulation system typically fixed to the external face of masonry or concrete structures. Such systems are normally proprietary. They can improve the appearance of the building and can be installed when performing other external repairs to structure, render repairs or roof replacement. The insulation is generally fixed using mechanical fixing and adhesives.

All external wall insulation systems should have approved certification.

Typically, two finishing systems are used:

Wet systems, see Figure 54

— a wet finish of acrylic/synthetic render with a cementitious under coat embedded on a mesh;

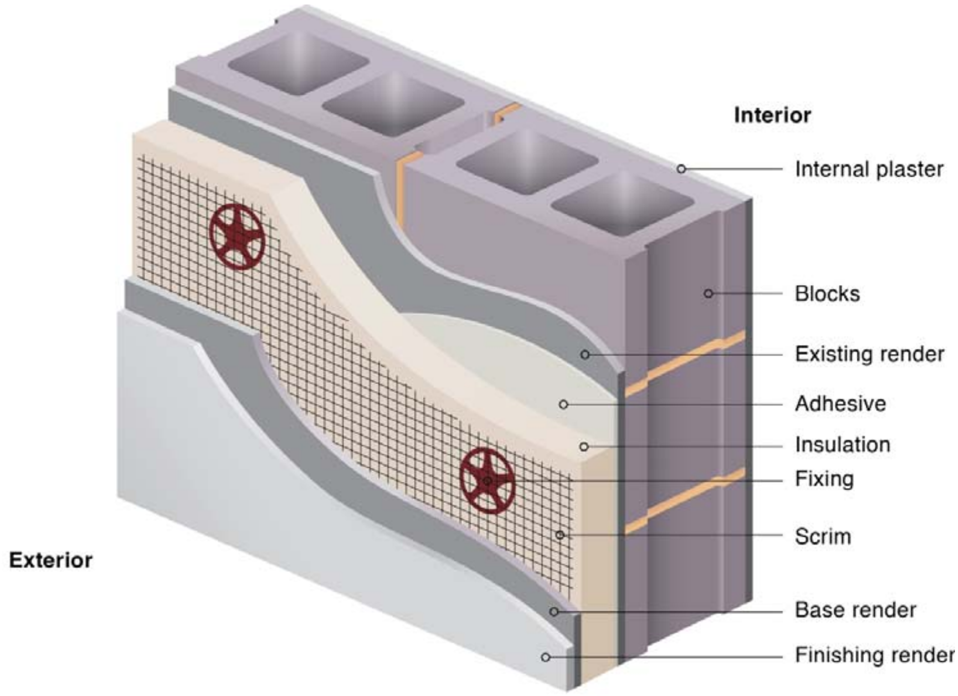


Figure 54 - Typical wet render system

Dry systems, see Figure 55;

— where dry claddings are fixed with adhesive to a ridged mesh overlaying the insulation layer, or,

— dry cladding is fixed to a structural frame to create a ventilated cavity.

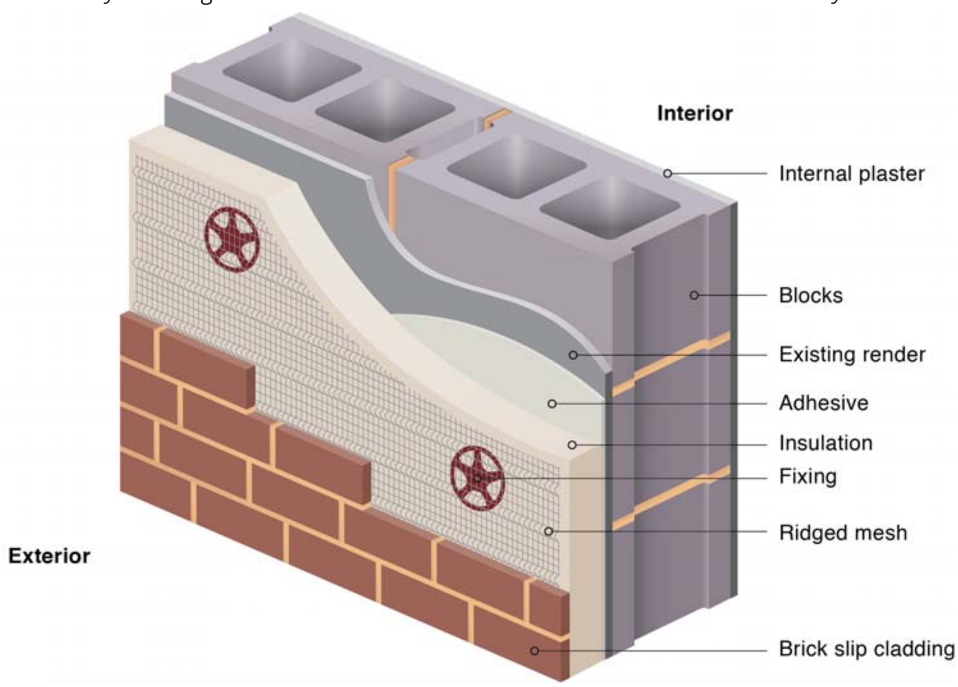


Figure 55 - Typical dry system

Dry systems are available with finishes in brick slips, cement board, timber or aluminium. These act as rain screens and may require additional membranes to allow for any water creeping behind the finish. Some systems are sealed to prevent water ingress, whereas others are unsealed to allow some water to infiltrate under extreme conditions behind the rain screen. A cavity is incorporated behind the rain screen to allow any moisture to pass down the wall without penetrating the insulation.

7.3.2.2 Design considerations

The following design considerations should be addressed when selecting external insulation for use on a dwelling.

7.3.2.2.1 Disruption to occupants

The level of disruption due to external works and interruptions to services should be assessed. This may include:

— restricted car access/parking or side entrance access;

— interruption to drainage/wastes from sanitary appliances;

— interruption to flues/heating appliances;

— relocation of gas meters

7.3.2.2.2 Thermal bridging

The key thermal bridge junctions for external wall insulation may be addressed as follows:

— where ground floor thermal bridges are being eliminated this may require placement of suitable external insulation to footpath level, see Annex H. Further thermal improvements may be achieved by bringing insulation below ground level and may require removal of footpaths;

— sills may require specific detailing to avoid thermal bridging;

— external insulation should abut the roof insulation to form a continuous layer, otherwise a thermal bridge may occur. To eliminate the cold bridge at the wall roof junction removal of the soffit may be required.

The use of external wall insulation terminating at the mid point of party walls, creates no greater surface condensation risk than the existing construction to an adjoining dwelling, see Annex G.

To reduce thermal bridging heat loss internal insulation may be returned along the party wall for a minimum of 300 mm, see Annex H.

7.3.2.2.3 Adaptation of roof lines

Where external insulation meets verges, eaves or concrete barge, specific detailing is required and roof lines should be considered.

Where the proposed thickness of insulation extends beyond the existing roof line (e.g. eaves, barges or soffit) careful consideration should be given to specific details, e.g. modification of roof or flashings.

7.3.2.2.4 Condition of external wall

For external insulation, the condition of the exterior of the wall should be assessed. Render finishes should be in good condition. Pebble dash (wet and dry dash) does not provide an even surface for the adhesive to bond to and should be adequately prepared or removed.

NOTE System design should withstand the wind pressures (including suction) and thermal stresses appropriate to site location and installation.

7.3.2.2.5 Public footpath/boundary encroachment

EWI may be restricted where the dwelling faces onto public footpaths. Relevant Local Authorities should be consulted where the installation affects the width of the public footpath.

Owners of neighbouring properties should be consulted where the installation of EWI encroaches on their property.

7.3.2.2.6 Planning approval

Approval may be required where EWI materially alters the external appearance of the building. The designer should ascertain from the relevant Local Authority at design stage whether planning permission/restrictions apply.

7.3.2.2.7 External services

The following modifications to services on the external wall may be required:

- repositioning of down pipes, soil pipes and gullies;
- the extension of gas meter boxes, electricity supply meter boxes and modification of flues and boiler condensate drains.

7.3.2.2.8 Impact resistance

Systems should provide impact resistance appropriate to project specific design requirements. The system should have adequate resistance to severe mechanical or malicious impact and abrasion where walls are exposed, e.g. walls of private dwellings at ground level.

Impact resistance for external insulation systems are classified as follows:

- category i : a zone readily accessible at ground level to the public and vulnerable to hard impacts but not subject to abnormally rough use;
- category ii : a zone liable to impacts from thrown or kicked objects, but in public locations where the height of the system will limit the size of the impact; or at lower levels where access to the building is primarily to those with some incentive to exercise care;
- category iii: a zone not likely to be damaged by normal impacts caused by people or by thrown or kicked objects.

NOTE The above classifications do not include acts of vandalism.

The design should include the prevention of damage from impact by motor vehicles or other machinery. Preventive measures such as the provision of protective barriers or kerbs should be considered.

7.3.2.3 Installation considerations

The following provides general guidance for the installation of external wall insulation systems. In all cases, detailed installation instructions as provided in the system certification should be adhered to.

7.3.2.3.1 Site survey and preparatory works

A pre-installation survey should be carried out to confirm suitability of substrate for application, pull out resistance for mechanical fixings, fire stops and modifications required, e.g. external services, sills, eaves and verges.

The substrate should be prepared in accordance with system certificate guidance. The exterior surface of the wall should be sound and free from dampness.

Any loose finish, defective render should be removed or repaired prior to application. Preparatory works can include brushing down of walls, washing with clean water and treatment with a fungicidal wash where necessary. Rough or course surfaces may require additional coating to form smooth substrate.

Any causes of dampness such as leaking gutters or down pipes should be repaired. Where there is evidence of rising damp, remediation measures should be carried out.

Access requirements for the works should be identified to allow for the provision of plant, power, fresh water and a safe area for working including preparation of the renders and safe access for working for contractors, occupants and the public. Safe provision for working at height should be allowed for as necessary.

7.3.2.3.2 Fire

The following installation provisions should be taken into account for the prevention of fire spread:

- internal fire spread (structure): the masonry or concrete structure, to which the system is applied, should be designed to provide the necessary fire resistance;

- external fire spread: the external surfaces of the system should be classified as Class O for fire spread of flame.

Above two stories additional stainless steel fire fixings should be used for insulation batts to take account of the extra duty required under fire conditions.

Vertical and horizontal fire barriers should be provided at each compartment wall and floor, including the second floor level of a three-storey single occupancy house, see Figure 56.

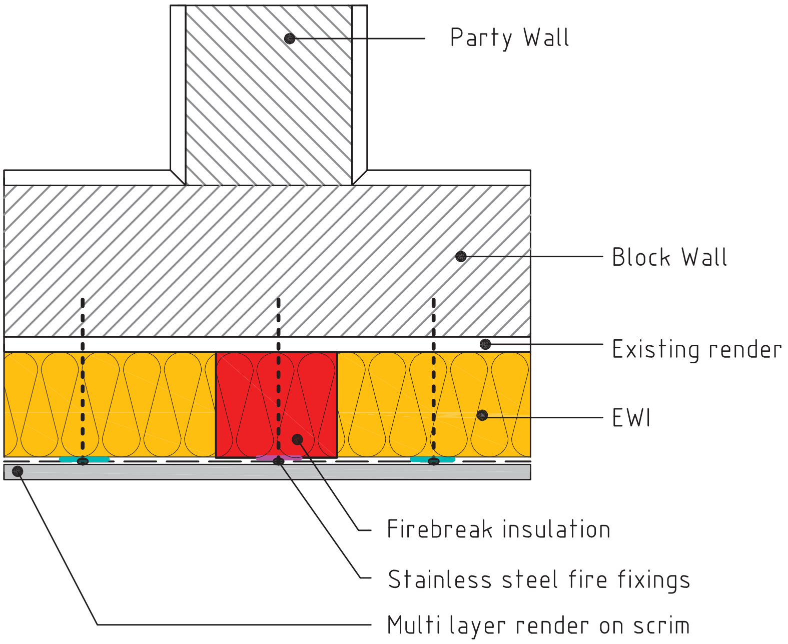


Figure 56 - Fire break to vertical or horizontal junction, floor or party wall

Horizontal and vertical firebreaks, where required, should be adhesively bonded to the substrate and mechanically fixed using stainless steel fixings. Spacings should be in accordance with certificate specifications. The fire barrier should be of non-combustible material (i.e. mineral fibre), be at least 100 mm wide, continuous and unbroken for the full perimeter of the building and for the full thickness of the insulation. Additional layers of mesh should also be applied at these locations. The fixing design should take account of the extra requirements under fire conditions.

Where chimneys are on the external wall, the insulation should be non combustible or combustible insulation should be separated by solid non-combustible material not less than 200 mm thick. Fire requirements of the system certification should be followed.

7.3.2.3.3 Fixings to structure

Fixings to the external fabric will need reinforcement to resist movement that may affect joints on soil, rainwater, gas and water pipes, see Figure 57.

Satellite dishes are subject to wind load that may cause indenting into the insulation with the potential for failure of the waterproof render. A treated timber ground to the depth specified by the system certificate should be installed.

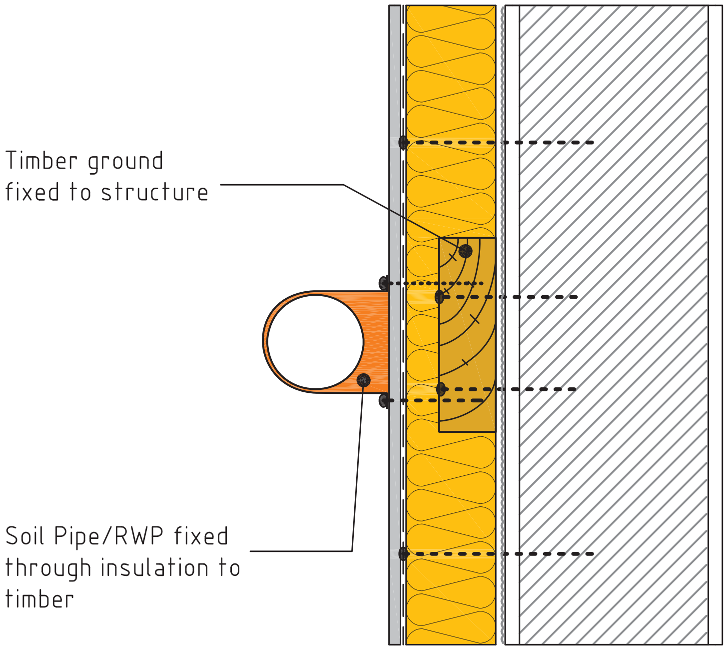


Figure 57 - Fixing services through external insulation

7.3.2.3.4 Flue penetrations

For flue penetrations through external insulation a possible approach is shown in Figure 58. For specific flue details the system certificate should be followed.

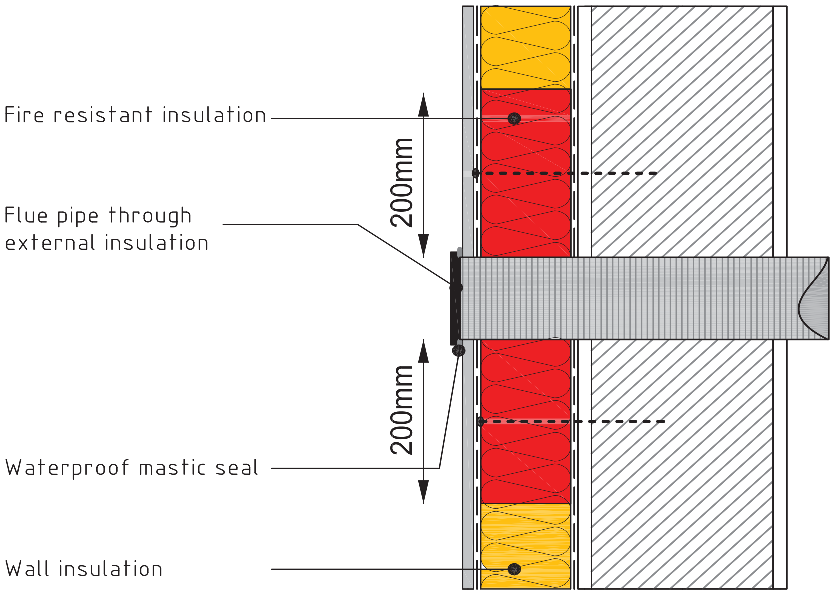


Figure 58 - Flue penetration through external insulation

The mesh used on the insulation around the flue may differ from the mesh used elsewhere so refer to certificate instructions for mesh and render used around flues.

7.3.2.3.5 Services

7.3.2.3.5.1 Gas meter boxes

The guidance provided by Bord Gáis Networks should be complied with when externally insulating a wall where a gas meter is already installed.

For dwellings with natural gas installations, Bord Gais Networks should be contacted. They will then provide the necessary assistance to either move the meter box to a suitable alternative location or temporarily remove and then refit the meter box on completion of the works.

7.3.2.3.5.2 Electricity supplies

The external wall insulation installer is not permitted to interfere with ESB Networks wires, cables or equipment and any alterations should only be carried out by suitably trained ESB Networks' personnel. ESB Networks' personnel may also be required to move any meter boxes on external walls depending on the circumstances. Surface mounted boxes should be extended to be flush with final EWI surface finish. Accordingly, where electricity wires or cables are attached to external walls or soffits, they should be relocated. ESB Networks should be contacted in advance of the works commencing in order to arrange for the required alterations.

7.3.2.3.5.3 Telecoms and television

Surface mounted boxes should be extended to be flush with final EWI surface finish. Where surface mounted cables are used they should be relocated onto the new surface. When non flexible cables are being repositioned caution should be taken to ensure the cable remains intact.

7.3.2.3.6 Procedure

The following provides guidance for installation procedures:

- modifications of down pipes, soil and vent pipes, pipe extensions, meter locations and other services should be as detailed in design specification. All pipe work should be relocated as required to accommodate the insulation;
- movement joints should be provided in accordance with the system's technical specifications;
- prior to application of base and finish coats, all necessary protective measures such as taping off of existing window frames and covering of glass should be in place;
- renders (adhesives, base coats, primers, finish coats) should be applied in accordance with outdoor temperature, precipitation, wind and sunlight conditions specified by system certification. Until fully cured, the coatings should also be protected from rapid drying;
- in sunny weather, work should commence on the shady side of the building and be continued following the sun to prevent the rendering drying out too rapidly;
- starter track and base beads, typically at DPC level should be accurately aligned to provide a horizontal first line of insulation panels, see Figure 59;
- the insulation boards should be attached to the wall by applying a specified adhesive to the boards.
- the insulation boards are then supplementary mechanically fixed at the approved spacing to certificate specification to keep the boards in place while the adhesive sets to full strength. These fixings (type, arrangement and number per m^2 as applicable) should be provided in accordance with project specific design requirements based on pull out test results, substrate type, wind-loading data;
- subsequent rows of insulation boards are installed on top of the starter track and positioned so that the vertical board joints are staggered and overlapped at the building corners;

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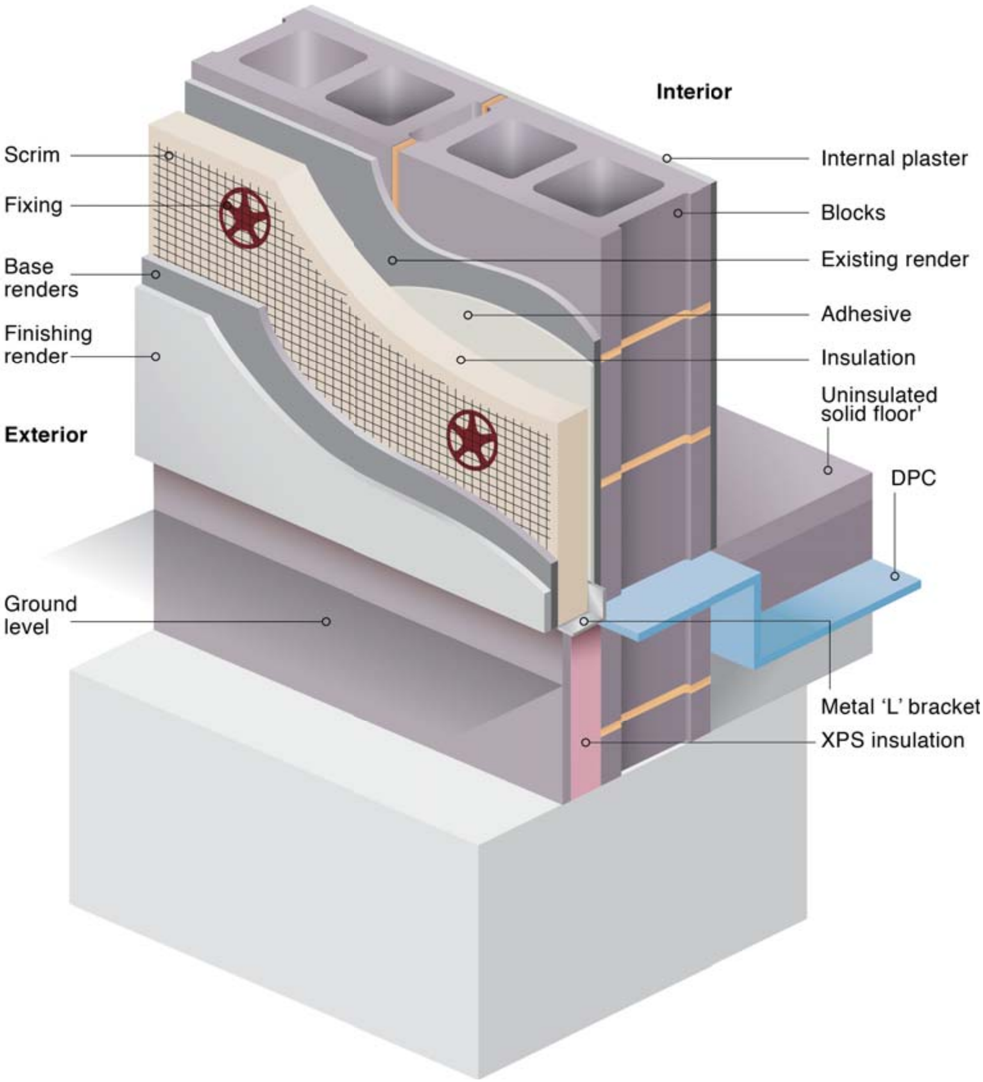

Figure 59 - External insulation at ground level

- gaps of larger than 3 mm should be filled with slivers of insulation or spray foam;

- the insulation should be returned into reveals, sills and jambs in accordance with the approved details. All junctions between EWI and existing window frames should be adequately sealed to prevent the ingress of moisture. The insulation should overlap at the corners, and fit without gaps. Where clearance is limited, strips of approved insulation should be installed to suit available margins. For additional guidance, see *Acceptable Construction Details* on the Department of Environment, Community and Local Government website;

- where windows and doors are being replaced they may be relocated towards the external face of the existing structure to reduce thermal bridging but at all times should be supported by the structure. Details should be in accordance with approved certification;

- once the insulation layer is applied, a mesh scrim should be fixed over the insulation. This is secured in place with the base layer of render and should be fully embedded into this layer. The mesh can be laid horizontally or vertically, but joints in the mesh should be avoided at joins in the board;

- an additional diagonal reinforcement should be applied around the façade openings. This involves embedding diagonal strips of mesh in the reinforcing mesh;

- once this layer has dried sufficiently subsequent layers can be built up according to the specification, with the top layer being the final colour layer;

- primers should be applied in accordance with the certificate holder's instructions and allowed to dry fully prior to the application of the finishing coat. Render primers prevent penetration of impurities from the adhesive into the render, protects and reinforces the substrate, and increases the bond strength between the render and the substrate;

- finishing coats should be applied in accordance with the certificate holder's instructions;

- for below the DPC, the insulation should be more robust, such as an XPS board to provide resistance to impact and capillary action. To avoid internal surface condensation the insulation should extend 150 mm below finished floor level. To minimise the effects of cold bridging, the insulation may be extended below ground level, and where possible to the footings, see Annex H. This will require excavation around the perimeter of the building;

- EPS boards should not be exposed to UV light for extended periods prior to the application of the render coatings;

- at all locations where there is a risk of insulant exposure (e.g. window reveals, eaves or stepped gables) the system should be protected, e.g. by an adequate overhang or by purpose-made sub-sills, seals or flashings, see Annex H Figure H.4;

- where the external insulation meets intersecting walls etc. and the abutting structure cannot be cut back, the edge of the insulation where it meets the wall should be protected using proprietary closure trims;

- anchors to minimise the thermal bridge effect during the installation of railings, exterior lighting, shutter guide rails, canopies, aerials, satellite dishes etc. should be installed in accordance with the certificate holder's instruction, see Figure 57;

- all rendering should be carried out in accordance with I.S. EN 13914-1:2005: *Design, preparation and application of external rendering and internal plastering – External rendering*;

- when obstructions, such as a garden fence or boundary walls, abut external walls it is recommended to cut back the boundary wall to allow for the continuation of the external insulation system where practicable;

- all necessary post-application inspections should be performed and the homeowner's manual completed and handed over to the homeowner accordingly.

7.3.2.3.7 External insulation and cavity walls

External insulation may be used on cavity walls when the cavity is filled. The methods shown in Figure 54 or Figure 55 should be adopted for this application.

For dwellings where the cavity may have been previously filled during original construction or an earlier energy retrofit, this may be established by a boroscope or an infrared survey.

Where cavity walls are unfilled then the use of external wall insulation is not recommended due to thermal bypass. This reduces the thermal performance of the wall and leads to a poorer U-value. The recommended approach is to full fill the cavity with an appropriate insulation to prevent thermal bypass.

7.3.2.3.8 External insulation and hollow block walls

The use of EWI on hollow block walls can lead to thermal bypassing in gable walls as these are not capped and extend beyond the insulated ceiling. This will reduce the thermal performance of the wall and lead to a poorer U-value. The thermal bypassing should be prevented by the filling or sealing of the voids. One method is to introduce a suitable sealant (e.g. adhesive bead or spray foam) into each block at roof insulation level on the gable wall or as per product certification so as to prevent the bypassing. Walls at eaves are normally closed by a solid block but should be checked and sealed where necessary.

7.3.3 Internal wall insulation (IWI)

7.3.3.1 Description

Internal wall insulation is a method which consists of the provision of a layer or layers of insulation on the internal face of the existing structure. The following systems are described below:

— thermal laminated board;

— insulation between battens with thermal laminate board over; and

— insulation between independent stud.

7.3.3.2 Design considerations

7.3.3.2.1 Wall condition

External render should be in good condition prior to installing internal insulation. Remedial action should be taken to eliminate ingress of water to the wall fabric. Dry-lining should not be used to isolate dampness. The source of dampness should be rectified and the walls allowed to dry thoroughly. External pointing or rendering reduces moisture penetration. Solid walls should be examined for signs of dampness and assessed to determine what systems are suitable. Where dampness cannot be eliminated the only method of internal insulation is to construct an inner frame of treated timber or metal located at least 30 mm clear of the masonry wall. The resulting air space will also require ventilation, by way of airbricks positioned at high and low level, and this should be taken into account when determining the new U-value of the construction. The alternative to providing a ventilated cavity, is to either provide external cladding/render to protect the wall from wind driven rain and then install IWI directly to the wall surface.

7.3.3.2.2 Existing internal finish

The IWI fixing method depends on the existing internal wall construction.

For internal insulation, where the masonry wall is plastered directly, any of the IWI solutions described may be used. For existing walls, wallpaper, skirting, picture rails, gloss paint and projecting window boards should be removed. The wall surface should be clean and dust free.

For existing plasterboard on dabs, it is not possible to assess whether the dabs are able to support the additional weight of the laminate insulated plasterboard, therefore the plasterboard and dabs should be removed to provide a smooth substrate. Where the block wall finish is unplastered and therefore potentially porous resulting in poor airtightness, a parging coat of plaster should be applied, to improve the airtightness of the final works.

For plasterboard on battens, the condition of battens should be investigated and where they are found to be in a serviceable condition the battens may be retained and the new IWI fixed directly to them through the existing plasterboard. Where the battens are not in a serviceable condition, the plasterboard and battens should be removed entirely. Where insulation exists, it would be in poor condition and should be removed and replaced with insulation to an appropriate U-value.

7.3.3.2.3 Insulation thickness

Internal insulation reduces the size of rooms by the thickness of the insulation system. Most rooms can accommodate this reduction but it can be critical in bathrooms, WCs and small kitchens, and may therefore influence the choice of insulation. Thermal laminate wall boards bonded by adhesive to the wall generally takes up the least space, whereas a timber stud frame kept clear of the wall will intrude at least 90 mm. Corridors and stair widths may also be reduced where space allows however, minimum widths as required by Building Regulations should be maintained.

7.3.3.2.4 Structural elements penetrating insulation

When choosing internal insulation, it is likely that floor joists will penetrate the layer of insulation into the wall which was previously warmed by the room but now is likely to be much colder. These joists should be in good condition with no rot or insect attack prior to fitting the insulation. Where repairs are needed the joists resting on the wall should be replaced with joist hangers, to provide a long term solution and prevent future decay to a major structural element.

7.3.3.2.5 Occupant disruption

Rooms cannot be used by occupants whilst installation of insulation and relocation of services, fixture and fittings are taking place.

7.3.3.2.6 Thermal bridging

Internal insulation is effective at addressing thermal bridging at openings and the ceiling wall junction. Thermal bridges at structural penetrations and ground floor wall junction require careful consideration. Stepped and staggered terraced dwellings can also present problems of thermal bridging, when the construction is of single leaf. The effect of the thermal bridging in these conditions can be reduced by returning the dry-lining at least 300 mm along the internal wall.

The use of internal wall insulation terminating at the party walls, as described in Annex G, creates no greater surface condensation risk. To reduce thermal bridging heat loss internal insulation may be returned along the party wall for a minimum of 300 mm, see Annex G.

7.3.3.2.7 Exposure to wind-driven rain

It is essential that walls are of a suitable condition to prevent moisture penetration with respect to the driving rain index.

For conditions assessed as moderate/severe, properly rendered single leaf walls may be suitable for dry-lining. A notional cavity should be provided behind the dry-lining to provide a break in any moisture transmission path, see 7.3.3.2.1.

Only where an assessment of the wall condition by a competent assessor shows no signs of wetness internally can a ventilated airspace be disregarded.

Where single leaf walls subject to moderate/severe driving rain are protected with impervious external cladding or cladding with a drained and ventilated void, these are suitable for IWI without a notional cavity.

7.3.3.2.8 Airtightness

All gaps in an internal wall insulation solution should be sealed as any air passing through joints or junctions with floors and ceilings will flow behind the insulation and may diminish the thermal efficiency of the insulation and lead to interstitial condensation.

A wet plaster finish is a good method of achieving high levels of airtightness.

Plaster should be taken down behind the skirting and up to window frames and other openings.

Any services passing through the insulation should be sealed. This can be achieved with plaster, sealants, tapes or proprietary membranes that adhere to the walls and seal around the services.

When addressing airtightness, ventilation should also be considered, see Clause 10.

7.3.3.2.9 Interstitial condensation

Interstitial condensation occurs where the temperature in the fabric drops below the dew point temperature, for further information, see 4.5. When installing internal insulation the risk of interstitial condensation should be addressed. The use of approved details and VCLs generally limits this risk.

Junctions should be designed to ensure a continuous VCL is achieved, especially at ceiling and floor junctions and joints between laminate boards. Careful detailing should be ensured at service penetrations. A VCL can be achieved by using polyethylene sheet (e.g. 500 gauge), or with an integral layer, e.g. in thermal laminate boards, see Table 3 for further guidance. In all cases, the weak points are at the joints between the sheets or boards and where pipes or other services penetrate the lining. All joints between laminate insulated plasterboard should be sealed in accordance with the manufacturers' recommendations. Plasterboard manufacturers also supply a plasterboard primer that helps control vapour penetration at the surface of the board, but this should be an addition to and not an alternative to polyethylene sheet or an integral vapour control layer.

NOTE Where polyethylene is used as a VCL it should be a minimum thickness of 0,12 mm (500 gauge), minimum vapour resistance of 250 MNs/g and should not be made from recycled material.

7.3.3.2.10 Sealing of IWI

To ensure that the insulated dry-lining will perform thermally as intended, the wallboard should be sealed with adhesive or battens around its perimeter with adjoining walls, the floor and ceiling. This also functions as a fire barrier for any void. It should also be sealed around windows, doors and other openings. Where the seal is omitted or incomplete, cold air from the space behind the insulation can leak into the room and reduce the effect of the insulated lining.

7.3.3.2.11 Dry-lining window and door reveals

Window and door reveals can be sources of condensation and mould if not insulated correctly, but where the amount of visible window frame is too small the full thickness of the insulated dry-lining cannot be applied. Where this is the case an insulated window lining board (e.g. expanded PVC) can be used.

The lining should not restrict ventilators or opening mechanisms. It may be necessary to remove the existing plaster to accommodate an adequate thickness of insulation within the limited space available. Where windows are being replaced the new jamb and soffit details can be designed to accept the insulated lining. The sill board should generally also be insulated and deep enough to cover the edge of the wall insulation.

Where air tightness is being addressed tapes should be used to seal windows/doors to the specified airtightness barrier.

7.3.3.2.12 Acoustics

When the insulation is returned along a separating wall, care should be taken to maintain an acceptable level of sound reduction between dwellings. The use of rigid thermal laminates returned along masonry walls can, due to resonance in the lining, show a marked reduction in sound insulation. Where sound insulation is important, a mineral wool thermal laminate wallboard should be bonded directly to the wall surface. Alternatively, an independent frame, fixed clear of the wall at floor and ceiling only, should be used. The frame should be in-filled with glass-wool or mineral wool batts 50 mm thick. For best results the frame should be covered with two layers of 12,5 mm wallboard with staggered joints.

7.3.3.2.13 Internal services, fixtures and fittings

Skirting, architraves, fitted wardrobes etc. should be removed and replaced as required. The work may also involve the relocation of services, pipes, radiators and electrics. Provision should also be made for fixing of heavy items to walls.

7.3.3.2.14 Staircases and corridors

The width of the staircase or corridor should not be reduced to less than minimum requirements by the application of IWI. It may be necessary to install a reduced depth of insulation in these areas and increase the level elsewhere to compensate for this reduced performance. Alternatively, the use of insulation with a lower thermal conductivity may be used to maintain the width in these areas.

7.3.3.3 Installation considerations

The interior wall surface should be structurally sound and free from dampness. Any repairs should be carried out ahead of the installation, and walls should be allowed to dry out prior to the works commencing.

Any existing structural or dampness problems should be resolved before applying any insulation.

Provision should be made for the fixing of heavy items such as kitchen cupboards, or items that will have a level of force applied, such as banisters and grab rails.

Additional battens should be fixed at these locations, or a sheet of ply fixed behind the finishing board.

Electrical cables are generally designed to function with free air around them. Passing cables through insulation should be avoided where possible. Where cables are passing through insulation they should be assessed for capacity and rating, see 6.3.1.7 for further guidance.

7.3.3.3.1 Thermal laminate board fixed to single leaf walls

Figure 60 shows a laminated board, comprising of an internal finishing board adhered to insulation, incorporating a vapour control layer between the insulation and the board finish.

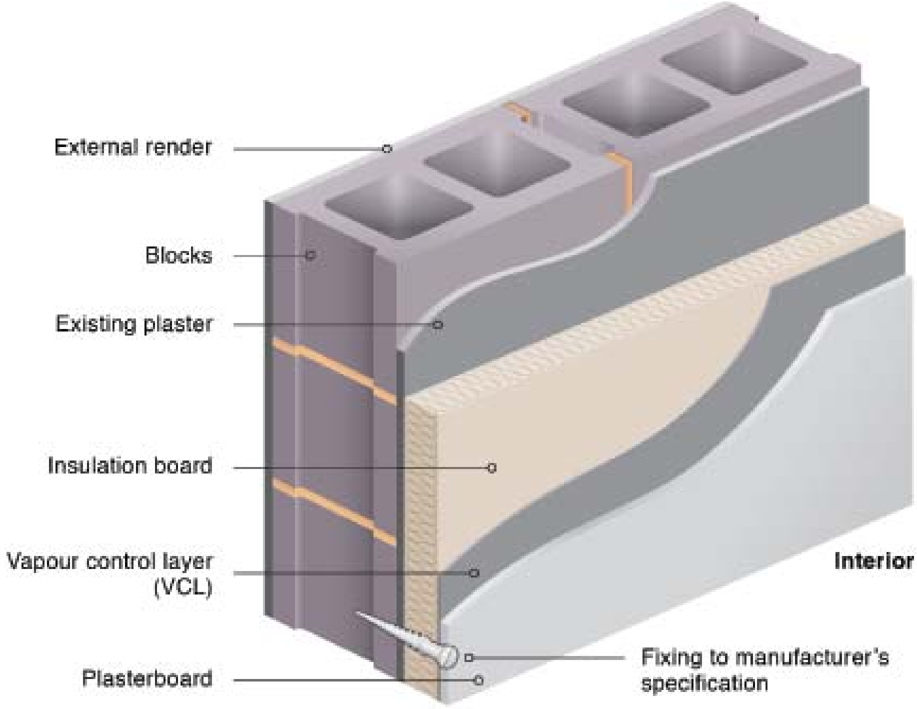

Figure 60 - Thermal laminated board fixed to internal face of wall

7.3.3.3.1.1 Procedure

The following provides guidance for installation procedures:

- services such as heating pipes and electrical sockets should be removed by a qualified person;
- where a radiator cannot be re-positioned to an internal wall or be floor mounted, a ply or OSB timber plate should be secured to the wall surface through the thermal laminate into the existing masonry;
- the wall should be flat and defect free. For plaster finished blocks the thermal laminate can be applied directly to the wall, ensuring that all cracks are filled, and any loose sections should be removed and made good;
- where plaster is being removed, the exposed surface of the wall should be pointed/cement washed to seal any holes/cracks;
- any previous plasterboard on dabs or on timber studs should be removed prior to installation. Where substrate is un-rendered a parging coat should be applied to improve the airtightness;
- where a smooth finish cannot be achieved, another method of fixing the thermal laminate should be adopted, such as the use of plaster dabs or timber battens;
- where cupboards are wall hung, a timber batten should be fixed to the wall along the top line of the cupboards to provide a robust fixing. Other fixtures (e.g. curtain rails) also require battens;

- fixings can be either drilled into the concrete using slim anchor fixings or masonry screws that require a pre-drilled pilot hole at the spacing in accordance with the relevant manufacturer' specifications. Metal fixings should penetrate at least 35 mm into the masonry;
- all joints should be closely abutting, and gaps larger than 2 mm filled with spray foam or slivers of insulation;
- where cables are present in the wall, the wall should be chased where possible and the cables recessed and installed in conduit. It is recommended that chasing tools which limit depth of the chase are used. In hollow block walls the provision of a service void may be necessary. Cables should be extended or replaced, so that they extend through the full depth of the proposed insulation layer and finishes with sufficient excess for fixing or working. Where there is no other option than to run cables through the insulation, these should be in accordance with national rules of the Electro Technical Council of Ireland (ETCI) The location of potential service penetrations should be determined by offering up thermal laminate board. Slots should not be formed in thermal laminate to accommodate service penetrations, under any circumstances. A hole should be drilled through the thermal laminate, slightly larger than the diameter of the service pipe or cable and the service should be slotted through the hole;
- to ensure vapour and air tightness, all edges of insulation boards should be continuously sealed at floors, ceilings and jambs. Care should be taken to ensure insulation boards are continued to the floor level. All board joints should be taped and all service entry points sealed to ensure the continuity of the vapour control layer;
- light switches and sockets should be secured to thermal laminate board.

7.3.3.3.2 Thermal laminate board on dabs or battens fixed to single leaf walls

An alternative to mechanically fixing directly to the wall is to use dabs of plaster or timber battens to fix the thermal laminate to the existing wall. Where the wall surface is sound then either dabs of plaster or timber battens can be applied to the wall at regular intervals and as a continuous strip at the top, bottom and edges (e.g. at junctions with walls and openings) of the thermal laminate board. This prevents fire spread in the void behind the thermal laminate board. The sealing of perimeters also prevents the thermal bypassing behind thermal laminate board. This method is particularly suited to uneven walls. Where the existing wall is painted the manufacturers do not recommend the use of dabs, see Figure 61.

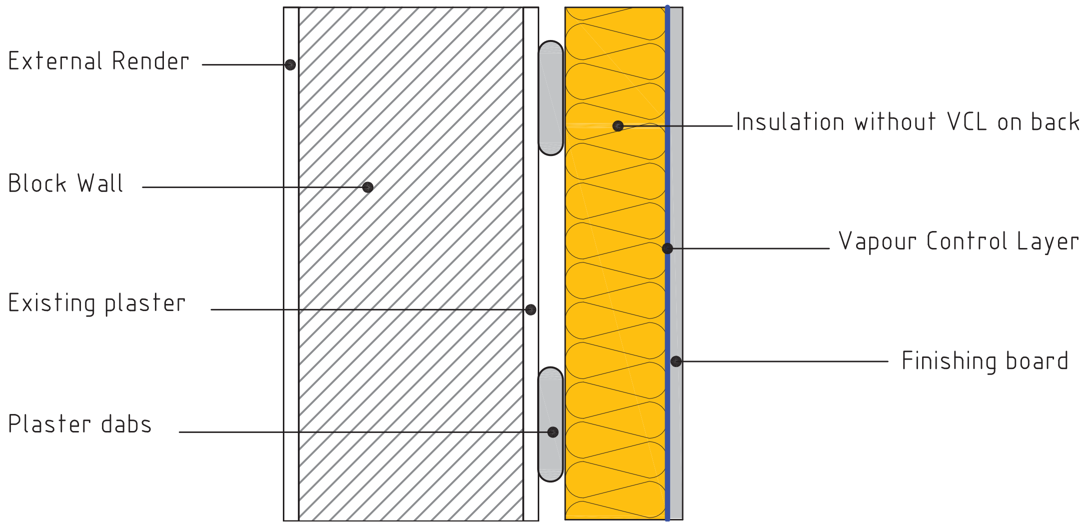

Figure 61 - Thermal laminate board on plaster dabs

Plaster dabs are not suitable for foil backed laminate boards, battens should be used instead. Plaster dabs are suitable for mineral wool boards or closed cell boards such as EPS or PIR/PUR. Additional mechanical fixings may be required under fire safety requirements, according to the certificate specification.

7.3.3.3.2.1 Procedure

The following provides guidance for installation procedures:

— where existing plaster is to remain, all cracks should be filled, and any loose sections should be removed and made good. Where plaster is to be removed, the exposed surface of wall should be pointed/cement washed to seal any holes/cracks. Where the existing wall surface is level and smooth, the thermal laminate board may also be fixed directly to the wall surface in accordance with 7.3.3.3.1.1;

— where any services such as pipes or cables are present in the wall, or mounted on the wall, these should be extended or replaced. They should extend through the full depth of the proposed insulation layer and finish with sufficient excess for fixing or working. Where radiators cannot be re-positioned to an internal wall or be floor mounted, a ply or OSB timber plate should be fixed to the wall surface and secured through the thermal laminate into the existing masonry or timber battens;

— when using plaster dabs, the thermal laminate manufacturer's guidance regarding location of dabs should be followed. A continuous strip of dab should also be applied to the edges as well as to the top and bottom of the board. Additionally, a continuous strip of plaster should be provided around services such as light switches and sockets. Some insulation types may require additional mechanical fixings to be provided once the dabs have set. Any such manufacturer recommendation should be followed as directed;

— when using timber battens, the battens should first be levelled and securely fixed. The fixings should extend at least 35 mm into the masonry beyond the existing plaster layer. All timber battens in contact with masonry/concrete should be appropriately treated with preservative;

— the location of potential service penetrations should be determined by offering up the thermal laminate board. Slots should not be formed in thermal laminate to accommodate service penetrations. A hole should be drilled through the thermal laminate, slightly larger than the diameter of the service pipe or cable and the service should be slotted through the hole;

— the thermal laminate should be secured to the wall or timber battens, in accordance with manufacturers' requirements.

— to ensure vapour and air tightness, all edges of insulation boards should be continuously sealed at floors, ceilings and jambs. Care should be taken to ensure insulation boards are continued to the floor level. All board joints should be taped and all service entry points sealed to ensure the continuity of the vapour control layer;

— light switches and sockets should be secured to thermal laminate board.

7.3.3.3.3 Thermal laminate boards over insulation between battens fixed to single leaf walls

Figure 62 shows the use of battens with insulation between and thermal laminate board fixed to the battens.

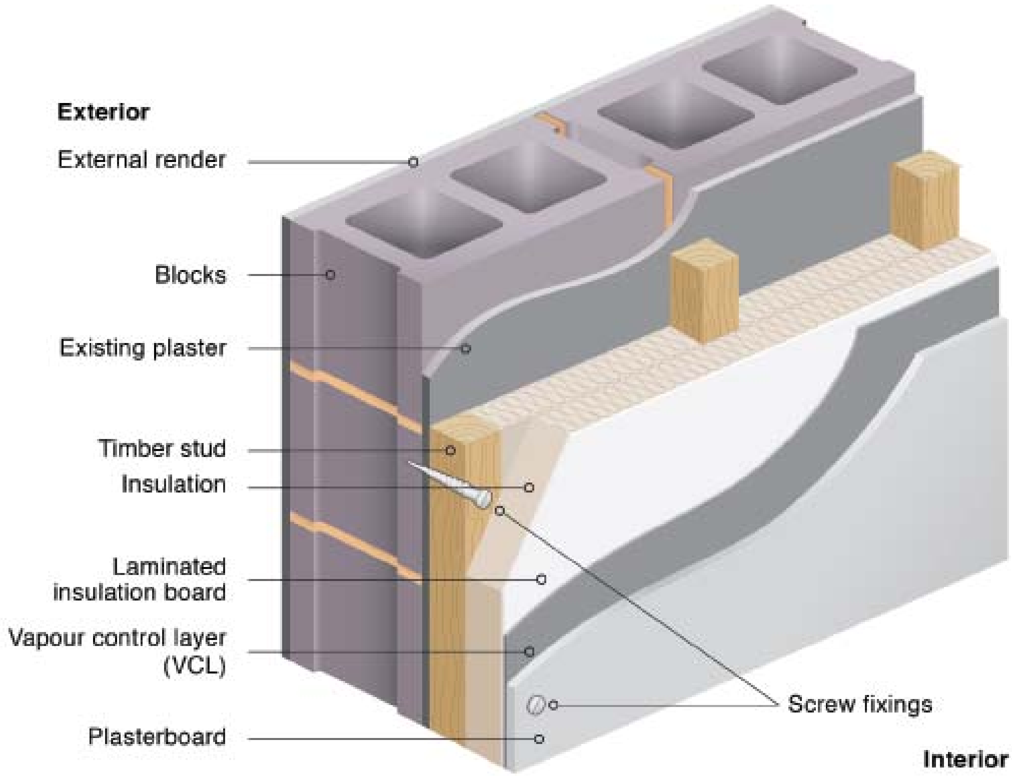

Figure 62 - Thermal laminate board over insulation between battens

7.3.3.3.3.1 Procedure

The following provides guidance for installation procedures:

- where existing plaster is to remain, all cracks should be filled, and any loose sections should be removed and made good. Where plaster is to be removed, ensure that exposed surface of wall should be pointed/cement washed to seal any holes/cracks;
- where any services such as pipes or cables are present in the wall, or mounted on the wall these should be extended or replaced. They should extend through the full depth of the proposed insulation layer and finish with sufficient excess for fixing or working. Where it is not possible to extend the service, this should be replaced and installed in a service void. For further guidance on service voids in the construction, see 7.3.3.3.4;
- the timber battens should be installed at no more than 600 mm centres with a top and bottom timber plate, all timber should be securely fixed. The fixings should extend at least 35 mm into the masonry beyond the existing plaster layer and 25 mm into floor/ceiling joists as appropriate. All timber battens in contact with masonry/concrete should be appropriately treated with preservative;

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- where rigid insulation is used between the battens, the location of potential service penetrations should be determined by offering up the insulation board to the wall. A hole should be drilled through the insulation board slightly larger than the diameter of the service pipe or cable and the service should be slotted through the hole;

- where using a flexible insulation a small hole through the insulation may be formed, or where a service is close to the edge of the insulation a slot may be cut in the insulation to allow the service to penetrate the insulation layer;

- where rigid or flexible insulation is installed between the battens, no gaps should be left between the insulation and the timber battens, i.e. the insulation should fill every space between all timbers present. Where gaps occur these should be filled with either insulation or insulation foam;

- the secondary layer of thermal laminate board should be fixed across the face of the timber battens. Service penetrations may be formed as for rigid insulation above. All service penetrations should be taped or provided with a proprietary sleeve;

- to ensure vapour and air tightness, all edges of insulation boards should be continuously sealed at floors, ceilings and jambs. Care should be taken to ensure insulation boards are continued to the floor level. All board joints should be taped and all service entry points should be sealed to ensure the continuity of the vapour control layer;

- light switches and sockets should be secured to the thermal laminate board;

- where radiators cannot be repositioned to an internal wall or be floor mounted, a ply or OSB timber plate should be fixed to the timber battens through the laminate board. The radiator mounts should be fixed to the timber plate and radiators re-mounted.

7.3.3.3.4 Secondary layer over insulation between battens with service void fixed to single leaf walls

Figure 63 shows the use of a timber batten to form a service void over insulation between studs (new or existing).

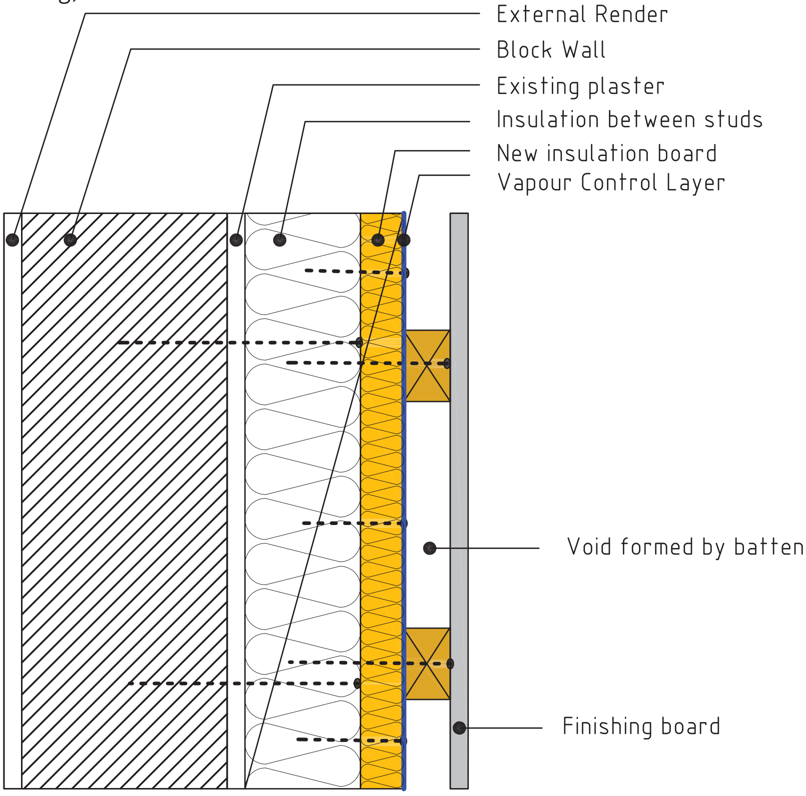

Figure 63 - Service void formed by timber batten

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7.3.3.3.4.1 Procedure

The following provides guidance for installation procedures:

- where existing plaster is to remain, all cracks should be filled, and any loose sections should be removed and made good. Where plaster is to be removed, the exposed surface of wall should be pointed/cement washed to seal any holes/cracks;
- where it is not possible to extend a service pipe or cable, this should be replaced and installed in a service void between the vapour control layer and plasterboard.;
- treated timber battens should be fixed at no more than 600 mm centres with a top and bottom timber plate. The battens should first be levelled and securely fixed. The fixings should extend at least 35 mm into the masonry beyond the existing plaster layer and 25 mm into floor/ceiling joists as appropriate;
- where rigid or flexible insulation is installed between the battens, no gaps should be left between the insulation and the timber battens, i.e. the insulation should fill every space between all timbers present. Where gaps occur these should be filled with either insulation or insulation foam. Care should be taken to ensure insulation boards are continued to the floor level;
- a secondary layer of rigid insulation should be fixed directly to the timber battens;
- to ensure vapour and air tightness, the vapour control layer should be fixed over the secondary insulation layer. The VCL edges should be sealed to floor and ceiling. Side and end joints should be kept to a minimum. Joints in flexible membranes should be formed over solid backing members or a rigid substrate. Where joints occur they should be lapped at least 50 mm and sealed;
- timber battens forming the service void should be fixed through the secondary insulation layer to the wall battens;
- the services should be secured/mounted onto the side of the void timber battens. Every effort should be made to prevent damage occurring to the vapour control layer. Where any damage to the VCL occurs it should be repaired with tape;
- plasterboard should be secured to the timber battens;
- all service entry points and joints between plasterboard should be sealed with scrim, and edges should be sealed to floor and ceiling. Excess VCL previously lapped out to floor and ceiling should be trimmed;
- the surface mounted light switches and sockets should be secured to plasterboard. Where the service void is deep enough a recessed service box may be used by clamping to the plasterboard only;
- Where radiators cannot be repositioned to an internal wall or be floor mounted, a ply or OSB timber plate should be fixed to the timber battens through the laminate board. The radiator mounts should be fixed to the timber plate and radiators re-mounted.
- where radiators cannot be repositioned to an internal wall or be floor mounted, a suitably designed fixing structure should be provided to give adequate support.

7.3.3.3.5 Insulation board fixed to wall with service void formed by Metal Furring (MF) fixed to single leaf wall

Figure 64 and Figure 65 illustrate the use of MF stud to achieve a service void.

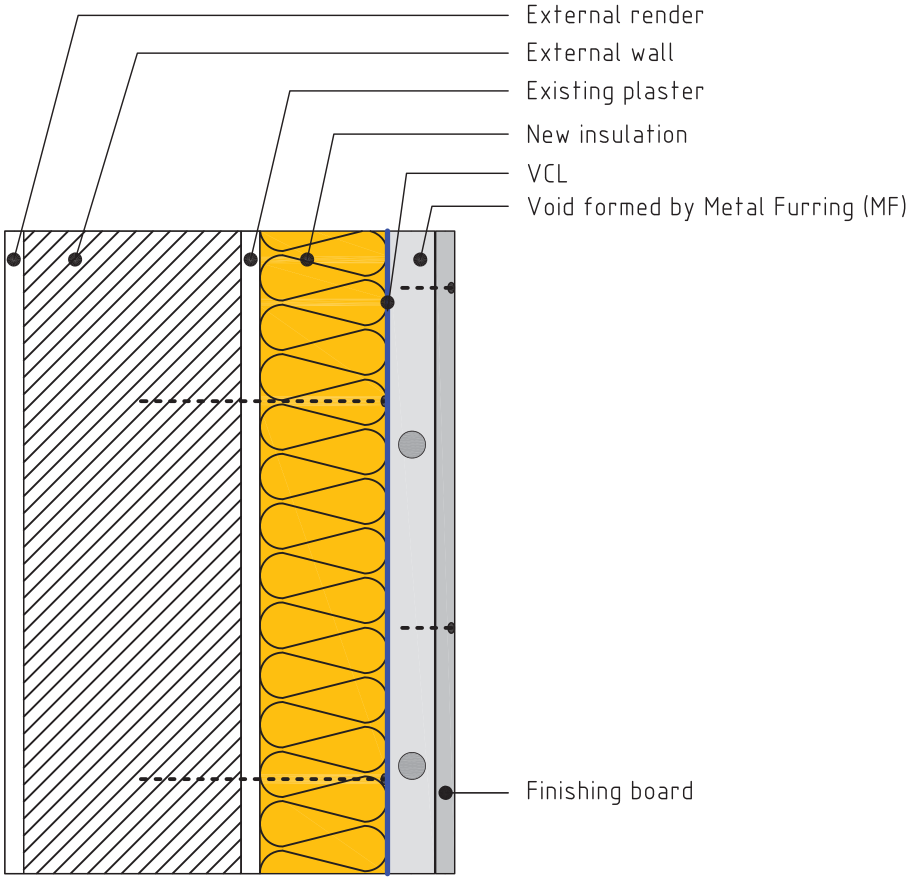

Figure 64 - Insulation board fixed to wall with cavity formed by Metal Furring (MF)

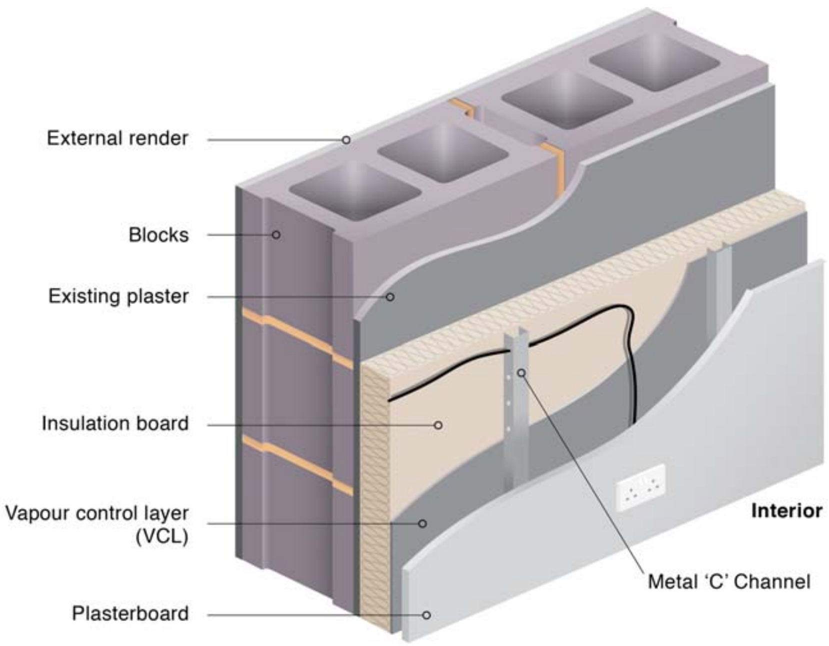

Figure 65 - Internal insulation and Metal Furrings channels

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7.3.3.3.5.1 Procedure

The following provides guidance for installation procedures:

- a rigid insullation board should be fixed directly to the wall. The service void should be constructed through the use of metal furrings or full depth metal C-sections. This allows the insulation layer to remain intact and the performance of services should not be affected;
- the installation procedure is described in 7.3.3.3.4, except that the vertical timber battens can be eliminated, and the insulation should be mechanically fixed to the wall. To ensure vapour and air tightness, the vapour control layer should be fixed behind the furrings;
- the VCL edges should be sealed to floor and ceiling. Side and end joints should be kept to a minimum, joints in flexible membranes should be formed over solid backing members or a rigid substrate, should be lapped at least 50 mm and be sealed;
- the U-channel should be fixed to the floor and ceiling up against the VCL, care should be taken not to damage the VCL;
- C-channels should be slotted into the U-channel to form the MF wall frame, in accordance with manufacturers' requirements. Cable or pipes should be run through the service void as necessary and the finishing board should be fixed to the frame. The joints may be taped and filled, or a skim finish provided over the completed wall surface;
- light switches and sockets to wall should be reinstated;
- where radiators cannot be repositioned to an internal wall or be floor mounted, the radiator mounts should be secured to the C-channels, or otherwise a ply or OSB timber plate should be secured to the C-channels. The radiator mounts should be fixed to the timber plate and re-mounted.

7.3.3.3.6 Cavity walls with IWI

Figure 66 shows IWI on a partially filled cavity wall. Figure 67 shows thermal laminate board fixed to full-filled cavity wall.

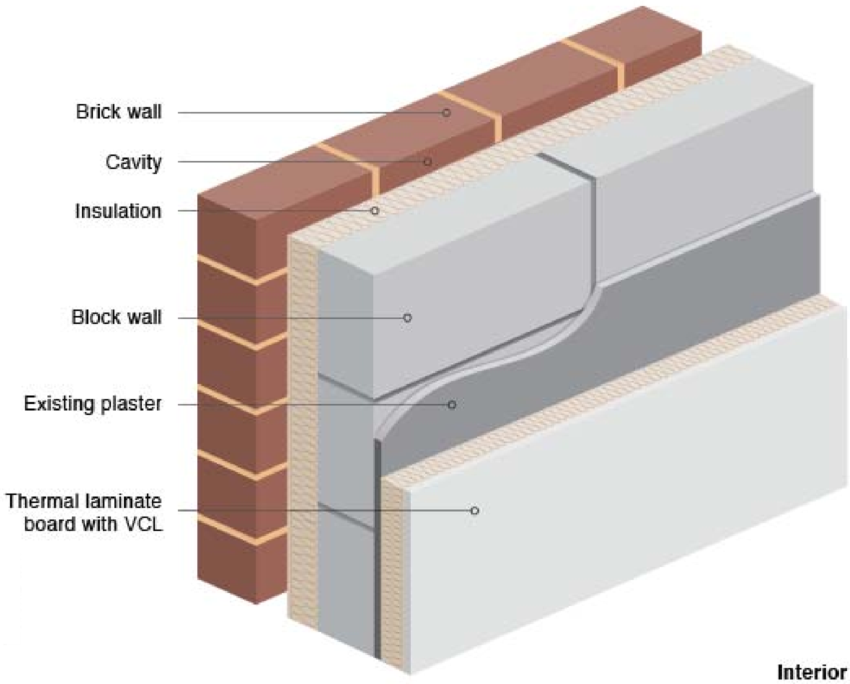


Figure 66 - Partial fill cavity with IWI top up

WALLS

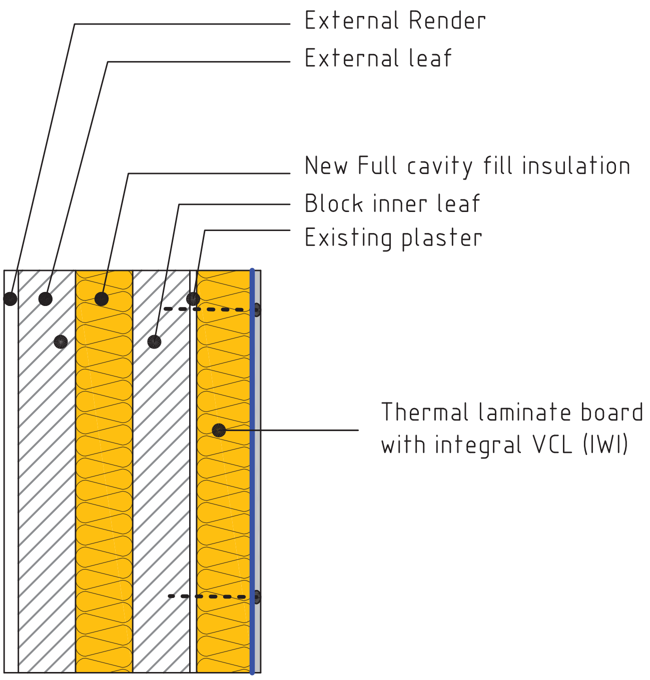


Figure 67 - Full fill cavity with added IWI

7.3.3.3.6.1 Procedure for cavity walls

There are likely to be a range of internal and external finishes that can impact on the insulation solution:

Procedures for installing internal wall insulation on cavity walls is described for single leaf walls in 7.3.3.3.1 to 7.3.3.3.5. which includes the provision of service voids if required.

7.3.3.3.7 Timber frame walls with IWI

Timber frame should not be externally insulated or cavity filled, so the options are to replace the insulation within the studwork, and/or to fit insulation to the internal face.

7.3.3.3.7.1 Procedure for timber frame with no insulation

The internal finishing board should be removed and insulation fitted to the full depth of the stud.

Plasterboard appropriate to the fire rating of the wall should be fitted to the studs to maintain adequate fire resistance and structural integrity/racking strength.

Where an improved U-value is required a thermal laminate board should be fitted over the plasterboard.

An appropriate VCL should be fitted on the warm side of the insulation.

7.3.3.3.7.2 Procedure for timber frame with insulation to partial depth of the studwork

Insulation should not be fixed over existing partially fill studwork in order to avoid interstitial condensation, see 7.3.3.2.9.

The existing internal plasterboard finish and VCL should be removed and either insulation topped up to the full depth of the studwork, or the existing insulation should be removed and replaced to the full depth of the studwork.

Plasterboard appropriate to the fire rating of the wall should be fitted to the studs to maintain adequate fire resistance. To ensure structural integrity/racking strength the plasterboard should be at least the thickness of the original board.

Where an improved U-value is required a thermal laminate board may be fitted over the plasterboard.

An appropriate VCL should be fitted on the warm side of the insulation.

7.3.3.3.7.3 Procedure for timber frame with existing insulation to the full depth of the studwork

Provided the plasterboard and existing VCL are all intact and there is no sign of decay and insulation is still filling the full void (a thermal imaging survey may confirm this), the walls may be upgraded with additional internal insulation, e.g. thermal laminate board, see Figure 68. When using this method the thermal resistance of the new internal insulation should be no greater than the thermal resistance of the existing construction. For U-values less than 0.21 W/m²K an interstitial condensation risk analysis should be carried out.

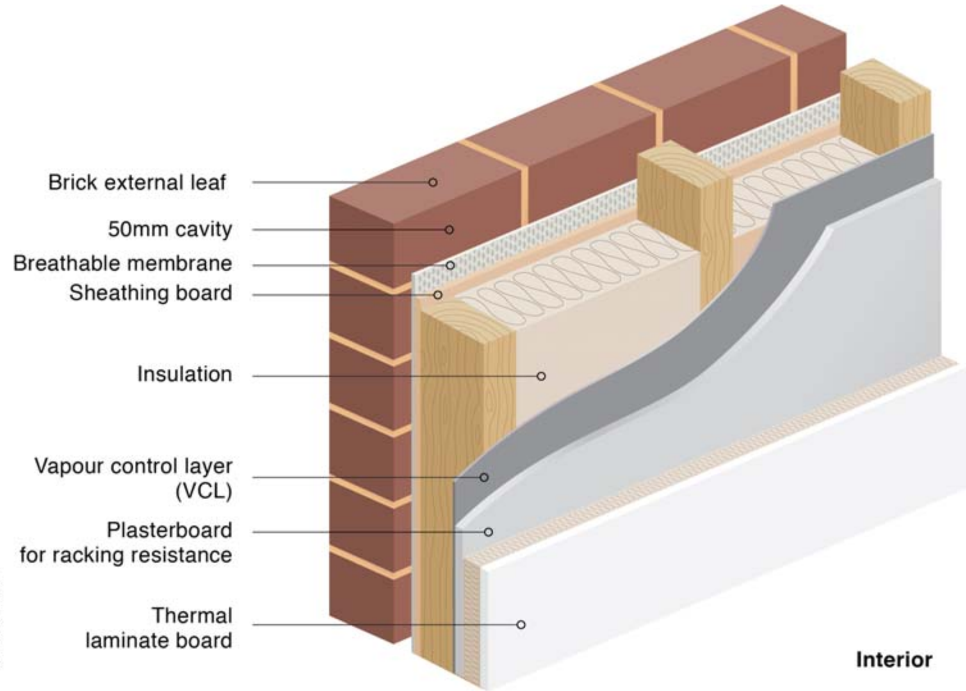


Figure 68 - Thermal laminate board to timber frame

An appropriate VCL should be fitted on the warm side of the insulation.

The installation process is described in 7.3.3.3.3.

Where a service void is required the installation process is described in 7.3.3.3.4.

7.3.3.3.8 Steel frame walls with IWI

For steel framed walls any improvement to the fabric should be through additional internal insulation as the void within the frame is filled with insulation, usually EPS. For older systems there may be a partial void within the frame, and, in these instances, it is necessary to remove the plasterboard layer and fill the void within the frame with a similar insulation material to the existing. To determine the exact make up of the wall it may be necessary to carry out an invasive survey.

7.3.3.3.8.1 Procedure

Where the survey indicates the insulation is filled up to the plasterboard, insulation may be fitted directly onto the existing plasterboard as shown in Figure 69 and Figure 70.

Where the insulation features an air gap between the insulation and the inside face of the plasterboard (as shown in Figure 52 and Figure 53), the plasterboard should be removed and the insulation topped up with the same product to the full depth (see Figure 71 and Figure 72).

Once the frame has been fully filled with insulation, and where the U-value is sufficient to achieve the required target, plasterboard with the appropriate fire rating to maintain adequate fire resistance should be fitted. Where an improved U-value is required a thermal laminate board may be fitted over the plasterboard.

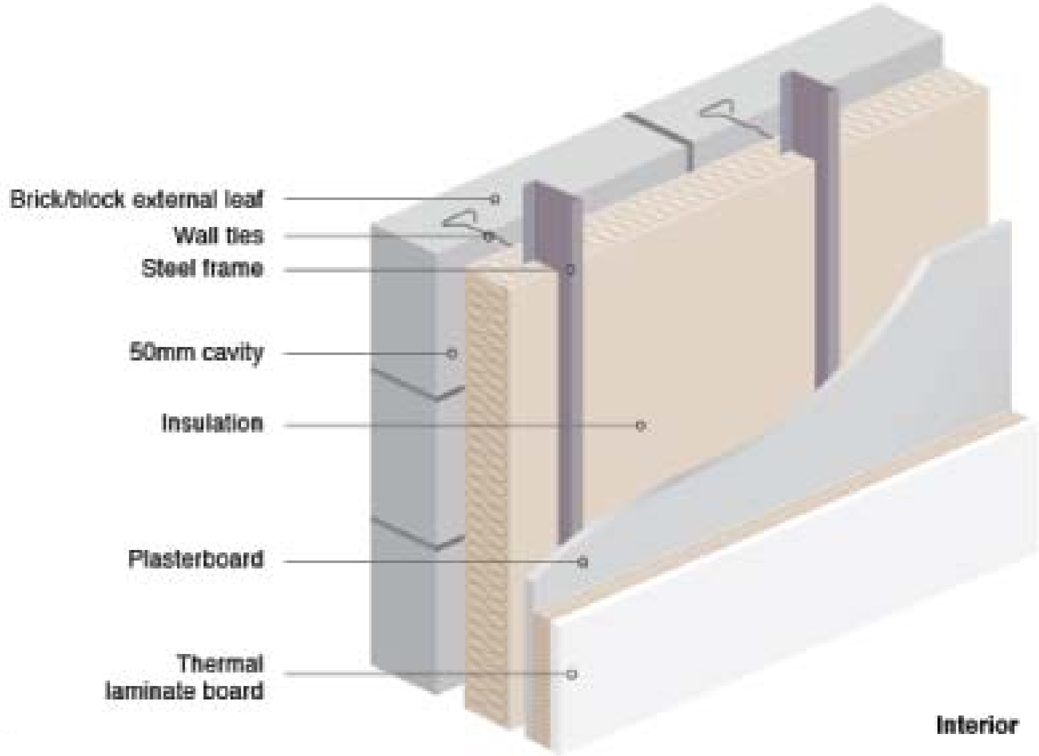


Figure 69 - Full filled steel frame wall with internal insulation

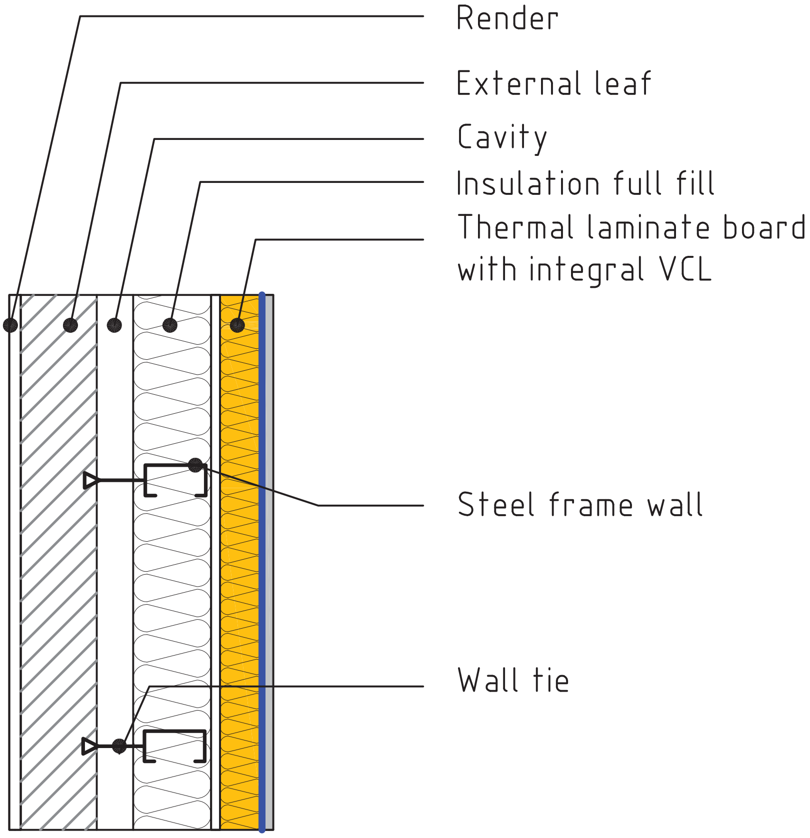


Figure 70 - Steel frame with thermal laminate added and existing board in place (plan view)

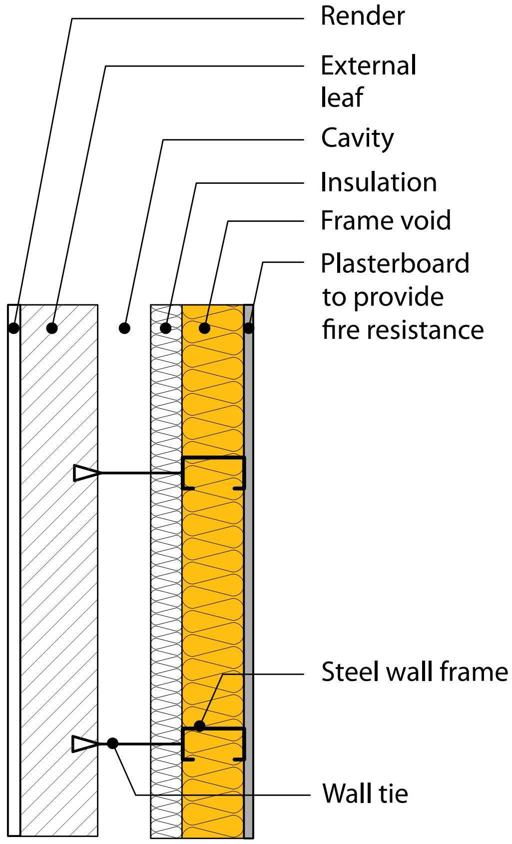


Figure 71 - Warm light steel with full fill insulation in frame void (plan view)

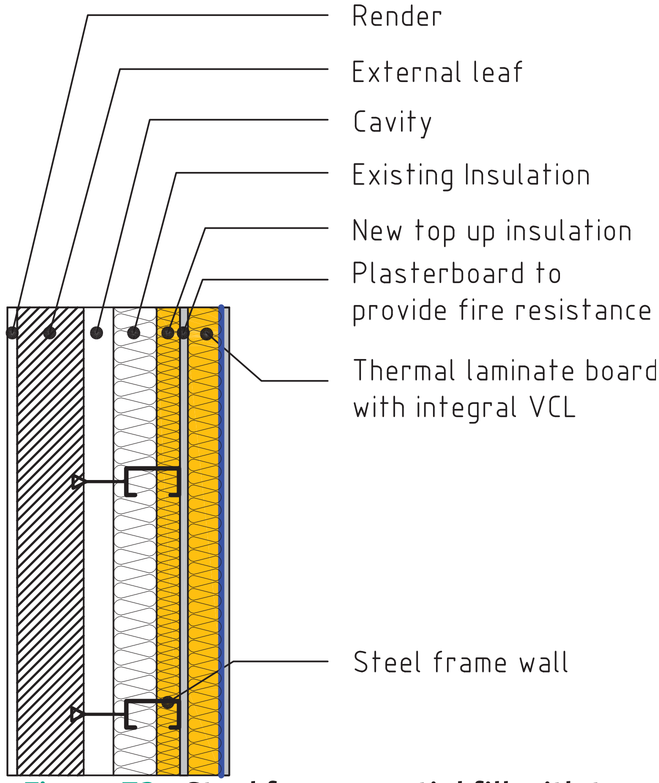


Figure 72 - Steel frame, partial fill with top up and thermal laminate (plan view)

7.3.4 Cavity wall insulation (CWI)

7.3.4.1 Description

Cavity wall insulation is a method of insulating existing masonry cavity walls by filling an empty cavity with blown or injected insulation.

The insulants available for cavity fill are commonly blown mineral wool and polystyrene beads. Insulation systems should be approved.

Filling cavity walls is an effective method of reducing heat loss through this type of wall, and reductions of up to 60 % are possible. Filling these may not achieve the full thermal improvements required, and may need to be supplemented with internal or external insulation to achieve the desired U-value, see Figure 67.

7.3.4.2 Design considerations

The following design considerations should be addressed when selecting cavity wall insulation for use on a dwelling:

7.3.4.2.1 Exposure

The suitability of insulation depends mainly on the local exposure to driving rain and the condition of the existing construction. Cavity wall insulation is certified for use in masonry walls up to 12 m in height subject to the conditions in the product certificate. The exposure of the walls to wind-driven rain should be assessed and related to any restriction on the particular type of cavity fill being considered. The map in Annex D illustrates the levels of wind driven rain. Any area higher than 5m^2/sec/year should not have the cavities filled where the external face is open jointed. In these cases internal insulation, or full fill cavity with external insulation which provides protection, should be used.

NOTE System certificates provide maps which identify exposure zones and specify conditions where full-fill cavity insulation can be used.

7.3.4.2.2 U-value specification

The amount of cavity insulation which can be installed is subject to the width of the existing cavity.

Where advanced U-values are required it is necessary to use a combination of measures or internal insulation only. See B.3 for typical cavity wall insulation U-values.

7.3.4.2.3 Thermal bridging

In general cavity wall insulation does not increase the risk of surface condensation. Cavity wall insulation does not directly address heat loss through thermal bridges. The application of internal insulation at cill board level assists in preventing surface condensation, see Annex G.

For further reduction in heat loss due to thermal bridges internal or external insulation solutions may be used with cavity wall insulation.

7.3.4.2.4 Services

Services, electrical cables, wall vents, underfloor vents and flues should be identified in order to provide adequate protective measures.

7.3.4.2.5 Material suitability

Blown insulation in a partially filled cavity wall should only be used where the particular blown insulation material has been certified for use in existing partially filled walls and for use with the existing insulation material.

Table 20 highlights the requirements for introducing EPS insulation into a partially filled cavity.

Table 20 - Conditions for introducing EPS insulation into a partially filled (Type 3) cavity wall

In all instances involving the use of blown EPS insulation in cavity walls partially filled with EPS boards, the following minimum conditions should be met:

- all the general restrictions and conditions of the relevant certification.
- a minimum remaining cavity width of 50 mm or a width in accordance with the relevant product certification should be present in the existing wall;
- additional boroscope inspections are performed, on all elevations, to fully assess the condition of partial fill boards. This is performed as part of a more robust and critical analysis of the condition of the (remaining) cavity;
- where there is significant dislodgement of the existing boards or substantial blockage of the cavity (e.g. by blocks, debris etc.) cavity fill may not be suitable. Where dislodgement or blockages are localised it may be possible to remediate these by;
    - pushing/securing partial fill board to the inner wall leaf face;
    - clearing of blockages/debris etc.;
- a depth stop should be used on the drill bit (used to drill fill holes) to ensure no damage is caused to the existing insulation;
- an adjustment of the glue ratio may be required (which should be reduced to the minimum required to set the bead) to induce a free flow of bead which will help to overcome any irregularities in the (remaining) cavity;
- additional training should be provided for installers (by the certificate holder) to include all aspects of partial fill applications including training on performing remedial action as/when required;
- evidence of dampness in the wall or cavity indicates that the wall should not be pumped without a thorough investigation and remedial work being carried out beforehand;

7.3.4.2.6 Cavity suitability

An assessment of each dwelling should always be carried out to determine the suitability of the walls for cavity fill.

Where defects are identified, these should be satisfactorily rectified before work begins. Any dampness problems should be investigated to determine the cause and then remedied.

The cavity should be continuous. Where bricks have been used as wall ties and bridge the cavity, as in some older dwellings, the wall is unsuitable for filling. A cavity should be at least 50 mm wide or a width in accordance with the relevant product certification.

Where chimneys are adjacent to the cavity, the insulation should be non-combustible, or combustible insulation should be separated by solid non-combustible material not less than 200 mm thick. Fire requirements of the system certification should be followed.

7.3.4.3 Installation considerations

7.3.4.3.1 Site survey

A survey should be carried out prior to installation to ascertain the suitability of the dwelling. A complete survey report (including a boroscope survey) should be prepared and retained.

Particular problems should be specifically identified. Essential ventilation openings such as those providing ventilation for combustion appliances or under floor ventilation and all flues in the cavity wall should be checked. Where adequate sleeving or other cavity closures are not present, installation should not proceed until these openings have been sleeved or otherwise modified to prevent blockage by the insulant. The tops of cavity walls should be closed and holes in the inner and outer leaves should be sealed. Cavity filling should not be carried out unless electrical cables are placed in conduits.

Services, electrical cables, wall vents, underfloor vents and flues should be sleeved through both leaves of the wall and precautions taken to isolate polystyrene insulation from hot flues.

7.3.4.3.2 External inspection of the wall

The external leaf of the wall should be in good condition and any necessary repairs should be undertaken. Cracks in the wall should be carefully inspected and the causes ascertained. Cracks may be caused by shrinkage and these are easily repaired. Alternatively, cracks may be due to sulphate attack, ground subsidence or wall tie corrosion in which case specialist advice should be sought.

Areas of spalled masonry (caused by frost action or by the crystallisation of salts) should be identified and cured. Where areas are isolated, cavities may be filled after repairs have been made. Dwellings with widespread spalling are unsuitable for cavity filling only and may be best insulated in combination with external insulation. Similar criteria should be applied to spalled or hollow renderings.

Mortar joints should be inspected for excessive cracking of mortar and defective pointing. Any necessary repairs should be made. External walls should be checked for bowing and leaning.

Similarly, lintels and windows out of plumb should be identified and rectified.

The cause of any moisture ingress should be identified and repaired, e.g. leaking gutters, downpipes, etc.

Walls painted externally with paints that are impermeable to water vapour are unsuitable for cavity fill.

Holes in the outer leaf at wall heads may need sealing to prevent loss of cavity fill material.

7.3.4.3.3 Internal inspection

Damage to internal decoration caused by penetrating rising damp should be investigated and rectified.

Where there is any indication of condensation, the cause should be identified and remedial measures taken.

Dry lining should be properly sealed and be in good condition.

Holes in the inner leaf and open cavities at wall heads may need sealing to prevent ingress of fill into the dwelling.

Services, ventilation ducts and flues should be sleeved through both leaves of the wall and precautions taken to isolate polystyrene insulation from hot flues.

7.3.4.3.4 Cavity inspection

Cavities should be checked for the presence of electrical wiring. Where present, the wiring should be relocated or sleeved before filling.

Other defects, e.g. missing wall ties, debris or mortar blocking the cavity, should be identified and, if they cannot be remedied, the cavity may be unsuitable for filling. These items should be covered in the assessment of the wall for filling.

To ensure that cavity wall insulation is only installed where it is appropriate, the assessment and installation procedure should include the following:

- determining that the wall is a masonry wall with unfilled cavities;
- inspecting the general condition of the external wall;
- Identifying any constructional defects that first need to be remedied, e.g. failed pointing;
- checking on the inside of external walls to see if there are any existing dampness problems which need to be remedied;

- checking any penetrations of the external wall, e.g. for flues and air ventilators;
- checking if the cavity of a directly adjacent house has already been filled, e.g. in a terraced or semi-detached dwelling;
- checking the exposure of the wall for the type of insulation system to be used;
- where a semi-detached or terraced dwelling is to be insulated, the insulation is contained by inserting a cavity barrier at the line dividing the dwellings. After filling, the cavity barrier is retained in the cavity and the drill holes filled;
- cavity wall insulation is a specialist job and should be carried out by a trained contractor. The contractor is generally responsible for assessing that the walls are suitable for filling. The installation method varies with the type of system.

7.3.4.3.5 Blown mineral wool, EPS beads and granules

The recommended pattern of injection holes for the system and sequence of filling is given in the relevant product certification.

Where the filling time is less than estimated, the cavity may not be full and the procedure should be repeated.

Where the filling time is longer than estimated, the proceduere should be stopped and the cause investigated.

On completion, the quantity of insulant used should be compared with the estimated quantity. A variation of more than 10 % may indicate missed areas, wrong filling density, or that areas of the structure other than the external cavity may have been filled.

Where this is the case the density setting on the blowing machine should be checked, the density in the cavity should be checked and any gaps in the fill identified. Check the interior of the dwelling to make sure that the fill hasn't entered.

After filling, the following areas should be checked and cleared of any material: air vents, service ducts, venting equipment, chimney flues, combustion air ducts adjacent to the filled cavity, and weep holes. Injection holes should then be made good.

EPS beads are spherical with diameters varying between 2 mm to 8 mm. They are very free flowing and therefore require fewer injection holes through the outer leaf. Granules, being irregular in shape, are less free flowing.

Due to the free flowing nature of EPS beads, particular care should be taken to avoid loss through holes in the inner leaf, around service entry points etc.

When the cavity is full, back pressure will stop the flow of beads, at which point the adhesive valve should be closed.

It is not necessary to fill gable peaks as long as the height of the cavity wall insulation is not less than 200 mm above the top of the loft insulation. Where the gable forms part of a heated living space or the edge of the thermal envelope the drilling and filling process should be extended to the apex of the gable walls.

Conventionally constructed cavity walls filled with EPS should present no unacceptable fire hazard where the cavity is capped. Any openings in the capping at the top of cavity walls should be closed.

Polystyrene should not come into contact with PVC-coated electric cables to avoid embrittling the cable insulation.

NOTE For specific details refer to the relevant product certification.

8. Openings

8. Openings

8.1 General

This clause addresses retrofit measures for windows, doors and rooflights in dwellings. Windows and semi or fully glazed doors are unique in energy efficiency in that they allow heat and light gains into the dwelling as well as being responsible for heat loss. This clause describes typical openings currently in use in dwellings and suitable retrofit measures for each type of opening.

8.2 Opening types in existing dwellings

8.2.1 Windows

8.2.1.1 General

Typically the glazing installed in windows is either single or double glazed. The two main types of windows are:

— casement windows; and

— sliding sash windows.

8.2.1.2 Casement windows

The casement window (or casement) consists of a fixed section(s) and opening section(s). The opening sections are attached to the frame by two or more hinges. Generally casement windows are side or top opening and are hung on conventional butt hinges, storm proof hinges or reflex hinges that use a system of linked sliding bars to move the casement out from the sub-frame. Figure 73 shows a typical casement window with side and top hung sections.

The glass panes are generally set in a rebated frame and sealed with bevelled putty, glazing compound or glazing beads to secure the glass.

Casements are made from timber, aluminium, uPVC or steel. Improved airtightness may be achieved if the opening lights of a casement can close tightly against draughtproofing seals or gaskets within the frame. The frames of older windows will generally have an inferior airtightness performance, due to poor fitting and lack of draughtproofing.

Casement windows represent the largest proportion of window types used in more recent dwellings.

Windows have often been replaced in existing housing and now over 60 % of the housing stock has some form of double glazing. The quality and the performance of existing double glazing varies depending on specification at time of installation and age.

8.2.1.3 Sliding sash windows

Sash or hung sash windows consist of one or more movable panels or “sashes” which forms a frame that holds the panes of glass. Although any window with this style of glazing is technically a “sash”, the term is used almost exclusively to refer to windows where the glazed panels are opened by sliding vertically, or horizontally see Figure 74.

To facilitate opening and closing, the weight of the glazed panel is usually balanced by a sash weight (counter-weight) concealed within the window frame. The sash weight is connected to the window by a sash cord or chain that runs over a pulley at the top of the frame. Spring balances are also used.

Existing timber sashes tend to be single glazed and draughty. The box sections that contain the sash weight are a source of thermal bridging and draughts.

Many original timber sashes have been replaced by uPVC, aluminium or steel sashes. These tend to be old and the performance may have deteriorated since their installation. Seals that were fitted may have perished, and faulty guides and rails can cause the sashes to sit awkwardly in the frame allowing gaps to occur.

NOTE More detail on heritage windows is available in the DEHLG publication “*Energy efficiency in traditional buildings*”.

Figure 73 - Casement window

Figure 74 - Sliding sash windows (uPVC)

8.2.1.4 Applicable retrofit methods

8.2.1.4.1 Overview

The applicable retrofit methods for windows are:

- draughtproofing of existing windows, either the glazing or frame, or both;
- secondary glazing of existing windows;
- re-glazing of existing windows within the frame; and
- replacement window unit.

Appropriate retrofit measures depend on the condition and thermal performance of the existing window. Where the frame is in good condition all the retrofit measures should be appropriate for all glazing and frame types. Where the frame is in poor condition window replacement is the only option.

8.2.1.4.2 Draughtproofing

Many windows can be thermally improved by reducing the amount of air leakage through gaps where the openings meet the frames, or the frame fit within the opening. Details on reducing draughts are given in 8.3.3.

Proprietary systems are available or specialist contractors can undertake a complete overhaul of the existing windows.

8.2.1.4.3 Secondary glazing

Where there are heritage/planning issues which might preclude the replacement of the windows as a whole or upgrading the glazing within the frames, then installing secondary glazing internally will preserve the outer appearance.

This is particularly relevant to sash windows. *Research into the performance of traditional windows: Timber Sash Windows by English Heritage* has shown that estimated losses by conduction and radiation through a sash window can be reduced by:

- 40 % to 50 % by closing curtains or lowering plain blinds;

- 50 % to 60 % by using shutters or insulating blinds with reflective surfaces facing outdoors; and
- over 60 % by using secondary glazing with a low emissivity coating which can be increased where curtains blinds or shutters are also used.

8.2.1.4.4 Re-glazing

Where double glazing units have failed but the frames are still in good condition then it may be possible to replace these glazing units. These may be to an improved U-value compared to the original units. when upgrading from single to double glazing, a thin double glazed unit may be used or, alternatively, an evacuated glazing unit may be adopted.

8.2.1.4.5 Replacement Window

This requires the removal of the existing window and full replacement of the complete window unit comprising the frame and glazing.

Reasons for replacement of window units may be for energy improvement, security, aesthetics or end of service life, i.e. the repair costs are comparable to, or more than the cost of a new window or door.

8.2.1.5 U-values

The glass units have a centre pane U-value, and the windows have a whole window U-value which accounts for the conductivity of the frame as well. Typical U-values for windows are given in Table 21.

Table 21 - Typical U-values for windows

Window type	Typical U-value (W/m²K)	
	Centre pane	Whole window
Single glazed	5,5	4,8
Low performance double glazed	2,7	3,2
High performance double glazed, low-e coating, argon filled	1,1	1,6
High performance triple glazed, low-e coating, argon filled	0,6	0,9
Secondary glazing [1]	N/A	1,8
1) The overall performance of secondary glazing is dependent upon many aspects of both the existing retained glazing and the secondary glazing installed, as well as any requirement to provide ventilation between the two. In the table a new double glazed secondary unit is assumed.		

Recent technology advances in glass have improved the thermal efficiency considerably. Re-glazing improves the centre pane U-value, but this improvement is not of the same order as a whole window replacement, since the existing window frame will not have the same thermal performance as that of a modern window frame.

Single glazing has a centre pane U-value of 5,5 W/m²K, and older double glazing units have a centre pane U-value of about 2,7 W/m²K. New coatings and gases have improved centre pane U-values for double glazed units to 1,1 W/m²K and triple glazing to 0,6 W/m²K, giving whole window U-values of up to 1,6 W/m²K and 0.9 W/m²K respectively.

Recent improvements in frame technology have produced even better whole window performance.

The method of defining the U-value of openings for Building Regulations when windows are being replaced, is that the overall average U-value of the replacement windows achieves a performance based on the area of openings being 25 % of the dwelling's total floor area. The exact minimum requirement should be confirmed before replacement.

A replacement of part of a window, such as the glass, a sash or door leaf is considered a repair so the updated U-values do not apply.

The window U-values should be varied based on the total floor to openings area ratio. Table 22 gives an example of the various U-values required based on the total floor to openings area ratio of 25 % where the requirement for the window U value is 1,6W/m²K.

Table 22 - Permitted variation to U-values for openings

Permitted variation in combined areas and average U-values of external doors, windows and rooflights.	
Average U-value of windows, doors and rooflights (W/m² K)	**Maximum combined area of external doors, windows and rooflights, expressed as percentage of total floor area**
0,8	58,9 %
1,0	44,8 %
1,2	35,1 %
1,3	31,9 %
1,4	29,2 %
1,5	26,9 %
1,6	**25,0 %**
1,7	23,3 %
1,8	21,9 %
1,9	20,6 %
2,0	19,4 %
2,2	17,5 %
2,4	15,9 %
2,6	14,5 %

8.2.2 Doors

8.2.2.1 General

Doors are generally solid, semi-glazed or fully glazed and framed from solid timber, uPVC or aluminium.

Solid timber doors generally only achieve a U-value of 3,0 W/m²K. For doors that are semi glazed, the U-value is a combination of the proportion of the appropriate window U-value and that of the non-glazed part of the door. Certified energy ratings are available for doors.

The door is included in the average U-value calculation for the whole house openings, so any shortfall of a single element (such as retaining a solid front door) should be compensated elsewhere by exceeding the target U-value for the windows and/or roof lights.

Table 23 shows how window performance compensates for poorer performing doors when openings make up 25 % of the total floor area.

Table 23 - Typical U-values needed to achieve weighted average of 1,6 W/m²K

Opening type	**U-value** (W/m²K)		
	Overall minimum performance requirement for openings	**Front and back doors with poorer U-value**	**Front door only with poorer U-value**
Front door	1,6	3,0	3,0
Back door	1,6	3,0	1,6
Windows	1,6	1,2	1,4
NOTE The values represent an average semi detached dwelling.			

OPENINGS

8.2.2.2 Applicable retrofit methods

8.2.2.2.1 Overview

The applicable retrofit methods for doors are:

- draughtproofing of existing doors;
- re-glazing of existing doors within the frame;
- replacement door units; and
- porch.

Appropriate retrofit measures depend on the condition and thermal performance of the existing door. Where the frame is in poor condition door replacement is the only option.

8.2.2.2.2 Draughtproofing

Draughtproofing to door jambs may be fitted and should reduce air leakage. Proprietary systems are available. It is a cost effective and unobtrusive way to improve thermal comfort and reduce heat loss as well as improving noise insulation and reducing dust ingress, see 8.3.3.

8.2.2.2.3 Re-glazing

Where the existing doors and frames are in a reasonable condition, single or poorly performing double glazing units may be replaced with high performance glazing units, see 8.3.5.

8.2.2.2.4 Replacement Doors

Doors can be replaced with a door of improved thermal performance to reduce the overall heat loss through openings. There is an opportunity to upgrade the thermal performance of doors when the existing door is replaced due to its condition, age where it is poorly fitting or to increase security.

8.2.2.2.5 Porch

Adding a porch to the outside of an existing door improves the overall thermal performance, see 5.2 for guidance on planning considerations.

The new outer door should meet the improved energy performance requirements.

8.2.2.3 U-values

The overall U-value of a door (including its frame) depends upon the proportion and type of glazing present. Table 24 assumes a 50 % proportion where glazing exists and the remainder of the door is timber.

Recent improvements in insulated panel door technology further improves whole door performance.

Table 24 - Typical timber door U-values

Door type	Whole door U-value (W/m^2K)
Solid timber door	3,0
Single glazed	3,9
Double glazed	3,1
High performance double glazed, low-e coating, argon filled	2,4
High performance triple glazed, low-e coating, argon filled	1,9

OPENINGS

8.2.3 Rooflights and dormers

8.2.3.1 Rooflights

Rooflights are windows which are built into the roof to allow light into the building, see Figure 75. They are flat or at the same pitch as the roof. Rooflights may vary from old iron framed units, through to timber single glazed, and double glazed units.

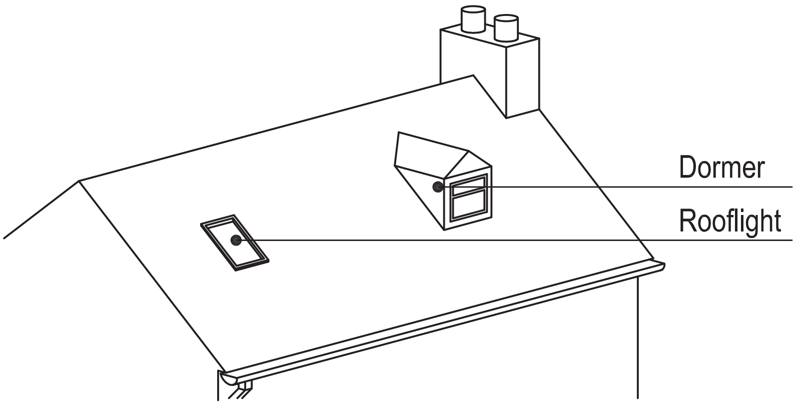


Figure 75 - **Examples of rooflight and gabled dormer**

8.2.3.2 Dormers

A dormer is a structure built out from a pitched roof to accommodate a vertical window. While the properties and retrofit measures for the window are the same as for those installed in walls, see 8.2.1.4, the dormer construction poses a number of additional problems.

The angles and junctions pose particular problems regarding interfacing the different planes of insulation. The space on the plane elements adjacent to the dormer window can be limited. It is necessary to use the highest performing insulation in this area to achieve the optimum U-value for the whole dormer. It may also be necessary to increase the performance elsewhere in the roof to allow for a reduction in performance of this element. The guidance given in 7.3.3.3.7 for upgrading timber frame walls is applicable to cheeks of dormers.

Many different types and shapes of dormer exist the most common type in Ireland is the gabled dormer, see Figure 75.

8.3 Retrofit measures

8.3.1 General

Where the dwelling is a protected structure, is located in a architectural conservation area or the style is being changed, the local planning or conservation officer should be consulted for guidance to ensure that any changes to the appearance of a dwelling do not require planning permission or are not in breach of planning regulations.

Guidance on retrofit measures for openings to these dwellings is contained in the DEHLG document, *Energy efficiency in traditional buildings.*

Windows which open on to a public road or path should be inward opening or fitted with restrictors, in order to protect pedestrians. However, consideration should also be given for the opening area being able to provide the required level of purge ventilation, see 8.3.2.3 for further information.

The ratio of opening area to floor area is an important factor in determining the maximum allowed heat loss element of the glazing.

Increasing the layers of glass may reduce the level of daylight passing into the room so consideration should be given to the respective impacts of double and triple glazing. The selection of a clearer low-iron glass may reduce this issue.

8.3.2 General design considerations

8.3.2.1 Condition of openings

Windows and doors should be assessed to determine:

- frame condition and type;
- level and effectiveness of draughtproofing present;
- ease of opening and closure;
- glazing panel specification; and
- current condition and performance with regard to security.

Windows can either be overhauled, regularly serviced, upgraded or replaced. Parts of window frames may be replaced if they are made of timber and the glazing may be renewed if the unit has failed.

A lack of regular maintenance e.g. painting, can lead to distortion of the window frame. Hinges to casements may be damaged and prevent closing. Locking mechanisms on casement are another common failure.

Sash cords often fail and should be replaced. More modern sash spring mechanisms are another common area of failure.

The age of the windows generally determines their performance. Prior to the 1980s windows were mostly single glazed, whereas later new build and replacements are mostly double glazed.

It can be difficult to source parts for windows so this should be taken into account when assessing retrofit options.

8.3.2.2 Condensation

Condensation may occur during cold weather particularly on single glazing and metal parts of windows without thermal breaks. Replacement window frames with thermal breaks substantially reduces the risk of surface condensation.

Retrofitting measures may increase the risk of condensation when ventilation is reduced by any of the following measures:

- removing or sealing chimneys;
- substituting solid floors for suspended floors; and
- providing draughtproofing to the windows and doors.

Where ventilation is adversely affected by retrofit measures additional ventilation should be provided, see Clause 10.

8.3.2.3 Ventilation

With increasing importance placed on improving airtightness, consideration should also be given to providing adequate ventilation requirements and maintaining indoor air quality.

When replacing windows, background ventilation can be provided via trickle ventilators, see Figure 76 fitted in the frame, as these are an effective way to introduce ventilation into a dwelling. They can also provide the supply air needed to allow fans within the wet areas to work effectively.

Individual rooms in some older dwellings with solid walls and solid floors can be airtight when fitted with modern glazing or draught proofing. Ventilation should therefore be assessed with respect to the overall dwelling and the individual room, particularly where fuel burning appliances are fitted, see Clause 10.

When replacing windows, consideration should be given to the sizes of opening sections for both purge ventilation, (see 10.2.2.1.3) and fire egress.

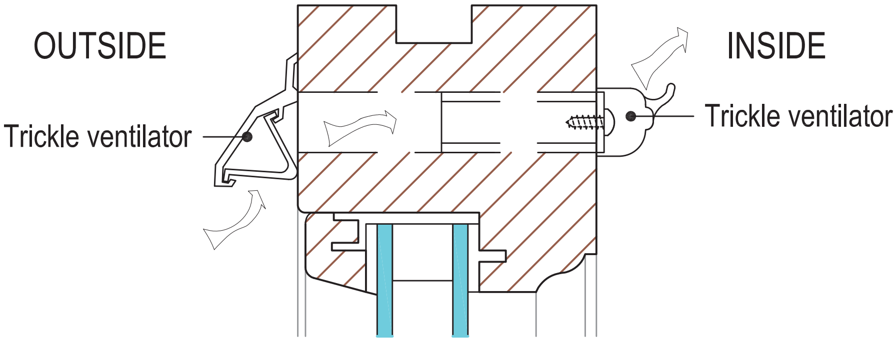


Figure 76 - Example of a trickle ventilator

8.3.2.4 Overall thermal performance

Window energy ratings may be used to compare the energy performance of different window constructions.

The Window Energy Performance (WEP) rating shown in Figure 77 has been developed to show a whole window performance. The WEP rating system should consider the following:

- the climate zone;
- U-value of the glass and the whole window unit;
- airtightness of the window frame;
- the solar factor (g-value) of the window, i.e. how much solar heat is transmitted through the window; and
- the total solar energy transmittance (solar factor g⊥) is the fraction of the incident solar radiation that is totally transmitted by the glass.

The WEP Certificate Energy Index combines the following characteristics to show how well a window assembly performs:

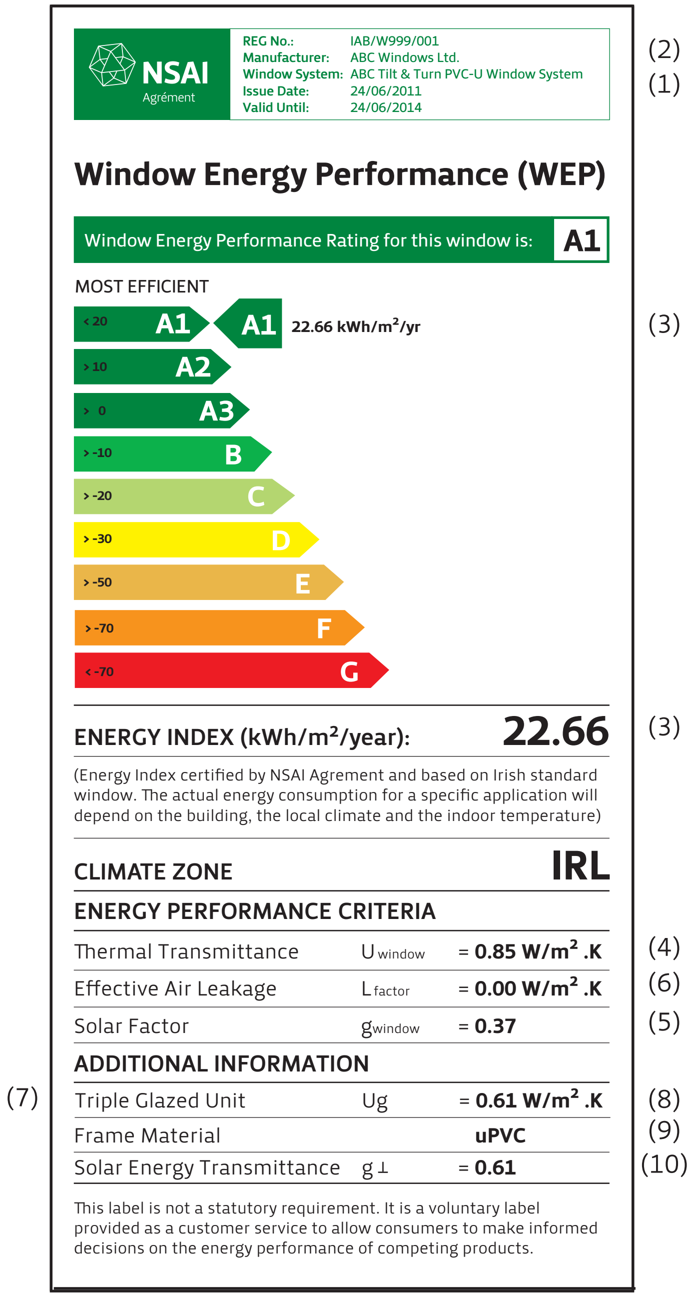
a. The thermal transmittance (U_{window} or U_w) is a measure of the insulation properties of the window assembly. The published U-value combines the thermal transmittance for both the glazing and the window frame as a whole unit. Thermal looping within the glazing cavity is accounted for in the calculation of the U-value.

b. The solar factor (g_{window}) or Solar Heat Gain Coefficient (SHGC) measures how well the whole window unit blocks heat caused by sunlight. Heat gain can be beneficial in winter months but can also present consumers with additional cooling loads in summer months. The solar factor is expressed as a number between 0 and 1. A lower solar factor means less heat gain.

c. The air leakage (L_{factor}) is a measure of the airtightness of a specific window assembly. The weakest point in any window arrangement tends to be around the seals on an opening section of window. A window arrangement should achieve a Class 4 air tightness rating when tested at 600 Pa to I.S. EN 12207:1999. As a result well-made windows should have little or no air leakage. The lower the air leakage of the window assembly, the greater its overall efficiency.

U-values for doors should be certified by a third party certification body.

U-values or Energy Indices for windows or doors that have been independently certified for Irish conditions, by an accredited body, should be used in preference to generic values.



Key

1	window assembly name
2	manufacturer
3	WEP energy certificate index
4	thermal transmittance of window
5	solar factor
6	air leakage
7	identification of double or triple glazed
8	thermal transmittance of glazing unit
9	frame material
10	solar transmittance

Figure 77 - Window energy performance label

When selecting windows both the U-value and solar heat gain of the window should be considered. Southerly facing windows have higher solar gains and Northerly facing windows have higher heat losses. The use of low emissivity coating on the glazing allows the transmittance of solar radiant heat through the glazing and reflects all radiant heat back into the dwelling thus capturing solar gain. This is illustrated in Figure 78. New double glazed units may be used to maximise heat gain and aid retention while glazing units with better U-values may be appropriate for mitigation of heat loss. Triple glazed have a lower solar heat gain coefficient than double glazed units yet provide a better U-value.

Where external cleaning of windows needs to be minimised, then self-cleaning glass should be considered. The coating on the glass uses the sun to break down the dirt which is then washed off by rain.

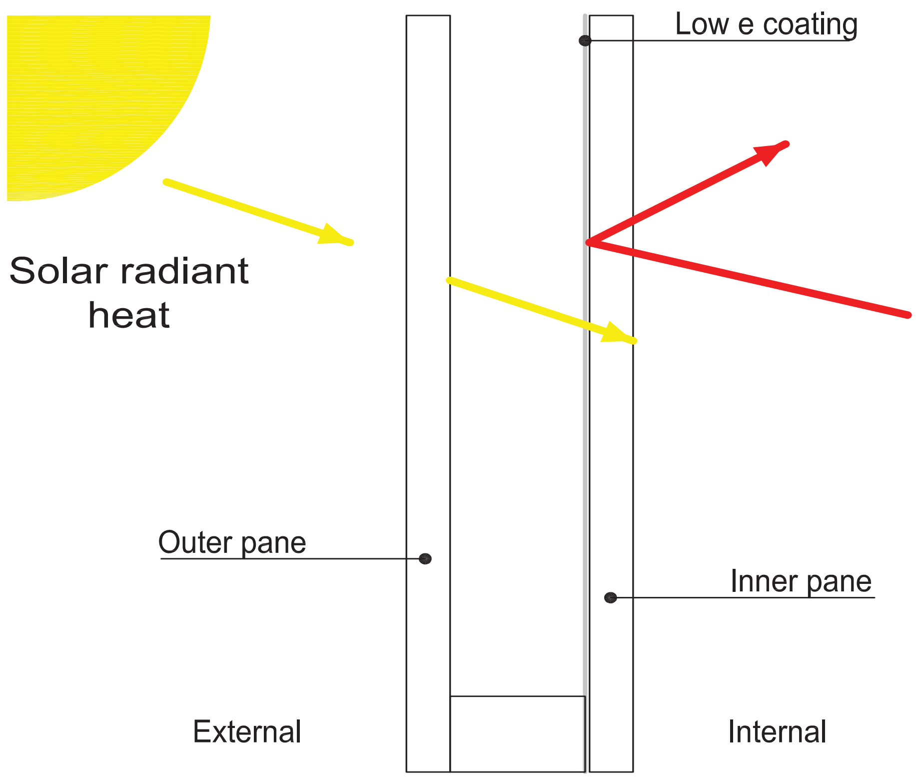


Figure 78 - Solar transmittance through double glazed unit

8.3.2.5 Thermal bridging

When replacing windows with new thermally efficient windows, consideration should be given to insulation levels at the window heads, reveals and sills due to potential thermal bridging. See Annex H for guidance on installing relevant types of insulation at windows.

Windows may be provided with deeper frames in order to accommodate increased depths of insulation on reveals and sills in order to reduce thermal bridging and the risk of surface condensation.

Care should be taken to ensure any opening lights are not restricted by the return of the insulation.

Where replacement windows are being provided in conjunction with external insulation, repositioning the window to the outer face of the existing wall minimises the thermal bridge. The positioning of the windows should not compromise the fixing of windows. Relocation of the window will also require repositioning of sills. All works should be in accordance with EWI certification.

Insulation to reduce thermal bridging and the risk of surface condensation may be installed under the window board where replacement windows are being provided, in conjunction with cavity wall insulation or internal wall insulation, See Annex H.

Where replacement windows only are being provided and walls have a poor thermal performance there is an increased risk of condensation at the reveals. This risk may be mitigated by the provision of insulation at the reveals.

A thermal bridging analysis evaluates the risk of mould growth occurring and assists in establishing the improved insulation levels required at the reveals to eliminate this risk.

8.3.2.6 Means of escape

Existing windows may not provide adequate means of escape in the event of fire in accordance with Building Regulations, i.e. they have large fixed panes and a small opening casement at the top of the window. Replacement bedroom windows should meet minimum dimensions for escape or rescue as far as practicable.

For other habitable rooms, opening sections should not be reduced or altered to an extent that reduces their potential for escape or rescue.

There may be instances where a window on a fire escape route needs be fire rated and non-openable to ensure that means of escape is maintained.

NOTE For further guidance see Building Regulations TGD part B.

8.3.2.7 Safety measures

Older windows are likely to have lead in the paint and this should be stripped using a chemical stripper rather than sanding, and always in a well ventilated space.

8.3.2.8 Sound

Secondary glazing is often used to reduce the transmission of external noise into a dwelling (e.g. those located on busy roads) so consideration should be given to maximise its thermal performance.

Replacement windows with high thermal performance and airtightness seals also provide improved noise reduction.

8.3.2.9 Safety glazing

Where glazing is being replaced; safety glazing should be installed as per the locations shown in Figure 79.

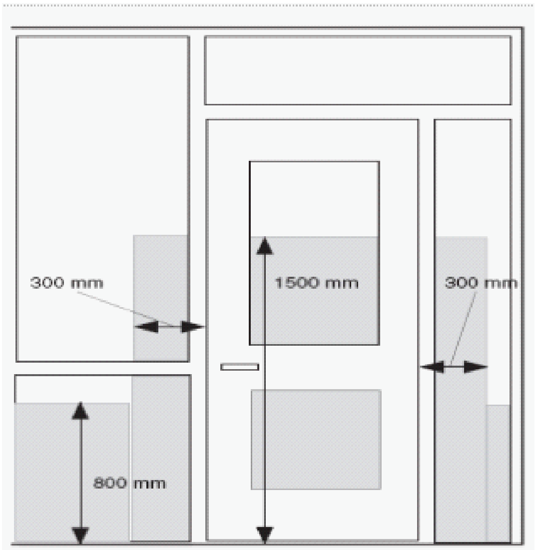


Figure 79 - Safety glazing requirements

8.3.3 Draughtproofing

8.3.3.1 General

Draughtproofing may be fitted to timber sash, casement windows and doors to improve their airtightness performance. Several proprietary systems are available. It is a cost effective way to improve thermal comfort, reduce heat loss, improve noise insulation and reduce dust ingress. Some proprietary draughtproofing systems also make sash windows easier to slide up and down.

Before draught-proofing, any necessary repairs should be carried out and sashes or opening lights should operate properly within the frame.

Replacing faulty or loose fitting parts (e.g. hinges, handles and locking mechanisms) also improves performance. Timber windows may be refurbished with parts readily available. The cutting of grooves to insert draught-proofing may not be appropriate for some particular old or delicate window frames. uPVC windows are generally manufactured from a standard range of mechanisms which can be sourced through suppliers.

Modern doors tend to have high performance ironmongery to achieve improved levels of security. These should be regularly serviced to ensure they continue to perform well. Multi-point locking mechanisms should be regularly maintained and lubricated to ensure the locking points are clear

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from debris. Repairs to these should be carried out by a locksmith.

8.3.3.2 Selection considerations

A range of different types of seal may be incorporated into re-glazed or replacement windows and doors; as shown in Table 25. Most work on the principal of compression between the frame and the opening element to provide the seal. These seals come in a variety of materials such as EPDM, foam, rubber, PVC and profiles for different locations and applications, e.g. V-strips, P-strips, E-strips. Seals should be fitted so as to still allow the windows and doors to be secured.

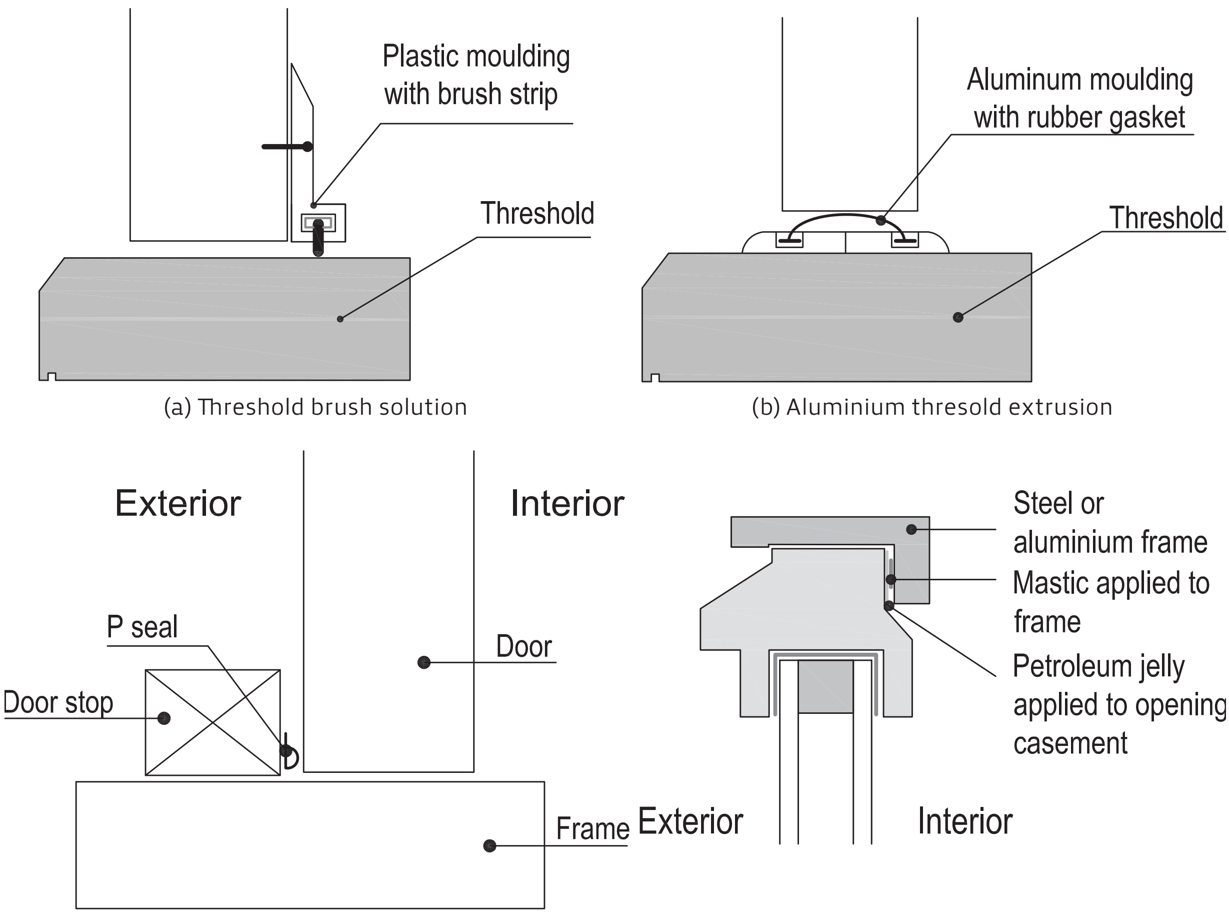
Table 25 - Draughtproofing methods and their application

Method	Application
Brushes	**Doors** **Sliding sashes**
Compressible strips e.g. V-strips / P-strips / E-strips	**Doors** **Casements**
Foam seals	**Doors** **Sliding sashes**
Mastic	**Metal casements**
Extrusions	**Door thresholds**

Letterbox brushes also provide a reduction in possible causes of draughts, and may be retrofitted to existing doors as well as being incorporated into a new replacement door.

8.3.3.3 Installation considerations

Manufacturer's literature should be followed for correct installation and positioning of proprietary seals. Typical seal installations and applications are shown in Figure 80.



(a) Threshold brush solution

(b) Aluminium thresold extrusion

(c) Plan of door frame with compressible seal

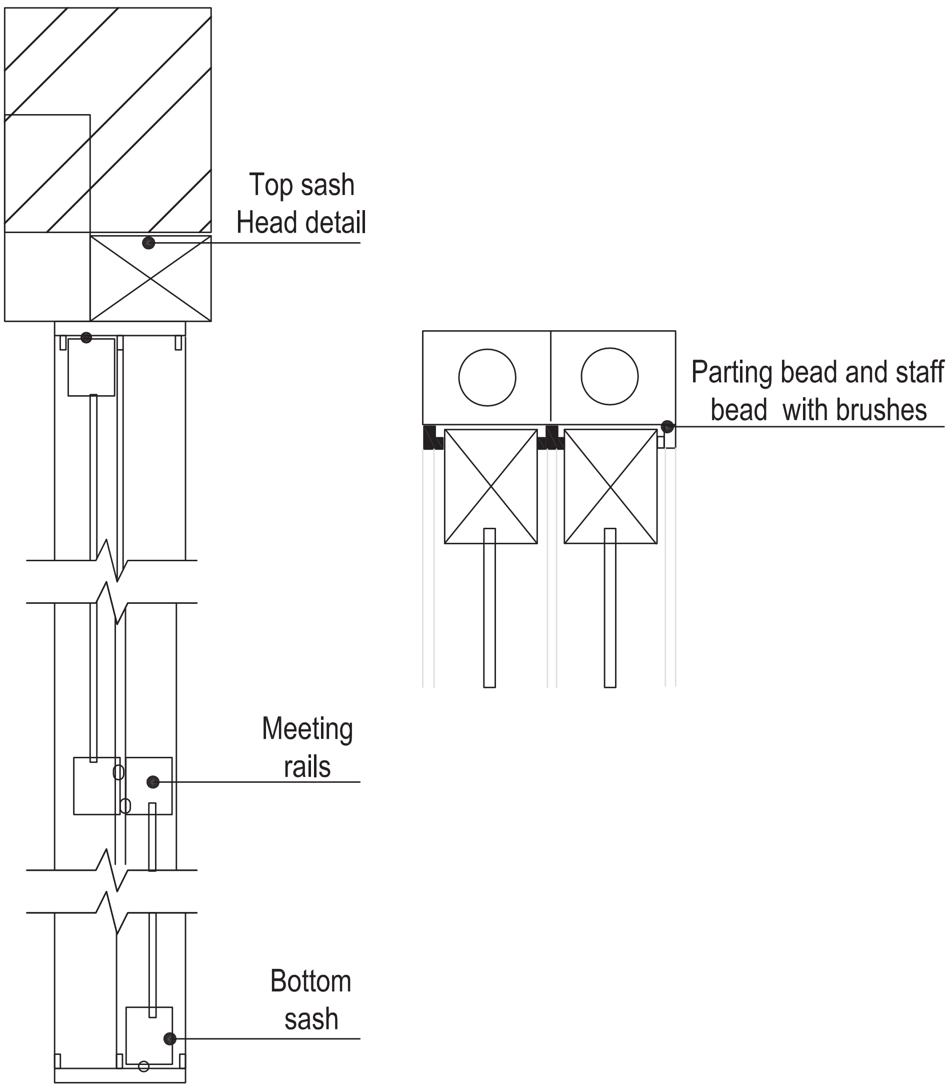
(d) Draughtproofing metal windows

Figure 80 - Typical seal installations and applications

Where the introduction of a proprietary seal may hinder the secure closing of a metal casement window, a mastic sealant should be used. Petroleum jelly should be applied to the opening casement and a line of sealant applied to the frame edge. The window should then be closed tight, secured and left for 24 hours for the sealant to set.

Sash windows may be upgraded using proprietary systems which replace the existing parting bead with a vinyl gasket or brushes; improving the airtightness. Coupled with brushes and gaskets, a sash window can be improved significantly. These should be fixed into routed channels to ensure they remain close fitting and still allow the sashes to move up and down freely. Often these systems can improve the opening of the window, as they guide the sashes. The box that holds the weights remains a potential area of air leakage, see Figure 81.

Further guidance on draught proofing is available in BS 7880:1997 – '*Code of practice for draught control of existing doors and windows in housing using draughtstrips*'.



(a) Vertical Section

(b) Plan view

Figure 81 - Potential air leakage from box sash upgrades

8.3.4 Secondary glazing, blinds, shutters and curtains

8.3.4.1 Secondary glazing

Secondary glazing is another window fitted on the inside of the existing window. It is generally a single glazed product, although double glazed versions are available. Secondary glazing reduces heat loss, dust ingress and provides good insulation against noise.

The glass panes should be secured by compression gaskets or beading into framing sections. These in turn may be mounted by way of rollers, glides, hinges or spiral balances into the frame which allows the individual panes or panels to hinge open or slide horizontally or vertically. This gives access to the existing primary window for ventilation and escape, see Figure 82. Secondary glazing should not be fitted where it would interfere with existing windows, shutters and linings.

The exceptions are Lift-Out Units and Fixed Units, which as the names imply, are either lifted in and out, or are permanently fixed.

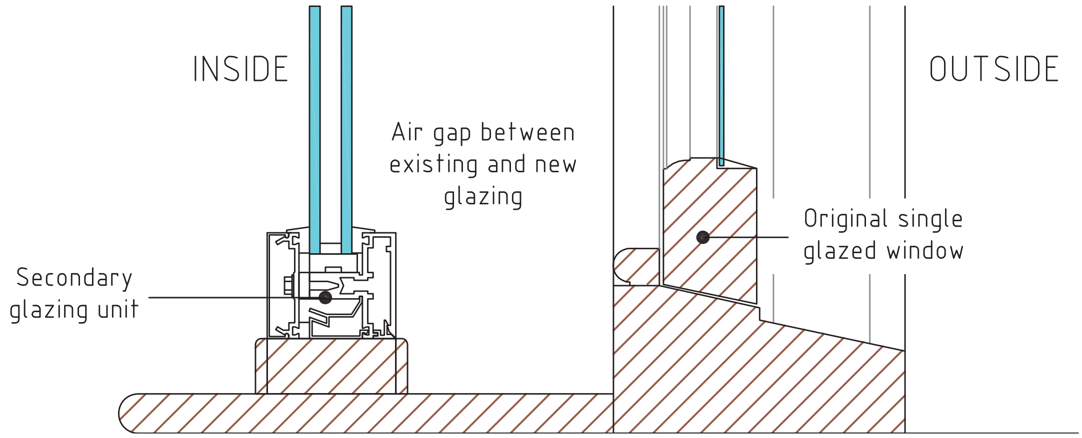


Figure 82 - Examples of side hung and sliding secondary glazing

8.3.4.2 Blinds, shutters and curtains

The thermal performance of the window element may be improved by the installation of blinds, heavy curtains or shutters. These contribute to heat retention within a room where the windows are poorly performing and there are restrictions on improvements. They also have the added value of reducing overheating on rooms with a south facing aspect.

Blinds and shutters should be tight fitting and blinds may also be insulated, honeycombed and lined with reflective surface which should face outwards.

8.3.4.3 Selection considerations

In dwellings where it is not possible to change the external appearance of windows because of planning restrictions, discrete secondary panels may be used.

Secondary glazing should be tight fitting and may only be effective if kept fully closed and any seals or gaskets regularly serviced.

8.3.4.4 Design and installation considerations

8.3.4.4.1 Condensation

To avoid condensation risks and improve thermal performance of a single glazed secondary glazing unit, the original window should be draughtproofed.

8.3.4.4.2 Existing openings

Where escape is required from existing windows, secondary glazing should not impede egress.

Where purge ventilation is required from existing windows, secondary glazing should maintain this ventilation.

Existing levels of background ventilation should be maintained. Where trickle vents are removed background room ventilation should be provided or increased.

8.3.5 Re-glazing

8.3.5.1 General

Re-glazing consists of replacing existing low thermal performance glazing in the existing window frame with higher performance double or triple glazing panes. The overall window U-value will be less as the original poor thermal performing frames are retained.

This is possible where the existing rebate is of sufficient depth to allow for the fitting of either vacuum glazing systems or purpose made double glazed sealed units. This can improve U-values significantly at cheaper cost and causes less disruption than a full replacement. Replacement should not be carried out where the new units would be too heavy for the existing window frames.

8.3.5.2 Design and installation considerations

The replacement of glass panes in existing multi-paned sashes with double glazed units is generally not possible. This is due to the narrow mullions and transoms. Small glazing rebate dimensions of existing windows is incompatible with the technical requirements of double glazed units, which usually require a much larger rebate and a corresponding enlargement of member size. Narrow double glazed vacuum sealed units with improved U-values may be used in narrow rebates.

Where double glazed units have failed; normally noticeable by condensation visible within the glazed cavity, the unit should be replaced. Any cracks in either of the panes of a unit indicate a loss of gas (where present) and reduced performance. It will also allow ingress of moisture, so the unit ceases to be effective. Failed double glazed units have a similar thermal resistance to single glazing.

Energy efficient replacement panes for rooflights are readily available from rooflight suppliers and manufacturers. Generally, glazing in rooflights should only be replaced with glazing units of the same dimensions and thickness for all frame types.

8.3.6 Window and door replacement

8.3.6.1 General

Total replacement of windows is the most effective way to reduce heat loss, increase airtightness and improve thermal comfort levels. It also provides the opportunity to facilitate the provision of background ventilation through the use of trickle ventilators integrated into the window frame.

Windows and doors may be replaced for reasons other than thermal performance such as improved security, reducing draughts and improving appearance.

Full replacement should be considered where the existing windows/doors are at the end of their serviceable life, parts are no longer available or as part of a larger retrofit of the dwelling.

8.3.6.2 Selection considerations

Where the dwelling is in an area of architectural interest, it may be necessary to retain the style of the windows/doors, and any replacements should be as close a match as possible to the existing. Any changes should be carried out in consultation with the local planning department or conservation department.

8.3.6.3 Design considerations

8.3.6.3.1 Ventilation

Where trickle ventilators exist these should be retained in any replacement windows. Replacement windows may also provide the opportunity to provide additional background ventilation through larger trickle ventilators in the window frame, see 10.2.2.1.1.

8.3.6.3.2 Means of escape

Where windows are replaced it is recommended that bedroom windows should be as far as is practicable escape or rescue windows. In the case of other habitable rooms, opening sections should not be reduced or altered to an extent that reduces their potential for escape or rescue. Where doors are required as a means of escape, the replacement doors should provide the same level of egress.

8.3.6.3.3 Guarding

Guarding should be provided for any window where the base of the opening light is more than 1400 mm above external ground level and is less than 800 mm in height above internal floor level.

8.3.6.3.4 Frames

The size and shape of frames and glazing bars have a significant effect on light transmission. In this respect, windows in older buildings often had slender glazing bars. More modern frames generally have larger sections. Typically, metal frames take 20 % of an opening area and PVC or timber frames take 30 % of the area. The impact of this on daylight levels should be considered when replacing windows.

A thermal break is where a material of lesser conductivity is inserted within the frame to reduce the heat loss path across the frame, see Figure 83.

Frame members of metal without thermal breaks are poor insulators.

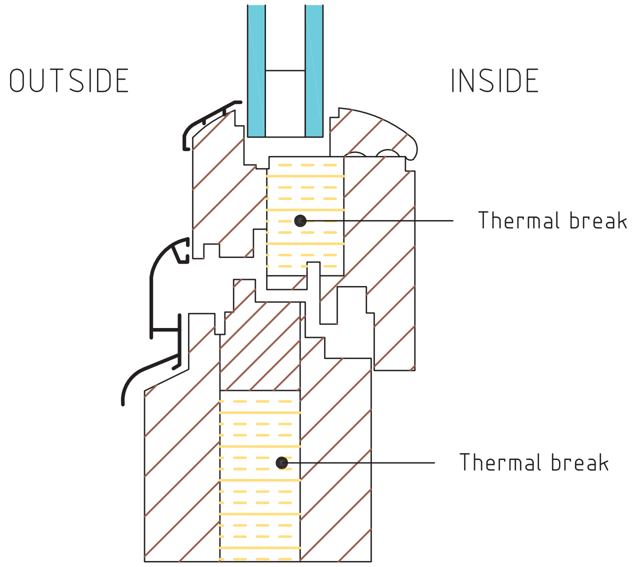


Figure 83 - Thermal break

8.3.6.3.5 Glazing

Triple and double glazing sealed units with 16 mm or 20 mm cavities are generally available. A triple glazed unit gives the best thermal performance. These are fitted to aluminium, wood and PVC-u frames.

To achieve lower transmittance values low emissivity glazing should be used, and the space between the panes filled by inert gases such as argon or krypton. The low-emissivity coatings allow light to pass through the glazing in one direction, but reflect the majority of long wave radiation or heat, emitted from inside the building. This increases the 'greenhouse effect' of glazing, allowing solar radiation into the building but trapping heat inside. Filling the cavity between panes with inert gases reduces the heat loss through the cavity by suppressing convection. Coatings and inert gases reduce the overall U-value of the glazing panels.

8.3.6.4 Installation considerations

8.3.6.4.1 Airtightness

When replacing windows the airtightness should be addressed by sealing around the window frame internally. Suitable airtightness tapes or sealants should be used with appropriate durability.

8.3.6.4.2 Internal impact

Consideration should be given to disruption and redecoration necessary when full replacement takes place.

8.3.6.4.3 Damp Proof Courses (DPC)

Vertical and head DPCs may not be fitted in existing dwellings.

Replacement of windows and doors may facilitate the introduction of DPCs where not previously installed.

9. Floors

9. Floors

9.1 General

This clause covers the different types of floor construction, insulation methods and materials available to achieve energy savings.

There are three typical constructions are described:

- ground supported concrete floors;
- suspended precast concrete floors, and
- suspended timber floors.

9.1.1 Ground supported concrete floor

9.1.1.1 General

Ground supported floors are referred to as solid floors as they are normally constructed from a solid slab of concrete with no voids, and these were typically laid on a bed of hardcore, see Figure 84. Early floors did not incorporate any insulation. Since the 1940s a damp proof membrane was included beneath the concrete to prevent moisture ingress.

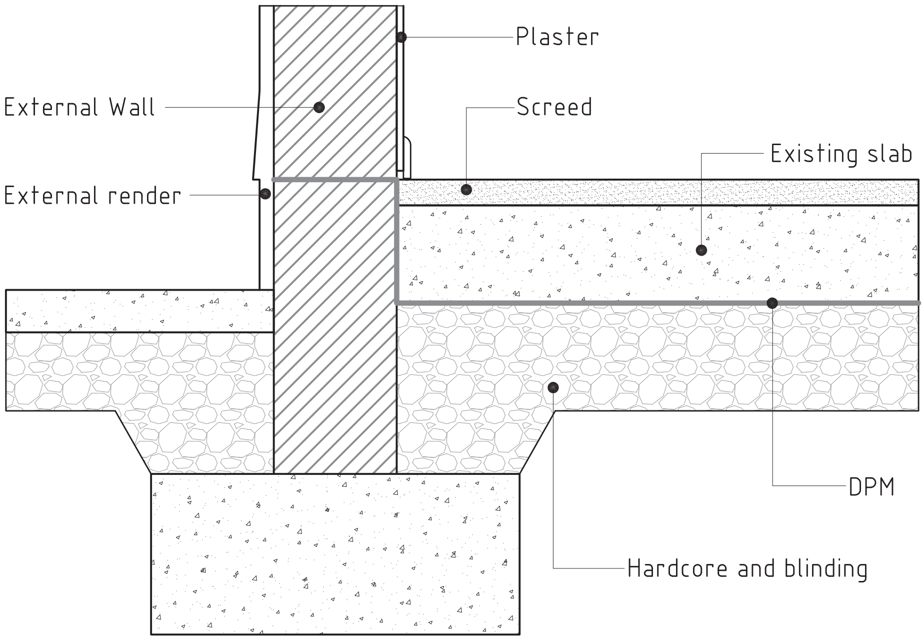


Figure 84 - Typical example of an existing un-insulated floor slab

9.1.1.2 Applicable retrofit methods

The most appropriate retrofit method for a ground supported concrete floor in good condition can be an over floor solution as described in 9.2.3.

Where the floor is in poor condition or the DPM has failed it may be necessary to replace the floor as described in 9.2.4.

Annex C provides the thickness of insulation required to achieve various U-value levels for a ground supported concrete floor for a typical dwelling.

9.1.2 Suspended precast concrete floor

9.1.2.1 General

The two common forms of suspended precast concrete floors used in Ireland are:

— beam and block floors,

— precast hollow core floor slabs.

Beam and block floors are used on ground floors where the depth to load bearing ground is unsuitable for ground support slabs. Inverted 'T' shaped concrete beams span between the walls and these are infilled with concrete blocks with screed or concrete applied to the top, as shown in Figure 85. A reinforcing mesh may be used to provide a stable suspended floor, which can then support internal partition block walling. Later systems incorporated insulation into the construction, but most of these systems have no insulation.

Precast hollow core slab floors are used on ground floors where the depth to load bearing ground is unsuitable for ground supported slabs. The slabs span between walls and are designed to carry all loads including internal partition walling.

NOTE Caution should be taken to ensure that the area beneath a suspended ground floor is ventilated to prevent the build-up of condensation and hazardous soil gases, such as radon.

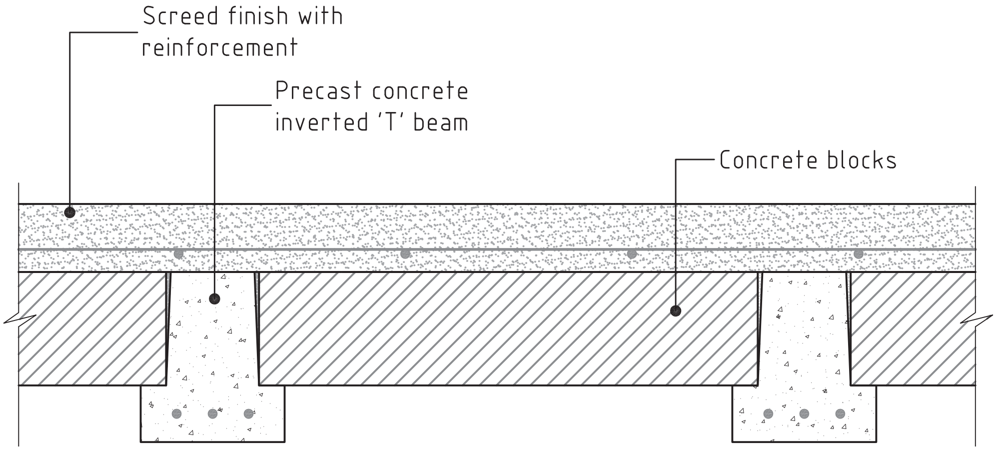


Figure 85 - Block and beam floor

9.1.2.2 Applicable retrofit methods

To insulate this type of floor, insulation should be installed on top of the existing floor finish incorporating a floor finish such as ply or chip board, or a screed finish. The floor to ceiling height determines the amount of insulation and floor finish which may be incorporated, see 9.2.3 for suitable methods.

Where sufficient space is available for safe access, or a basement exists, fitting insulation to the underside of the slabs is an option, see 9.2.2.

Annex C provides a table showing the thickness of insulation required to achieve various U-value levels for a block and beam floor for a typical dwelling.

9.1.3 Suspended timber floor

9.1.3.1 General

A suspended timber ground floor, shown in Figure 86, is constructed by timber joists spanning from wall to wall to support the floor decking or boarding. The joists may be supported on the outside walls by means of metal joist hangers or built into the blockwork. Longer spans are supported by timber cross members or sleeper/dwarf walls.

Suspended timber ground floors offer little thermal resistance due to their thickness and because the void is vented to the outside air. Cold air may also leak through gaps between the floorboards into the dwelling above.

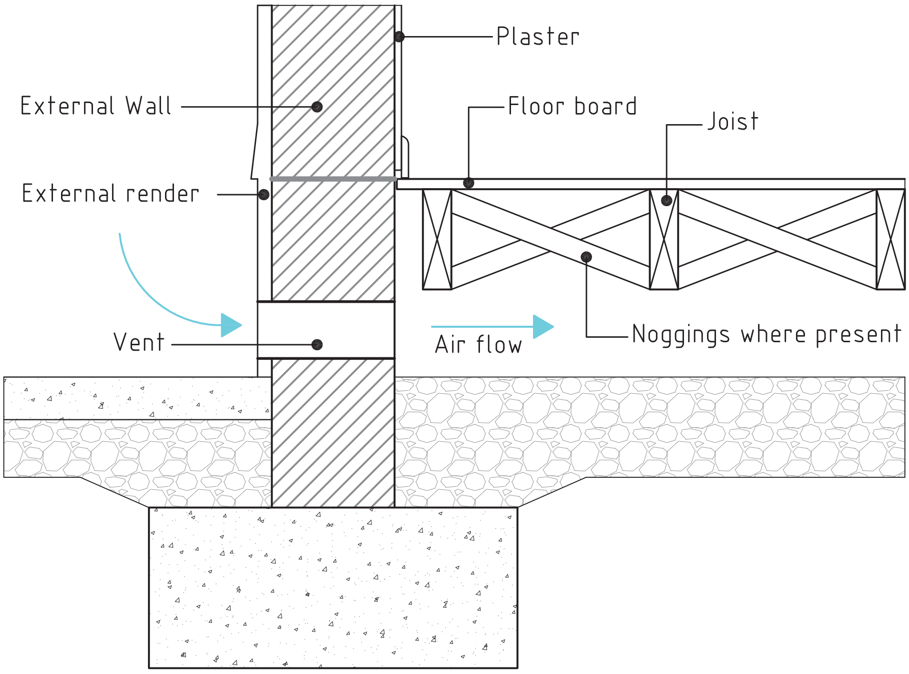


Figure 86 - Suspended timber floor

9.1.3.2 Applicable retrofit methods

Where the floor boards can be lifted, underfloor insulation may be used, see 9.2.2. This method may also be used where there is a void which allows safe access to install insulation under the floor.

Where the floor finish cannot be lifted and there is sufficient floor to ceiling height, an over-floor solution may be used, see 9.2.3.

Where the floor is in poor condition, consideration should be given to a complete replacement, see 9.2.4.

Table C.2 provides guidance for the thickness of insulation required to achieve various U-values for a suspended timber floor for a typical dwelling.

9.2 Insulation methods

9.2.1 General

9.2.1.1 Selection considerations

Table 26 provides information on insulation materials which are suitable for use with each method of intervention.

Table 26 - Appropriate insulation type for each floor type

Insulation type	Thermal conductivity (λ) W/mK	Suspended floor	Solid floor	Replacement floor
Mineral fibre	0,040	Yes	No	No
Closed cell foam, PIR, PUR, phenolic	0,020-0,025	Yes	Yes	Yes
Spray foam	0,025	No[1]	No	No
EPS	0,030-0,035	Yes	Yes	Yes
XPS	0,035	Yes	Yes	Yes
1) Underside of basements can be appropriate for spray foam				

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9.2.1.2 Floor condition

For suspended timber floors, all joists and boarding should be in good condition. Any timbers affected by dry or wet rot should be replaced and the source of the problem identified and rectified prior to retrofitting the insulation. This may be due to a bridged damp proof course or inadequate ventilation to the floor void.

Where the timbers rest on a solid wall which is prone to driven rain, there is a potential for rot occurring in these locations in the future, especially where internal insulation is also being installed. This is an opportunity to install joist hangers to prevent any deterioration of the joists. Any timber affected by wood boring insect attack should be replaced and the remaining timber treated against further attack.

For block and beam as well as concrete floors any areas of failure should be addressed, whether in the DPM or around the perimeter. Soil or paving levels to the exterior of the brickwork should be at least 150 mm below the DPC level to prevent any ingress of moisture to the perimeter.

Areas of dampness may be due to leaking water supply or heating pipes within the slab. These should be excavated and repaired, and the concrete or screed reinstated. Where the DPM to a slab has failed, the whole floor should be excavated and completely replaced, as isolated repairs are difficult to accomplish without causing further damage to the DPM.

9.2.1.3 Radon

Consideration should be given to the prevention of radon ingress.

In the case of ground supported slabs, it may be necessary to install a combined DPM and radon barrier where the floor is being replaced. It may also be necessary to install a radon sump.

For suspended floors, it may not be possible or necessary to retrofit a radon barrier. Adequate ventilation of the underfloor void helps to disperse any radon build-up.

NOTE Further information on radon protection is available on the Radon Protection Institute of Ireland (RPII) website www.rpii.ie and in BRE GRG 37/1 *Radon solutions in homes*.

9.2.1.4 Occupant disruption

For underfloor solutions, the work is disruptive to occupants and involves restricting access to large parts of the dwelling or decanting occupants for the duration of the retrofit works.

Over floor solutions may be carried out while the dwelling is occupied, but where the floor height is raised significantly door heads may need to be raised, skirting removed and replaced, and electrical sockets may also need to be raised.

9.2.1.5 Underfloor heating

When installing insulation, there is an opportunity to fit pipes for underfloor heating. The most common approach is to lay flexible pipes into a screed, but systems are also available for suspended timber floors using metal plates to distribute the heat more effectively.

Underfloor heating is well suited to low temperature systems such as ground and air source heat pumps so this should be considered in conjunction with a choice of heating system. When laying a screed, consideration should be given to the marginal costs of installing the pipes to facilitate combining underfloor heating with low temperature energy sources in the future.

The current recommendation for underfloor heating systems is for U-values no greater than 0,15 W/ m^2K.

9.2.1.6 Flood risk

Where the dwelling lies within a flood risk area, the insulation materials used for the floor should be able to resist deterioration if exposed to flood waters, e.g closed cell materials perform better in these conditions than fibrous materials.

9.2.1.7 Thermal bridging

The junction between floors and walls is a key thermal bridge. Consideration should be given to the provision of insulation at this junction to minimise surface condensation risk, see Annex G and Annex H.

Internal insulation where applied should be continuous with any existing edge insulation.

Where external insulation is applied, there is an opportunity to carry the insulation to a minimum of 150 mm below finished floor level, see Annex H, Figure H.1 and H.2.

9.2.2 Underfloor insulation

9.2.2.1 General

Underfloor solutions involve lifting the floor to gain access to the void below and fixing insulation to the gaps between or underside of the joists. Only timber floors can be retrofitted in this way. Where safe access is available from below such as a garage, cellar or passageway then underfloor insulation can also be used for concrete suspended floors.

9.2.2.2 Design considerations

9.2.2.2.1 Floor condition

All timbers should be inspected for damp, rot or infestation. Remedial works should be carried out prior to insulation.

9.2.2.2.2 Ventilation

Cross-ventilation should be maintained below the floor in order to remove moisture and prevent timber rot and mould growth. Ventilation openings should not be blocked with insulation. A vapour control layer should not be used with timber ground floors as it may trap moisture.

Any gaps in the floor should be sealed to prevent draughts entering the house from the ventilated space under the floor.

9.2.2.2.3 Fire

When fitting to the underside of a floor that forms the ceiling of a cellar or garage the insulation material should be resistant to moisture and have the appropriate fire resistance for ignition and surface spread of flame. Further fire compartmentalisation may be required, for example by fixing a fire resistant board to achieve a ½-hour or one hour fire resistance according to fire requirements.

9.2.2.2.4 Services

Water pipes (e.g. for central heating and cold water services) should be adequately insulated particularly where the pipes run below the thermal envelope.

NOTE See BS 5422: 2009 *Method for specifying thermal insulating materials for pipes, tanks, vessels, ductwork and equipment operating within the temperature range –40°C to +700°C* and Good Building Guide 40 - *Protecting pipes from freezing for further information.*

9.2.2.2.5 Airtightness

The addition of central heating may cause a wood floor to gradually dry out and shrink over the first few heating seasons. The resulting gaps and cracks may allow cold air to enter from the ventilated space under the floor, especially in older houses with square-edged floorboards. Draughts between the floorboards may be reduced by either fixing hardboard over them or replacing with chipboard. An airtightness membrane may also be fitted. Service penetrations should be sealed with appropriate gaskets/sealants.

9.2.2.3 Installation considerations

Where the existing joists are in good condition and not showing any signs of wet or dry rot, the existing floorboards should be lifted and insulation laid between the joists. Quilt insulation should be supported by netting and rigid board should be fixed to infill the joists, see Figure 87 and Figure 88.

In some circumstances, it may only be possible to fill the full depth of the joists with insulation. Extending insulation below the bottom of the joists may restrict the sub-floor ventilation needed to remove moisture and prevent wet or dry rot. When upgrading a suspended floor, vents should be checked to ensure adequate ventilation of the void. The gap between the wall and the nearest floor joist should be filled with insulation, whether the wall is internal or external, to reduce thermal bridging.

There is greater scope to insulate an existing suspended timber floor where there is a basement below, and this is less disruptive as insulation may be placed between and below the joists. The basement ceiling should also have plasterboard fixed directly to the underside of the joists to provide fire resistance. Rigid insulation backed with plasterboard (to maintain fire resistance) may be fixed underneath the basement ceiling to improve the floor's thermal performance further. This also applies to suspended upper floors over exposed and semi-exposed areas, such as those with rooms above garages, walkways and recesses, which are currently areas of large heat loss in many existing dwellings.

9.2.2.4 Mineral wool Insulation between the joists

Underfloor insulation to a suspended timber floor using netting is shown in Figure 87. The installation should include the following:

- lift all the boards taking care not to damage any tongue and groove where present;
- staple netting to the joists allowing enough to hang into the gaps to accommodate the insulation or an approved windtight vapour permeable membrane may also be used in lieu of netting (where this is used ensure the external surface is faced towards the ventilated void);
- lay insulation into the netting to the full depth of the joists, according to the U-value requirements;
- fill the gap between wall and joist with insulation,
- to provide improved airtightness, an airtightness membrane may be laid over the joists. The membrane should be:
  - lapped and taped,
  - lapped up the wall,
  - lapped under the skirting if this has been removed, and at least lapped up above the boards.
- Reinstate the floor boards.

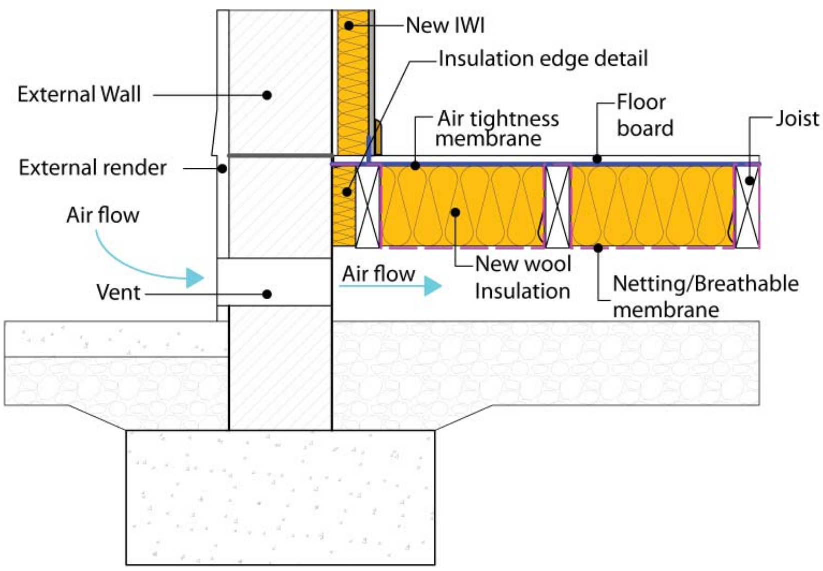

Figure 87 - Insulation to suspended timber floor with mineral wool and IWI

9.2.2.5 Rigid board insulation between the joists

Figure 88 shows underfloor insulation to a suspended timber floor using rigid boarding. The installation should include the following:

- lift all the boards taking care not to damage any tongue and groove where present;
- fix battens to the joists to suit the depth of insulation being provided, see Figure 88;
- cut the rigid board to fit tight between the joists, where gaps occur these should be filled with either rigid insulation or insulation foam;
- fill the gap between wall and joist with insulation;
- to improve airtightness, seal the edges of the insulation with a proprietary sealant, or, alternatively, lay an airtightness membrane over the whole area, staple to joists, overlapping and sealing, and lap up the walls under skirting;
- reinstate floorboards;

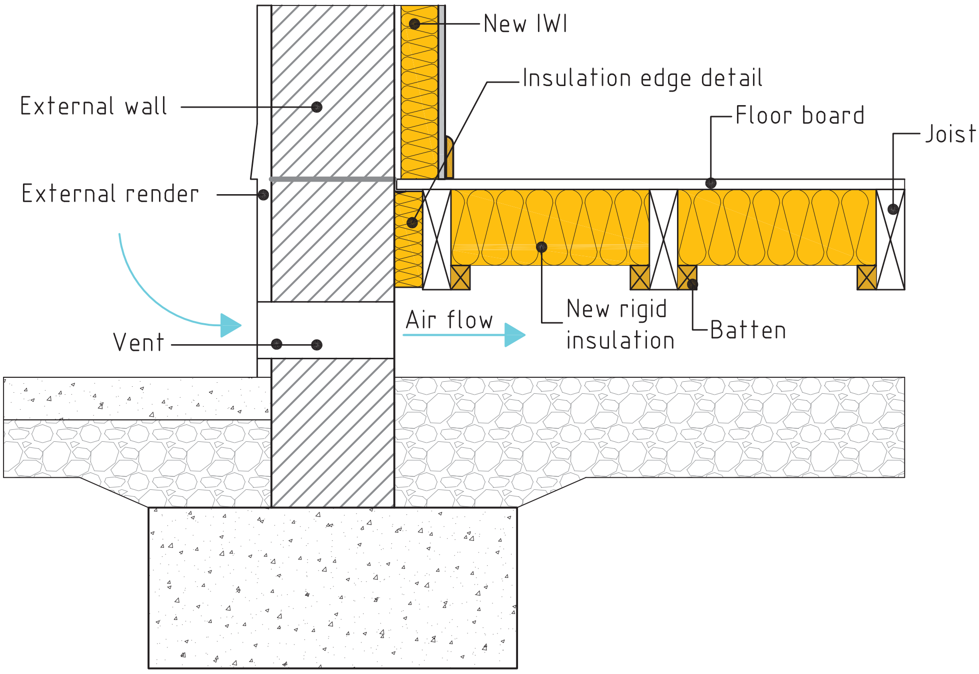

Figure 88 - Underfloor insulation with rigid board shown with IWI

9.2.3 Over floor insulation

9.2.3.1 General

Over floor solutions are used where the floor cannot be lifted due to it being a solid floor, such as concrete, or a suspended floor (i.e. block and beam or hollow core). Insulation should be provided above the existing floor and a new surface provided over the insulation. The new surface should consist of a concrete/screed surface or timber floor which should be on battens or floating (supported by insulation).

9.2.3.2 Design considerations

9.2.3.2.1 Floor condition

Where the floor is in good condition insulation may be incorporated above the floor. Where the floor is in poor condition due to damp ingress or structural failure it may be necessary to replace the floor, see 9.2.4.

Any gaps in the floor should be sealed to reduce air infiltration.

9.2.3.2.2 Impact on room heights

By adding insulation on top of the existing floor slab the finished floor level will be higher. The raised floor level generally requires the re-fixing of skirting boards, and door heights may also need to be reduced. However, this can cause:

— unequal or excessive step heights at staircases and external doors;

— incorrectly positioned door handles;

— a reduction in room height, or;

— necessitate adaptations to period features.

Such impacts may conflict with Building Regulation requirements, making it impractical to insulate the floor.

Increasing floor height may also require modification to fitted furniture, e.g. kitchen units, sanitary ware and wardrobes, etc.

9.2.3.2.3 Services

Water pipes (e.g. for central heating) should be well insulated.

9.2.3.3 Installation considerations

A layer of insulation may be installed on top of the existing concrete floor. Use of a high performance material may allow for a reasonable improvement in thermal performance whilst minimising the impact of raising the floor level. Figure 89 shows how to accommodate insulation above an existing concrete floor. The installation should include the following:

— doors and skirting should be removed, and any low lighting sockets or pipes raised;

— provision for raising door heights should be allowed for at this stage;

— the floor should be dry and defect free;

— insulation should be laid according to the required depth to achieve the required U-value;

— a minimum of 20mm insulation should be laid around the perimeter of the floor;

— the screed should be laid on top. Where underfloor heating pipes are being installed a greater depth of screed should be installed in accordance to the manufacturer's specification.

— instead of a screed a floating floor may be fitted over the insulation. This should be a tongued and grooved floor and should:

  — be made of ply or timber;

  — be glued at the joints;

  — have a 10 mm minimum expansion gap at the walls; and this gap should be filled with a compressible material such as cork strips.

— raising the floor may adversely affect accessibility, as well as requiring modifications. In this case doors may need shortening and skirting and low-level electrical sockets may need to be raised.

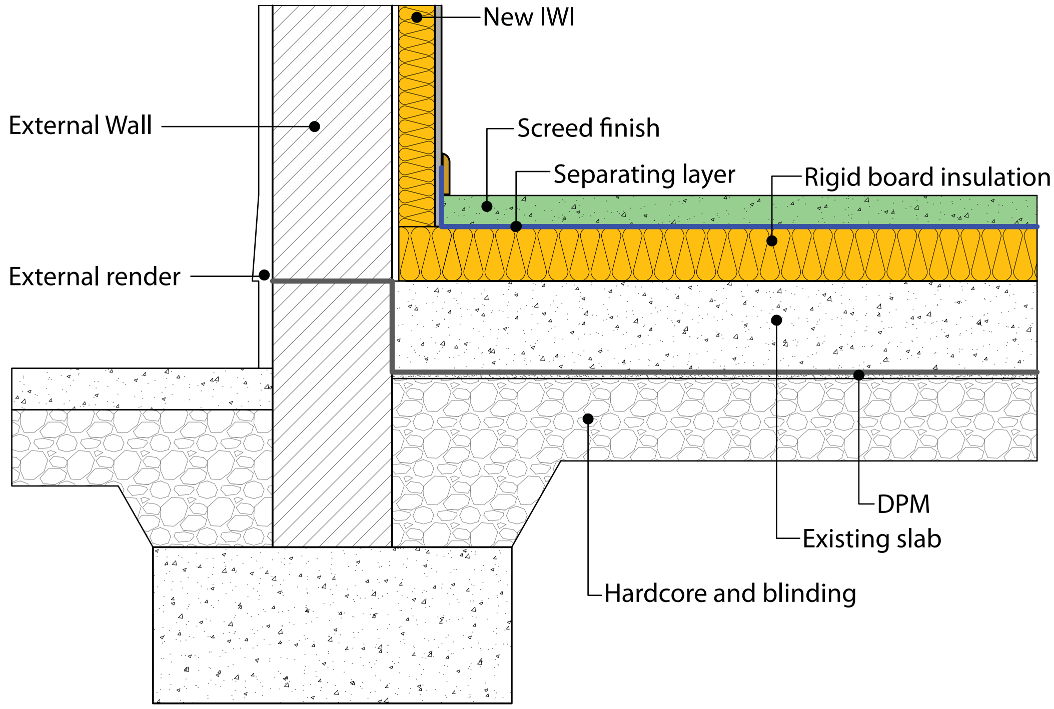

Figure 89 - **Insulation laid over an existing floor slab with internal wall insulation**

9.2.4 Replacement floor and insulation

9.2.4.1 General

Suspended timber floors may be replaced with new suspended floor and insulation installed as in 9.2.2.3 or replaced by a ground supported slab where the ground bearing capacity is suitable see 9.2.4.3.

Replacement of ground supported slabs facilitate installation of improved levels of insulation, damp proof membrane and/or radon barrier, see 9.2.4.3 and Figure 90 .

9.2.4.2 Design considerations

The insulation may either be placed above or below the concrete floor. Consideration should be given to maintaining insulation continuity and should ideally interface with the wall insulation to elimate thermal bridging.

Replacing a floor is an infrequent event so it is important to achieve the highest thermal resistance possible. Where replacing a floor the installation of underfloor heating should be considered to take advantage of low temperature heating system. Alternatively, underfloor heating pipes may be installed for any future low temperature heating system.

9.2.4.3 Installation considerations

The following provides guidance for replacement floors:

— when replacing a suspended floor all existing timber should be removed. Any debris or organic material should be removed from the cavity. Air bricks should be removed and bricked up;

— where breaking out an existing solid concrete floor any services should be identified and isolated, this may include mains water, gas and electricity. Any electric circuits should be re-routed or placed in suitable ducting;

— it may be necessary to level the floor with suitable hardcore. A radon sump with extraction pipe may be fitted as a precautionary measure;

— a layer of blinding should be laid over the hardcore, and a heavy gauge DPM fitted. A radon barrier should be fitted in “high radon” areas. This should lap up the walls to beyond the finished floor level which should be a minimum of 150 mm above existing ground level where practicable;

— rigid insulation should be laid to the required thickness. This should return up the perimeter of the wall up to finished floor level. Where under floor heating is being installed it should be fitted to the insulation according to the manufacturer’s specification.

— the concrete floor to the required thickness over new insulation when supported by hardcore. Where a concrete sub floor has been installed over the hardcore, insulation may be fitted over the subfloor and a screed finish used.

— internal insulation should then be fixed to the wall as required.

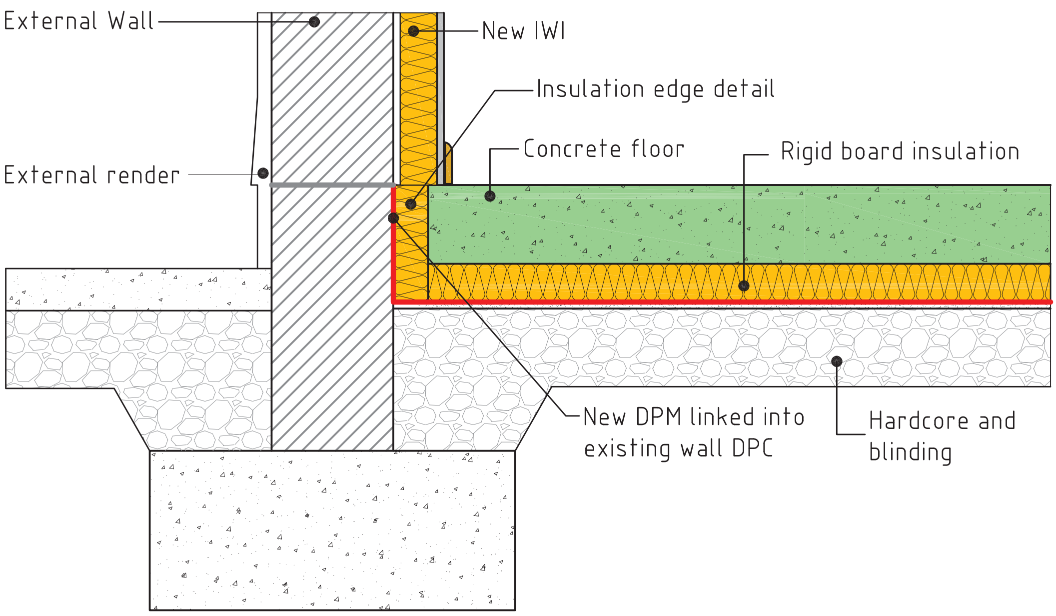

Figure 90 - Replacement floor

10. Ventilation

10. Ventilation

10.1 Traditional forms of ventilation

In the majority of existing dwellings, prior to retrofit, ventilation is provided by some or all of the following:

- openings such as windows and doors to provide purge ventilation and a means of cooling;
- background ventilation through purpose provided wall ventilators;
- adventitious ventilation, which includes:
  - purpose provided ventilation through vent grills or air bricks for heating appliances, and chimneys;
  - infiltration, i.e. air leakage through gaps and cracks in the dwelling structure.

10.1.1 Window and door openings

Opening windows and doors is the traditional way to remove pollutants, e.g. water vapour, odours, and provides a means of cooling. Where designed ventilation is not present and windows are left shut for long periods of time due to external noise or security reasons, surface condensation may occur in poorly insulated dwellings.

Where double glazing is retrofitted, the surface temperatures of the glazing and the surrounding uninsulated walls and ceilings are comparable, leading to an increase in surface condensation and mould growth in the corners of many rooms and in cupboards where air movement is restricted, see Figure 91.

Figure 91 - **Mould at external wall and ceiling junction**

10.1.2 Background ventilation

In more recent dwellings, and in some locations where building bye-laws applied, background ventilation was provided through wall or trickle ventilators, to ensure adequate indoor air quality (IAQ). Indoor air quality is air which is free of pollutants that cause irritation, discomfort or health effects to occupants. These were typically installed in all habitable rooms. A background ventilator is generally an opening, sometimes sleeved in the external wall, with a deflector cover or louvered cover internally. Ventilation is provided through these ventilators through cross ventilation due to pressure differences across the dwelling see 10.2.2.1.1.

NOTE Good indoor air quality (IAQ) may be defined as the air that is free of pollutants that cause irritation, discomfort or negative health affects to occupants. Air temperature and relative humidity also affect comfort and health of the occupants.

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10.1.3 Adventitious ventilation

Adventitious ventilation may be considered as:

- purpose-provided permanent ventilation which provides additional levels of ventilation through open grills, vents and chimneys etc. This should not be considered as being air leakage, as the ventilation serves a direct purpose such as the permanent provision of fresh air for heat producing appliances to burn cleanly and safely. When the heat producing appliance is not in use, the ventilation remains and can supply additional fresh air for the occupants and remove water vapour and other indoor pollutants;

- air leakage through cracks and gaps in a dwelling's structure such as:

  - ill fitting windows;

  - suspended timber ground floor and unsealed penetrations for services such as radiator pipes passing through the floor;

  - waste pipes which are incorrectly pointed where they penetrate external walls etc.

Generally adventitious ventilation is not controllable by the dwelling occupants.

The result of adventitious ventilation and air leakage means that heated air is ventilated out of the dwelling. The cold replacement air may cause draughts leading to poor thermal comfort and requires heating.

Purpose provided ventilation should be maintained when it is still required, whereas air leakage should, as far as practically possible, be eliminated.

10.2 Improvement methods

10.2.1 General

10.2.1.1 Choice of appropriate ventilation system

The ventilation strategy is an integral part of the holistic design of the retrofit of a dwelling. Where the clauses of this SR address thermal upgrading of the fabric elements (roofs, walls and floors etc.), guidance is given on how to reduce air leakage through the building fabric. Consequently, it is important to provide adequate ventilation in dwellings so as to ensure a good level of IAQ.

Achieving specific air permeability in either new or retrofitted dwellings is complex, and the ventilation strategy should take into account the possibility that the dwelling may be made significantly more airtight.

The following ventilation strategy options should be considered:

- natural ventilation with intermittent extract fans, see 10.2.2;

- passive stack ventilation (PSV), see 10.2.3;

- single room heat recovery ventilation (SRHRV) see 10.2.4;

- mechanical extract ventilation (MEV), see 10.2.5;

- mechanical ventilation with heat recovery (MVHR).

The type of ventilation system/method chosen should be determined by both the level of retrofit proposed and the level of air permeability which may be achieved, see Table 27.

Table 27 - **Suitable ventilation strategies for dwelling retrofit**

Ventilation strategy	Level of retrofit		
	Single room or partial house retrofit	Whole house retrofit	Retrofit to advanced air permeability level
Natural with extract fans	Y	Y	N
Natural with PSV	Y	Y	N
SRHRV	Y	Y	N
MEV	N	Y	Y
MVHR	N	Y	Y

Potentially all systems/methods of achieving adequate ventilation may be appropriate to a whole dwelling retrofit.

Where a high level energy efficiency whole house retrofit is proposed, airtightness testing is recommended to ensure that an advanced air permeability level has been achieved.

NOTE Testing should be carried out in accordance with I.S. EN 13829:2000 "*Thermal performance of buildings: determination of air permeability of buildings: fan pressurization method*". Additional guidance is provided in the ATTMA publication TS1 '*Measuring air permeability of Building Envelopes*'.

Where airtightness improvements are likely, but not necessarily to the levels which require whole house ventilation systems to be installed, then either intermittent extractor fans (including single room heat recovery ventilation) or, PSV systems may be utilised. The appropriate levels of background ventilation should be provided, see 10.2.2.1.1.

Where an energy efficiency retrofit to an advanced level of air permeability (i.e. below 5m^3/hr/m^2 is intended, a centralised MEV system may be considered. For low air permeability levels a MEV system with a low Specific Fan Power (SFP) of less than 0,30 W/(l/s) is more energy efficient than natural ventilation methods. See 10.2.1.5.2 for further information on SFP.

MVHR may be used where an air permeability of less than 5 m^3/hr/m^2 is achieved. As the airtightness of the dwelling improves the energy efficiency of the MVHR improves.

10.2.1.2 Air permeability / leakage

Adventitious ventilation described in 10.1.3 consists of purpose provided ventilation and air infiltration. Purpose provided permanent ventilation should be maintained whereas air leakage is additional air infiltration and should be eliminated where practically possible.

Air leakage ingress leads to excessive heating requirements and may lead to poor thermal comfort.

Air leakage egress, which may contain water vapour, can pass through the gaps and cracks of the building envelope and cause interstitial condensation within the structure. Where interstitial condensation occurs on structural elements such as lintels, timber framing members and wall ties, then long term exposure may lead to deterioration of the fabric structure.

Air leakage paths are not always readily observable and can be indirect, with air moving through the internal structure of the dwelling before terminating in a remote location, distant from the internal source of the air leakage.

An example of this is shown in Figure 92, where the air leakage path of cold incoming air ends in one

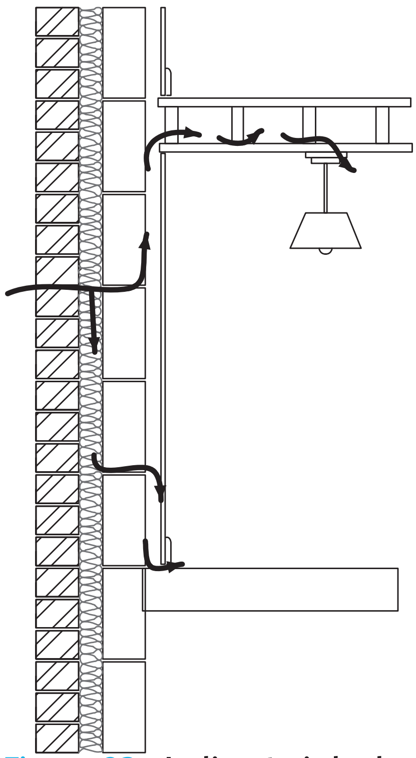

Figure 92 - **Indirect air leakage paths**

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room, but enters the dwelling in a different location initially.

As part of a whole house energy efficient retrofit, consideration should be given to carrying out an airtightness test both before and after the retrofit. Airtightness testing before a retrofit can offer the opportunity to locate and remediate existing air leakage paths when used in conjunction with a smoke pencil test.

Determining the existing air leakage paths before a retrofit most likely means that the retrofit itself should be more cost effective and an improved air permeability may be achieved.

Carrying out a post completion airtightness test, as part of the snagging process, assists in improving airtightness still further, and provides another opportunity to ensure that gaps etc. are identified and sealed.

Detailed guidance on achieving airtightness is provided in the clauses on walls, floors and roofs of this S.R. Where an airtightness test is not planned, the checklist, shown in Table 28, gives a list of measures that, if most or all are adopted, will likely lead to a refurbished dwelling achieving an air permeability below 5 $m^3/hr/m^2$.

Table 28 - Checklist of retrofit measures to achieve an air permeability below 5 $m^3/hr/m^2$

• full double, triple or secondary glazing; • effective closures on trickle vents and other controllable ventilation devices; • all external doors fitted with integral draught seals and letter box seals; • internal and external sealing around door and window frames; • fully filled cavity external walls, externally insulated walls, walls using an internal airtightness barrier or solid external walls; • impermeable overlays and effective edge sealing of suspended floors; • careful sealing of junctions between building elements such as walls to floors and walls to ceilings; • careful sealing around attic hatches; • careful sealing around flue penetrations; • careful sealing around internal soil pipe; • careful sealing around domestic water and heating pipes passing into externally ventilated spaces; • careful sealing of all service penetrations in the building fabric (electricity, gas, water, drainage, phone, TV aerial etc.); • careful sealing around overflow pipe for WC; • all cable channels for light switches and power sockets carefully sealed; • all cable entry for lighting and ceiling roses carefully sealed. Recessed lighting should not penetrate ceilings separating attic spaces from rooms unless suitably sealed.

Failure to implement any of the measures in Table 28 may result in the air permeability exceeding 5$m^3/hr/m^2$. Due care and attention should be taken to achieve this performance level.

10.2.1.3 Insulation improvements

Many existing dwellings, especially uninsulated dwellings, cannot be heated adequately. Improving the thermal envelope will reduce heat loss and lead to higher internal temperatures. With a higher internal temperature, the internal air can hold a significant amount of additional water vapour. Air leakage paths should be minimised to help reduce interstitial condensation.

When the retrofit consists only of cavity wall insulation and roof insulation, then mechanical extraction should be installed to all wet rooms as part of this process, and existing attic hatches etc. should be draught proofed. Even where existing windows are not being replaced, consideration should be given to providing background ventilation to all habitable rooms where none is currently provided. See 10.2.2.

Relevant clauses of this S.R outline how to improve insulation levels and at the same time improve airtightness. When improving insulation, ventilation should be considered at the same time.

10.2.1.4 Combustion appliances / spillage tests

Introducing mechanical extraction may cause spillage of combustion products where either an open-flued (non-room sealed) heat producing appliance exists. Spillage occurs when the extraction rate of the fan causes a depressurisation in the room containing the heat producing appliance, which in turn may reverse the flow of air containing the combustion gases through the appliance's flue.

The ventilation system should be designed to ensure the likelihood of spillage occurring is reduced to an absolute minimum. This may be achieved by first ensuring that sufficient fresh air is continuously and permanently available in the room where the heat producing appliance is located. The relevant installation Standards for the fuel/product type should be followed.

NOTE Where the manufacturer's information is available, these should be followed unless they conflict with the Building Regulations.

The permanent ventilation supply to a room containing both extraction and a non-room sealed heat producing appliance should be located between the extract fan location (including all forms of mechanical ventilation) and the appliance. The additional background ventilation should then be installed closer to the extractor location than the permanent ventilation but not closer than 0,5 m. This may require the permanent ventilation to be ducted so that it can be suitably located for use by the heat producing appliance.

Spillage tests should be carried out to all non-room sealed heat producing appliances whether in a room where extraction is installed or not.

NOTE Suitable guidance can be found in IP 21/92 *Spillage of flue gases from open-flued combustion appliances* and IP 7/94 *Spillage of flue gases from solid-fuel combustion appliances*. Guidance on appropriate spillage test procedure for gas-fired appliances is available in BS 5440-1: 2008 and BS 5440-2:2009 and for oil fire appliances in OFTEC technical books 2,4 and 5.

The room where the heat producing appliance is located should be supplied with permanent ventilation. In a room with a heating producing appliance that is not room sealed, it is recommended to install a carbon monoxide (CO) detector to I.S. EN 50291 with an end of life indicator as an extra precaution. This should not be considered as a substitute for proper installation and maintenance of the appliance.

10.2.1.5 Ventilation system efficiency

10.2.1.5.1 General

The energy efficiency of the ventilation system may be optimised by using:

- efficient types of fan motors;
- energy saving control devices, and, where applicable,
- heat recovery devices.

The energy efficiency parameters for mechanical ventilation systems may be obtained from the SAP Appendix Q database used by DEAP .

10.2.1.5.2 Specific Fan Power (SFP)

Mechanical ventilation systems require electrical power to operate, including power to the fans, compressors, transformers, controls and safety devices. The term 'specific fan power' is used to compare the electrical energy use for different ventilation systems as installed, i.e. allowing for system resistance through the unit and the ductwork.

A well designed ventilation system should minimise the energy usage while still achieving the required extract ventilation rate as outlined in Table 31 and Table 32. In addition to this, an assessment of the likely level of air permeability should be made before a specific type of ventilation system is chosen. In Table 29 the suggested levels of air permeability, specific fan power and system type are given. This choice may be informed by carrying out a pre-retrofit airtightness test.

10.2.1.5.3 Energy saving control devices

The amount of ventilation needed in a room depends on the pollution levels in that room and room occupancy. Automatic controls may be included with all types of ventilation system. These reduce the level of ventilation where the source of the pollution and/or the pollution level is low, and thus saves energy.

There are three types of control categories:

- automatic control using:
  - timers which allow for a specific overrun time period when the fan is switched off;
  - occupant sensors, such as personnel infrared detector;
  - humidity sensors, which activate when the relative humidly rises/falls beyond set values.
- manual control by the owner, e.g a hit and miss grill or fan switches;
- fixed/uncontrolled – a permanently fixed open device for example a grill for the purpose of combustion air.

The designer of the system should take care to ensure that reducing the ventilation rate in response to a low level of one pollutant does not result in a high level of another pollutant.

10.2.1.5.4 Heat recovery devices

Most ventilation heat recovery for dwellings are ‘air to air’ types, see Figure 93. They recover heat from extracted air and use it to pre-warm the replacement fresh air from outside of the dwelling. The effectiveness of this process is known as the unit’s ‘heat exchange efficiency’, the proportion of otherwise wasted heat recovered by the process, and this is usually expressed as a percentage.

A heat recovery unit of the MVHR system reduces the amount of energy (from a heating system) needed to heat up the incoming air to the desired room temperature. This benefit should be balanced against the electrical power required to run the system.

These systems both extract moist air from wet rooms and transfer a significant proportion of the heat contained in that air (through a heat exchanger, i.e. no mixing occurs) to incoming fresh air which is supplied to the habitable room.

These systems work best (i.e. are cost effective and energy efficient) in highly insulated and airtight dwellings, see Table 29.

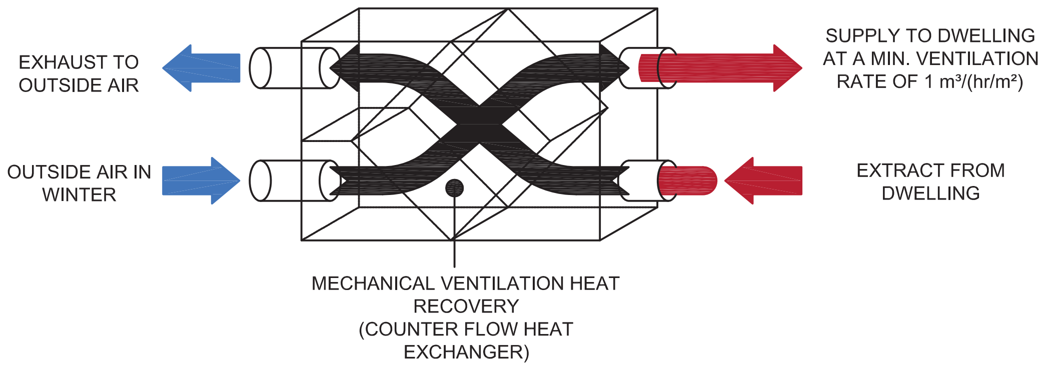

Figure 93 - **Heat recovery unit**

Table 29 - Recommended energy efficiency selection criteria and minimum performance specifications for ventilation systems

Type of ventilation system	Suitable energy efficiency envelope air permeability range ($m^3/(m^2hr)$)	Maximum SFP (W/(l/s))	Minimum Heat Recovery Efficiency %
Intermittent extract fans	5 and above	0,5	n/a
PSV	5 and above	n/a	n/a
MEV	5 and below	0,3	n/a
MVHR (see note)	5 and below	0,8	85
NOTE A MVHR unit which may be shown to be equivalent (or better) to this overall level of performance is also acceptable.			

10.2.1.6 Sound

Noise generated by ventilation fans may propagate through ductwork and may disturb occupants of a dwelling. Noise reduction may be achieved through selection and specification of quieter equipment and the correct design of ductwork, fittings and mountings in accordance with the manufacturers' recommendations.

Noise generated from outside the dwelling may enter through the fans, ductwork and wall ventilators. This may be mitigated by installing sound attenuation measures and where external may be subject to planning requirements.

NOTE Further guidance is available in BS 8233 – *Sound Insulation and Noise Reduction for Buildings*.

10.2.2 Natural ventilation with intermittent extract fans

10.2.2.1 Design considerations

The basic principle of ventilation is to replace indoor air with fresh outdoor air through purpose-provided openings. There are two natural mechanisms that drive ventilation: one wind driven, the other temperature driven which is also known as the 'stack effect', see 4.6.

It should be noted that both these natural forms of ventilation can be suppressed in summer as both wind speeds are generally lower and external air temperatures higher. Additionally, these natural mechanisms are not always easily controllable by the dwelling's occupants, hence these natural forms of ventilation should be augmented by the following design specific ventilation measures, which come in three levels:

- background ventilation;
- intermittent extract ventilation;
- purge ventilation.

10.2.2.1.1 Background ventilation

Background ventilation facilitates natural ventilation which ensures reasonable IAQ and the removal of excess moisture within the dwelling. This is often achieved by providing a sleeved wall ventilator or by trickle ventilators in the head of the window or door although this is not the only

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possible means. See Figure 94 and Figure 95.

When performing retrofit works it may be necessary to provide additional background or extract ventilation in existing dwellings. Table 30 provides guidance for the provision of ventilation for different retrofit measures where the anticipated air permeability will be greater than 5 $m^3/hr/m^2$ post works completion.

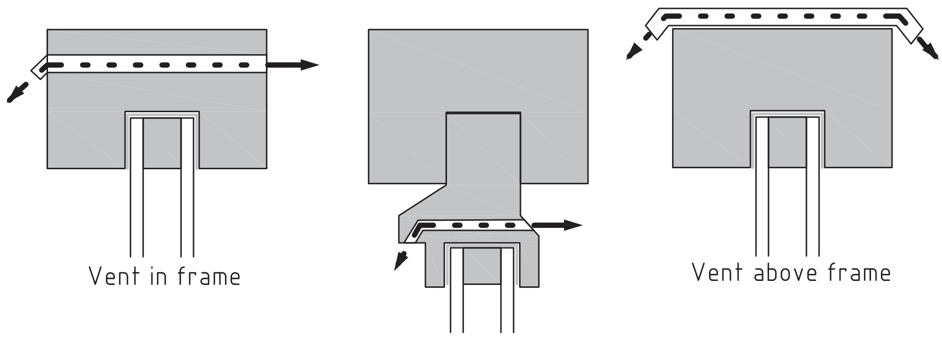

Figure 94 - Trickle ventilators to windows

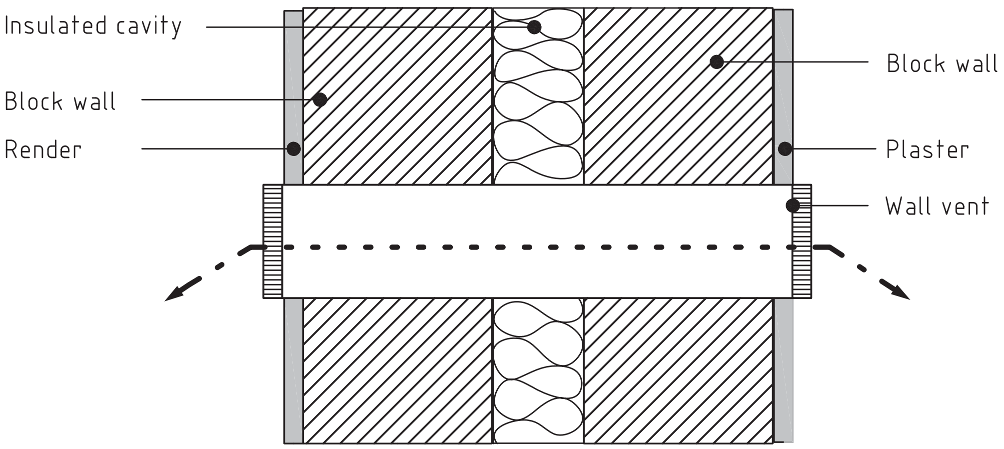

Figure 95 - Through wall ventilation

Table 30 - Guidance for the provision of ventilation for retrofit works with air permeability levels >5 $m^3/hr/m^2$

		Existing Dwelling Condition		
Retrofit Works		**A. No existing background ventilation in some or all habitable rooms and no extract ventilation in wet rooms**	**B. Existing purpose provided background ventilation in each habitable room. No extract ventilation provided in wet rooms**	**C. Existing purpose provided background ventilation in each habitable room. Extract ventilation provided in wet rooms**
1	Internal/External/ Cavity Insulation for Walls	Background ventilation should be provided to rooms without background ventilation in accordance with Column 2, Table 31 It is advised to provide extract ventilation in wet rooms in accordance with Column 3, Table 31 Where evidence of inadequate ventilation exists (e.g. mould, condensation) - extract ventilation should be provided to all wet rooms in accordance with Column 3, Table 31	No requirement to upgrade background ventilation It is advised to provide extract ventilation in wet rooms in accordance with Column 3, Table 31 Where evidence of inadequate ventilation exists (e.g. mould, condensation) - extract ventilation should be provided to all wet rooms in accordance with Column 3, Table 31	No requirement to provide further ventilation
2.	Replacement of Windows			
3.	Sealing/insulating of timber suspended floors			
4	Two or more of the above measures done in combination or separately	Background and extract ventilation should be provided in accordance with Table 31	No requirement to upgrade background ventilation Extract ventilation should be provided to all wet rooms in accordance with Table 31	No requirement to provide further ventilation

NOTE Covered/Damaged covers on ventilators should be replaced with equivalent or better. Deficiencies or faults in ventilator grills or fans should be rectified and returned to intended working condition.

NOTE Where ventilation exists and severe conditions of condensation or mould growth have developed, specialist advise should be sought.

Table 31 - Minimum levels of background and extract ventilation as specified by Table 30

Room usage	Minimum background ventilation (mm^2)[d]	Intermittent extract fan rating (l/s)
Habitable room	6 500	Not required
Kitchen[a]	6 500	60 (reduced to 30 for suitably sited extracting cooker hood)
Utility room[a]	6 500	30
Bath or shower room[b]	Not required	15
WC (only)[c]	Not required	6

a) Where the room has no external wall, a floor area of less than 6,5 m^2 and background ventilation cannot be provided then extraction fan to operate with a 15 minute overrun etc.

b) Where the room has no external wall and background and purge ventilation cannot be provided then the extraction fan should operate with a 15 minute overrun etc.

c) Where a window opening for purge ventilation exists then the window alone may be relied upon to provide extract ventilation.

d) Ventilation area as stated above is free area. Equivalent area is measured in accordance with the method specified in I.S. EN 13141-1: 2004. The above values should be multiplied by 0,8 to obtain equivalent areas.

During the process of providing a whole house retrofit, the air permeability that can be achieved may well exceed current typical new build levels. Where good levels of air permeability (i.e. below 5 $m^3/m^2/hr$) are achieved the specific guidance in Table 32 should be followed. The improvements required to achieve this level of air permeability are described in Table 28.

Table 32 - Minimum levels of background and intermittent extract ventilation when the air permeability is expected to be below 5 $m^3/hr/m^2$

Room usage	Minimum background ventilation (mm^2)[c,d]	Intermittent extract fan rating (l/s)
Habitable room	7 000	Not required
Kitchen[a]	3 500	60 (reduced to 30 for suitably sited extracting cooker hood)
Utility room[a]	3 500	30
Bath or shower room[a]	3 500	15
WC (only)[b]	3 500	6

a) Where the room has no external wall, then extraction fan to operate with a 15 minute overrun etc.

b) Where a window opening for purge ventilation exists, then the window alone can be relied upon to provide extract ventilation.

c) Ventilation area as stated above is free area. Equivalent area is measured in accordance with the method specified in I.S. EN 13141-1: 2004. The above values should be multiplied by 0,8 to obtain equivalent areas.

d) The minimum total equilavent area of background ventilators providing general ventilation should be 42 000 mm^2 with an additional 7 000 mm^2 for each additional 10 m^2 floor area above the first 70 m^2 of floor area measured. For single storey dwellings situated at ground level or on any storey up to four storeys, an additional 7 000 mm^2 per dwelling should be provided. The minimum level of background ventilation recommended for each room is unlikely to provide the total background ventilation required for the dwelling as a whole.

Background ventilation should be distributed around the dwelling as evenly as possible to ensure there are no parts of the dwelling that are substantially less ventilated than others.

Where proprietary background ventilators are used they should comply with I.S. EN 13141-1 and should be installed to manufacturers' instructions. All background ventilation should be located at least 1,75 m above floor level (to prevent draughts). Background ventilators may be either manual or automatically controlled.

Replacement fresh air should be able to move unhindered throughout the dwelling and as such transfer between rooms should be facilitated. This may be achieved by either providing an undercut at the base of internal doors of 10 mm above finished floor level (including coverings, i.e. carpet or laminate flooring), a ventilated door frame head or through some form of open vent in the door or walls.

Where doors/frames are required to protect a means of escape, i.e. fire doors, these should not be undercut unless allowed by manufacturers' recommendations. Alternatively, doors may be replaced with doors certified for having a threshold gap.

10.2.2.1.2 Intermittent extract ventilation

10.2.2.1.2.1 General

Extract ventilation allows for the rapid removal of water vapour and other pollutants at source to the outside, and helps to reduce the likelihood of these pollutants spreading throughout the remainder of the dwelling.

All wet rooms should be fitted with a mechanical extract fan[1], see Table 31 for recommended in-use flow rates.

Moist air is buoyant, and to ensure that as much as possible is removed as soon as it is produced, the mechanical extract terminal should be located no lower than 400 mm below the ceiling level, and may either be ceiling or wall mounted. Where an extracting cooker hood is provided, these should generally be located within 650 mm ~ 750 mm vertically above the cooker hob, unless they have been suitably tested and should then be sited in accordance with manufacturers' recommendations. For rooms with both extract fans and background ventilators, these should be located at least 500 mm apart.

For wet rooms where mechanical extract ventilation is provided and there is no provision for general ventilation by means of a controllable background ventilator, and no provision for purge ventilation by means of an openable window, the mechanical extract ventilation should include an automatic 15 minute overrun (after switch off). In the case of a kitchen, utility room or bathroom without WC, control by humidistat is acceptable as an alternative to 15 minute overrun.

For dwellings with a single aspect façade, such as back to back dwellings, it may not be possible to provide sufficient transfer of background ventilation between rooms. Extract fans should be located remotely from the rooms with background ventilation/opening windows to promote cross ventilation in the dwelling or an alternative ventilation method should be provided.

Any proposed ventilation installation should not compromise existing fire prevention measures, e.g. fire protected shafts, walls, floors or corridors.

Where wall mounted extract fans are installed dampers may be provided on the outlet to reduce draughts.

In dwellings fitted with mechanical extraction which also include an open flued heat producing appliance, see 10.2.1.4.

10.2.2.1.2.2 Fan controls

Intermittent extract fans may operate with a variety of controls:

- timers are used to ensure that fans only operate for a set period of time, and may be used where a wet room does not have an openable window. These should be wired into the lighting circuit of the wet room, so they activate as soon as the room is in use;
- manual switches, either by the use of a pull cord located in the wet room, or a normal switch positioned outside the wet room, but close to the entry point, may be used to activate the extract fan;
- occupancy sensors use a passive infrared detector (PIR) to detect the presence of someone in the wet room to activate the extractor fan. These may be fitted with either a timer, a manual or automatic override to switch off the extract fan;
- humidity sensors may be used as another automatic way to switch extractor fans on or off, or to switch a continuously running extractor fan (a SRHRV for instance) from a low level background ventilation provision to a boost level when the relative humidity of the room increases. These may also be fitted with either a manual or an automatic override to switch off the extractor.

1 It is possible to replace the requirement for an extract fan where a suitably designed PSV system is installed.

10.2.2.1.2.3 Fans and ductwork

Mechanical extract fans should be chosen to achieve the specified airflow rate having regard to location, length and type of ducting and size and type of outlet grill.

Axial fans are normally only suitable for use with a short length of through-the-wall ducting. The duct should be the same size as the fan outlet, and should be installed to allow for a slight fall to the outside to ensure that any condensate or driven rain that makes it through the outlet grill can drain away. For a bathroom however, due to the lower extraction rate required, axial fans may be acceptable for ducting up to 1,5 m in length and no more than two 90° bends.

Centrifugal fans can generally be used with ducting up to 3 m in length and one 90° bend for a kitchen extractor, or up to 6 m in length and two 90° bends for a bathroom extractor.

Where this ducting is taken through the room void it should be insulated to prevent condensation within the duct. This insulation should be the equivalent of at least 25 mm of mineral wool having a thermal conductivity no worse than 0,040 W/mK.

10.2.2.1.3 Purge ventilation

Purge ventilation is required to aid the removal of high concentrations of pollutants and water vapour, and from occasional activities such as painting and decorating.

In habitable rooms, where:

- the opening section(s) of a window can open more than 30°;
- the window is a sliding sash;
- where the openings consist of patio or French doors.

The total opening(s) area should be at least equal to 5 % (1/20th) of the floor area of the room.

Where the window opening angle in habitable rooms is between 15° and 30°, the minimum opening(s) area should be at least 10 % (1/10th) of floor area.

Where a habitable room is also an inner room (i.e. only entered through another (the access) room) and there are no external windw/door openings in the inner room, then a permanent opening of at least 5 % of the floor areas of both rooms combined should be provided between the rooms. The access room should provide window/door openings that achieve 5 % (or 10 % depending on the opening angle) of the combined floor area.

Additionally, a habitable room window or door opening may be covered by a conservatory or a similar space. Window/door openings should be provided between the habitable room and the conservatory and from the conservatory to the external, that achieves either the 5 % or 10 % of the combined floor area depending on the opening angles in both.

10.2.2.2 Application in retrofit

Natural ventilation with the use of intermittent extract fans is a suitable system in any type of energy efficient retrofit where airtightness levels are greater than 5m³/hr/m², see 10.2.1.1 and Table 27.

10.2.2.3 Installation considerations

10.2.2.3.1 Ductwork and fans

The following should be considered when installing ductwork and fans:

- where the extractor fan is fitted with a filter, this should be easily accessible for the dwelling occupants, i.e. not located above a large obstruction;
- humidity controlled extractor fans should be installed and commissioned as per manufacturers' instructions;
- ductwork connecting the extractor fan to the outlet terminal should be insulated where it passes through any unheated spaces, such as the roof void, to prevent condensation within

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the ducts. This insulation should be the equivalent of at least 25 mm of mineral wool having a thermal conductivity no worse than 0,040 W/mK;

— where the outlet terminal passes through the structure (such as an external wall), ensure that any rainwater that could penetrate the outlet grill runs back to the outside;

— where purpose provided ventilation is no longer required, e.g. a fire place is no longer in use, or the open flued combustion appliance is removed or replaced by a room sealed alternative, then consideration may be given to removing any redundant permanent ventilation. Redundant flues or chimneys may also be removed or sealed;

— most mechanical ventilation fans include filters that ensure contaminants do not adversely affect the operation of the fans. Where filters exist, such as in cooker hoods, it is essential that they are cleaned (or where necessary replaced) regularly to ensure that the extract rate can be maintained.

10.2.2.3.2 Sealing a fireplace no longer in use

In the case of a fire place that is no longer in use, the chimney should be sealed, see Figure 96, as it will become a major air leakage path which no longer has a purpose. The chimney should be sealed:

— within the room; and

— at the ceiling level of any insulated roof to ensure that the chimney breast within a heated room does not contain cold air. This should prevent the potential for both surface and interstitial condensation on or within the chimney.

Above the level of the insulated ceiling the chimney should be:

— ventilated from within the roof space to the outside of the dwelling; and

— capped to prevent ingress of moisture or rain whilst maintaining ventilation.

Alternatively, ventilation of the flue should be maintained by a vent in the sealed fireplace. Where the chimney is on an external wall, the internal face should be insulated.

Any alterations to flues should be performed by a suitably qualified person.

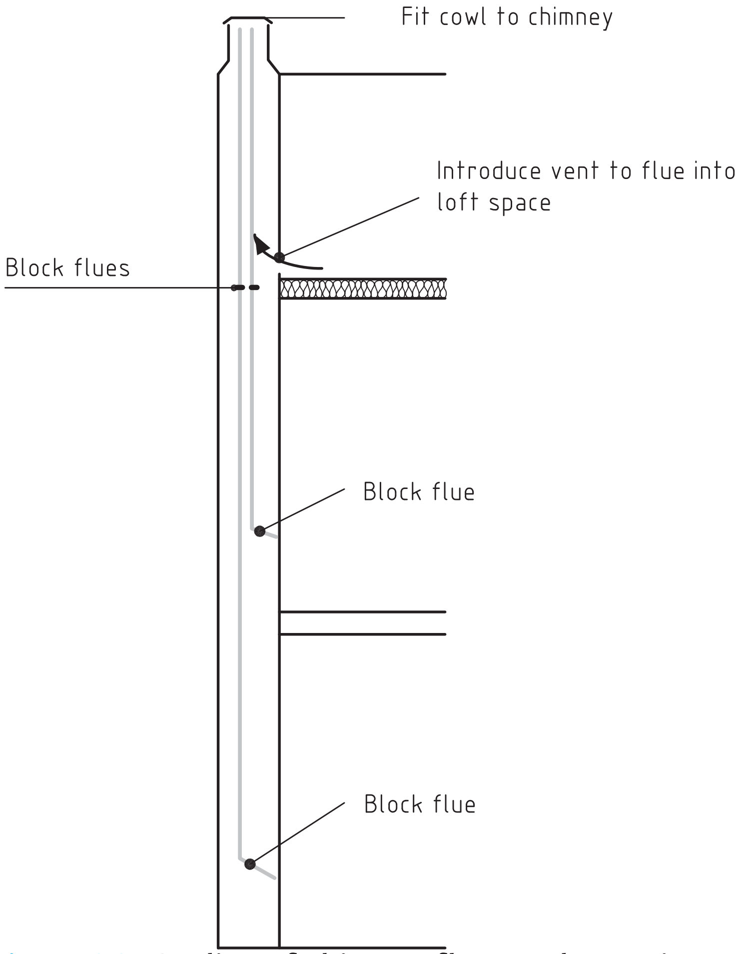

Figure 96 - **Sealing of chimney flues no longer in use**

10.2.3 Passive Stack Ventilation (PSV) systems

In principle, the use of a PSV system as part of an energy efficiency retrofit is an alternative to using intermittent extract fans.

10.2.3.1 General

Incorporating the ductwork required for a PSV system in an existing dwelling may not be possible. The ductwork should be installed correctly to ensure adequate ventilation. Incorrect design/installation may lead to the dwelling having reduced energy efficiency, or surface condensation leading to mould growth.

At design stage, duct routes should be identified. Duct routes generally travel from the inlet grill set in the wet room ceiling and through the roof void to an appropriate roof terminal.

A PSV system utilises the natural buoyancy of moist air combined with the stack effect and, to a lesser extent, wind driven pressure differences. An open vertical pipe from a wet room allows the moist air to rise through the pipe to the outside of the dwelling.

The following factors should be taken into consideration in the design to ensure this type of ventilation works effectively:

- the ductwork should be as near to vertical as possible;
- the internal diameter of the duct should not be less than 125 mm;
- all ducts should serve only one wet room for their entire length;
- any ductwork passing through an unheated space should be insulated;
- the duct should either terminate at, or close to, the roof ridge.

10.2.3.1.1 Provision of vertical ductwork

It may be unlikely that the layout of the dwelling will allow for the ductwork from each wet room to rise vertically directly to a ridge terminal. In the design of the location of the ductwork, consideration should be given to ensuring that the duct (most likely in the roof void) has no more than two offsets using swept bends that are at no more than 45° from the vertical and preferably no more than 30° from the vertical, see Figure 97.

The majority of ducts should consist of rigid pipes. All ductwork should be supported in such a way that no sagging can take place that might dislodge a section.

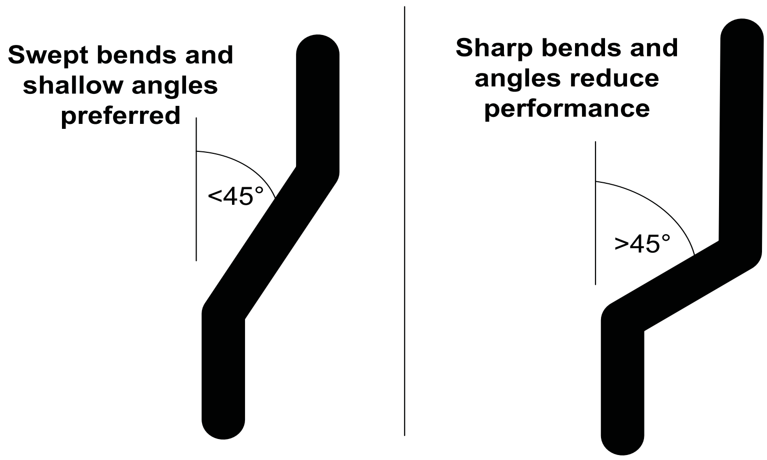

Figure 97 - No part of the ductwork should be more than 45° from the vertical

10.2.3.1.2 Opening grill

The opening grill can be fixed or can be controllable, see 10.2.3.1.9. The grill should provide at least the same free ventilation area as the cross section of the duct being used. Where there is some degree of manual operation, the appropriate free ventilation area should be achieved when the grill is in the fully open position.

10.2.3.1.3 Ductwork diameter

Duct sizes should be at least 125 mm in diameter. Where a non-circular duct is to be used, the cross-sectional area of the duct and the internal flow resistance should be equivalent to the circular duct and have a minimum dimension no less than 90 mm.

10.2.3.1.4 Independent ducts

Each duct from every wet room should be independent throughout its entire installation. Combining ducts may lead to moist air from one room over spilling through the ductwork into another room.

10.2.3.1.5 Insulated ductwork

Where the ductwork passes through an unheated space, such as the roof void, the ductwork should be insulated throughout its entire length within that space. The ductwork should be insulated to ensure that the moisture within the air mass does not condense within the ducts, which would then drain back down the ductwork to the rooms below. The insulation to the duct should be the equivalent to at least 25 mm of a material having a thermal conductivity of 0,04 W/mK.

10.2.3.1.6 Outlet terminal

The most effective outlet for a PSV, is suitably designed ridge terminal, see Figure 98. Where it is not possible to achieve this, the duct should be run vertically through the roof slope with the outlet terminating at the ridge height not more than 1,5 m horizontally from the ridge. A suitably approved cowl recommended by the system manufacturer should be used.

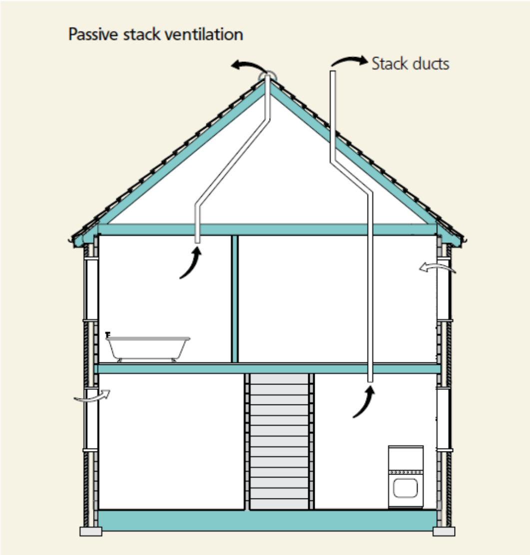

Figure 98 - Passive stack ventilation

10.2.3.1.7 Background ventilation

Recommendations for the provision of background ventilation rates are given in 10.2.2. It is not necessary to install background ventilation in the wet rooms where a PSV is installed. The equivalent area of all background ventilation should be at least equal to the combined internal cross-sectional area of all PSV ducts installed, even if this is a larger background ventilation area required than calculated from the floor area of the dwelling.

10.2.3.1.8 Purge ventilation

Recommendations for the provision of purge ventilation for habitable and wet rooms are given in 10.2.2.1.3. However, in wet rooms fitted with PSV systems, the system is acceptable as purge ventilation where the room does not have an external wall, although it may take longer for the PSV system to purge the room in question.

For rooms only containing a WC, an opening window is adequate for the purposes of purge ventilation, and in such circumstances a PSV system is not required for this room.

10.2.3.1.9 Humidity controlled systems

Controllable grills are more energy efficient as they only allow moist (warm) air out when moisture is present. As with manually controlled grills, the appropriate free ventilation area should be achieved when a humidity controlled grill is in the fully open position. It is recommended that the controls are set to open the grill when relative humidity within the wet room reaches 40 %, and that the grill is fully open when the relative humidity rises to 60 %.

10.2.3.1.10 Fire precautions

A single family dwelling of up to two storeys is classified as a single fire compartment. For the purposes of fire preventative measures a PSV system is the same as other building services.

Where a single family dwelling extends above two storeys, all ductwork within the dwelling (but not the roof void) should be encased in an enclosure which provides a minimum of half hour fire protection/separation. In the roof void, where the duct penetrates the ceiling, suitable fire stopping should be provided.

Where a PSV system is being installed, the design should not compromise the existing fire compartmentalisation and advice from a specialist fire consultant should be sought.

NOTE See Building Regulations TGD B.

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10.2.3.1.11 Noise

As a PSV system effectively provides a duct from within a room to the outside environment, it is possible that noise can penetrate to the inside of the dwelling. In situations where external noise is likely to be intrusive, some form of sound attenuation may be provided. Fitting a sound attenuator where the PSV system passes through the roof void is likely to be effective.

10.2.3.2 Application in retrofit

PSV systems are most appropriate where either the wet room has a roof space directly above it, such as bungalows, or where the wet rooms are vertically above each other.

Where the existing dwelling is close to a taller building, then the taller building may interfere with the wind flow over the roof of the dwelling and therefore restrict the ability of a PSV system to operate effectively. The design of the PSV should take account of adjacent tall buildings and guidance is available in IP13/94 and GPG 268.

10.2.3.3 Installation considerations

The performance of a well designed PSV system may be compromised by poor installation because of the system's reliance on lower pressure natural driving forces, i.e. the stack effect and wind pressure differences. Incorrectly installed ductwork may lead to poor IAQ and potential health problems for the dwelling's occupants. The following should be considered when installing a PSV system:

- Before an installation begins, the design should be rechecked by the installer to ensure that the installation can proceed. Where the system as designed is not possible, or can be improved the design should be revised before installation commences. The manufacturer's recommendations should be followed where appropriate.
- the ducts should be of rigid materials. Only where an offset is required should flexible ductwork be used;
- ducts should be fully supported along their entire length to ensure that the duct runs straight and there will not be any kinks at any bends or at the connections to either inlet grills or outlet terminals;
- ducts should be adequately fixed to the inlet grill and outlet terminal to ensure no leakage of moist air into the dwelling;
- where the inlet grill is manually controlled, this should be easily accessible for the dwelling's occupants, i.e. not at excessive height;
- inlet grills and outlet terminals should be a type that is as recommended by the PSV system manufacturer;
- where a duct is taken through the roof slope (i.e. not to a ridge terminal) the duct should be within 1,5 m horizontally of the ridge, and the height of the duct should be at least to ridge level. At the point where the duct penetrates the roof slope should be provided with a suitable flexible flashing;
- systems should be installed to manufacturers' specifications.

10.2.4 Single room heat recovery ventilators (SRHRV)

SRHRVs are a development of the extract fan. They provide a balanced flow of supply air to and extract air from wet rooms. A heat exchanger recovers heat from the outgoing air to pre-heat the replacement fresh air. The units are typically dual speed, with the low speed sufficient to provide background ventilation, but the high speed boost flow rate should achieve the intermittent extract rate, see 10.2.2.

The whole house ventilation rate should still be achieved through the use of background ventilation, as SRHRV units only ventilate the rooms in which they are installed.

In terms of energy efficiency, the heat recovered from the extracted air can compensate significantly for the energy needed by the fans to run continuously.

With this type of ventilator there is potential for moist air to re-enter the wet room or that some of the fresh air supplied is removed by the extraction.

10.2.5 Mechanical extract ventilation (MEV)

10.2.5.1 Design considerations

10.2.5.1.1 Continuous extract ventilation

Where continuous extract ventilation is proposed (i.e. centralised or decentralised MEV) the minimum ventilation rate is the higher of the total extraction rate required due to the presence of wet rooms, or the minimum whole house ventilation rate determined from the number of bedrooms (and hence the potential maximum occupancy level), see Table 33. A decentralised MEV system consists of individual fans in each wet room that run continuously, though the flow rates may be manually or automatically boosted when needed.

To clarify use of Table 33, where a dwelling has, for example, a kitchen and only one bathroom, the minimum extraction rate is 21 l/s whenever there is one, two or three bedrooms. However, for a four bedroom house the minimum whole house ventilation rate is 25 l/s, and hence the minimum extraction rates of either/both the kitchen and/or bathroom be increased. In most cases, it is likely that the continuous extraction rate will be higher than the minimum whole house ventilation rate.

Table 33 - Minimum levels of extract and supply ventilation when continuous extraction is used

Room usage	Continuous extraction rating (l/s)		Number of bedrooms	Minimum whole house ventilation rate (l/s)
Kitchen	13	or	1	13
Utility room	8		2	17
Bath or shower room	8		3	21
WC (only)	6[a]		4	25
			5	29

NOTE Each habitable room should be provided with minimum background ventilation of 3 125 mm^2 free area.

a) Where the window opening size is 10 % of the floor area of the WC and is relied upon to provide extract ventilation then this should not be included in the sum of total extraction rate calculation.

Only MEV systems that are included in SAP Appendix Q and that have a specific fan power (SFP) no greater than 0.3 W/(l/s) should be installed. The sizing of appropriate ductwork should be in strict accordance with the size and type of ductwork that formed part of the SAP Appendix Q testing of the MEV unit.

MEV systems and their components should be certified to the relevant I.S. EN 13141 standards.

The MEV unit will have at least two flow settings. The lower flow setting should achieve the whole dwelling ventilation rate, determined by the number of bedrooms, see Table 33, and the upper boost flow rate which achieves the extraction rates from each of the wet rooms present.

Where an open-flued heat producing appliance is located in a dwelling that also contains mechanical extraction, it should be installed and commissoned in line with the recommedations in 10.2.1.4 (combustion appliances/spillage tests).

10.2.5.1.2 Location of MEV unit and ductwork

The existing dwelling layout may not easily lend itself to installing ductwork, and therefore suitable siting of the MEV unit is critical. The unit should be accessible for maintenance and repair, and should be located in a position which will not disturb the dwelling's occupants. This means that the roof space may not be the best location (due to lack of access and working space etc.), and where possible locating the unit in an upper floor cupboard (insulated for sound proofing) may be a better option.

The layout of any and all ducts should contain as few bends as possible. The ductwork itself should be made of rigid materials, and where a rigid bend cannot be used, then short lengths of flexible bends can be used. All ductwork should be adequately supported to ensure no kinks occur at bends and where the ducts connect to the inlet terminal or onto the MEV unit.

The outlet terminals should be kept at least 300 mm away from window/ventilation openings and the flue terminal of any room sealed heat producing appliances.

10.2.5.1.3 Background ventilation

A continuously running MEV system partially depressurises the entire dwelling. To allow for sufficient replacement air, each habitable room should be fitted with background equivalent ventilation area of at least 3 125 mm^2, see Figure 94 and Figure 95. Background ventilation should not be installed in a wet room.

Care should be taken to ensure adequate cross ventilation throughout the dwelling.

10.2.5.1.4 Purge ventilation

Purge ventilation for habitable rooms and wet rooms should be provided in accordance with 10.2.2.1.3. In wet rooms the MEV system is acceptable as purge ventilation where the room does not have an external wall, although it may take longer for the MEV system (even at boost level of flow rate) to purge the room in question.

For rooms only containing a WC, an opening window is adequate for the purposes of purge ventilation. Where there is no window in the WC the MEV system should provide extraction.

10.2.5.1.5 Humidity controlled systems

Controls should be provided which allow for either manual or automatic switching to boost whenever a wet room is in use.

Automatic controls should be set to switch to boost when relative humidity within the wet room reaches 70 %, and that the boost remains on until the relative humidity reduces to 50 %.

10.2.5.1.6 Provision of ductwork and fan

When designing a MEV system, a suitable and accessible location should be determined for both the MEV unit and the ductwork to ensure that the system as a whole is capable of operating at optimum level through regular maintenance. The location should also be considered for sound transmission, ductwork layout and impact on any fire resisting construction within the dwelling. Ductwork should be as straight as possible, made from rigid pipes with a minimum of flexible sections limited to changes in direction

10.2.5.2 Application in retrofit

A MEV system should be considered where it is intended to achieve relatively low air leakage rates,typically 5 $m^3/hr/m^2$ or less.

10.2.5.3 Installation considerations

A MEV system should be installed by a suitably trained installer. Following installation, the MEV system should be commissioned to ensure that the designed air flow rates are achieved at both background and boost levels. The following should be considered:

- before an installation begins, the design should be rechecked by the installer to ensure that the installation can proceed. Where the system as designed is not possible, or can be improved the design should be revised before installation commences. The manufacturer's recommendations should be followed where appropriate;

NOTE A good practice design/installation guide (including future maintenance provisions) is available from http://www.sap-appendixq.org.uk/documents/MEV_Installation_Guide_Final.pdf

- the installer should agree an installation schedule with the main contractor. Typically the rigid ductwork should be installed before any other services are provided, such as plumbing/cabling etc;
- all joints of the ductwork should be correctly sealed and pressure tested to ensure no leakage of air can occur;
- ductwork should be insulated where it passes through any unheated spaces, such as the roof void, to prevent condensation within the ducts. This insulation should be the equivalent

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of at least 25 mm of mineral wool having a thermal conductivity no worse than 0,040 W/mK;

- all ductwork and connections should be as airtight as possible through appropriate taping or solvent cementing of joints;
- the MEV unit itself may be fitted with a condensation drain, which should be connected to a foul or surface water drainage system with water trap as appropriate;
- the use of flexible ductwork should be kept to the absolute minimum, and only used where the use of rigid ductwork is not possible;
- the installer should keep a marked up copy of the installation where ductwork has been temporarily terminated, to ensure that drill holes for terminals etc. can be done as accurately as possible;
- ensure that the connections between the ducts and the inlet grills are not kinked if they are made of flexible ductwork;
- where the MEV unit is fitted with a condensation drain, ensure that this discharges to the foul water drainage system of the dwelling;
- where the outlet terminal passes through the structure (such as an external wall), ensure that any rainwater that could penetrate the grill will run back to the outside;
- where the outlet terminal is to be connected to a roof ventilation tile (or similar) ensure that it is suitably sized;
- as soon as the installation is completed, the fan speeds should be set to achieve the designed flow rates, and a suitable calibrated flow meter used to commission the system.

10.2.5.4 Mechanical ventilation with heat recovery (MVHR)

Where retrofit construction works provide the opportunity to install both supply and extract ductwork and the air permeability is planned to be better than 5 $m^3/hr/m^2$, a MVHR unit will recover the heat from the extracted air and transfer it to the supply air.

Further guidance is available in the installation/commissioning guide supporting TGD F (see http://www.environ.ie/en/Publications/DevelopmentandHousing/BuildingStandards) and GPG 268 provide detailed guidance on the installation of these units.

11. Heating & hot water systems

11. Heating and hot water systems

11.1 General

This clause describes typical space heating and hot water systems and provides guidance for the appropriate retrofit measures.

NOTE Further guidance is provided in the Building Regulations and the DECLG SEAI *Heating and Domestic Hot Water Systems for dwellings – Achieving compliance with Part L* (HDHW Compliance Guide) giving recommendations to ensure that any replacements, upgrades or improvements meet requirements applicable at the time of replacement.

11.2 Preliminary considerations

11.2.1 Types of traditional heating system

Traditional existing heating systems typically found in the housing stock are listed in Table 34.

11.2.2 Identification of current heating system

The current heating and hot water system should be identified so that the scope for improvement may be established. In addition the following information should also be identified:

- fuel type;
- heat generator;
- hot water storage vessel (if any);
- distribution and circulation arrangements (if applicable); and
- controls.

Unless space and water heating are provided by a single combined system a separate survey should be made of each.

Table 34 should be used as an aid to classifying the system. Where a system does not correspond exactly with any of the definitions in Table 34, it may still be considered a traditional heating system if it shares the main characteristics of one of those listed.

Based on the system(s) surveyed, an assessment should be made of the potential for improvements or full or partial replacement as described in 11.4.

Table 34 - Main types of traditional heating and hot water systems

A. Solid fuel heating systems		
Ref.	Type	Description
EX1	Open fire	Inset on a hearth, there is a visible fire not enclosed by glass or metal doors. Can burn a wide variety of fuels but has poor heating efficiency as combustion cannot be controlled.
EX2	Range cooker	Installed in “living area” to provide some room heating in addition to a cooking function.
EX3	Room heater or stove (closed appliance)	A firebox enclosed behind heatproof glass or metal doors. Provides significantly improved efficiency compared with an open fire since rate of burning and combustion can be controlled.
EX4	Back boiler for water heating only	Boiler integrated with open fire, range cooker, room heater or stove. Gravity circulation to a direct or indirect hot water storage vessel.
EX5	Back boiler for central heating and water heating	Boiler integrated with open fire, range cooker, room heater or stove. Pumped circulation via 1 or 2–pipe system to heat emitters. Either pumped or gravity circulation to a hot water storage vessel. Pump controlled by manual switch, time switch or pipe thermostat.
EX6	Back boiler linked to gas or oil heating system	Boiler, see EX5, combined with a gas or oil fired central heating boiler system with some controls.
B. Gas/oil heating systems		
EX7	Gas/oil room heater	Inset in hearth or stand-alone heater used to heat individual rooms.
EX8	Gas/oil fired central heating boiler	Space heating via1 or 2-pipe distribution system, open-vented or sealed system, and using gravity or pumped circulation for the domestic hot water circuit. Some controls such as time clocks or TRV’s may exist.
EX9	Warm air unit	Central warm air unit with ducting to provide space heating, with time and temperature controls. Water heating provided by separate appliance.
C. Electric heating systems		
EX10	Electric convectors and radiators	Individual appliances, with individual controls using electricity on standard tariff.
EX11	Electric storage heaters	Storage heaters with individual controls, using electricity on an off-peak tariff. Some electric convectors or radiators are generally installed for supplementary heating.
EX12	Electric water heating	Individual water heating appliances or hot water storage cylinder with electric immersion heater(s).
NOTE	Variants of the above may be encountered.	

11.3 Heating and Hot water demand

11.3.1 Space heating demand

The space heating demand of the building should be determined by a heat loss calculation. Where heat emitters have been assessed as satisfactory and are not being replaced, the space heating requirement may be determined on the “whole house” heating demand. Where the heat emitters are being replaced a “whole house” calculation should not be used; instead the heat loss for individual rooms should be calculated so that emitter sizes may be determined.

NOTE A full design method which will give the heat loss for individual rooms is given in the CIBSE *Domestic Heating Design Guide* and a whole house calculation method may be found in CE54 *Whole house boiler sizing method for houses and flats*, Energy Saving Trust (EST) 2010.

11.3.2 Water heating demand

The water heating demand of the building should be determined by using recommended guidance from the CIBSE *Domestic heating design guide* or BS 6700. An additional boiler allowance for hot water demand of between 2-3kW is generally applied where regular boilers supply heating and hot water. A hot water cylinder of 117-140 litres capacity is usually adequate for dwellings with a single bathroom.

11.4 Heating and hot water system improvements and replacement choices

11.4.1 Improvements to existing systems

Consideration should be given to whether the existing system should be retained and improved, or replaced. Improvement, refers to what may be achieved by modifications or replacement of individual components, retaining the same system type and generally the same fuel. It may be uneconomical to improve a heating system which is old, inefficient, and nearing the end of its useful life; instead replacement should be recommended following the guidance in subsequent clauses. The decision to repair or replace depends on the, reliability history of the appliance/system, the cost and availability of spares and the scope for economic repair. Typical useful life of a boiler is around 15 years. The following Improvements should be considered:

- permanent ventilation to open flued appliances, see table 35;
- insulation of accessible pipework (outside the heated living space);
- insulation of the hot water cylinder and primary circuit;
- replacement of gravity hot water circulation with fully pumped circulation, where existing system is suitable to be pressurised[1];
- installation of controls where the existing set is deficient. Controls for gas, LPG, and oil boiler systems should include a programmer, room thermostat, TRVs in other rooms, and a cylinder thermostat for hot water control. Controls for electric heating should include thermostats and timers. Controls for solid fuel boilers should take account of the need for adequate heat dissipation;
- zoning of space heating and hot water systems where practical;
- ensuring the controls provide boiler interlock where a boiler provides both space and water heating services;

Table 35 - Guidance for the provision of adequate supply of air for combustion appliances

Retrofit Works		A. No existing supply of air in room containing a fixed open flued appliance.	B. Adequate supply of air provided in each room containing a fixed open flued appliance.
1	**Wall Insulation, window replacement or sealing/ insulation of suspended floors carried out BUT NO new open flued appliance fitted.**	**Permanent ventilation should be provided in the room containing the appliance, (see note).**	**No requirement to upgrade permanent ventilation.** **Recommended to ensure ventilation is unblocked, in good condition and permanently open.**
2.	**New open flued or flueless appliance fitted.**	**This work falls within the Building Regulations Part J- Heat Producing Appliances. See TGD J for further guidance.**	**This work falls within the Building Regulations Part J - Heat Producing Appliances. See TGD J for further guidance.**
3	**Provision of new balanced flue appliance.**	**This work falls within the Building Regulations Part J- Heat Producing Appliances. See TGD J for further guidance.**	**This work falls within the Building Regulations Part J - Heat Producing Appliances. See TGD J for further guidance.**
NOTE This permanent ventilation will also suffice for Background ventilation, see clause 10.			

1) May not be always practicable in solid fuel systems.

HEATING AND HOT WATER SYSTEMS

11.4.2 Replacement fuel/energy source

Where a full replacement of the heating system is necessary, consideration should be given to alternative fuels/energy source and system types. The prospect of changing to a different fuel/energy source should be considered as the first step in complete replacement of a heating system. An alternative type of system and/or fuel may raise the efficiency of heat generation, reduce fuel/energy usage and reduce environmental impact by reducing CO_2 emissions. An estimate should be made of the savings in fuel/energy consumption and CO_2 emissions by changing to other fuels/energy sources and system types, where they are technically, economically, and functionally feasible. The primary energy factor and CO_2 emissions of fuels/energy sources commonly used for heating are given in Table 36.

Where practicable, an alternative fuel/energy source should be selected which will result in higher efficiencies and lower CO_2 emissions. Both the relative CO_2 emissions factors, as given in Table 36 and the efficiency of the heat generator determines the total emissions.

Multi-fuel appliances should use the most efficient fuel with the lowest carbon emissions.

Where a community heating system serves the area, this should be considered. The cost of connection, running costs and practical issues should be investigated.

Where the existing fuel/energy source is:

- solid fuel (e.g. coal) – where the appliance is being retained wood should be used to reduce CO_2 emissions where this is practical. Otherwise mains gas should be used (if available), then LPG or oil depending on the relative feasibility, capital and fuel costs;

- mains gas, LPG or oil – mains gas, where available, should be used in preference to oil or LPG. Otherwise the same fuel source should normally be retained, as the cost of replacing the fuel store will be significant;

- electricity – mains gas should be considered, where available in preference to oil or LPG which still have an advantage with respect to lower CO_2 emissions. Consideration should be given to communal heating for high density developments. Where electricity is retained a heat pump rather than resistance heating should be considered;

- dual fuel link-up – where the main heating system is gas or oil fired and the secondary system is solid fuel this combination may be retained. The solid fuel option should preferably be wood, where practicable and a large and accessible storage area for it can be provided.

Table 36 - Primary energy factor and CO_2 emission factors[2] of fuels/energy sources used for heating

Fuel	Primary Energy Factor	Emission factor ($kgCO_2$ /kWh)
Mains gas	1,1	0,203
Bulk LPG (propane or butane)	1,1	0,232
Bottled LPG	1,1	0,232
Heating oil	1,1	0,272
Bio fuel blend B30 K	1,06[a]	0,193[a]
Biodiesel from renewable sources only[b]	1,3	0,047
Bioethanol from renewable sources only[b]	1,34	0,064
House coal	1,1	0,361
Anthracite	1,1	0,361
Manufactured smokeless fuel	1,2	0,392
Peat briquettes	1,1	0,377
Sod peat	1,1	0,375
Wood logs	1,1	0,025
Wood pellets in bags (secondary heating)	1,1	0,025
Wood pellets – bulk supply (primary heating)	1,1	0,025
Wood chips	1,1	0,025
Solid multi-fuel	1,1	0,369
Electricity	( )[c]	( )[c]
Electricity displaced from grid	( )[c]	( )[c]

a) From SAP 2009

b) Biodiesel or bioethanol verified as being from renewable sources only. Fuel type of biodiesel or bioethanol should not be selected where the appliance can burn any other fuel (for example kerosene mixed with biodiesel or pure kerosene). Fuel factors for biodiesel and bioethanol sourced from SAP 2009.

c) Emission factor will change over time. The latest factor can be obtained at http://www.seai.ie.

11.4.3 Replacement systems

Table 37 shows a range of possible replacement systems covering both individual room heating and central heating and hot water systems. Three levels are shown:

- Level A – an upgrade using the same fuel/energy source as the existing systems;
- Level B – an improved upgrade, possibly using a different fuel/energy source;
- Level C – an advanced upgrade using a renewable source.

The SEAI HARP (Home Heating Applicance Register of Performance) database provides a database of the efficiencies of heat producing appliances. This should be referred to when selecting new appliances.

2) From Table 8 of DEAP Manual Version 3.2.1

Table 37 - Replacement heating system (same fuel/energy source) options

Fuel	Level A	Level B	Level C
Room Heating			
Solid fuel (SF)	**M1** A room heating appliance which consists of a firebox and flue outlet enclosed behind a door of heat proof glass. This category excludes any appliance for which the combustion air supply cannot be controlled. HETAS Appliance Categories E1, E2 and E3 from Table 16 of HDHW Compliance Guide.	**B1** Closed room heater fuelled by wood only. HETAS category E4 from Table 16 of HDHW Compliance Guide.	
Electric	**M2** On-peak panel heater(s) should include time switch and integral or separate thermostats.		
Gas/Oil	**M3** Fixed room heater. As table 7 (Gas) and section 3.5 (oil) from HDHW Compliance Guide.	**B3** Room-Heater with a minimum efficiency of 5 percentage points higher than given in Table 7 and Section 3.5 of HDHW Compliance Guide.	
Central heating / hot water			
Solid fuel	**M4** Boiler. HETAS appliance categories F, G1, G2, J1, J2, J3 and J4 from table 16 of the HDHW Compliance Guide. Should have thermostatic control of burning rate. Indirect hot water cylinder with thermostat. Full set of basic controls, time switch or programmer, room thermostat, single heating zone control, boiler interlock where firing is electrically controlled.	**B4** Wood pellet boiler. HETAS category J5 from Table 16 of HDHW Compliance Guide. High performance indirect hot water cylinder with thermostat. Full set of controls: (programmer, room thermostat(s), two heating zones, two pipe system, TRVs on all radiators except in rooms with a room thermostat, boiler interlock).	**A4** As B4 with solar collector for water heating and twin coil cylinder.
Electric	**M5** Storage heaters with automatic charge control and output control. On-peak supplementary heaters should have individual timers and thermostats. Hot water cylinder with immersion heater with time switch. **M6** Electric boiler. Indirect hot water cylinder with thermostat. Full set of basic controls (time switch or programmer, room thermostat, single heating zone control, boiler interlock.	**B6** Boiler with thermal store sized to provide the majority of the heating from off-peak electricity.	**A5** Heat pump – see 11.15.2 Indirect hot water cylinder with thermostat and control suitable for use with heat pump.
Gas/LPG/ Oil	**M7** Condensing boiler. Indirect hot water cylinder with thermostat. Full set of basic controls (time switch or programmer, room thermostat, single heating zone control, boiler interlock). Minimum efficiency of boiler as required at Building Regulations applicable at time of replacement.	**B7** Condensing boiler, (regular boiler) with minimum seasonal efficiency (HARP value) :- Gas: 90 %, LPG: 92 %,Oil: 93 %. High performance indirect hot water cylinder with thermostat. Full set of controls: (programmer, room thermostat(s), two heating zones, two pipe system, TRVs on all radiators except in rooms with a room thermostat, boiler interlock). The heating circuit should be divided into at least 2 separate zones except for single-storey open-plan dwellings in which the living area is greater than 70 % of the total floor area. Two-pipe circuits should be used throughout.	**A7** As B7 with solar collector for water heating and twin coil cylinder. **A12** Micro-CHP, see 11.15.3.

Fuel	Level A	Level B	Level C
Gas/LPG/ Oil (Cont'd)		A high performance cylinder should have heat exchanger and insulation properties exceeding the requirements of BS 1566. The standing heat loss should not exceed 1.15 x (0.2 + 0.051 $V^{2/3}$) kWh per 24 hours, where V is the capacity in litres e.g. a 120 litre cylinder should have 50mm of PU-foam insulation (density 30 kg/m³). All cylinders should be labelled with the standing heat loss in kWh/24hours. Separate timing channels should be provided for the hot water circuit and each space heating circuit. This should be provided using two programmable room thermostats, one with additional timing capability for hot water.	
Dual fuel 'link-up' system (solid fuel with gas or oil)	**M8** A dual fuel link-up system will include both a solid fuel boiler and a gas or oil fired boiler. The primary pipework arrangements should be thermally separated. This is generally achieved by having a twin coil cylinder or heat exchanger to completely separate the primary circuits for each boiler. Each boiler should have independent feed, expansion and venting arrangements. Specialist advice should be obtained to ensure that system design, controls and electrical systems are suitable and energy efficient.	**B8** As B7 but modified to include link-up system. Top-up should be provided by a solid fuel boiler using wood fuel. Category E2, E4 and J5 from Table 16 HDHW Compliance Guide.	**A8** As B7 with solar collector for water heating and twin coil cylinder or MicroCHP
Warm Air Gas or Oil	**M9** Replacement warm-air unit. Time switch or programmer, room thermostat, single heating zone control, boiler interlock. Circulator linked to Hot water cylinder with thermostat. Fully pumped circulation.		
Water heating			
Solid fuel	**M10** Solid fuel boiler. HETAS appliance categories E1, E2, E3, E4, F, G1 and G2 from Table 16 of HDHW Compliance Guide. Gravity circulation to indirect hot water cylinder.	**B10** Solid fuel boiler as M10. Pumped circulation to indirect hot water cylinder. Clock/programmer and room/cylinder thermostat.	
Electricity	**M11** Hot water cylinder with immersion heater(s) with time switch. Replacement hot water systems should follow the requirements given in DOM9, TEHVA .	**B11** See M11. Hot water cylinder large enough to heat most of the hot water required by off-peak electricity. Time switch.	
NOTE Where reference is made to "HDHW Compliance Guide", this refers to DECLG SEAI *Heating and Domestic Hot Water Systems for dwellings – Achieving compliance with Part L* .			

11.4.4 Replacement choice

The choice of heating system replacement options from Table 38 depends on the existing system and the technical and economic feasibility of the upgrade.

Table 38 takes the range of existing systems shown in Table 34 and provides replacement options using the same fuel and an alternative fuel to improve sustainability. In Table 38, Level C options are not included.

Table 38 - Replacement heating system options

Existing Systems		Replacement systems	
Ref.	Type	Same fuel	Different fuel
A. Existing solid fuel heating systems			
EX1	Open fire	M1	B1 B3 (if mains gas available)
EX2	Range cooker	M4	Gas fired unit (if mains gas available)[1] Oil fired unit[1]
EX3	Room heater or stove	M1	B1 B3 (if mains gas available)
EX4	Boiler for water heating only	M10 & B10	
EX5	Boiler for central heating and water heating	M4 or B4	B7
EX6	Boiler linked to gas or oil heating system	M8	B8 B7
B. Existing gas/oil heating systems			
EX7	Gas/oil room heater	B3 M3	Use mains gas in preference to oil/LPG B1
EX8	Gas/oil fired central heating boiler	B7 M7	Use mains gas in preference to oil/LPG B4
EX9	Warm air unit	M9	B7 and Use mains gas in preference to oil/LPG
C. Existing electric heating systems			
EX10	Fixed on-peak panel heaters.	M2 A5	B1 B3 M3 B7 District Heating Scheme – where practicable.
EX11	Electric storage heaters	Review tariff options M5 A5	B7 Use mains gas in preference to oil/ LPG District heating - where practicable
EX12	Electric Water heating	M11	Gas fired unit (If available)
1) Minimum efficiency requirements in HDHW Compliance Guide sections 2.3 and 3.3.			

11.5 Gas boilers

11.5.1 Options

Some existing gas boilers are of the regular type (sometimes called ‘conventional’ or ‘heat only’). Space heating is provided directly and domestic hot water is heated in a separate hot water storage vessel. Units designed to fit directly in the fireplace are referred to as back boiler units (BBU).

Combination or ‘Combi’ boilers deliver both space and water heating without a separate hot water storage vessel. These are less common as they require direct connection to mains water supply to which restrictions apply or alternatively can be pumped from cold water storage tank.

All boilers used as replacements should be condensing and should have a minimum efficiency as required by the Building Regulations applicable at the time of replacement (as defined by its HARP value) and not worse than the seasonal efficiency of the controlled service being replaced. Where the installation of a condensing boiler would be impractical or excessively costly, a non-condensing boiler may be installed instead. In this case, the Condensing Boiler Installation Assessment

Procedure[3] should be followed to confirm it is cost justified. This assessment should be carried out by a competent person and where it shows that an exception is allowable, a non-condensing boiler may be fitted. The assessment form should be given to the building owner as the form may be needed for compliance purposes.

Many existing boilers may have open flues whereas most gas condensing boilers have balanced flues. Existing flues or chimneys for non-condensing boilers may not be suitable for use with condensing boilers due to the lower temperature of the flue products and the fact that persistent condensation will occur. Flues for use with condensing boilers should have a designation in accordance with TGD J. This aspect should be considered at an early stage, as the route for the replacement flue and its maximum allowable length may mean the replacement boiler should be located in a new position. The flue systems should comply with the boiler manufacturer's instructions and/or I.S. 813 where applicable.

NOTE For futher guidance see Building Regulations, TGD J.

A non-balanced flue, where the air intake and flue outlet are run to separate locations, may be available for some boiler models. The air intake can remain at low level but the flue outlet, and hence the plume of combustion products, can be directed at high level to avoid nuisance and obstructions. This option should only be used where it is provided or approved by the boiler manufacturer. The equipment is sometimes referred to as a 'Plume management kit'.

11.5.2 Design considerations

For boiler replacement it should not be assumed that the existing unit is sized correctly. The original sizing may have been incorrect, and since installation it is likely that the dwelling insulation levels will have been improved. Space heating and hot water demand should be established as given in 11.3.1 and 11.3.2. The boiler should be sized to meet the maximum load expected on the system, which will include heat emitters, hot water system and pipework losses. The design boiler output in the non-condensing mode should always be used when sizing the boiler.

Where the boiler only is being replaced, a whole house sizing method may be used. Where heat emitters are also being replaced a room by room full design heat loss sizing method should be used.

11.5.3 Installation considerations

The gas installation should be designed in accordance with the requirements of I.S. 813 *Domestic Gas installations* and should only be worked on by Registered Gas Installers.

The boiler should be located such that there is sufficient space to undertake the installation without difficulty. Where the replacement boiler is being fitted in the existing location it should be ensured that the manufacturer's minimum installation clearances are followed. The location should provide sufficient access for repair, maintenance and servicing.

Where possible, the boiler should be located in a heated area to save energy. Where this is not possible frost protection should be considered.

Open flue boilers should not be installed in, or draw their combustion and ventilation air from, bedrooms, bathrooms, shower rooms or garages.

Room-sealed boilers may be installed in bath and shower rooms provided particular requirements are followed, further information is available in ET 101 and I.S. 813. Where boilers are being installed in certain locations such as; under stairs, in a basement or cellar, in a loft, attic or roof space the provisions of I.S. 813 should be complied with. Consideration should be given to the weight of the boiler, provision of ventilation, safe access and fire resistance.

Where the existing boiler is a back boiler unit (BBU), it may not be possible to replace it directly with a similar type that meets the minimum efficiency requirements. In this case, a regular condensing boiler in a new location should be installed.

The boiler manufacturer's installation instructions for flues and ventilation should be followed.

The flue terminal positions should be in accordance with the safety distances set out in Technical Guidance Document J, I.S. 813 for gas boilers. Where the existing boiler location is retained and a condensing boiler is to be fitted, the condensing boiler flue terminal should be fitted such that the plume of wet flue products does not impinge on or significantly affect the use of the dwelling and also the neighbouring buildings. Care should be taken to locate flue outlets from condensing boilers away from parts of a building that may be damaged by frequent wetting. The direction of the flue may be altered by specialist diversion kits which should be appropriate for the flue,

3 HDHW Compliance Guide, Appendix A, *Guide to the condensing boiler installation assessment procedure for existing dwellings*.

appliance and fuel being used.

A terminal guard should be fitted where the terminal is less than 2 m from ground level. The guard should withstand the corrosive effect of condensate, e.g. be made entirely from stainless steel.

The new boiler location should be such that a suitable condensate drain point may be reached without difficulty. Condensing boilers should be installed such that there is an adequate method to dispose of the condensate. It should be ensured that the drain point can be reached from the proposed boiler position using corrosion resistant pipework at an angle of at least 3°.

Suitable drain points may be as follows:

— an internal stack pipe;

— a waste pipe;

— an external drain,

— gully;

— rainwater hopper; or

— a purpose-made soakaway.

Internal drain points which allow gravity discharge should be used as a first priority since they are less likely to become blocked by frozen condensate. Where gravity discharge to an internal termination is not possible a condensate pump may be considered. Where no other discharge method is possible, then an externally run condensate pipe to an external gully may be considered but should be of restricted length, increased diameter and provided with weatherproof insulation. Where the pipe discharges into an open drain or gully, the pipe should terminate below the grating level but above the water level.

NOTE Further guidance is given in the Appendix A to HDHW Compliance Guide, '*Guide to the Condensing Boiler Installation Assessment Procedure*'.

Where the boiler replacement is to use LPG, the boiler installation details are generally similar to natural gas. It should be noted that LPG can be more hazardous than natural gas since it is heavier than air and can collect in low lying places. LPG appliances should be installed in accordance with the provisions in I.S. 813 by a Registered Gas Installer. The location and siting of LPG storage tanks should be in accordance with the provisions in I.S. 3216.

When a solid fuel back boiler is no longer needed and the customer wants to continue using the fireplace, the back boiler should be removed and any pipework to the solid fuel hot water system disconnected and made safe. Where an open fire is to remain in use (or may be brought back into use) a replacement fire back should be installed so that the fire can be safely used.

11.6 Oil boilers

11.6.1 Options

Some existing oil boilers are of the regular type i.e. sometimes called 'conventional' or 'heat only'. Space heating is provided directly and domestic hot water is heated in a separate hot water storage vessel.

Combination or 'Combi' boilers can both space and water heating without a separate hot water storage vessel. They are less common as they require direct connection to a mains water supply to which restrictions apply.

All boilers used as replacements should be condensing and should have a minimum efficiency (its HARP value) as required by the Building Regulations applicable at the time of replacement. The efficiency should be no worse than the seasonal efficiency of the controlled service being replaced. Where the installation of a condensing boiler would be impractical or excessively costly, a non-condensing boiler may be installed instead. In this case, the *Condensing Boiler Installation Assessment Procedure* should be followed to confirm it is cost-justified. This assessment should be carried out by a competent person and where it shows that an exception is allowable a non-condensing boiler may be fitted. The assessment form should be given to the building owner as the form may be needed when the building is sold.

Many existing boilers may have open flues whereas most condensing boilers have balanced flues. Existing flues or chimneys for non-condensing boilers may not be suitable for use with condensing boilers due to the lower temperature of the flue products and the fact that persistent condensation will occur. Flues for use with condensing boilers should have a designation in accordasnce with TGD J. This aspect should be considered at an early stage, as the route for the replacement flue and its maximum allowable length may mean the replacement boiler should be located in a new position. The flue systems should comply with the boiler manufacturer's instructions and/or B.S. 5410.

NOTE For futher guidance see Building Regulations, TGD J.

The option of a non-balanced flue, where the air intake and flue outlet are run to separate locations may be available for some boiler models. The air intake can remain at low level but the flue outlet, and hence the plume of combustion products, can be directed at high level to avoid nuisance and obstructions. This option should only be used where it is provided or approved by the boiler manufacturer. The equipment is sometimes referred to as a 'Plume management kit'.

11.6.2 Design considerations

For boiler replacement it should not be assumed that the existing unit is sized correctly. The original sizing may have been incorrect, and since installation it is likely that the dwelling insulation levels have been improved. Space heating and hot water demand should be established as given in 11.3.1 and 11.3.2. The boiler should be sized to meet the maximum load expected on the system, which should include heat emitter, hot water system and pipework losses. The design boiler output in the non-condensing mode should always be used when sizing the boiler.

Where the boiler only is being replaced, a whole house sizing method may be used. Where heat emitters are also being replaced a room by room full design heat loss sizing method should be used.

11.6.3 Installation considerations

The boiler should be located such that there is sufficient space to undertake the installation without difficulty. Where the replacement boiler is to be fitted in the existing location it should be ensured that the manufacturer's minimum installation clearances are followed. The location should provide sufficient access for repair, maintenance and servicing.

Where possible, the boiler should be located in a heated area to save energy. Where this is not possible frost protection should be provided.

Open flue boilers should not be installed in and/or draw their combustion and ventilation air from bedrooms, bathrooms, shower rooms or garages.

Room-sealed boilers may be installed in bath and shower rooms provided particular requirements are followed, further information is available in ET 101 and B.S. 5410. Where boilers are being installed in certain locations such as; under stairs, in a basement or cellar, in a loft, attic or roof space the provisions of B.S. 5410 should be complied with. Consideration should be given to the weight of the boiler, provision of ventilation, safe access and fire resistance.

NOTE See OFTEC Technical Information Book 4 section 1.2, for further guidance.

The new boiler location should be such that a suitable condensate drain point can be reached without difficulty.

The boiler manufacturer's installation instructions for flues and ventilation should be followed. Detailed recommendations are given in BS 5410-1.

The flue terminal positions should be in accordance with the safety distances set out in Technical Guidance Document J and BS 5410 for oil boilers. Where the existing boiler location is retained, and a condensing boiler is to be fitted, the condensing boiler flue terminal should be fitted such that the plume of wet flue products does not impinge on or significantly affect the use of the dwelling and also the neighbouring buildings. Care should be taken to locate flue outlets from condensing boilers away from parts of a building which may be damaged by frequent wetting. The direction of the flue may be altered by specialist diversion kits which should be appropriate for the flue, appliance and fuel being used.

A terminal guard should be fitted where the terminal is less than 2 m from ground level. The guard should withstand the corrosive effect of condensate e.g., made entirely from stainless steel.

The existing air supply provisions should be checked to confirm that they are satisfactory for the replacement boiler. Where existing air supplies are inadequate new ventilation provision should be made as given in Part J of the Building Regulations.

Where a replacement appliance is of the open-flue type, care is required to ensure the flue route, flue type, material and termination is suitable and provision for removal of condensate is made.

Condensing boilers should be installed to allow an adequate method to dispose of the condensate. It should be ensured that the drain point can be reached from the proposed boiler position using corrosion resistant pipework with a continuous fall at an angle of at least 3°.

Suitable drain points may be as follows:

— an internal stack pipe;

— a waste pipe;

— an external drain,

— gully;

— rainwater hopper;

— a purpose-made soakaway.

Internal drain points which will allow gravity discharge should be used as a first priority since they are less likely to become blocked by frozen condensate. Where gravity discharge to an internal termination is not possible a condensate pump should be considered. Where no other discharge method is possible, an externally run condensate pipe to an external gully should be considered but should be of restricted length, increased diameter, provided with weatherproof insulation. Where the pipe discharges into an open drain or gully, the pipe should terminate below the grating level but above the water level.

NOTE Further guidance is given in *Heating and Domestic Hot Water Systems for dwellings - Appendix Guide to the Condensing Boiler Installation Assessment Procedure*, DECLG and SEAI.

The type, size and position of an oil tank should be considered. It should be mounted on a suitable base and the requirements for bunding and prevention of environmental hazard should be met.

Oil supply piping should meet requirements for size, location and protection against damage. The installation should include a remote sensing fire valve fitted outside the dwelling.

NOTE For the installation of oil storage tanks and supply system, see *Building Regulations Technical Guidance Document J*, and OFTEC *Technical Information* Book 4.

When a solid fuel back boiler is no longer needed and the customer wants to continue using the fireplace, the back boiler should be removed and any pipework to the solid fuel hot water system disconnected and made safe. Where an open fire remains in use (or may be brought back into use) a replacement fire back should be installed so that the fire can be safely used.

11.7 Solid fuel boilers

11.7.1 Options

Existing solid fuel boilers are generally of the following types as categorised by HETAS, see HETAS Guide and Table 16 of HDHW Compliance Guide:

— open-fires with high output boilers (D1-D4);

— room heaters and stoves with boilers (F);

— range cookers with boilers (G1, G2);

— independent boilers (J1-J5).

Most existing solid fuel boilers are combined with an open fire, room heater, stove or range cooker and often will be linked to a separate hot water cylinder using gravity circulation. Depending on their heat output, they may also provide space heating to heat emitters. Many of the units are designed to fit in the fireplace and they are referred to as back boiler units (BBU).

These units may burn wood, wood pellets, turf, house coal, manufactured smokeless fuels and anthracite. Where solid fuel is being retained, the first choice for the replacement unit should be to burn wood or wood pellets. All room heaters combined with a boiler should be of the "closed appliance" type.

NOTE For guidance on Smoke Control Areas see DECLG website.

All boilers used as replacements should meet relevant I.S. and BS standards and include thermostatic control. Independent boilers have the highest efficiencies and also the greatest turn-down. They should have a minimum efficiency no less than specified in Table 39. For further information see HDHW Compliance Guide.

Table 39 - Solid fuel appliance categories and minimum efficiencies

Category	Appliance description	Minimum efficiency % (gross calorific value)
F	Room heater with boiler	67
G1	Range Cooker with boiler not exceeding 3,5 kW	50 (boiler only)
G2	Range Cooker with boiler above 3,5 kW	60 (boiler only)
J1/2/3	Independent boiler (batch fed)	65
J4	Independent boiler – anthracite	70 rising to (above 20,5 kW) 75
J5	Independent boiler – wood pellet	77

Before confirming the replacement solid fuel option, a survey of the existing chimney, hearth and air supplies should be undertaken. The practicalities and additional costs of remediation works should be taken account of when replacing solid fuel systems.

Systems using a solid fuel boiler should be designed so as to ensure that all heat generated when the boiler is slumbering is dissipated.

Some existing systems are referred to as 'dual fuel link-up' in which a solid fuel boiler is also connected to an open vented central heating system operating on gas or oil. This arrangement facilities having a room heater combined with an oil or gas central heating system thus allowing the flexibility to use either system.

Both replacement and existing installations of this type should use wood fuel for the solid fuel boiler as a first priority.

11.7.2 Design considerations

For boiler replacement it should not be assumed that the existing unit is sized correctly. The original sizing may have been incorrect, and since installation it is likely that the dwelling insulation levels have been improved. Space heating and hot water demand should be established as given in 11.3.1 and 11.3.2. The boiler should be sized to meet the maximum load expected on the system, which includes heat emitters, hot water system and pipework.

Where the boiler only is being replaced, a whole house sizing method may be used. Where heat emitters are also being replaced a room by room full design heat loss sizing method should be used.

Where a back boiler unit is combined with a fire or room heater, the sizing of each unit should be such that the ratio of heat-to-air and heat-to-water is related to the relative heat requirements of the room in which the units are located and the total heat requirements of the dwelling. Where the room heater is oversized, the heat output to the rest of the dwelling may be restricted.

The boiler manufacturer's instructions regarding heat dissipation and 'slumbering' should be followed.

Solid fuel boilers should not be fitted in sealed heating systems unless permitted by manufacturer's instructions. Where possible, and boiler manufacturers' instructions permit, a fully pumped system should be used. All systems using a solid fuel boiler should be designed so as to ensure that all heat generated when the boiler is slumbering is dissipated, without reliance on continuing operation of the pump, see Figure 103. These systems should be designed such that they operate in a "fail-safe" mode. They should be installed and commissioned by competent persons.

Dual link systems should be designed to operate in a safe manner particularly with regards to maintaining open vented expansion pipes and balancing of the system. Where a dual fuel link-up system is being used, the size and output of the appliances linked should be considered relative to the heat requirements of the dwelling.

11.7.3 Installation considerations

The existing flue may not be suitable for the type of fuel and appliance being used. Flue block or metal system chimneys specifically designed and installed for gas or oil open fires are not generally suitable for solid fuel appliances. Where the replacement appliance is to use the existing chimney, a survey should be carried out to confirm that it is of suitable design and construction and in serviceable condition. For both new and existing chimneys, it will be necessary to consider the height, flue cross section, insulation level, flue terminal design, access for cleaning, and air tightness. Where necessary an existing chimney should be swept clean before installing a boiler to it. Manufacturer's instructions regarding lining existing chimneys should be followed.

The flue termination should be suitable for use with the fuel type used by the appliance, see TGD J.

NOTE For further guidance on flue designations see Building Regulations *Technical Guidance Document J, Heat Producing Appliances*. See also guidance from the Solid Fuel Association; www.solidfuel.co.uk and HETAS; www.hetas.co.uk.

The boiler should be located such that there is sufficient space to undertake the installation without difficulty, taking account of any requirements for the chimney and hearth. Where the replacement boiler is to be fitted in the existing location it should be ensured that the manufacturer's minimum installation clearances are followed. The location should provide sufficient access for repair, maintenance and servicing.

The existing air supply provisions should be checked to confirm that they are satisfactory for the replacement boiler, see Table 35. All installations should have a correctly-sized purpose made, non-closable vent to ensure sufficient air for combustion. Where new or additional vents are provided, they should be sited to minimise cold draughts.

Extract fans should not be sited in the same room as the appliance. Where an extractor fan is fitted in the dwelling, additional ventilation may be required in the same room to avoid negative pressure affecting the operation of the chimney, see 10.2.1.4.

Any motorised valves used in the pipework should be of the 'normally-open' type in the case of power or component failure for safety reasons.

Where a dual fuel link-up system is being considered, care should be taken to ensure the pipework arrangements linking the systems are safe and effective. This may be achieved by having a twin coil cylinder or heat exchanger to completely separate the primary circuits for each boiler. Each boiler should have independent feed, expansion and venting arrangements. The system design, installation, controls and electrical systems should be safe, suitable and energy efficient and specialist advice obtained as appropriate.

When a solid fuel back boiler is no longer needed and the fireplace is to remain in service, the back boiler should be removed and any pipework to the solid fuel hot water system disconnected and made safe. Where an open fire is to remain in use (or may be brought back into use) a replacement fire back should be installed so that the fire can be safely used.

Room heaters with back boilers are not designed to be used without water circulation. Back boilers may become redundant when heating systems are upgraded. Where a room heater is still required the existing back boiler room heater should be replaced by a room heater with no back boiler.

For solid fuel bulk storage it is recommended that there should be a weatherproof, robust fuel store with easy access for delivery and removal of fuel. The store should be capable of containing at least six weeks supply (for mineral fuel this should be at least 0,5 tonne). The opening through which the fuel is tipped should be accessible. Table 40 shows recommended storage for domestic systems supplying primary heating and hot water with deliveries approximately every three months:

Table 40 - Recommended bulk wood biomass storage requirements

Dwelling size (floor area m²)	Wood pellets m³	Wood chips m³	Logs – stacked m³
<80 m²	1,5	3,5	3
80-160 m²	2	5	4
>160 m²	3	6	5

11.8 Electric heating systems

11.8.1 Options

Most existing electric heating systems make use of storage heaters or electric boilers coupled to heat emitter systems. Where direct acting on-peak heating systems, including electric ceiling and under floor systems are being replaced, specialist advice may be obtained as appropriate.

Electricity suppliers provide reduced off- peak electricity tariff options. Before replacement storage heating is chosen the current electricity tariff options should be considered.

Where an existing storage heater system or electric boiler system requires replacement, alternative heating options such as gas/oil wet central heating or a heat pump should be considered. In high density developments district heating and Combined Heat and Power (CHP) schemes should also be considered.

Replacement storage heaters should have both automatic charging control plus controls to adjust the heat output. Fan-assisted storage heaters should be considered for rooms not occupied throughout the day, so that heat delivery can be delayed until the times required. Also integrated storage/direct acting units may be used to provide a more consistent room temperature over the day. This may increase running costs by consuming additional on-peak electricity.

Direct-acting panel heaters/convectors used in intermittently used rooms should be fitted with both time and temperature controls. Where permanently installed fan-heaters are used, e.g. in bathrooms, the unit should include a timer which will only allow operation for a fixed time.

11.8.2 Design Considerations

For storage heater replacement it should not be assumed that existing units are sized correctly. The original sizing may have been incorrect, and since installation it is likely that the dwelling insulation levels have been improved. A suitable design method to ensure the correct sizing and selection should be used see DOM 8, *Guide to the Design of Electric Space Heating Systems*, TEHVA.

Where on-peak electric boiler systems are used, space heating and hot water demand should be established as given in 11.3.1 and 11.3.2. Where possible a thermal store should be included to take advantage of cheaper off-peak electricity. Where a boiler with a wet or dry thermal store is used the store should be sized correctly in relation to heating needs and specialist advice should be sought as appropriate.

11.8.3 Installation considerations

To minimise losses it is recommended that storage heaters are not positioned under a window; a location on an inner wall as close as possible to an external wall is recommended. Consideration should be given to access and egress from doorways and the location of local isolation switches so they are accessible.

11.9 Warm Air Systems

Existing warm air systems provide space heating by the controlled distribution of warm air via ducts to individual rooms. Warm air heaters incorporate a fan which is completed isolated from the combustion system. Modern units include step-controlled burners and infinitely varying fan speed to provide close control of temperature.

Replacement of the heater unit is the most straightforward retrofit option. Replacement should meet the guidance for zoning and control given in the HDHW Compliance Guide. New heaters should be provided with time and temperature controls. Where extensive modifications are being made, dwellings with a usable floor area of up to 100 m^2 should be divided into at least two space heating zones with independent timing controls if practicable. Where greater than 100 m^2, the independent zones should have separate timing and temperature controls.

Many existing warm air heaters incorporate a circulator water heater connected to a common flue. The water heater is a separate appliance with its own controls which are separate from the air heater. Where practical the primary circulation to the hot water cylinder should be pumped. Control of the hot water circuit should be using a cylinder thermostat and time control which is wired such that when there is no demand, both pump and circulator are switched off.

Where ductwork is replaced it should be insulated. See BS 5422.

NOTE For guidance on installation see BS 5864.

11.10 Water heating

11.10.1 Options

Where the existing water heating system is coupled to an existing gas, oil or solid fuel central heating system, the system improvement considerations are system circulation and control, hot water storage capacity, insulation and heat exchanger performance.

Where the existing domestic hot water is heated by electricity, the system improvement considerations are the hot water storage capacity, insulation, the availability and choice of off-peak tariff options or an alternative heating source.

The use of water heating appliances which require direct connection to a mains water supply are not recommended. Where these exist it is recommended that they are replaced by an alternative e.g. connected to cold water storage system.

Where practicable, if a hot water system is being upgraded consideration should be given to the installation of a solar thermal system or alternatively, to fitting a hot water cylinder with an additional heat exchanger to allow for solar heating to be installed at a later date.

11.10.2 Design considerations

Water heating systems should be specified to meet the requirements given in the HDHW Compliance Guide .

Replacement hot water cylinders should be sized to meet the hot water demand as given in 11.3.2.

Replacement indirect vented hot water cylinders should be used in combined fully-pumped heating and hot water systems and should comply with the performance requirements in BS 1566 Type P cylinders.

Where replacement indirect vented hot water cylinders are to be used with gravity hot water systems they should comply with the performance requirements of BS 1566 Type G cylinders.

New cylinders should be factory insulated such that the standing heat loss does not exceed 1,28 x (0,2 + 0,051 $V^{2/3}$) kWh per 24 hours. All cylinders should be labelled with the standing heat loss in kWh/24 hours. Where V is the nominal storage capacity in litres. e.g. a 120 litre cylinder to BS 1566 should have 35 mm of PU-foam insulation (density 30 kg/m^3).

Indirect cylinders should also be labelled with the heat exchanger performance in kW as measured by BS 1566:2002 (vented). Where cylinder capacity (V) in litres is less than 200, the ratio of V to heat exchanger performance (in kW) should not exceed 10, e.g., a 150 litre cylinder should have a minimum heat exchanger performance of 15 kW. Where V is 200 or above the cylinder should have a minimum heat exchanger performance of 20 kW.

Replacement electrically heated direct hot water cylinders should be factory insulated such that the standing heat loss does not exceed 1,28 x (0,2 + 0,051 $V^{2/3}$) kWh per 24 hours. All cylinders should be labelled with the standing heat loss in kWh/24 hours.

NOTE Further design guidance for electric hot water systems is given in DOM 9, *Guide to the Design of Electric Water heating Systems*, TEHVA.

The grade of construction for the hot water cylinder should be selected depending on the operational pressure e.g. static or pumped. See BS 1566-1 and I.S. 161.

Indirect hot water cylinders in combined heating and hot water systems should be controlled using a cylinder thermostat, motorised valve and boiler interlock except in some solid fuel boiler systems where this may impede the heat dissipation, and may require a slumber radiator/heat sink, see 11.13.

Electrically heated direct hot water cylinders should have immersion heater(s) controlled by integral thermostats. The thermostats should incorporate a safety cut-out independent of the main thermostat, to limit the water temperature, should the thermostat fail. This cut-out should not reset automatically. Where existing immersion heaters are being used in upgraded systems, this requirement should be checked.

Where a solar thermal hot water top-up system is being fitted specialist advice should be obtained.

NOTE For further guidance see S.R. 50-2 *Code of Practice for building services – Part 2 Solar Panels* , NSAI; *Solar Heating, Design and Installation Guide*, CIBSE.

HEATING AND HOT WATER SYSTEMS

11.10.3 Installation considerations

Hot water primary circuits should be fully pumped except in solid fuel systems where gravity circulation is generally used.

Pipework should be designed so that heat loss from stored hot water does not occur by gravity circulation.

Existing hot water cylinders without insulation or poorly insulated should be fitted with a hot water cylinder jacket in accordance with BS 5615.

11.11 Room heaters

Where solid fuel room heaters are being replaced, the use of a 'closed' room heater will significantly reduce running costs and emissions.

Replacement gas fires should be of a type given in Table 7 of the HDHW Compliance Guide. Decorative fuel-effect fires should not be used for space heating as their efficiency is very low relative to heating appliances. Replacement oil-fired independent room heating appliances should have a minimum efficiency of that specified in the HDHW Compliance Guide.

Where possible the use of on-peak direct electric heaters should be avoided unless sited in a highly insulated dwelling with low heat demand. They should include a programmable time switch and integral or separate thermostatic control.

Adequate ventilation should be provided for room heaters.

NOTE For further details refer to HDHW Compliance Guide, Building Regulatons Technical Guidance Document J and I.S. 813.

11.12Heating pipework and heat distribution/emitter systems

11.12.1 Options

An open-vented system is pressurised by a feed and expansion cistern and includes a vent pipe open to atmosphere, see Figure 99. A sealed system is not open to atmosphere and includes an expansion vessel with a diaphragm to accommodate variations in water volume, see Figure 100. The type of system (open vented or sealed) should not affect energy efficiency. Existing systems are usually open-vented. Replacement systems and upgrades may follow either arrangement.

Hot water primary circuits should be fully pumped, except in some solid fuel systems where boiler manufacturer's instructions specify gravity circulation only.

Where heat emitters require replacement, the room heat requirements should be checked and the appropriate replacement type selected e.g. panel, LST (low surface temperature - a safer option where young children or elderly may be at risk), fan convector (where rapid response required), under floor, etc.

11.12.2 Design considerations

Open systems should include a feed and expansion cistern with suitable sized warning pipe in case of overflow, see Figure 99[4]. The volume should be sufficient to ensure the expansion of the system's primary water may easily be accommodated. The cistern should not be used for any other purpose. The open safety vent pipe should rise from its point of connection and should not contain restrictions such as valves.

Further information on the size and arrangements for feed and expansion pipes can be found in CIBSE *Domestic Heating Design Guide*.

In sealed systems the feed and expansion cistern is replaced with an expansion vessel incorporating a diaphragm to accommodate variations in water volume, see Figure 100[5]. The expansion vessel should have enough capacity to accommodate expansion of the whole primary water system. Additional safety controls including a pressure relief valve connected to an external discharge point should be fitted.

Where only the boiler is replaced, existing one-pipe systems may be retained if serviceable. Where

4 Minor components such as valves, controls, drains and vents are omitted for clarity

5 Minor components such as valves, controls, drains and vents are omitted for clarity

some circulation pipework/heat emitters are replaced a two-pipe system should be used.

Where a boiler is replaced and pipework changed, the design should avoid reversed circulation, which will cause the heat emitters to warm when only domestic hot water is operating. To avoid this all heating circuits should be taken from a common flow and all return circuits are taken from a common return before the return from the hot water cylinder is connected, see Figure 101.

11.12.3 Installation considerations

All water pipework, subject to practical constraints, should be insulated unless it contributes to the useful heat requirements of the dwelling. The primary circuit to the hot water cylinder should be insulated throughout, subject to practical constraints. All pipes connecting to a hot water cylinder, including the vent, should be insulated for at least 1 m from their point of connection to the cylinder.

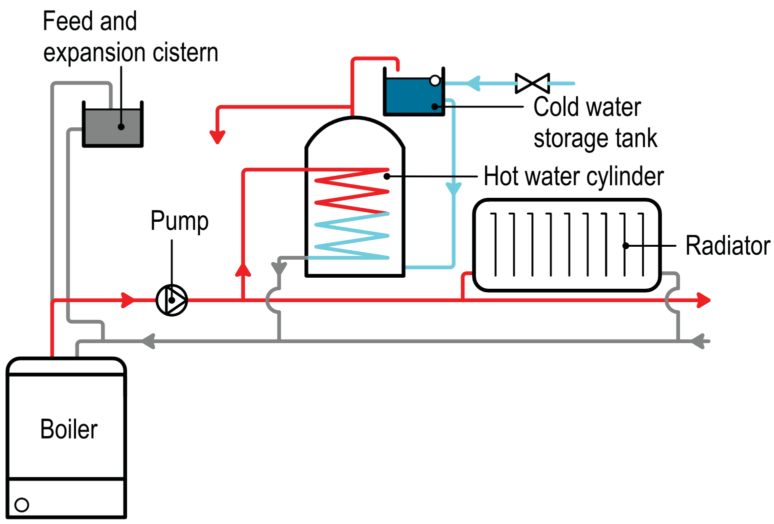

Figure 99 - **Open system**[4]

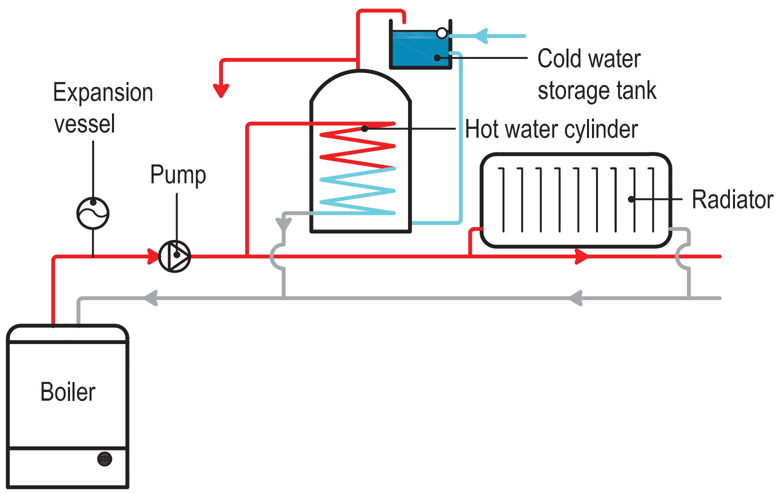

Figure 100 - **Sealed system**[5]

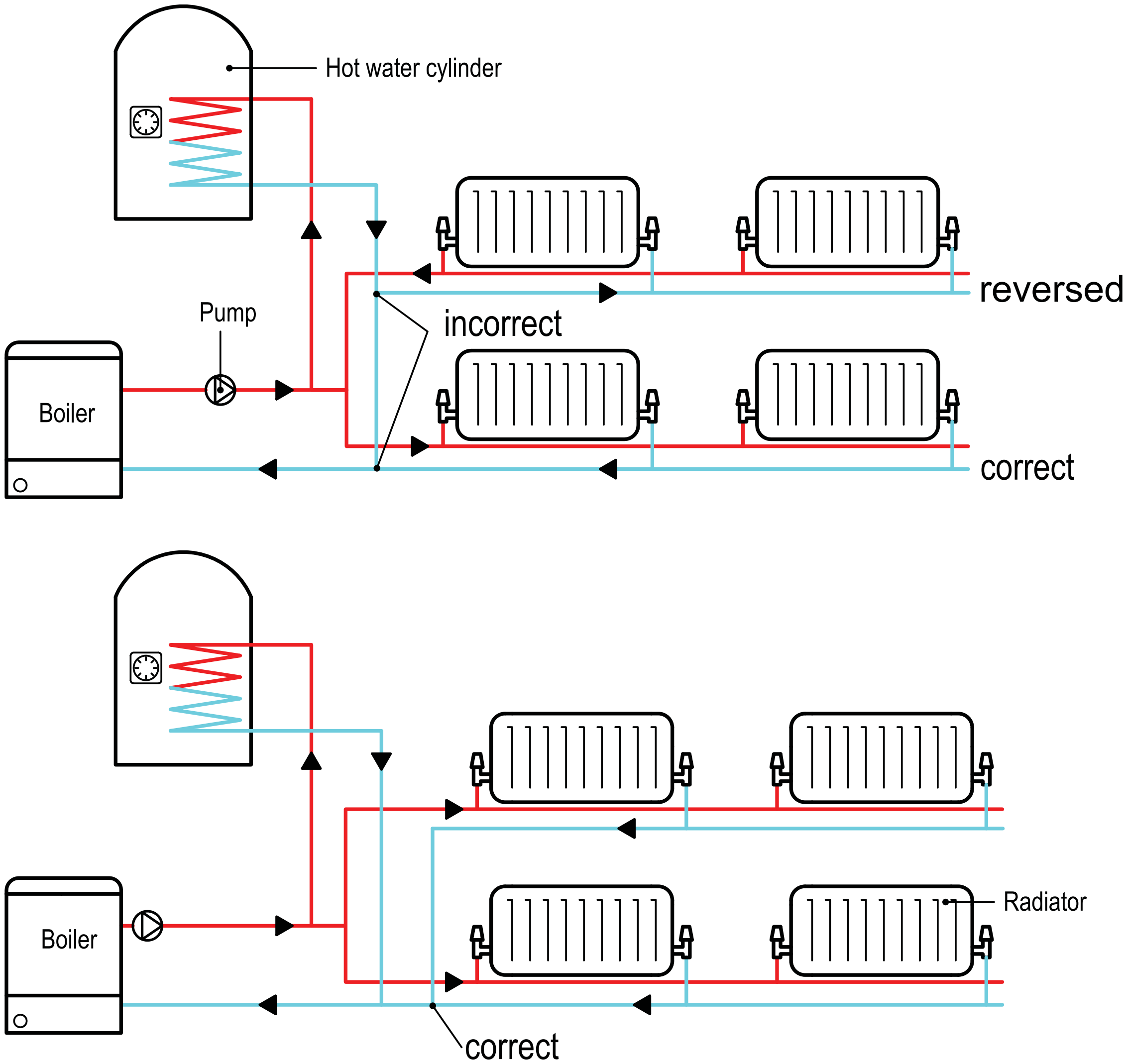

Figure 101 - **Avoiding reversed circulation**[5]

Pipework in an unheated area should be protected against damage from freezing with suitably sized pipework insulation.

NOTE See HDHW Compliance Guide and BS 5422.

All water pipework should be correctly sized to take account of pressure losses and include provision for venting and draining and safe isolation.

Where sealed systems are used, arrangements for filling and topping up the system should take account of restrictions governing the connections to mains water supply. Solid fuel boilers should not be fitted in sealed heating systems unless permitted by manufacturer's instructions.

Wall-mounted heat emitters should preferably be sited under windows and should be fitted between 100-150 mm above the finished floor level.

Manufacturers' instructions should be followed in regard to the height of the circulator within the system. Where a self-adjusting circulator is used it should be ensured that the minimum flow rate through the boiler cannot drop below that recommended in boiler manufacturer's instructions, particularly when subject to the operation of automatic boiler bypass valves.

Where connecting to existing pipework, special sizes/connectors may be required to ensure proper connection as there are differences between existing and currently available plumbing fittings.

Both new and existing systems should be thoroughly cleaned and flushed out before a new boiler is fitted. There are three cleansing and flushing options:

— mechanically-assisted powered cleanse and flush (power flushing);

- mains pressure cleanse and flush for sealed systems and open-vented systems with the feed and vent temporarily capped-off;
- cleanse and flush using gravity, with the assistance of a circulator pump.

A suitable method should be chosen depending on the age and condition of the system, the materials of construction and any previously identified system problems.

A suitable corrosion inhibitor should be used in the primary boiler circuit once cleanse and flush is complete to minimise corrosion and the formation of scale and sludge. The boiler manufacturer's instructions should be referred to in order to ensure suitable cleaning, softening and inhibitor products are used and any special requirements for particular models or materials are observed.

NOTE Further guidance is given in BS 7593. *Treatment of Water in Domestic Hot Water Central Heating Systems* and draft prS.R. 50-1 Code of practice — Building services — Part 1: *Domestic heating and plumbing the treatment manufacturer's instructions.*

11.13 Controls

11.13.1 Options

Where the boiler is being replaced or the system upgraded, the control system selected will depend on whether a Level A or Level B upgrade is being performed and also whether the usable floor area of the dwelling is greater than 100 m². For further details see the HDHW Compliance Guide.

For Level A – see Table 37 options M4, M6, M7 and M8

For Level B – see Table 37 options B4, B6, B7 and B8

Where the total usable floor area of the dwelling is over 100 m² floor space, for Level B there should be at least two space heating zones each having separate time and temperature controls.

Where an existing gas or oil fired semi-gravity system is being upgraded to M7 without changing the boiler, it should include the following controls:

- a programmer with separate heating and hot water channels;
- room thermostat for each zone;
- cylinder thermostat;
- boiler interlock;
- 2-port motorised valve on the gravity circuit to the hot water cylinder. The valve size should be such that gravity circulation is not inhibited;
- a check valve to inhibit gravity circulation to the radiator circuit;

TRVs may be fitted whilst the system is drained.

Where an existing solid fuel semi-gravity system is being upgraded to M4 without changing the boiler, it should include the following controls:

- a programmer with separate heating and hot water channels;
- room thermostat for each zone;
- cylinder thermostat;
- it should be ensured that the boiler manufacturer's instructions for heat dissipation through a slumber radiator are followed.

TRVs may be fitted whilst the system is drained.

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If a fully-pumped system with one heating zone to be upgraded to Level A, it should include the following controls:-

— a programmer with separate heating and hot water channels;

— room thermostat for the zone;

— cylinder thermostat;

— two 2-port motorised valves or one 3-port motorised valve for space heating and hot water control;

— boiler interlock for oil and gas boilers;

— an automatic bypass valve, if the boiler manufacturer's instructions require one;

— TRVs should be fitted on all heat emitters except in rooms where a room thermostat is fitted;

— for solid fuel boilers – additional controls for heat dissipation through a slumber radiator.

For Level B a programmable room thermostat with additional timing capability for hot water should be used in place of separate units.

Where a fully-pumped system with two heating zones is to be upgraded to Level A, it should include the following controls:-

— two programmable room thermostats one of which has additional timing capability for hot water;

— cylinder thermostat;

— three 2-port motorised valves for two space heating zones and one hot water zone;

— boiler interlock for oil and gas boilers;

— an automatic bypass valve if the boiler manufacturer's instructions require one;

— for solid fuel boilers – additional controls for heat dissipation through a slumber radiator;

— TRVs should be fitted on all heat emitters except in rooms where a room thermostat is fitted.

For Level B a programmable room thermostat with additional timing capability for hot water should be used in place of separate units.

The preceding options refer to the use of motorised valves to control individual zones. As an alternative, communicating TRVs that have the capability to respond to commands from a central controller may be used. The central controller should be able to turn off TRVs completely at times when heating in the zone is not required. When all TRVs are turned off in all zones the central controller should also turn off the boiler (electrically), unless there is a call for heat from a separate service (e.g., water heating). Failure to meet the last condition means that boiler interlock is not complete. The use of programmable TRV may also be considered as long as the system design includes boiler interlock.

11.13.2 Design considerations

For Level A upgrade (see Table 37), when a gas or oil fired boiler is replaced or system upgraded there should be separately controlled fully-pumped circuits for heating and hot water using either one 3-port or two 2-port motorised valves, see Figure 102. There should be a separate timing for heating and hot water, a room thermostat should be used to control space heating and a cylinder thermostat for hot water.

For some solid fuel boilers, fully-pumped systems are not recommended and manufacturer's instructions should be followed. This include arrangements for heat dissipation and gravity hot water, see Figure 104.

For Level B upgrade (see Table 37), when using gas or oil fired boiler, each heating zone should be controlled using a programmable room thermostat, one of which should include additional timing capability for the domestic hot water. Each space heating zone should be controlled by a motorised valve (either 2 or 3-port). Alternatively communicating TRVs may be used,see 11.13.3.

TRVs should be installed on all radiators except in rooms with a room thermostat or a slumber radiator. An automatic bypass valve should be installed where the manufacturer's instructions require one, or if they specify that a minimum primary flow rate has to be maintained whilst the boiler is firing.

All gas and oil-fired boiler-based systems should have boiler interlock. This means controls wired so that when there is no demand for either space heating or hot water the boiler and pump are switched off. An example of boiler interlock wiring is shown in Annex E.

Frost protection should always be considered for the dwelling, the boiler and heating system.

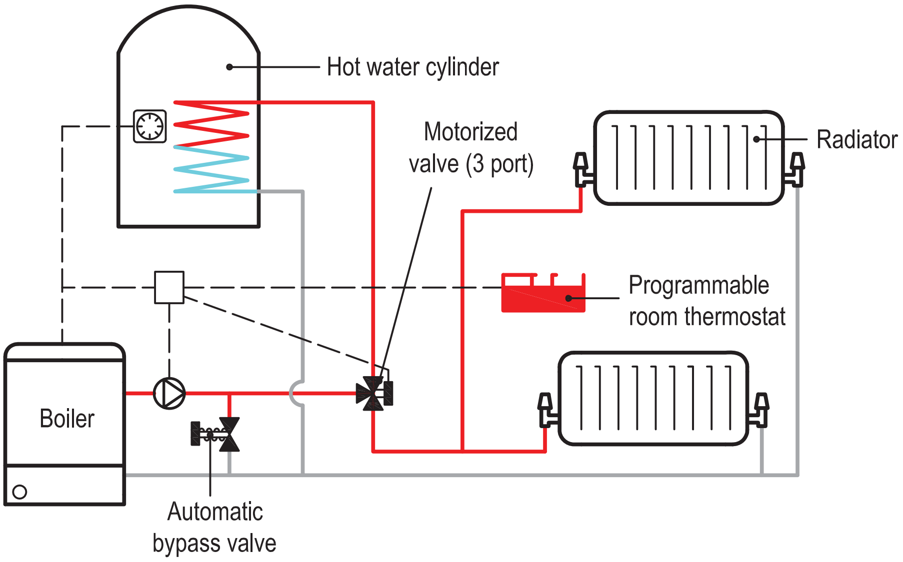


Figure 102 - Example of a possible schematic arrangement for gas/ oil boiler in single heating zone using one three port motorised valve.

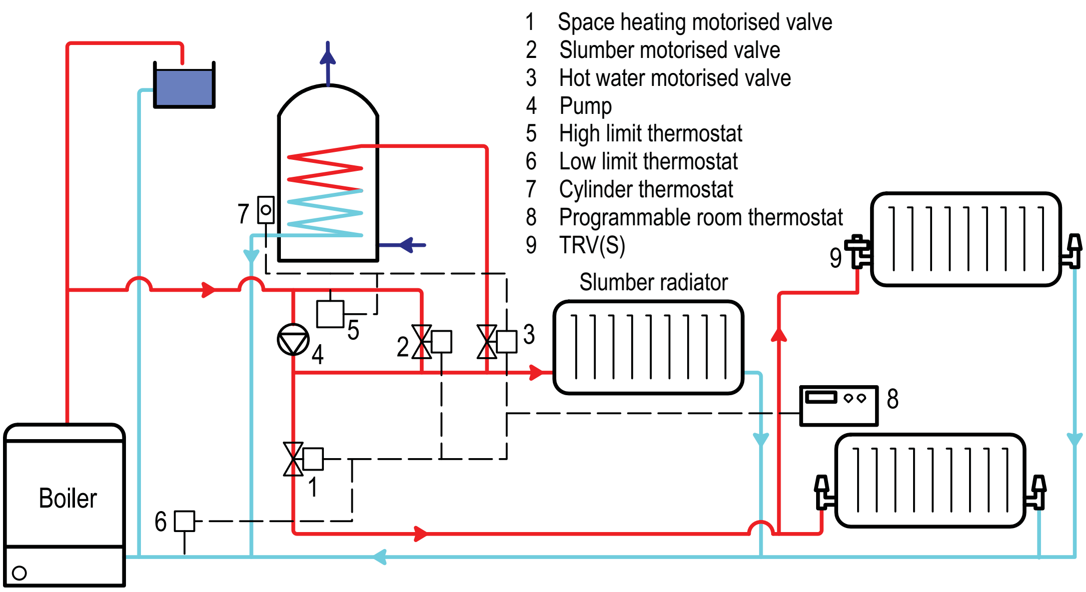


Figure 103 - Example of a possible schematic arrangement for solid fuel boiler with fully pumped circulation and one heating zone

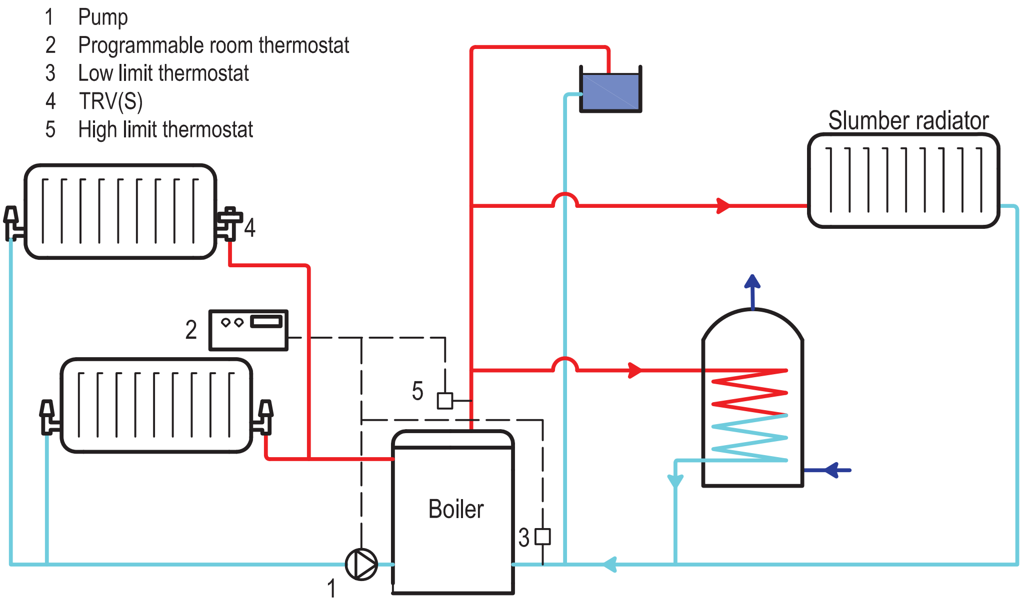


Figure 104 - **Example of a possible schematic arrangement for solid fuel boiler with gravity hot water and one heating zone**

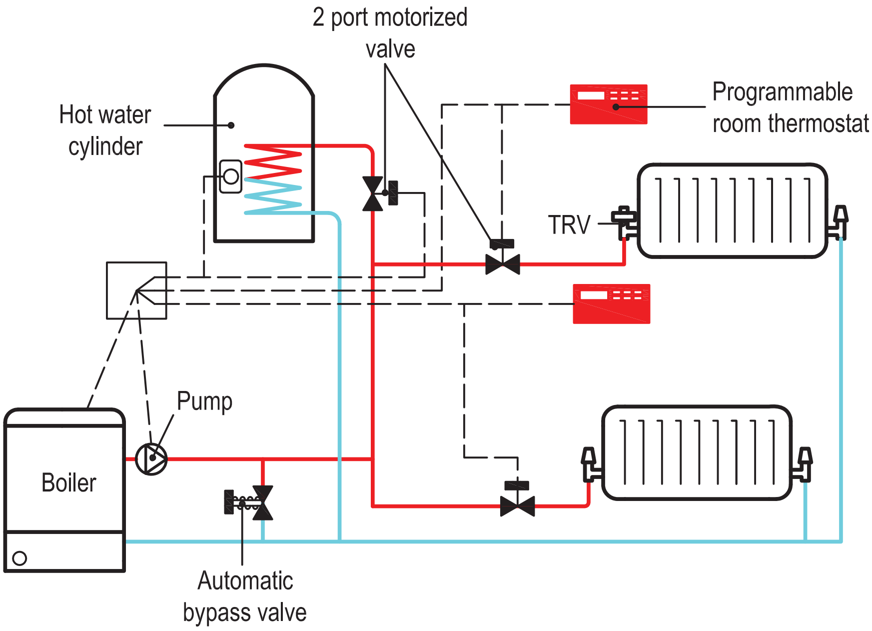


Figure 105 - **Example of a possible schematic arrangement for gas/oil boiler with two heating zones using three two port motorised valves**

Where a dual fuel link-up system is specified, the primary circuits to each boiler should be thermally separated. The circuit for the gas or oil boiler should include the Level A or Level B controls in 11.13.1. The system design, installation, controls and electrical systems should be safe, suitable and energy efficient and specialist advice obtained as appropriate. The use of purpose designed systems may be considered.

More advanced controls, such as weather compensation, enhanced load compensation, delayed/ optimum start and boiler modulating room thermostats may also be considered. Where weather compensation and load compensation controls are used with intermittent heating special provision should be made for cold starting conditions.

HEATING AND HOT WATER SYSTEMS

11.13.3 Installation considerations

Room thermostats (including programmable) should be located in a regularly heated area, away from draughts, internal heat sources and direct sunlight. They should be mounted approximately 1,5 metres from ground level and not in a room where supplementary heating is used, e.g. open fire. Time switches and programmers should be located where they can be easily reached, read and adjusted.

Cylinder thermostats should be located about one third of the way up from the base of a cylinder that includes one heating coil. Where two or more coils are fitted, manufacturer's instructions should be followed. Cylinder thermostats should be set to around 60 °C. If set too high, it may result in scalding, if too low it may increase the risk of legionella bacteria.

Motorised valves should not be positioned in the line of the open safety vent pipe or the feed and expansion pipe. Solid fuel systems should use normally-open motorised valves (i.e. they close only when power is applied) to ensure safe operation in the event of power failure or malfunction.

Where only the boiler is replaced, existing one-pipe systems can be retained if serviceable. Where some circulation pipework/heat emitters are replaced a two-pipe systems should be used.

Boiler interlock can be achieved by correct wiring interconnection of the room thermostat(s), cylinder thermostat, and motorised valve(s), see Annex E. Interlock may also be achieved by more advanced controls, such as a boiler energy manager. Standard TRVs alone are not sufficient for boiler interlock.

TRVs may be installed on the flow or the return to the radiator. Unless the TRVs are suitable for bi-directional flow, the direction of water flow should be taken into account when fitting. Where TRVs are being fitted to a one-pipe system, units designed for minimum flow resistance should be used.

Where an automatic bypass valve is fitted, it should be installed between the boiler primary flow and return, taking account of the direction of flow. It should be ensured that the valve has adequate flow capacity and is adjusted so that there is adequate flow through the boiler when all motorised valves and/or TRVs close.

Where frost air and pipe thermostats are used, the contacts should be wired in series and independent of time switch/programmer/room thermostat circuits so that protection is available 24 hours a day. Where the boiler itself has its own frost protection, consideration should also be given to the rest of the dwelling.

11.14 Final steps

11.14.1 Commissioning

To ensure safe and energy-efficient operation, all parts of a retrofitted heating and hot water system should be checked and adjusted to ensure they are working properly and the system brought to a state of readiness for normal service. This should include both new and existing parts of the system. In particular:

- the installation should be checked for compliance with the Building Regulations and any key documentation prepared including RGI certificates for domestic gas appliances;
- a suitable corrosion inhibitor should be used in the boiler primary water circuit to minimise corrosion and the formation of scale and sludge (subject to recommendations by the boiler manufacturer);
- the key system components should be checked for correct and safe operation;
- the controls should be set for normal heating and hot water service, after consultation with the householder;
- commissioning guidelines are provided for different systems in the HDHW Compliance Guide;

- where new appliances or flues are fitted to existing systems the overall installation (new and existing) should be checked and tested for safe operation e.g. smoke test to ensure integrity of flue and connected systems. Any faults found should be rectified;
- outside Smoke Control Areas, any fuel may be used subject to the solid fuel manufacturer's instructions for the appliance concerned. Within Smoke Control Areas guidance under S.I. No. 278/2000 should be followed;
- for replacement flues requirements for notice plates should be followed, see Table 41.

Table 41 - **Requirements for notice plates**

REQUIREMENTS FOR NOTICE PLATES
Where a hearth, fireplace (including a flue box), flue or chimney is provided (including cases where a flue is provided as part of the refurbishment work), a notice plate containing key information essential to the correct application and use of these facilities should be permanently posted in the building. The information should include the following:
a) the location of the hearth, fireplace (or flue box) or the location of the beginning of the flue;
b) the category of the flue and generic types of appliances that can be safely accommodated;
c) the type and size of the flue (or its liner if it has been relined) and the manufacturer's name;
d) the installation date and the installers name and registration number (where applicable).
Notice plates should be robust, indelibly marked and securely fixed in an unobtrusive but obvious position within the building such as:
a) next to the electricity consumer unit;
b) next to the gas consumer unit;
c) next to the chimney or hearth described.

11.14.2 Customer advice

Installers should instruct the householder how to set and use the controls properly and effectively.

All appropriate manufacturers' instructions should be left with the householder. It is recommended that the following is demonstrated to the householder:

- how to set the programmer clock and adjust it for GMT and summer time;
- how to separate space heating and domestic hot water time settings;
- the use of the time control override function;
- how to set summer hot water only;
- how to set room and cylinder thermostats;
- how to set TRVs.

NOTE For further guidance see '*Domestic heating by gas boiler systems: guidance for installers and specifier: Energy Efficiency Best Practice in Housing* (CE30), Annex E, for the functioning of a room thermostat, cylinder thermostat, programmer, programmable room thermostat, and thermostatic radiator valve (TRV).

The installer should explain:

- the function of room thermostats and TRVs and the need to set them carefully to avoid wasteful heating. They should be altered when the needs of the household change, and should not be treated as on/off switches;
- that the cylinder thermostat should be left at approximately 60 °C, since setting it higher may result in scalding while setting it lower may allow the growth of legionella bacteria;

— that the radiator lockshield valves and automatic bypass valve should not be adjusted once set by the installer;

— why it is better to switch space and water heating off when not required. It is expensive and wasteful to open windows while the heating system remains on;

— why it is better to use other more efficient heating sources instead of solid fuel appliances when only water heating is required;

— why it is better to turn the room thermostat down to frost protection levels (approximately 12 °C) unless a separate frost protection system has been fitted;

— that sealed boiler systems should have adequate system pressure and what to do if re-pressurising is needed;

— the importance of maintaining ventilation and the associated risks of carbon monoxide.

11.14.3 Servicing

Users should be made aware of the importance of regular servicing, both of the appliance and the system as a whole. This helps maintain the safety and efficiency of the heating appliance. Users of solid fuel appliances should be advised about the need for regular flue sweeping and that on some appliances, some parts (such as the throat plate) may need to be cleaned frequently. Domestic gas appliances should only be serviced by Registered Gas Installers.

11.15 Non-traditional space heating and water heating systems

11.15.1 Solar thermal hot water

Solar thermal hot water systems capture heat from the sun and use it for heating domestic hot water. Evacuated tube collectors or flat plate collectors may be used. They absorb the incident solar radiation, which is transferred to the domestic hot water supply through a water circuit and second coil in the domestic hot water storage cylinder. The size of the "solar zone" in the cylinder is an important parameter in determining how much solar heat may be stored.

The use of solar water heating provides the opportunity to reduce running costs and carbon emissions when used in conjunction with wet central heating systems. Depending on system design a thermal solar system can provide most of the average dwelling domestic hot water requirement in the summer. For design purposes in Ireland solar fractions between 50 % and 60 % are considered optimum.

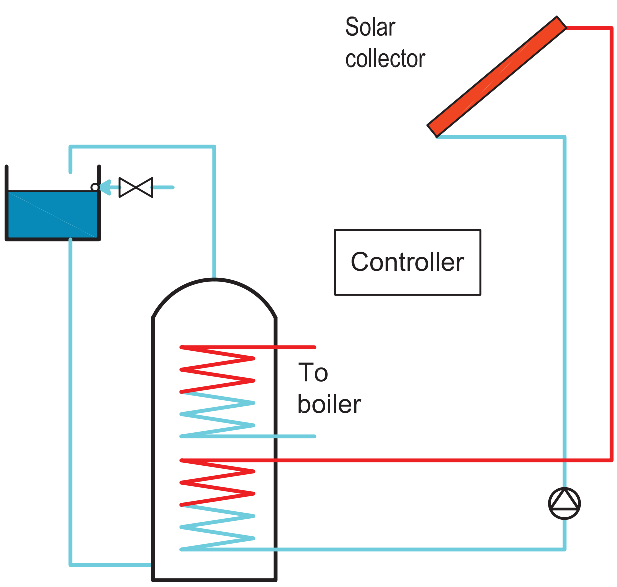


Figure 106 - Typical schematic of a solar water heating system for connection to a boiler

HEATING AND HOT WATER SYSTEMS

There is a range of different systems available, but the general principle is that roof-mounted solar collectors are heated by the sun, and the heated water is passed to a hot water storage cylinder with a separate solar heating coil. This water is then further heated to raise the temperature, if necessary, by the gas or oil-fired boiler system.

An example of a typical open vented system with a large cylinder containing an additional solar heat exchanger (usually referred to as "twin-coil") is shown in Figure 106. When systems are being upgraded and the hot water cylinder is being replaced, consideration should be given to installing a larger cylinder containing a solar heating coil. This facility will then save cost and disruption if it is decided to install solar heating panels at a later date.

Where this option is being considered separate guidance and advice should be sought.

NOTE For further guidance see S.R. 50-2 *Code of Practice for building services – Part 2 Solar Panels*, NSAI; *Solar Heating, Design and Installation Guide*, CIBSE.

11.15.2 Heat pumps

Heat pumps are a heating system replacement option which are worth considering mainly outside the gas supply area. The environmental benefit is affected strongly by the CO_2 emissions associated with the electricity supply.

Ground source or air source heat pumps can be specified. Ground source units make use of the energy stored as heat in the ground, and electricity is used to move it from the ground to the dwelling. Air source units concentrate the heat from the outside air and transfer it to the dwelling. Air source heat pumps are generally less efficient than ground source. Both types utilise a compression and evaporation cycle in a similar way to a domestic refrigerator.

Heat pumps operate more efficiently when the temperature lift is small. For these reasons larger radiators, or other heat emitters, than would be used for a boiler system are installed. This allows the temperature of the circulating water to be reduced while still providing sufficient heat to the rooms. For the domestic hot water service, in which primary water at about 65 °C is needed to heat the cylinder to 60 °C, the efficiency of the heat pump is significantly reduced and an immersion heater is generally provided for additional heating. Also it is important to size the unit to match the dwelling heat demand to avoid rapid stop-start operation which reduces efficiency and raises running costs. Thus the actual COP/efficiency in–use will depend very much on emitter size and how the system is controlled and used.

Heat pump systems have significantly higher capital and installation costs compared with traditional heating systems and therefore the benefits over the lifetime of the system should be carefully considered. Special procedures should be followed to design a satisfactory heating and hot water system using a heat pump.

NOTE The UK's MCS (Microgeneration Certification Scheme) has a series of Microgeneration Installation Standards (MISs) that cover a range of microgeneration technologies including heat pumps. See Section 4 (Design and Installation requirements) of MIS 3005 *Heat Pump Systems*'.

11.15.3 Micro-CHP

Micro-CHP is an engine or turbine and generator or fuel cell intended to provide both heat and power for individual dwellings. In some respects it operates in a similar way to a traditional boiler, at the same time generating electricity that can be used in the dwelling or exported to the grid for use by others. The micro-CHP unit may be designed either as a complete boiler replacement providing most or all of the heat for the dwelling, or as a low powered device to meet the heating and hot water base load with additional heating to come from separate appliances.

From an energy perspective, the total "efficiency" of a micro-CHP system may be similar to a condensing boiler but the electricity produced has a much higher commercial value than heat. It is the value of this electricity, and the offsetting of CO_2 emissions from central electricity generating plant, that justify the extra capital cost of a micro-CHP unit.

Micro-CHP systems should be selected and sized carefully to match the heating and hot water design requirements of the dwelling and so ensure optimum performance is obtained. They are significantly more expensive to buy and install than conventional boilers and the amount of electricity generation will significantly affect the economic benefits.

NOTE See Section 4 (Design and Installation requirements) of MIS 3007 'Micro-CHP' (Heat and electricity led) for guidance.

12. Residential lighting

12. Residential lighting

12.1 Introduction

This clause covers the guidance for residential lighting in three main areas of:

— general indoor lighting;

— directional indoor lighting; and

— outdoor lighting.

Typical solutions currently in use in domestic lighting including lamp and luminaire types, system layout and control schemes are described in 12.3. Recommendations for suitable retrofit measures are given in 12.4 and example applications are given in 12.5.

Correct lighting levels are essential for visual comfort, safety and for aesthetic effects. However, electric lighting consumes a lot of energy and significant energy savings can be made by the use of efficient electric lighting and maximising the use of daylight.

When implementing retrofit measures, guidance for lighting design and standards for energy efficient lighting should be consulted.

NOTE Further guidance is available in CIBSE SLL Code for Lighting, CIBSE SLL Lighting Handbook and I.S. EN 12464-1.

12.2 Existing types of lighting

12.2.1 General indoor lighting

The most traditional lamps for indoor residential lighting are tungsten lamps, see 12.3.1.1, tungsten halogen lamps, see 12.3.1.2, and compact flourescent lamps (CFLs), see 12.3.1.3.3.

There are various types of luminaires used for general indoor lighting, see 12.3.2.

Generally, lamps with warm colour appearance with colour temperatures of between 2 700 K to 3 000 K are considered to create a pleasant environment. Warm tungsten lamps should be replaced with CFL's which give a warm colour appearance. Low quality plug-in CFLs may give a cool colour apprearance.

Indoor lighting is usually controlled by local manual switches, see 12.3.3.2. Manual dimmer switches, see 12.3.3.3, and timers, see 12.3.3.6, are also used.

12.2.2 Directional indoor lighting

Directional indoor lighting includes task and accent lighting.

Task lighting is common in the vast majority of residential applications and is usually achieved by portable luminaires or table lamps, under cabinet lighting in kitchens, pendant luminaires over eating areas or vanity fixtures in bathrooms.

Accent lighting is rarer and is typically fitted by track and rail mounted luminaires or ceiling-recessed fixtures with asymmetric or adjustable beam direction.

The most predominant lamp type currently used for directional indoor lighting are tungsten halogen lamps. Some non-directional lamp types such as CFLs, tungsten lamps and fluorescent tubes may be incorporated in task lighting luminaires to provide directional lighting, such as under cabinet or vanity lighting. An increasing number of LED lamps are being used for directional lighting. See 12.3.

Directional indoor lighting is typically controlled via local manual switches, see 12.3.3.2.

12.2.3 Outdoor lighting

Typical outdoor lighting of domestic buildings includes lighting in porches, entry ways, paths, garden lighting or outbuildings.

Lanterns or downlighters using tungsten lamps or CFLs are typically used in porches or entry ways.

Paths may be lit using bollards incorporating CFLs, LED lamps or using ground-recessed spotlights fitted with LED lamps. See 12.3.1.

Wall-mounted downlighters fitted with CFLs or LED lamps, may be used to light outbuildings or pathways adjacent to the house. See 12.3.1.

Garden lighting is typically done by bollards or spotlights.

Outdoor lighting is usually controlled either via local manual switching daylight sensors and presence detectors. See 12.3.3.

There is an increasing variety of light fixtures fitted with LED lamps, a small integral photovoltaic panel and internal rechargeable batteries to provide autonomous outdoor lighting. Their light output is typically low and are therefore used for decorative purposes or for the lighting of pathways and gardens.

12.3 Lighting technology

12.3.1 Types of lamps

12.3.1.1 Tungsten lamps

Tungsten lamps are traditional incandescent lamps used for general lighting service or decorative lighting (i.e. candle-shaped or golf-ball shaped bulbs). Between 90 % and 95 % of the electrical power used by tungsten lamps is converted into heat and the lamps have a very low luminous efficacy (generally between 8 lm/W and 15 lm/W). Tungsten lamps have a relatively short life compared with other lamps, see Table 42.

The advantages of tungsten lamps include, excellent colour rendering, easy dimming, warm colour appearance, universal operating position and immediate full lighting level achieved when switched on. The use of control gear is not required.

Due to their inefficiency tungsten lamps have been phased out under European Regulation 244/2009/EC.

Tungsten lamps should not be installed as a retrofit measure.

12.3.1.2 Tungsten halogen lamps

Tungsten halogen lamps are incandescent lamps where the tungsten filament is sealed inside a quartz capsule containing a small quantity of halogen. This allows the lamp to burn hotter and more efficiently, producing whiter light than tungsten lamps.

Tungsten halogen lamps should be compliant with I.S. EN 60357, I.S. EN 60432-2, I.S. EN 60432-3.

Extra low voltage (ELV) versions of 6V, 12V and 24V should be fitted with transformers. Electronic units which can be dimmed may be installed.

The luminous efficacy is typically within the range of 10 lm/W to 25 lm/W. Higher efficiency versions using infrared reflective coating technology are available and use up to 30 % less energy than standard tungsten halogen lamps.

Tungsten halogen lamps should not be installed as recessed lighting as they may be an ignition source for fires.

There was a trend towards installing arrays of tungsten halogen downlights in spaces, this is an inefficient method to light a space and can give harsh shadows and a dark ceiling.

The small size of the halogen capsule makes these lamps more suitable for directional lighting applications, such as task and accent lighting. They have excellent colour rendering, are fully dimmable and attain full lighting levels immediately when switched on. However, tungsten halogen lamps are still relatively inefficient. More efficient replacement LED options are described in 12.4.1.3.

12.3.1.3 Fluorescent lamps

12.3.1.3.1 General

Fluorescent lamps include both linear fluorescent tubes and CFL's. They provide a range of colour rendering and a warmer colour appearance with colour temperatures of 2 700 K to 3 000 K are typically used in domestic environments.

Fluorescent lamps require a ballast to start the lamp and to ensure a precise flow of electrical current through the tube. High frequency electronic ballasts use less than half of the electricity required by conventional magnetic ballasts and also improve lamp life and reduce lamp energy consumption, eliminate flicker and noise.

12.3.1.3.2 Linear flourescent lamps

Linear fluorescent lamps are highly efficient, with a typical luminous efficacy in the range of 50 lm/W to 104 lm/W and have a relatively long life, typically up to 24 000 hours. Halophosphate lamps use a single type of phosphor which degrades over the lamp life resulting in loss of light output and have a low colour rendering.

12.3.1.3.3 Compact fluorescent lamp (CFL)

The compact fluorescent lamp (CFL) is a miniature version of the standard fluorescent tube. The CFL is available in a variety of sizes and shapes.

The CFL should be used to replace the less efficient tungsten lamp, see 12.3.1.1.

The CFL typically uses 75 % less energy for the same light output (typical luminous efficacy 20 lm/W to 88 lm/W), and reaches longer life (typically 8 000 h to 15 000 h). There are two types of CFLs available:

— plug-in CFLs with simple bayonet or Edison screw caps which have an integral ballast and may be used as direct replacements for tungsten lamps in most existing luminaires; and

— pin-base CFLs which need separate control gear and specially designed luminaires.

CFLs may take between 15 seconds to 30 seconds to reach full brightness. Those with electronic control gear reach full output within a few seconds.

Most 4-pin fluorescent tubes and 4-pin base CFLs can be dimmed, but it is not always possible to dim smoothly down to near extinction. With electronic dimming ballasts, it should be possible to dim some fluorescent tubes down to 2 % and 4-pin CFLs down to 5 % of their nominal light output. A small number of plug-in CFLs incorporate special gear which allows dimming, but generally plug-in CFLs cannot be dimmed, see 12.4.3.

12.3.1.4 LED lamps

A light emitting diode (LED) is a lamp based on semi-conductor technology. Recent improvements in efficacy, colour rendering and lamp life has made this an effective replacement lamp. White light can be produced either by combining red, green and blue LED lamps or by using phosphor coating to convert ultraviolet light (or blue light) to white. The features of LED lamps include:

— the provision of inherently directional light sources, suitable for decorative, accent and task lighting;

— a long life (10 000 to 50 000 hours) and luminous efficacy of between 40 lm/W and 70 lm/W which is fast improving;

— improved performance at low temperatures whilst requiring an appropriate heat sink or ventilation;

— may be dimmed, see 12.4.3.

LED lamps vary widely in their performance. The manufacturer should provide detailed information about the lamp output. LED lamps should be complaint to I.S. EN 62031 and other relevant European Standards where applicable.

LED lamps should not be installed as replacement lamps for enclosed luminaires.

Table 42 - **Summary of key characteristics for different lamp types**

Lamp type	Sample image	Luminous efficacy (lm/W)	Colour appearance[a] (K)	Colour rendering (Ra)	Lamp life (hours)
Tungsten lamp		8 to 15	2 700	100	1 000
Tungsten halogen lamp		10 to 25	2 700 to 3 000	100	1 500 to 2 000
T8 linear fluorescent lamp		50 to 96	2 700 to 6 500	50 to 98	8 000 to 24 000
T5 linear fluorescent lamp		80 to 104	2 700 to 6 500	82 to 95	8 000 to 24 000
T2 linear fluorescent lamp		55 to 70	2 700 to 6 500	80 to 85	8 000 to 12 000
Plug-in compact fluorescent lamp		20 to 74	2 700 to 6 500	80 to 90	6 000 to 12 000
Pin-base compact fluorescent lamp		30 to 88	2 700 to 6 500	85 to 90	8 000 to 15 000
LED lamp		40 to 70	2 700 to 6 500	60 to 90	10 000 to 50 000

a) Colour appearance may also be referred to as the colour temperature.

12.3.2 Luminaires

There are a large variety of luminaires to provide different types of lighting and to suit different lamp types. The most common luminaire types used for residential lighting are summarised in Table 43.

Luminaire should comply with a European Standard within the I.S. EN 60598 series.

Table 43 - Types of luminaire and lamp type

Luminaire Type	Fixing	Purpose	Lamp Types
Uplighter	Wall mounted or floor standing	Ambient lighting	All lamp types
Ceiling mounted	Ceiling	Ambient lighting	Tungsten lamp, see 12.3.1.1; or Fluorescent lamps, see 12.3.1.3
Ceiling recessed	Ceiling	Ambient or accent lighting (adjustable beam direction)	CFLs, see 12.3.1.3.3; Tungsten halogen lamp, see 12.3.1.2; or LED lamp, see 12.3.1.4
Chandelier	Ceiling	Ambient lighting in halls, foyers, or dining rooms higher than 3 m	Tungsten lamp, see 12.3.1.1; or CFLs, see 12.3.1.3.3
Pendant	Ceiling	Task lighting in kitchens or over an eating area or general lighting in particular areas	Tungsten lamp, see 12.3.1.1; or CFLs, see 12.3.1.3.3
Directional	Track and rail mounted	Accent lighting primarily; contribution to space ambience	Tungsten halogen lamp, see 12.3.1.2; or LED lamp, see 12.3.1.4
Under cabinet or under shelf	Cabinet or shelf	Task and accent lighting	Fluorescent tubes, see 12.3.1.3.2; longer 2-stick CFLs, see 12.3.1.3.3; or LED lamp, see 12.3.1.4
Vanity	Bathroom mirror	Mirror lighting	Fluorescent tubes, see 12.3.1.3.2; CFLs, see 12.3.1.3.3; or LED lamp, see 12.3.1.4
Portable floor standing	Floor standing	Ambient and/or task lighting	Tungsten lamp, see 12.3.1.1; or CFLs, see 12.3.1.3.3
Table lamp	Desks	Task lighting	Tungsten lamp, see 12.3.1.1; Tungsten halogen lamp, see 12.3.1.2; CFLs, see 12.3.1.3.3; or LED lamp, see 12.3.1.4
Lantern Bollard Wall-mounted Downlighter Ground-recessed spotlight	External walls, porches, patios, pathways, gardens, other external areas	Outdoor lighting	Tungsten lamp, see 12.3.1.1; Tungsten halogen lamp, see 12.3.1.2; CFLs, see 12.3.1.3.3; or LED lamp, see 12.3.1.4

12.3.3 Lighting controls

12.3.3.1 General

Lighting controls may save energy when properly specified. They range from simple switches to complex integrated lighting control and dimming systems.

12.3.3.2 Local manual switches

Localised switching may be used to turn lights either on or off via wall-mounted switches or individual pull cords on the luminaire. Modern solutions include infra-red switches operated by a portable or wall-mounted transmitter. Although easy to use, local manual switches may lead to energy waste if they are left on unneccessarily.

12.3.3.3 Manual dimmer switches

Dimmers give the user the ability to vary the intensity of the light level and to save energy. Dimmer switches should be fitted where compatible with the lamp type, see 12.4.3.

12.3.3.4 Presence and absence detectors

Presence and absence detectors generally use passive infra-red sensors to detect whether people are in the scanned area. They are typically used in outdoor lighting, wetrooms or for lighting of communal areas.

Full presence detection may result in unnecessary energy use if lighting is switched on when it is not required. In these circumstances absence detection may be used, as the occupancy sensor only switches lighting off and switching on is by manual control. Frequent switching can reduce the life of fluorescent lamps. All detectors should be compatible with the lamp type.

12.3.3.5 Automatic daylight sensors

Automatic daylight sensors, also referred to as photocell controls, can switch off or dim lights when there is sufficient daylight to provide adequate lighting. They are typically used for external lighting. A time delay is generally built in to cater for short-term variations in daylight e.g. by a passing cloud,

Photocells may be:

— integral to the luminaire;

— switch operated; or

— stand alone.

Compatibility with CFLs and LED lamps should be checked and confirmed before installation.

12.3.3.6 Timers

Timers can be preset to switch lighting on or off at pre-determined times.

Time-switches are typically push-to-operate switches often used in corridors that automatically switch off lights after a preset time.

In safety critical areas like staircases, there may be a risk that the lighting can go off when someone is still in the space; presence detectors should be used in preference to time switches.

Solar time switches may be used for controlling external lighting as they adjust the on/off times to coincide with dawn and dusk throughout the year.

12.3.3.7 Multi-sensors

Multi-sensors use a combination of passive infra-red presence detectors, daylight sensors and infra-red receivers for receipt of switching and dimming commands from portable or wall-mounted infra-red transmitters. Multi-sensors may be used to achieve energy savings by relating lighting to occupation and the extent of daylight, while also enabling user control and adjustment of lighting from wireless infra-red devices.

12.4 Retrofit measures

12.4.1 Lamp replacement

12.4.1.1 General

Residential lighting may be improved in terms of energy efficiency or quality of lighting, or a combination of both.

The easiest and most economic measure consists in re-lamping existing luminaires. The lamp type and parameters should be identified. Lamp replacement options are listed in Table 44. Where more efficient lamp alternatives are available, the type of the existing luminaires should be identified and the suitability for replacement lamps should be assessed. Where the replacement lamp type is not compatible with the existing luminaire the luminaire should also be replaced, see 12.4.2. Lighting controls may be added as recommended by the the retrofit specification.

Table 44 - **Lamp replacement options**

Existing solution	Replacement option
Tungsten lamps	**Plug-in CFLs of similar light output, warm colour appearance with colour temperatures (2 700 K to 3 000 K), and compatible type and shape**
T12 (38 mm diameter) fluorescent lamps	**Triphosphor T8 (25 mm diameter) tubes of similar length and wattage**
Halophosphate T8 fluorescent lamps, generally have a 3 digit code starting with a lower number e.g. 630, 740	**Triphosphor T8 tubes of similar length and wattage, (generally have a 3 digit code beginning 8 or 9 e.g. 830, 940)**
Tungsten halogen reflector lamps used for general lighting in open luminaires	**Highly efficient LED replacement lamps having warm colour appearance with colour temperatures (2 700 K to 3 000 K)**

Where required during redevelopment work or at changes in occupancy whilst rewiring, the entire lighting system should be replaced as appropriate, see also 12.4.4.

When replacing lamps, the type and parameters of both the replaced and replacement lamps should be identified to ensure correct quantity and quality of light. Manufacturers generally indicate the colour rendering and colour appearance of a lamp using a three-digit colour reference number which is often preceded by the lamp wattage, see Figure 107.

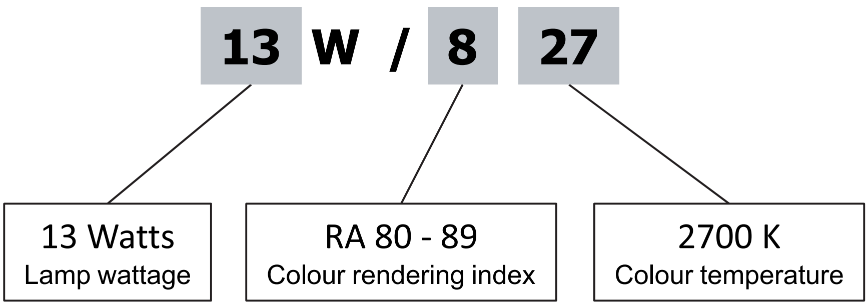


Figure 107 - **Manufacturers' indication of lamp parameters**

12.4.1.2 CFL type replacements

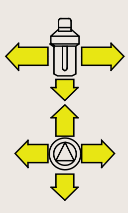
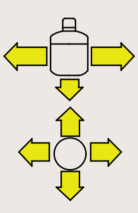
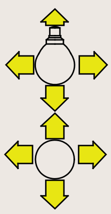
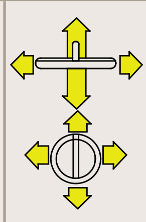
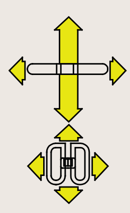
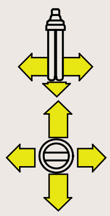
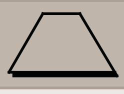
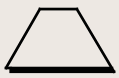
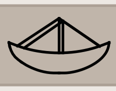
Low efficacy tungsten lamps should be replaced with plug-in CFLs with a corresponding colour appearance, see Table 42. Most CFLs emit a high proportion of their light from the side of the lamp and are less intense than tungsten lamps so have less penetration through many types of luminaires. The correct type of CFL should be selected based on the visual guide in Table 45 and the length of the replacement CFL lamp.

Where compatible CFL alternatives for the tungsten lamps are not available the luminaire should be replaced with luminaires specially designed for CFLs.

Where the CFL tube is shielded by a casing and resemble other lamp shapes such as traditional tungsten bulbs, candle bulbs and spotlights are not as efficient as unshielded CFLs. Although they are more efficient, unshielded CFLs should be used in locations where the lamp is not visible to occupants, e.g. in uplighters or luminaires with visual protection shields. Where the lamp is visible to occupants, shielded CFLs should be considered giving increased visual comfort and reduced risk of glare.

CFLs are ideal for locations with heavy or continuous use, such as living areas or kitchens.

Table 45 - Use of CFLs in common luminaire and their light distribution

Luminaire		CFL type					
							
	**Translucent shade**	Y	Y		Y	Y	
	**Opaque shade**			Y	Y	Y	
	**Translucent cylinder**	Y					Y
	**Translucent drum**	Y			Y	Y	Y
	**Translucent sphere**	Y					
	**Wall uplighter**	Y					Y
	**Pendant/ Free standing uplighter**				Y	Y	
	**Lamp holder**		Y	Y			

NOTE 1 The relative size of the arrows indicates the proportion of light in that direction.

NOTE 2 The Y indicates the most suitable CFL type for each style of luminaire.

12.4.1.3 LED lamp replacements

LED lamps specifically designed as direct replacements having warm colour appearance with colour temperatures of between 2 700 K and 3 000 K and high colour rendering (index above 70) should replace less efficient tungsten halogen lamps, see 12.3.1.2, and Table 42. Only LED lamps provided with the appropriate heat sinking should be installed as replacement lamps.

LED lamps which are not provided with appropriate heat sink should not be used in enclosed luminaires as the heat makes them inefficient and shortens their life.

Verification should be made to ensure that dimmable LED lamps are compatible with dimmers where installed, see 12.4.3.

12.4.1.4 Fluorescent tube lamp replacements

Halophosphate lamps should be replaced with multi-phosphor coating tubes. Multi-phosphor coating tubes are more efficient and with excellent colour rendering.

T12 (38 mm diameter) fluorescent lamps should be replaced with triphosphor T8 (25 mm diameter) fluorescent tubes of similar length and wattage in the same luminaires. T8 fluorescent tubes are available in the same lengths as the less efficient T12 (38 mm diameter) fluorescent tubes. T8 tubes give improved colour rendering, lumen maintenance, have a longer life and are up to 10 % more energy efficient.

Halophosphate T8 fluorescent lamps should be replaced with triphosphor lamps.

NOTE The colour rendering index of triphosphor tubes is generally 80 or 90, whereas halophosphate tubes have a colour rendering index of 60 or 70, see Table 42.

T5 (16 mm diameter) fluorescent tubes are more efficient than T8 fluorescent lamps but require different luminaires, see 12.4.2.

Smaller size tubes such as T2 (7 mm diameter), available in a variety of lengths, are an ideal option for vanity or under cabinet lighting.

12.4.2 Luminaire replacements

A more thorough retrofit measure consists of replacing the luminaires. Luminaires with electronic control gear reduce energy consumption and improve lamp performance, see 12.4.3. Dedicated luminaires incorporating dimmable electronic ballasts and CFLs that allow dimming should be used. Proper dimming can be achieved only if such dedicated luminaires are connected to compatible dimmers.

Dedicated luminaires should be used for LED lamps to ensure proper heat sinking thereby improving efficiency, improving lifetime and increasing optical control, see 12.4.1.3.

T5 fluorescent tubes are designed to operate more efficiently at higher temperatures than T8 tubes. Enclosed luminaires using T8 tubes should be replaced with similar T5 fluorescent luminaires.

Dedicated CFL or LED recessed luminaires having warm colour appearance with colour temperatures (2 700 K to 3 000 K) should replace recessed or enclosed luminaires using tungsten halogen lamps or tungsten lamps.

12.4.3 Improvements to controls

Existing controls may be improved through the use of dimmers.

Tungsten lamps and tungsten halogen lamps are suitable for dimming and modern domestic dimmers assist in saving energy. Some transformers may not be compatible with domestic phase-cut dimmers. The compatibility of controls with lamps and control gear should be verified with the manufacturer's instructions.

Most 4-pin fluorescent tubes and CFLs can be dimmed. Typically 2-pin fluorescent lamps, including plug-in CFLs that fit directly or via an adapter into a standard bayonet or Edison screw lamp holder, cannot be dimmed.

A dimmer should only be used with the type of lamp for which it is designed, see Table 46.

The dimmer should match the lamp, its ballast or transformer and load current.

Outdoor lighting controls may be improved through adding photocells, solar time switches or presence detectors.

Table 46 - Dimming options for lamp types

Lamp type	Dimming capability	Required gear for dimming	Remarks
Tungsten	Fully dimmable	Dimmer	Check compatibility.
Tungsten halogen	Fully dimmable	Dimmer, compatible transformer (if extra low voltage)	Check compatibility of all items.
Linear fluorescent	Dimmable down to 2 % if 4-pin base	Dedicated dimmer, compatible dimmable electronic ballast	Check compatibility of all items.
Plug-in CFL	Typically not dimmable	-	-
Pin-base CFL	Dimmable down to 5 % if 4-pin base	Dedicated dimmer, compatible dimmable electronic ballast	Check compatibility of all items.
LED	Typically down to 5 % if dimmable	Dedicated dimmer, compatible dimmable driver	Check compatibility of all items.

12.4.4 Replacement of the entire lighting system

A key opportunity to replace the entire lighting system in existing dwellings is during retrofit work or rewiring. This is a complex process which may require professional lighting design advice. The basis of all good lighting is an overall lighting design that provides a mixture of light and shade throughout the entire space.

When replacing the entire lighting system, light should be directed to where it is needed. General lighting should supplement any available daylight, with local lighting for more demanding visual tasks.

There are three basic types of lighting that work together to light homes. A good lighting plan combines all three types to light an area, according to function and style:

— ambient lighting provides general lighting with a comfortable level of brightness and may be achieved by ceiling or wall-mounted luminaires, recessed or track lights. Cove lighting may be used to create ambience in a formal space;

— task lighting is designed to help perform visual tasks in specific local areas, such as reading, cooking or sewing, and can be provided by portable floor or table lamps, pendant luminaires, under cabinet lights, recessed or track lighting;

— accent lighting adds drama to a room by creating visual interest, being used to emphasize paintings, house plants, sculptures, or to highlight the texture of a wall, drapery or outdoor landscaping, and is usually provided by track, recessed or wall-mounted luminaires for indoor lighting. Floodlights may be used for outdoor lighting.

A lighting scheme design should identify where lights may be positioned. Task lighting and sockets for reading lamps should be included in the scheme. Reduced background lighting levels create more contrast in a room and can save energy. Light for effect should supplement light for visual need and safety. The design should specify the lighting types required.

When redesigning the lighting system, the overall efficiency should be addressed. An efficient lamp should be installed in the most efficient luminaire for that lamp type, see Table 45.

In dwellings, each luminaire should have its own dedicated switch so that it is only on when required. Switches should be located in convenient places to encourage on/off switching as required. Dimmers are an efficient way of varying lighting. Compatibility of the lamps, ballasts and dimmers should be verified, see 12.4.3.

In areas which are naturally illuminated by daylight or are frequently unoccupied automatic controls may be considered. Photocells and presence sensors, see 12.3.3.4, used independently or combined in one unit are inexpensive. Luminaires can be purchased with one or more of these features built in.

Exterior lighting should be controlled by compatible photocells, timers and presence detectors as required by the control strategy. Luminaires using inefficient lamps (e.g. tungsten halogen bulbs) should incorporate photocells (daylight sensors) and presence detectors.

12.5 Example applications

12.5.1 General

This clause provides three energy efficient lighting installation examples. These examples address the following areas:

- general indoor lighting, see 12.2.1;
- directional indoor lighting, see 12.2.2; and
- outdoor lighting, see 12.2.3.

Lighting design should consider energy performance in order to provide energy efficient lighting solutions.

12.5.2 Example 1

This example provides for energy efficient lighting with manual controls:

- general indoor lighting should be a fluorescent type either CFLs or fluorescent tubes, see 12.3.1.3;
- directional indoor lighting used for task lighting or accent lighting should not use tungsten lamps. Tungsten halogen lamps, CFLs or LED lamps should be used for directional indoor lighting. Warm white CFLs should be used as direct replacements for tungsten lamps in task lighting fixtures such as portable floor standing luminaires or table lamps.wWhere fluorescent tubes are chosen for general, under cabinet, vanity or cove lighting, only triphosphor lamps should be used;
- manually operated lighting controls may be installed but a flexible arrangement of switches should be provided to ensure separate switching of individual luminaires or small groups of luminaires;
- outdoor lighting should not use tungsten lamps. Where external luminaires are fitted with tungsten halogen lamps, they should incorporate photocells (daylight sensors) and presence detectors.

12.5.3 Example 2

This example provides for energy efficient lighting with a minimum luminous efficacy of 45 lm/W with some automatic controls. Relevant recommendations of 12.5.2 should also be applied and the following should be included:

- a minimum of 75 % of the fixed luminaires used for general and directional indoor lighting should incorporate lamps with a luminous efficacy greater than 45 lm/W (such as CFLs or highly efficient LED lamps). Luminaires in cupboards are excluded;
- cupboards lighting should be fitted with door light switches;
- a minimum of 75 % of the external lighting should use energy efficient lamps of at least 45 lm/W. Compatible photocells, timers and presence detectors should be installed as required by the control strategy (see 4.6.3.3).

12.5.4 Example 3

This example provides for all energy efficient lighting to have a minimum luminous efficacy of 50 lm/W with automatic controls.

- relevant recommendations of 12.5.3 should also be applied;
- all fixed luminaires used for general and directional indoor lighting should incorporate lamps with a luminous efficacy greater than 50 lm/W (such as CFLs or highly efficient LED lamps). Luminaires in cupboards are excluded;
- LED luminaires should incorporate electronic dimmable control gear;
- fluorescent luminaires, linear and CFLs should utilise electronic gear;
- a flexible arrangement of switches should be provided to ensure separate switching of individual indoor luminaires or small groups of indoor luminaires;
- a comprehensive range of controls using dimmers, presence and absence detectors, daylight sensors and timers should be installed for general indoor lighting. Dimmers should be provided in occupied spaces (e.g. living areas, dining rooms, bedrooms or studies), presence detectors in communal areas and circulation areas, daylight sensors in communal areas with access to natural light;
- dimming should be provided for indoor directional lighting;
- all external lighting should use energy efficient lamps of minimum 50 lm/W. Photocell should be fitted on all outdoor lighting. Where there is intermittent traffic a presence detector should be installed with the photocell. Where a presence detector is not used a timer should be used to switch off lighting after a specified time.

Annexes

Annex A
(informative)

U-value tables (Roof)

A.1 U-values table

This Annex contains tables of U-values calculated for each of the roof types described in this Standard Recommendation.

— Pitched roof;

— Flat roof.

The tables show the roof's baseline (i.e. unimproved) U-value together with the insulation thicknesses required depending on the material's thermal conductivity in order to achieve improved U-value performances.

A.1.1 Pitched roof

Table A.1 - Insulation placed at ceiling level

	Uninsulated ceiling baseline U-value 2,3 (Wm²K)		
U-value (W/m²K)	**0,16**	**0,14**	**0,10**
Insulation thermal conductivity (λ) W/mK	Total insulation thickness needed (mm) [a]		
0,044	270	320	450[b]
0,040	250	300	400[b]
0,037	230	270	380[b]
0,032	220	240	350[b]
0,022[c]	160[c]	185[c]	260[c]

a) The first layer is placed between the ceiling joists, with the remainder placed above.

b) Insulation thickness of 350 mm or above may cause problems achieving roof ventilation at eaves level – see section 6.3.2.3 for further information.

c) High performance insulation can be used throughout or to facilitate inclusion of an access walkway or storage platform.

Table A.2 - Insulation placed between and below rafters

	Uninsulated ceiling		
U-value (W/m^2K)	**0,25**	**0,20**	**0,16**
Insulation thermal conductivity (λ) W/mK	**Total insulation thickness needed (mm)**[a]		
0,037	150	190[b]	235[b]
0,034	135	175[b]	220[b]
0,030	125	160[b]	200[b]
0,022	95	115	140
0,014	100[c]	120[c]	140[c]

a) The first 75 mm of insulation placed (or already exists) between 125 mm deep rafters, with the remainder fixed below.

b) Where the thickness of insulation below rafter exceeds 75 mm then this is to be installed in two layers with counter batten timbers used in middle layer fixed to existing roof rafters and third layer fixed to the battens.

c) Where plasterboard is bonded to advanced performance insulation, the first 75 mm of insulation between rafters is assumed to have thermal conductivity of 0.037 W/mK.

A.1.2 Flat roof

Table A.3 - Insulation placed above existing timber flat roof (warm deck)

	Uninsulated ceiling		
U-value (W/m^2K)	**0,25**	**0,22**	**0,20**
Insulation thermal conductivity (λ) W/mK	**Total insulation thickness needed (mm)**		
0,037	130	150	170
0,034	120	140	155
0,030	110	125	140
0,022	80	90	100

Table A.4 - Insulation placed between and below flat roof joists (cold deck)

	Uninsulated ceiling		
U-value (W/m²K)	0,25	0,22	0,20
Insulation thermal conductivity (λ) W/mK	Total insulation thickness needed (mm)[a]		
0,037	160	175	200[b]
0,034	150	165	185[b]
0,030	140	150	165
0,022	115	125	130
0,014[c]	120[c]	130[c]	135[c]

a) Assumed 100 mm placed (or already exists) between the 150 mm deep roof joists, and the rest placed below. Depth of insulation can be increased with greater depth of joists but 50 mm ventilation void should be maintained.

b) Where the thickness of insulation below roof exceeds 75 mm then this is to be installed in two layers with counter batten timbers used in middle layer fixed to existing roof rafters and third layer fixed to the battens.

c) Where plasterboard is bonded to advanced performance insulation, insulation between joists is assumed to have thermal conductivity of 0.037 W/mK.

Table A.5 - Insulation placed above existing concrete flat roof (warm deck inverted)

	50 mm existing insulated decking		
U-value[a] (W/m²K)	0,25	0,22	0,20
Insulation thermal conductivity (λ) W/mK	Total insulation thickness needed (mm)		
0,037	260	330	410
0,034	240	300	380
0,030	210	270	350
0,022	150	200	250

a) For a single layer of insulation above the membrane, with butt joints and open covering such as gravel, (f x) = 0,04.

NOTE The single layer of insulation with butt joints and open covering is considered to be the layout giving the highest correction to calculated thermal transmittance (ΔU).

Lower values of (f x) can apply for roof constructions that give less drainage through the insulation. Examples are different jointing arrangements (such as shiplap or tongue-and-groove joints), or different types of roof build-up. In these cases, where the effect of the measures are documented in certificate reports, values smaller than 0,04 for (f x) may be used. Where;

f is the drainage factor giving the fraction of p reaching the waterproofing membrane;
x is the factor for increased heat loss caused by rainwater flowing on the membrane, in (Wday)/(m²Kmm);
p is the average rate of precipitation in mm/day.

Annex B
(informative)

U-value tables (Walls)

B.1 U-value tables

This Annex contains tables of U-values calculated for each of the wall types described in this S.R:

— Hollow block;

— Cavity;

— Solid;

— Timber frame;

— Steel framed.

The tables show the wall's baseline (i.e. unimproved) U-value together with the insulation thicknesses required depending on the material's thermal conductivity and installation method used in order to achieve improved U-value performances.

In all of the tables, where the thermal conductivity is between the values quoted the thickness of insulation may be determined by interpolation.

The thicknesses recommended in these tables are indicative and depend on the installation methods used, e.g. number of fixings or thicknesses of bridged layers etc.

B.2 Hollow block wall

Table B.1 - U-value improvements for hollow block walls

Uninsulated hollow block wall (Baseline U-value 2,09 W/m²K)				
U-value (W/m²K)	**0,35**	**0,27**	**0,21**	**0,15**
Insulation thermal conductivity (λ) W/mK	**EWI or IWI insulation thickness needed (mm)**			
0,040	100*	140*	190*	250*
0,035	90*	120*	160*	220*
0,030	80*	110*	140*	200*
0,025	60	90*	120*	160*
0,020	50	70	90*	130*
0,015	40	50	65	95*
* Where internal insulation thickness exceeds 75 mm, the insulation may need to be installed in two or more layers: i.e. the first between battens, and the last layer as a laminate or separate layer.				

(INFORMATIVE) U-VALUE TABLES (WALLS)

B.3 Cavity wall

B.3.1. Type 1 cavity wall

Type 1 cavity walls (cavity that cannot be filled) having a baseline U-value of 1,55 W/m²K.

Table B.2 - U-value improvement for Type 1 cavity wall

Type 1 cavity wall (Baseline U-value 1,55 W/m²K)				
U-value (W/m²K)	**0,35**	**0,27**	**0,21**	**0,15**
Insulation thermal conductivity (λ) W/mK	**IWI insulation thickness needed (mm)***			
0,040	90*	125*	175*	275*
0,035	75	115*	150*	240*
0,030	65	100*	135*	200*
0,025	55	75	120*	175*
0,020	45	60	95*	135*
0,015	35	45	60	110*

* Where internal insulation thickness exceeds 75 mm, the insulation may need to be installed in two or more layers: i.e. the first between battens, and the last layer as a laminate or separate layer.

B.3.2. Type 2 cavity wall

Type 2 cavity walls (i.e. those that are or can be full-filled) have a baseline U-value of 1,55 W/m²K.

Such walls are unlikely to achieve a U-value less than 0,27 W/m²K through this method alone. Therefore, in addition to cavity insulation, a top-up of internal or external wall insulation is required to achieve the necessary U-value.

Table B.3 shows Type 2 cavity walls improved with cavity insulation by filling cavities of various widths.

These U-value figures are used as a baseline in Table B.4 to determine the required EWI or IWI thickness for further U-value improvements.

Table B.3 - Type 2 cavity wall improved with cavity insulation

Insulation thermal conductivity (λ) W/mK	**U-value** (W/m²K) **achieved by filling cavity width of:**		
	50 mm	**75 mm**	**110 mm**
0,040	0,67	0,50	0,36
0,037	0,64	0,47	0,35
0,033	0,60	0,44	0,32
0,026	0,52	0,38	0,27

Table B.4 - EWI or IWI thicknesses for U-value improvements for Type 2 cavity wall

Baseline U-value (W/m²K)		Cavity width												U-value (W/m²K)
		50 mm				75 mm				110 mm				
		0,67	0,64	0,60	0,52	0,50	0,47	0,44	0,38	0,36	0,35	0,32	0,27	
IWI or EWI Thermal conductivity (W/mK)	0,040	75	70	65	55									(0,35)
	0,035	65	60	55	45									
	0,030	55	55	50	40									
	0,025	45	45	40	35									
	0,020	40	35	35	30									
	0,015	30	30	25	20									
	0,040	90*	85*	75	65	60	55	50	35	30	25	15	N/A	(0,27)
	0,035	70	70	65	60	55	50	45	30	30	25	15	N/A	
	0,030	60	60	55	50	40	45	40	30	25	20	15	N/A	
	0,025	50	50	50	40	40	35	35	25	20	15	10	N/A	
	0,020	40	40	40	35	30	30	25	20	15	15	10	N/A	
	0,015	30	30	30	25	25	25	20	15	15	10	10	N/A	
	0,040	140*	135*	120*	115*	110*	105*	100*	90*	75	70	60	35	(0,21)
	0,035	115*	115*	115*	105*	100*	95*	90*	70	65	60	55	35	
	0,030	100*	100*	100*	90*	75	75	70	60	55	50	45	30	
	0,025	90*	75	75	70	65	65	60	50	45	45	40	25	
	0,020	65	60	60	55	50	50	45	40	40	35	30	20	
	0,015	50	45	45	40	40	35	35	30	30	25	25	15	
	0,040	225*	215*	210*	200*	195*	190*	185*	165*	160*	150*	140*	115*	(0,15)
	0,035	200*	190*	185*	175*	170*	165*	160*	145*	140*	135*	120*	105*	
	0,030	170*	165*	160*	150*	145*	145*	140*	125*	120*	115*	105*	90*	
	0,025	140*	140*	135*	125*	120*	120*	115*	105*	100*	95*	90*	70	
	0,020	110*	110*	110*	105*	95*	95*	90*	75	75	70	65	55	
	0,015	75	75	70	70	65	65	65	60	55	55	50	45	

NOTE The overall thickness of the external insulation may be reduced when insulation of a lower thermal conductivity is used to fill the cavity.

* Where internal insulation thickness exceeds 75 mm, the insulation may be installed in two or more layers: i.e. the first between battens, and the last layer as a laminate or separate layer.

B.3.3. Type 3 cavity wall

The baseline wall construction consists of:

- brick outer leaf,
- 50 mm residual cavity,
- 35 mm EPS (expanded polystyrene) slabs of thermal conductivity 0.040 W/mK, and,
- dense inner leaf plastered.

This gives a baseline U-value 0,70 W/m²K.

Under specific circumstances as described in 7.3.4.2.5, EPS insulation may be injected into a residual cavity where partial fill EPS boards were built into the wall during its original construction.

For this construction the baseline wall U-value reduces from 0,70 W/m²K to:

- 0,39 W/m²K for a residual cavity 50 mm wide filled with EPS bead of thermal conductivity 0,037 W/mK, or,
- 0,37 W/m²K for a residual cavity 50 mm wide filled with EPS bead of thermal conductivity 0,033 W/mK.

Additional internal or external insulation may be used to achieve improved U-values, see Table B 5..

Table B.5 - U-value improvement for cavity wall

Cavity wall (filled) (Baseline U-value 0,39[a] W/m²K)				
U-value (W/m²K)	**0,35 [b]**	**0,27**	**0,21**	**0,15**
Insulation thermal conductivity (λ) W/mK	**EWI or IWI insulation thickness needed (mm)***			
0,040		20	65	150*
0,035		20	60	140*
0,030		15	50	115*
0,025		15	40	100*
0,020		10	35	75
0,015		10	25	60

a) Where the baseline U-value is 0.37 W/m²K then subtract 5 mm from the insulation thicknesses in this table.

b) As the baseline U-value is close to the 0,35 W/m²K it may be ineffective to install such a thin layer of insulation so no thickness values are given.

* Where internal insulation thickness exceeds 75 mm, the insulation may be installed in two layers: the first between battens, and the second as a laminate or separate layer.

Where it is not possible to inject the partial fill cavity (with full fill) then internal wall insulation (IWI) should be used as outlined in U-value improvement for Type 3a cavity wall.

Table B.6 - U-value improvement for Type 3a cavity wall

Cavity wall (un-filled) (Baseline U-value 0,70 W/m²K)				
U-value (W/m²K)	**0,35**	**0,27**	**0,21**	**0,15**
Insulation thermal conductivity (λ) W/mK	**IWI insulation thickness needed (mm)***			
0,040	55	95*	135*	215*
0,035	45	75	125*	200*
0,030	40	65	110*	170*
0,025	35	55	90*	145*
0,020	30	45	70	120*
0,015	25	35	55	90*
* Where internal insulation thickness exceeds 75 mm, the insulation may be installed in two layers, the first between battens, and the second as a laminate or separate layer.				

B.4 Solid wall

U-value improvement for no-fines concrete wall is based on the worst case scenario for a no-fines wall (i.e. 305 mm rendered no-fines concrete wall, plastered) which has a baseline U-value 1,53 W/m²K.

Table B.7 - U-value improvement for no-fines concrete wall

No-fines concrete wall (Baseline U-value 1,53 W/m²K)				
U-value (W/m²K)	**0,35**	**0,27**	**0,21**	**0,15**
Insulation thermal conductivity (λ) W/mK	**EWI or IWI insulation thickness needed (mm)***			
0,040	90*	130*	170*	240*
0,035	80*	110*	160*	210*
0,030	70	95*	125*	180*
0,025	60	85*	110*	150*
0,020	50	60	90*	120*
0,015	35	45	65	90*
* Where internal insulation thickness exceeds 75 mm, the insulation may be installed in two layers, the first between battens, and the second as a laminate or separate layer,				

Table B.8 - U-value improvement for mass concrete wall

Mass concrete wall (Baseline U-value 2.20 (W/m²K)				
U-value (W/m²K)	**0,35**	**0,27**	**0,21**	**0,15**
Insulation thermal conductivity (λ) W/mK	**EWI or IWI insulation thickness needed (mm)***			
0,040	100*	140*	180*	260*
0,035	90*	120*	160*	230*
0,030	80	105*	140*	200*
0,025	65	90*	120*	170*
0,020	55	70	95*	140*
0,015	40	55	75	105*
NOTE The baseline U-value for a wall with, 22 mm external render (lambda = 1,0 W/mK), 275 mm mass concrete wall (medium density, lambda = 1,15 W/mK), a 13 mm lightweight plaster internally (lambda = 0,57 W/mK)				
* Where internal insulation thickness exceeds 75 mm, the insulation may be installed in two layers, the first between battens, and the second as a laminate or separate layer.				

B.5 Timber frame wall

Table B.9 shows U-value improvement for an unfilled timber frame wall with 90 mm deep studs, where the insulation either did not exist or has been removed. It represents where new insulation has been introduced into the full depth of the studwork and plasterboard appropriate to the fire rating of the wall is fitted to the studs. A thermal laminate board is fitted over the plasterboard where the required insulation is greater than 90 mm.

The baseline U-value for the unfilled wall is 1,17 W/m²K. This is based on 1 hour fire resistance to unfilled studs achieved by two layers of plasterboard to a wall adjacent to a boundary. The insulation thickness shown includes the 90 mm insulation between the studs.

Table B.9 - U-value improvement for timber frame wall

Timber frame wall (Baseline U-value 1,17 W/m²K)				
U-value (W/m²K)	**0,35**	**0,27**	**0,21**	**0,15**
Insulation thermal conductivity (λ) W/mK	**Total insulation thickness needed (mm)**			
0,040	100	130	170*	260*
0,035	90	120	160	240*
0,030	85	110	140	210*
0,025	75	105	125	170*
0,020	65	100	115	150
0,015	95[a]	105[a]	120[a]	150[a]
a) Where advanced insulation is used as the thermal laminate, the U-value calculation is based on mineral wool type 90 mm insulation placed between timber studs.				
* Where total insulation thickness exceeds 165 mm (i.e. including the first 90 mm between the timber studs and 75 mm as the laminate over the fire rated plasterboard) the insulation installed to the face of the timber frame wall may be installed in two or more layers, i.e. the first between battens, and the last layer as a laminate or separate layer.				

Table B.10 shows improvements to an unfilled timber frame wall with 90 mm deep studs where the insulation did not exist. The baseline for this construction is 1,17 W/m²K.

The new construction is a thermal laminate board fitted over the existing plasterboard. The void between the studs remains unfilled. The insulation thicknesses provided are for the new laminate board. Interstitial condensation occurring in air-spaces between layers of insulations should be avoided..

Table B.10 - U-value improvement for timber frame wall using thermal laminate board

Timber frame wall (Baseline U-value 1,17 W/m²K)				
U-value (W/m²K)	**0,35**	**0,27**	**0,21**	**0,15**
Insulation thermal conductivity (λ) W/mK	**IWI insulation thickness needed (mm)**			
0,040	85*	125*	170*	250*
0,035	70	110*	150*	220*
0,030	60	95*	130*	185*
0,025	50	70	110*	160*
0,020	45	65	100*	130*
0,015	30	40	55	100*

* Where internal insulation thickness exceeds 75 mm, the insulation installed to the plasterboard face of the timber frame wall may be installed in two or more layers, i.e. the first between battens, and the last layer as a laminate or separate layer.

Table B 11 has a baseline U-value for a timber frame wall where the existing timber frame 90 mm wall has insulation of lambda value 0,040 (λ) W/mK between the studs. The new insulation is a thermal laminate board fitted over the existing plasterboard onto the studs to retain racking strength and fire resistance. The insulation thicknesses are for the new laminate board added to the existing construction.

The baseline U–value for the existing insulated filled wall is 0,42 W/m²K.

Table B.11 - Required U-value improvement for timber frame wall using thermal laminate board

Timber frame wall (Baseline U-value 0,42 W/m²K)				
U-value (W/m²K)	**0,35**	**0,27**	**0,21**	**0,15**
Insulation thermal conductivity (λ) W/mK	**Additional insulation thickness needed (mm)**			
0,035	15	40	95*	150*
0,030	10	35	65	135*
0,025	10	30	55	120*
0,020	n/a	25	45	100*

* Where internal insulation thickness exceeds 75 mm, the insulation installed to the plasterboard face of the timber frame wall may be installed in two or more layers, i.e. the first between battens, and the last layer as a laminate or separate layer.

B.6 Steel frame wall

Table B.12 shows U-value improvements for a warm light steel frame wall as in Figure 52 with baseline U-value 0,45 W/m²K (assumed 1 hour fire resistance to studs).

The improvements to the warm light steel frame wall consists of filling the void on the plasterboard side before fixing internal thermal laminate board, see Figure 71 .

Table B.12 - U-value improvement for a warm light steel frame wall

Warm light steel frame wall (Baseline U-value 0,45 W/m²K)				
U-value (W/m²K)	**0,35[a]**	**0,27**	**0,21**	**0,15**
Insulation thermal conductivity (λ) W/mK	**Total additional insulation thickness needed (mm)**			
0,040	N/A	100	140	220*
0,035	N/A	95	130	200*
0,030	N/A	85	120	175*
0,025	N/A	75	125	150*
0,020	N/A	65	115	135
0,015	N/A	N/A	115[b]	140[b]

a) To improve the wall to.0,35 W/m²K requires the removal of the plasterboard layer and then only partially filling between the steel studs is not effective. Where the plasterboard is to be removed it is appropriate to fully fill between the studs before re-instating the plasterboard layer(s).

b) Where advanced insulation is used as the thermal laminate, U-value calculation is based on mineral wool insulation placed within the void between the studs.

*Where total additional thickness exceeds 145 mm (i.e. 70 mm top up between and 75 mm as part of laminate) then the insulation installed to the plasterboard face of the steel frame wall may be installed in two or more layers: i.e. the first between battens, and the last layer as a laminate or separate layer.

Table B.13 shows U-value improvements for a hybrid light steel frame wall where the insulation sits around the studs as shown in Figure 53 with baseline U-value 0,35 W/m²K (assumed 1 hour fire resistance to studs).

The improvements to the hybrid light steel frame wall consists of filling the remaining void on the plasterboard side before fixing internal thermal laminate board, see Figure 72.

Table B.13 - U-value improvement for a hybrid light steel frame wall

Hybrid light steel frame wall (Baseline U-value 0,35 W/m²K)				
U-value (W/m²K)	**0,35**	**0,27**	**0,21**	**0,15**
Insulation thermal conductivity (λ) W/mK	**Total additional insulation thickness needed (mm)***			
0,040	N/A	45	85	165*
0,035	N/A	45	75	145*
0,030	N/A	45	70	125*
0,025	N/A	45	60	105
0,020	N/A	35	55	85
0,015	N/A	N/A	90[a]	85[a]

a) Where advanced insulation is used as the thermal laminate, U-value calculation based on mineral wool type insulation placed in the void between the studs.

* Where total thickness exceeds 110 mm (i.e. 35 mm top up between and 75 mm as part of laminate) then the insulation installed to the plasterboard face of the steel frame wall may be installed in two or more layers, i.e. the first between battens, and the last layer as a laminate or separate layer.

Annex C
(informative)

U-value - Floors

C.1 U-value tables

The U-value for a ground floor is made up of the floor's thermal resistance and its geometry, specifically the ratio of the exposed floor perimeter (i.e. external walls) to floor area. Therefore, the U-value for an end terrace property will be poorer than for the mid terrace property next door, even if the same thickness and type of insulation is provided to both

U-value tables showing the insulation thickness necessary to achieve the required improvement standards for a specific dwelling geometry are given in this annex. These are indicative values and will vary depending on the exact floor construction. They assume no original insulation in the existing construction. Alternatively, detailed U-value calculations can be performed as described in I.S.EN ISO 13370:2007, or using appropriate software.

Table C.1 - Suspended precast concrete floor (U-values)

Uninsulated floor baseline U-value of 0,58 W/m²K				
U-value (W/m²K)	**0,45**	**0,25**	**0,21**	**0,15**
Insulation conductivity (λ) W/mK	**Insulation thickness needed (mm)**			
0,040	20	90	120	200
0,035	20	80	100	170
0,030	20	70	90	150
0,025	10	60	80	120
0,020	10	50	60	100
0,015	10	35	45	75

NOTE 1 A U-value of 0,15 W/m²K is recommmened when installing underfloor heating

NOTE 2 Dwelling type used for calculations is a semi detached house with a ground floor area of 63 m² with an exposed perimeter of 23 m²

Table C.2 - Suspended timber floor (U-values)

Uninsulated floor baseline U-value of 1,22 W/m²K				
U-value (W/m²K)	0,45	0,25	0,21	0,15
Insulation conductivity (λ) W/mK	Insulation thickness needed (mm)			
0,040	40	120	160	250
0,035	30	110	140	230
0,030	30	100	130	200
0,025	30	90	110	180
0,020	20	80	100	160
0,015	20	60	80	130
NOTE 1 A U-value of 0.15 W/m²K is recommmened when installing underfloor heating				
NOTE 2 House type used for calculations is a semi detached house with a ground floor area of 63 m² with an exposed perimeter of 23 m²				

Table C.3 - Ground supported concrete floor (U-values)

Uninsulated floor baseline U-value of 0,55 W/m²K				
U-value (W/m²K)	0,45	0,25	0,21	0,15
Insulation conductivity (λ) W/mK	Insulation thickness needed (mm)			
0,040	20	80	110	190
0,035	20	70	100	170
0,030	20	60	80	140
0,025	10	50	70	120
0,020	10	40	60	90
0,015	10	30	40	70
NOTE 1 A U-value of 0.15 W/m²K is recommmened when installing underfloor heating				
NOTE 2 House type used for calculations is a semi detached house with a ground floor area of 63 m² with an exposed perimeter of 23 m²				

Annex D
(informative)

Driving rain index

D.1 Driving rain index

The Driving Rain Index is the product of the average annual rainfall and the average annual wind speed. S.R. 325 classifies exposure of masonry structures to wind driven rain.

D.2 Classification of exposure to local wind-driven rain

The quantity of rain falling on a vertical surface, such as a wall, at any point depends on both the intensity of the rainfall and the wind speed. The BRE Report *Driving Rain Index* postulated that the quantity of rain falling on a vertical surface, such as a wall, was proportional to the quantity falling on a horizontal surface and to the local wind speed, and incorporated maps of an annual wind-driven rain index, which is the product of the annual local rainfall and the annual average airfield wind speed. A map showing the driving rain index for Ireland was prepared by the Meteorological Service and is shown in Figure D.1.

Rainfall varies considerably across the country but is largely unaffected by local features. Conversely, the general wind speed does not change so much across the country but is very much affected by local features, such as the spacing and height of surrounding trees and buildings and whether the ground is flat or steeply rising.

Table D.1 - Driving rain index

Simple exposure category	Driving rain index
Severe	Severe category obtains in districts where the driving rain index is 7 or more
Moderate	Moderate category obtains in districts where the driving rain index is between 3 and 7 except in areas which have an index of 5 or more and which are within 8 km of the sea or large estuaries where the exposure should be regarded as severe [a]
Sheltered	Sheltered category obtains districts where the driving rain index is 3 or less, excluding areas that are within 8 km of the sea or large estuaries the exposure should be regarded as moderate [a]
a) In districts of sheltered or moderate exposure, high buildings which stand above their surroundings, or buildings of any height on hill slopes or hill tops, should be regarded as having an exposure one grade more severe than indicated by the map.	

These simple categories cannot take account of all local circumstances. For example, if a building lies on high ground on the windward side, or on the windward slope of even a slight hill, or in a valley facing into the strongest rain-bearing winds, it may be more severely exposed than the average for the district. Such details can be studied in large scale maps and taken into account, while the Meteorological Service may be able to advise in cases of doubt.

The local spell indices are not precise, since they are derived from inherently variable meteorological data. This variability has been reflected in the definitions of the exposure categories by overlapping the indices at their boundaries. Where exposure categories overlap, see Driving rain index, the designer should decide which is the most appropriate category for the particular case, using local knowledge and experience.

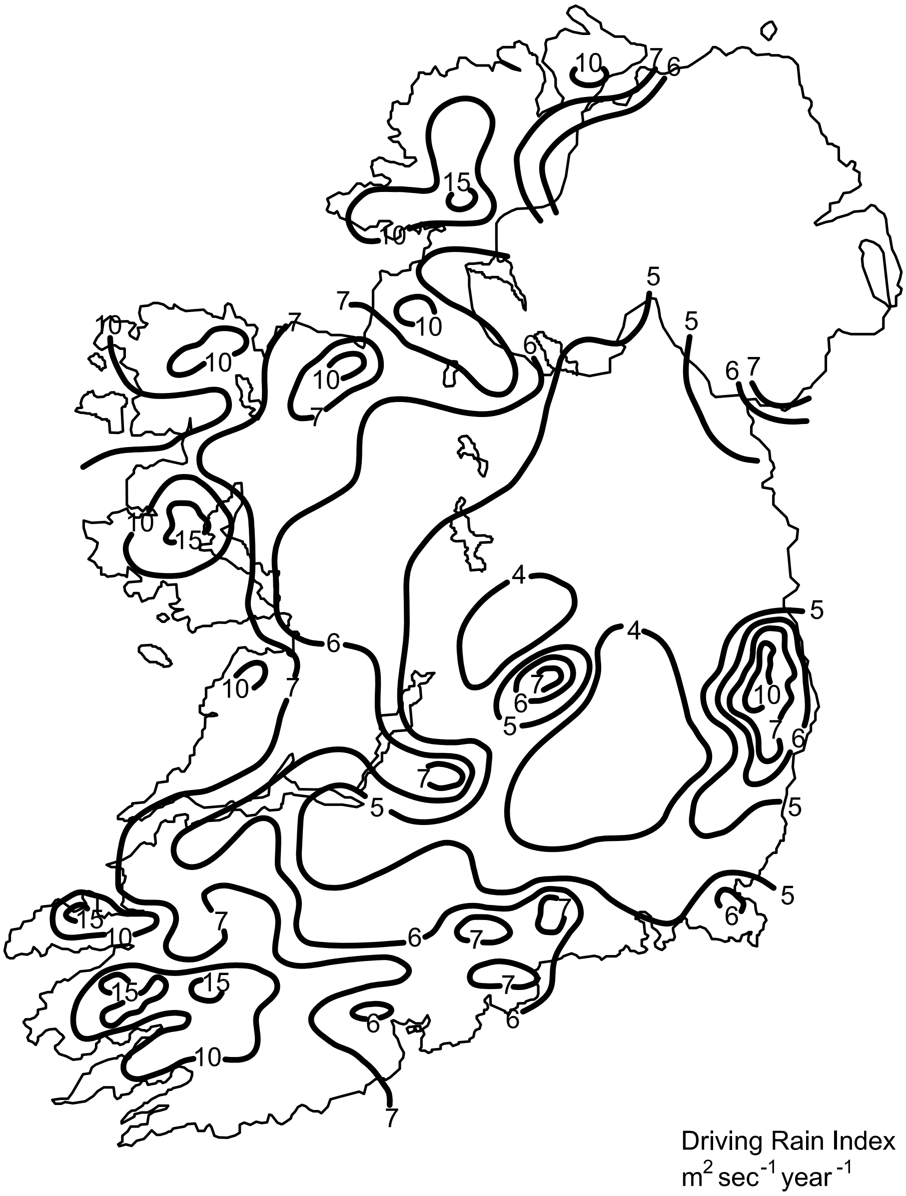


Figure D.1 - Driving rain index

Annex E
(informative)

Boiler interlock

E.1 Boiler interlock

Figure E.1 shows an example of the wiring that may be used to achieve boiler interlock in a regular boiler system with two 2-port motorised valves. It may be extended for any number of additional heating zones.

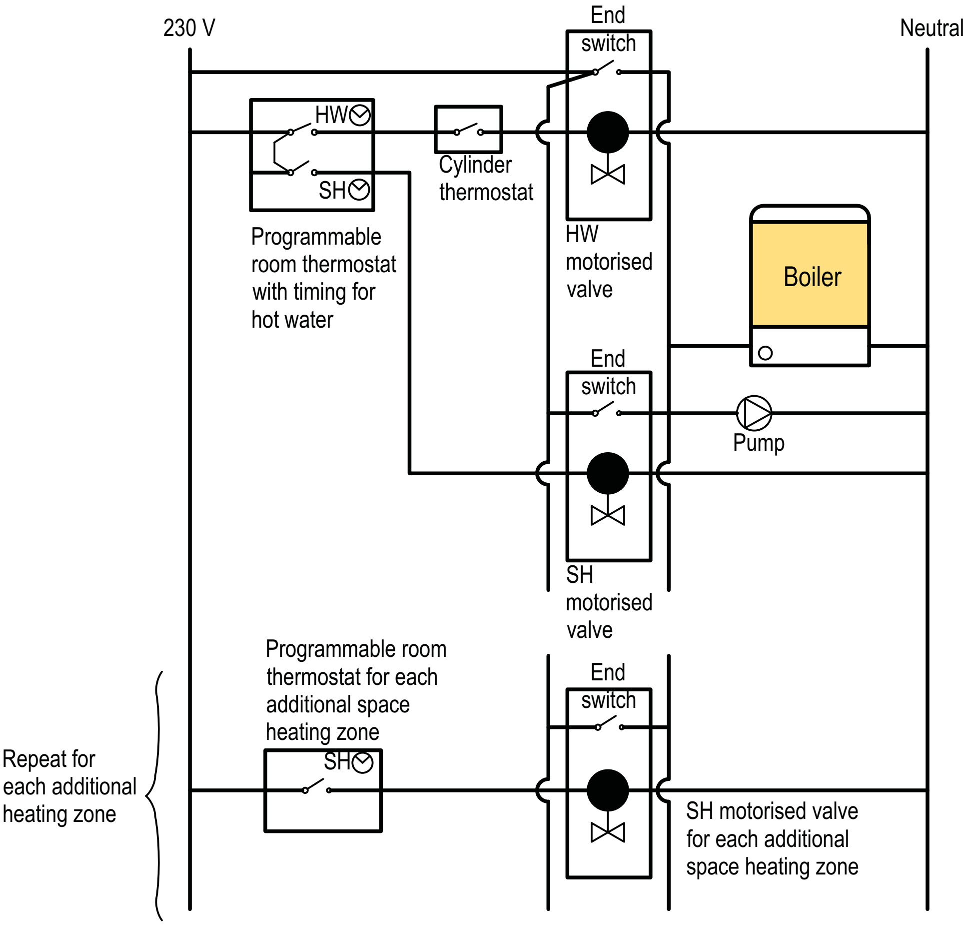


Figure E.1 - Example of wiring for boiler interlock

Annex F
(informative)

Project management

F.1 Retrofit project management

F.1.1. General

Retrofit projects take many forms, from a single task to a complete upgrade. Whatever form the project takes, consideration should be given to procurement, construction, administration and contractual issues.

Retrofit projects include the following:

— small scale (single tasks) e.g. replacement of windows;

— multiple works (combination of measures) e.g. loft and wall insulation;

— complete retrofit upgrade (single contract); or

— multiple dwellings retrofit upgrade (e.g. apartment blocks or terraces of houses).

The level of management and oversight of a retrofit project depends on its scope and the experience and expertise of the client. Energy efficiency expertise should be part of the design process for all projects.

F.1.2. Preliminary considerations

A whole house retrofit may necessitate the occupants leaving the dwelling for the duration of the project. This allows the contractor an unhindered approach to the work, speeding up the overall process and making it more cost effective.

The contractor should have appropriate insurance to cover any liabilities which may occur during the works. Clients should be advised that they need to consult their home insurance provider to ensure that the home is adequately insured when works are being carried out. Three or more quotations together with recent references may be obtained. Where competent installer schemes exist, contractors should be drawn from these lists.

A quote obliges the contactor to undertake the works for the stated amount, whereas an estimate may be subject to change, as it is not a fixed price. As a result, a quote should always be requested. A scope of works should be defined in order to obtain an accurate fixed price quote.

Where there are insufficient funds to carry out all the required works under a single contract it is important to plan the various interventions, so that over time all of the retrofit measures are completed in a cost-effective manner. Priority should be given to those interventions that deliver the greatest value for money, i.e. those interventions that achieve the greatest thermal improvement at the least capital cost. Consideration should also be given to grouping improvement works that can impact each other e.g. windows with wall insulation. The payback for grouped works when calculated together may compensate for individual interventions with longer paybacks. Each intervention should be complementary to the next and should not result in the removal of, or damage to previous measures in accommodating new systems. The use of the Building Energy Rating (BER), Dwelling Energy Assessment Procedure (DEAP) may help identify where the most energy efficient improvements may be made.

A method statement should be provided for larger retrofits and/or complex tasks in order to demonstrate how the different trades are to interact. The statement should also describe how the dwelling may be protected during the works with regard to damage to finishes, fixtures and fittings, protection from fire or flood, and how the site may remain secure.

Where works present a risk of injury or damage to people or property, a risk assessment should be drawn up to describe how the contractor intends to carry out the task and eliminate or manage such risks by way of a method statement. This may be particularly relevant where the householder remains in occupation during the works.

F.1.3. Contracts

F.1.3.1 General

When embarking on any works on a dwelling a form of contract should be in place prior to the works commencing.

A robust written contract protects the interests of both the client and the contractor. Standard forms of contract offer better protection compared to one drawn up by the contractor as this may not adequately reflect the interests of both parties.

Verbal contracts while valid in law, provide little protection if there is a failure to complete the works to a satisfactory level or if there is uncertainty as to the extent or quality of the works required.

F.1.3.2 Types of contract

Contracts typically take the form of:

- direct labour contracts where the client project manages the works. This may involve employees working under the direct supervision of the client and/or the coordination of single or multiple subcontractors;
- construction contracts where the client employs a consultant to prepare a schedule of works, specification and tender documents. The package of works may then be tendered and a contractor may be appointed to carry out the works;
- project management contracts where a client appoints a professional project manager to:
  - specify the works required; and
  - to tender and manage the various trades and professions who provide the specification and perform the works;
- pay as you save contracts may be provided by energy suppliers (electricity, gas and oil etc. companies), for energy efficient retrofit projects. The dwelling owner may contact the energy provider who performs an energy survey, makes recommendations and provides a contract to manage and complete the works. Payment for the works may be made as individual payments over a period of time, a lump sum or a combination of both.

Dwelling owners may choose any of the contract options. Where the client has little experience in construction or where the contract involves a large project or multiple dwellings, it is preferable to use the construction contract or project management option. In the case of pay as you save, the utility provider may provide the project management expertise.

F.1.3.3 Contract requirements

There are many forms of contract depending on the size and nature of the works. The following should be provided for, in all contracts:

- clearly state the name of the contractor and the employer (homeowner);
- a clear description of the works to be carried out, including preparatory works and protection of the dwelling and occupants. Drawings, where provided, should be referenced here;

- the price for the works, stating if it includes VAT or not;
- terms of payment should be stated, such as interim payments tied to achieving certain milestones;
- the retention monies and completion conditions should be specified;
- duration of the contract. This may either be expressed as a due completion date or a period of time to complete the works. A programme of activities may be included based on this duration. The circumstances that would require an extension to the contract should be defined;
- provisions for dealing with changes to the works. Where changes need to be made, a pre-approved system of agreeing these changes should be specified to avoid uncontrolled additions to the contract price or overruns. Details should be included as to how the cost of changes are to be agreed, if different to the main contract works;
- obligations on the contractor. This ensures that works are carried out in compliance with the Building Regulations, relevant codes of practice, national standards or specific requirements of the contract. It also covers the specification of materials to be used, ensuring that they are appropriate and fit for purpose. In addition, it requires the contractor to execute the works to an acceptable standard and in a safe manner;
- obligations on the employer (homeowner). This generally covers unhindered access to carry out the works without delay, and may cover temporary use of services and welfare facilities;
- possession of the site. Where the occupier has to vacate the dwelling it may be necessary for the site to be handed over to the contractor, who should take on responsibility and insurance of the site for the period of the works;
- approvals. The contracts should state who is responsible for seeking approvals from local planning departments and/or issuing Commencement Notices where required;
- defect liability. A period of liability for materials and workmanship should be stated in the contract, requiring the contractor to return to site and rectify any defects that arise during the period;
- dispute resolution and termination of contract. Where there are issues that cannot be resolved between the two parties then a provision should be stated for dealing with disputes, such as conciliation or arbitration before engaging in litigation. Where termination through a breach of contract is required, then the terms and timescales should be stated for either party to terminate;
- health and safety. The contract should provide that all relevant health and safety requirements are complied with and that contractor's personnel are adequately trained to operate to these requirements. Any contractor performing works should;
  - have a current, written Health and Safety Statement available for inspection if requested;
  - follow safe working practices for employees, customers and the public at all times in accordance with Health & Safety Authority guidelines; and
  - use equipment safely in accordance with manufacturers' instructions and store materials and equipment properly.
- contracts for professional services can adopt the professions' standardised conditions (e.g. RIAI, CIOB, EI, SCS), and where customised should include, as a minimum, role of professional

services provided, monitoring inspections and supervision, checks, reporting, technical support and responsibilities;

- both parties should sign and date the contracts and each retain a copy.

F.1.4. Contractor recommendations

The following should be in place prior to commencement of works:

- a contract appropriate to the works;

- current insurance policies. These should cover public liability and insurance of the works against related damage. These should be of sufficient value to cover any potential claims related to the works;

- bank reference or company accounts. A contractor should be able to provide either or both of these to demonstrate that they are financially stable and have the standing to complete the works unhindered by poor credit and failure to secure materials or labour;

- health and safety plan. A number of hazards are associated with existing buildings including minor demolition, working at height, the fixing of new materials and the use of hand and power tools. The works should avoid tripping and collision hazards for workers and occupants where the dwelling remains in occupation. Asbestos may be present, in some cases in a number of different materials in dwellings and where identified during the initial survey or by the contractor, appropriate measures should be put in place for its removal;

- staff structure for all on site personnel. It should be stated whether the contractor is going to use directly employed staff or sub-contractors. The main contractor is responsible for all subcontractors and their operations on site;

- the contractor should demonstrate they are acting safely and responsibly. They should comply with:

  - Health and Welfare at Work Act;

  - Safety, Health and Welfare at Work (Construction) Regulations; and

  - Safety, Health and Welfare at Work (Exposure to Asbestos) Regulations.

Further guidance is provided on the Health and Safety Authority website www.hsa.ie.

Annex G
(informative)

Thermal bridging

G.1 Surface condensation as a consequence of thermal bridging

Thermal bridging occurs, as described in Clause 4, Building Science, of this S.R., wherever the continuity of insulation is interrupted with a material which has a significantly higher thermal conductivity. The thermal bridge promotes increased localised heat flow, which in turn can lower the surface temperature at that location. Where the surface temperature is reduced significantly this can lead to surface condensation and possibly mould growth at that location. A property, of both the construction of the thermal elements and the use of the building, known as the 'Temperature Factor' (*f*) can be used to analyse the risk of surface condensation. The Temperature factor[1] is defined as the lowest internal surface temperature (T_{si}) minus external air temperature (T_e), all divided by the difference between internal and external air temperature ($T_I - T_e$):

$$f_{Rsi} = (T_{si} - T_e) / (T_i - T_e)$$

In dwellings, under normal levels of relative humidity, a temperature factor lower than 0,75 suggests that surface condensation may become a risk. Where the internal air temperature is assumed to be 20 °C and the external air temperature is assumed to be 0 °C, the critical internal surface temperature is 15 °C. Thus for any part of the internal surface of a dwelling to be at 15 °C or below indicates that this location is at risk of surface condensation occurring; a temperature much lower than 15 °C indicates a significant risk of mould growth.

This Annex describes a number of different locations where thermal bridging, either at junctions between thermal elements or around openings may occur when improving the U-values of the adjacent thermal elements. Modelling was undertaken using TRISCO thermal bridging software to evaluate these situations. The locations described have been set out with respect to the following wall types:

— solid wall with External Wall Insulation (EWI);

— hollow block wall with Internal Wall Insulation (IWI);

— cavity wall insulation (CWI);

— timber framed wall;

— steel framed wall.

The information within this Annex is for the purpose of preventing surface condensation following an energy efficient retrofit. Significant levels of heat loss due to thermal bridging may still exist, and it is recommended that this guidance is considered the minimum necessary level of performance acceptable.

G.2 Wall types

G.2.1 Solid wall (No-fines) with EWI

G.2.1.1 Junctions with a ground floor

When EWI is applied to a solid wall, it is the wall itself which then acts as a thermal bridge where it forms a junction with another element such as a ground floor. Thermal bridging modelling shows that when no perimeter insulation is provided below floor level (i.e. where the EWI finishes clear above external ground level) the temperature factor in this location is only 0,74, i.e. it falls below 0,75.

1 See BRE publication IP 1/06 – *Assessing the effects of thermal bridging at junctions and around openings.*

Figure G.1 shows the construction and the thermal conductivity of the material present.

The solid wall here has been provided with 130 mm of insulation with a thermal conductivity of 0,030 W/mK to provide an improved wall U-value of 0,21 W/m²K. External insulation does not extend below DPC level.

The equivalent thermal image output is shown in Figure G.2. For the thermal images, the upper

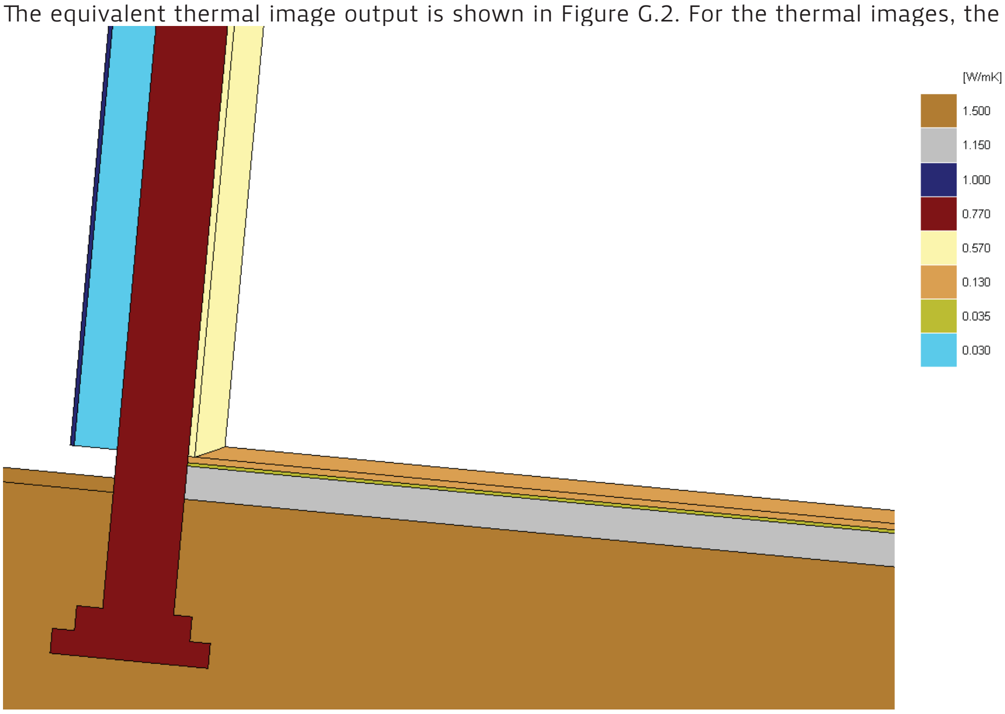


Figure G.1 - EWI solid wall-floor junction: Materials modelled in TRISCO

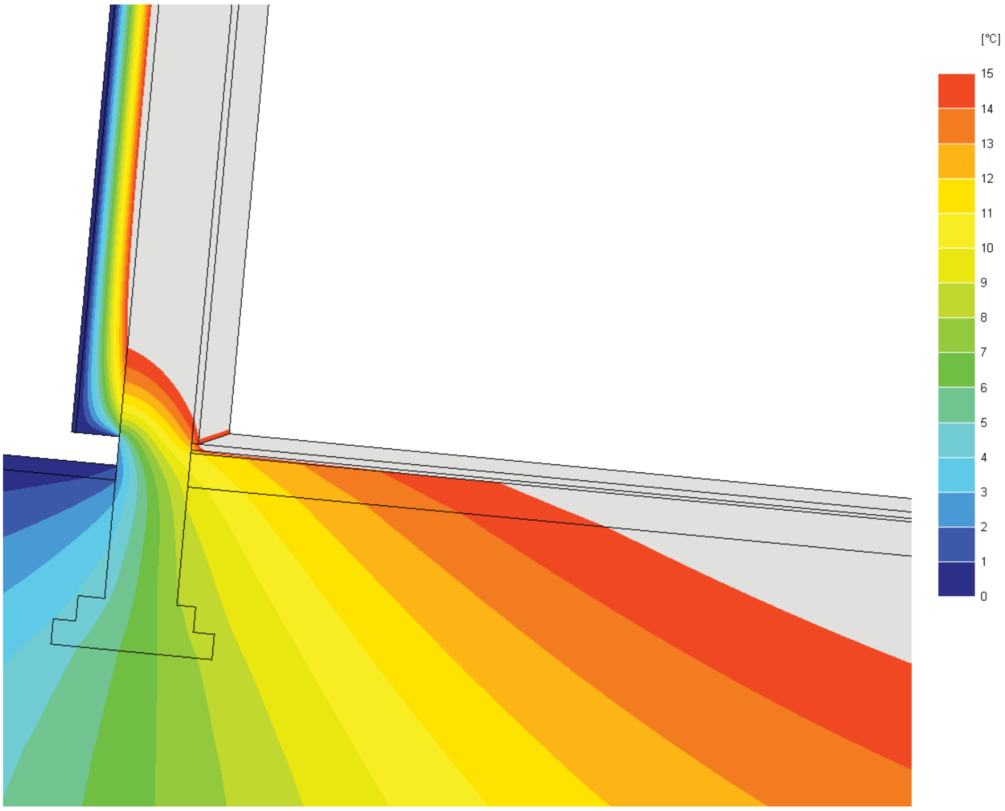


Figure G.2 - EWI solid wall-floor junction: Thermal image of TRISCO output

display temperature has been set to 15 °C so that if any part of the internal surface is coloured (i.e. not grey), then this shows where surface condensation could form.

Thus Figure G.2 shows that the internal surface temperature at the junction between the wall and floor is below 15 °C (temperature factor < 0,75) and would present a condensation risk.

By providing a minimum depth of external perimeter insulation, which extends down 150 mm from finished floor level, the risk of surface condensation is removed as here the surface temperature is approximately 16,5°C (temperature factor has increased to 0,825). Figure G.3 shows the construction and the thermal conductivity of the material present, and Figure G.4 shows the equivalent thermal image.

Figure G.4 shows that at no point is the internal surface temperature at the junction between the wall and floor below 15 °C, and thus there is no risk of surface condensation.

Where the ground floor consists of an upgraded suspended timber floor with insulation provided between the joists, the temperature factor, when the same perimeter insulation as shown in

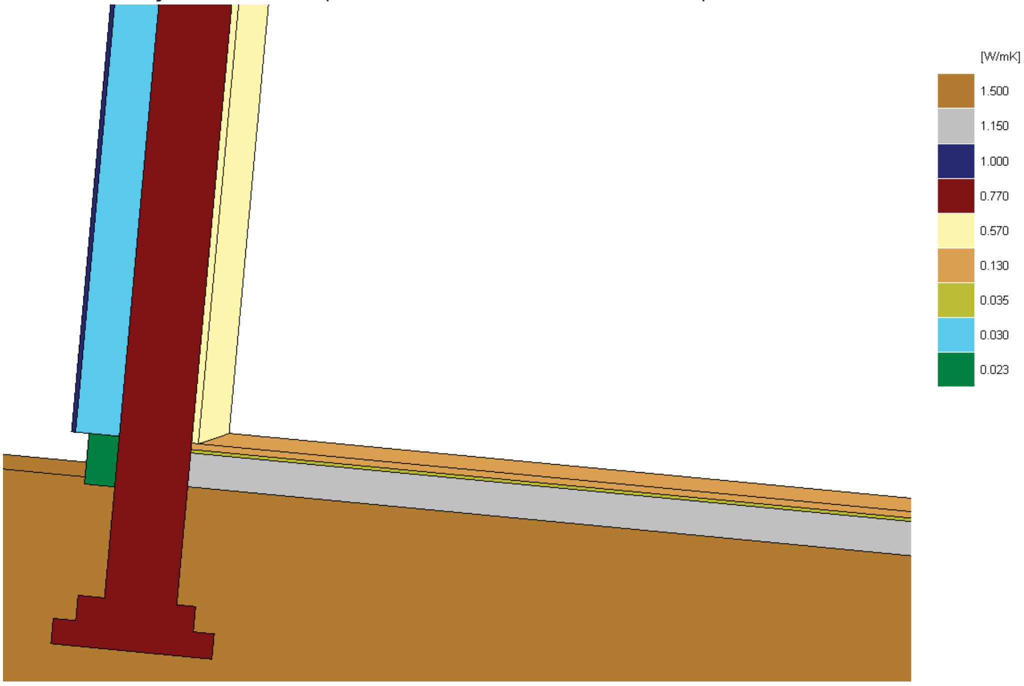


Figure G.3 - EWI solid wall-floor junction with perimeter insulation: Materials modelled in TRISCO

Figure G.3 is provided, is 0,81. Subfloor ventilation should be maintained through the perimeter insulation. Figure G.5 shows the TRISCO thermal image, which demonstrates that the internal surface temperature does not fall below 15 °C.

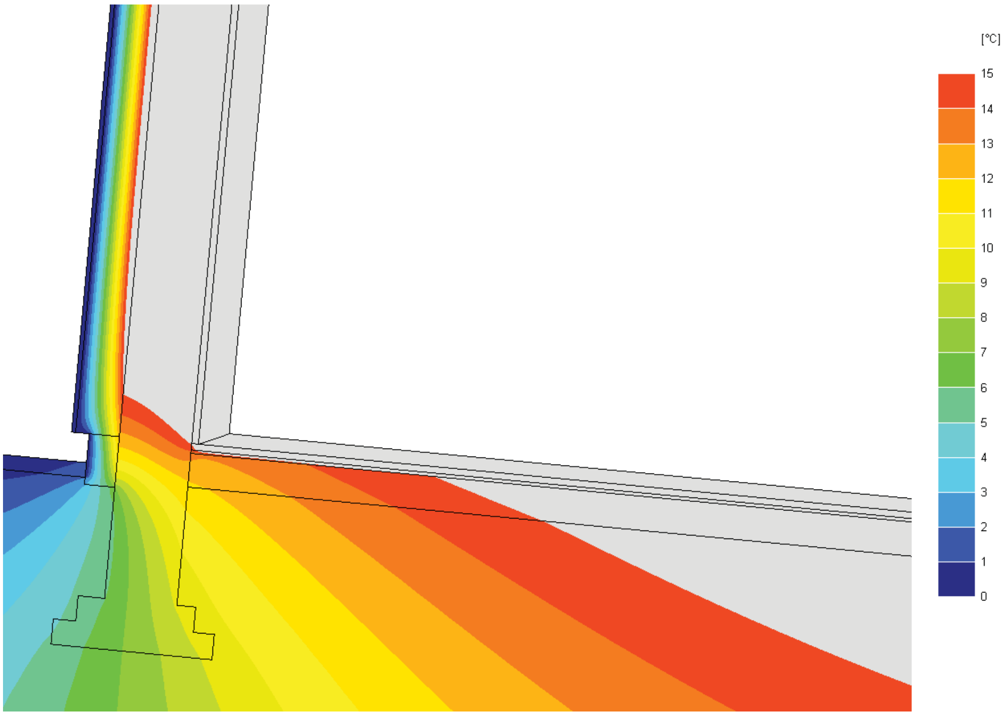


Figure G.4 - EWI solid wall-floor junction with perimeter insulation: Thermal image of TRISCO output

Where the ground floor consists of a replacement concrete floor (for either a previously uninsulated concrete floor or a timber floor which is being replaced) with insulation provided below the slab and internal perimeter insulation extending up 150 mm from the top of the under-slab insulation, the temperature factor is 0,77 and presents no condensation risk. External insulation does not extend below DPC level in this particular detail. Figure G.6 shows the TRISCO thermal image, which demonstrates that the internal surface temperature does not fall below 15 °C.

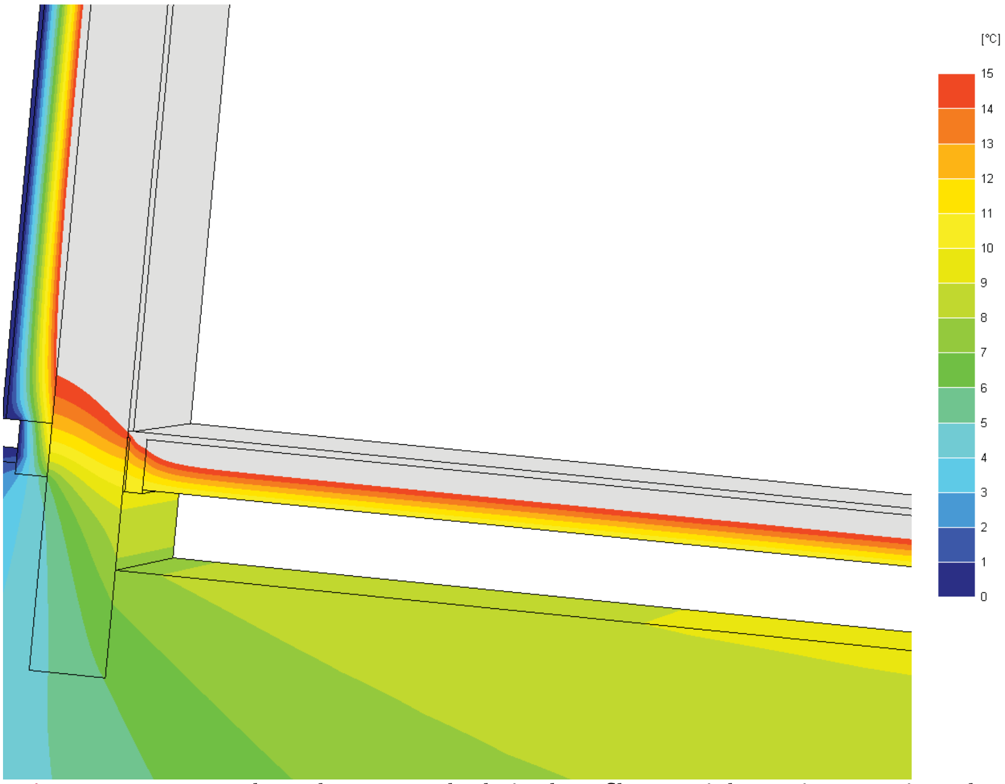


Figure G.5 - Insulated suspended timber floor with perimeter insulation: Thermal image of TRISCO output

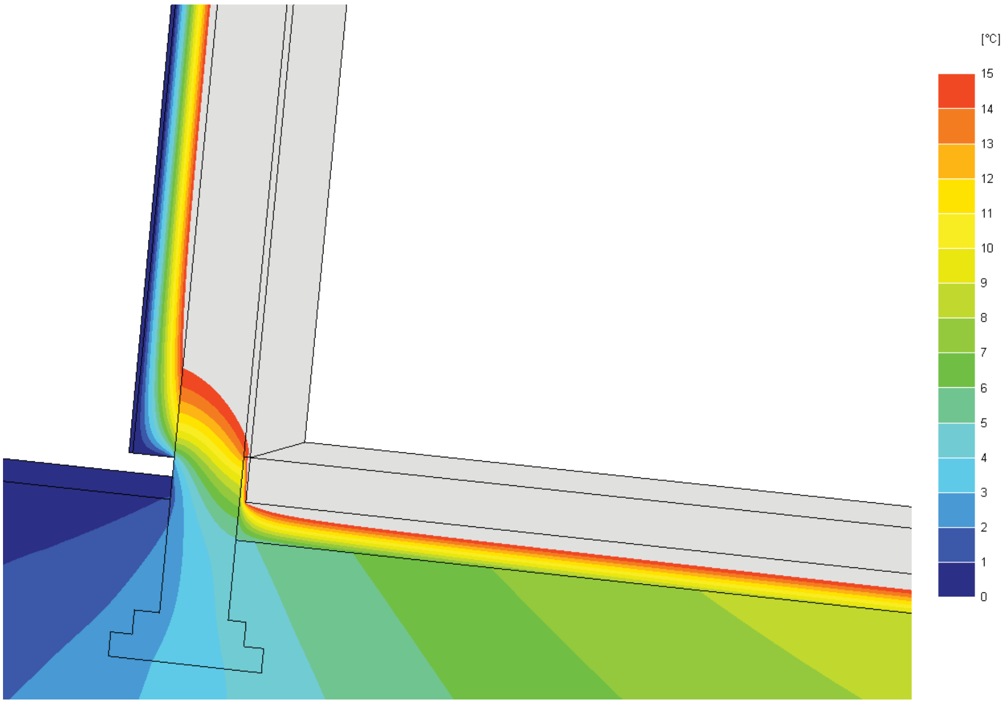


Figure G.6 - Insulated replacement concrete slab with internal perimeter insulation: Thermal image of TRISCO output

G.2.1.2 External wall junction with party wall

Figure G.7 shows the junction between a party wall and the solid external wall as modelled in TRISCO. Figure G.8 shows that the inside surface of a solid wall is already at a temperature below 15 °C as its temperature factor is 0,723. The focus therefore is whether the provision of EWI makes the existing situation worse.

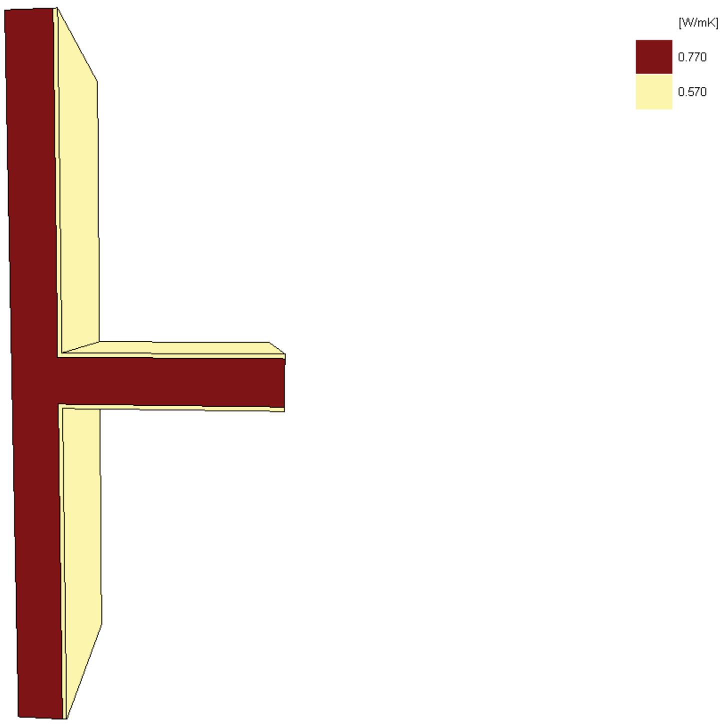


Figure G.7 - External wall junction with party wall (plan view): Materials modelled in TRISCO

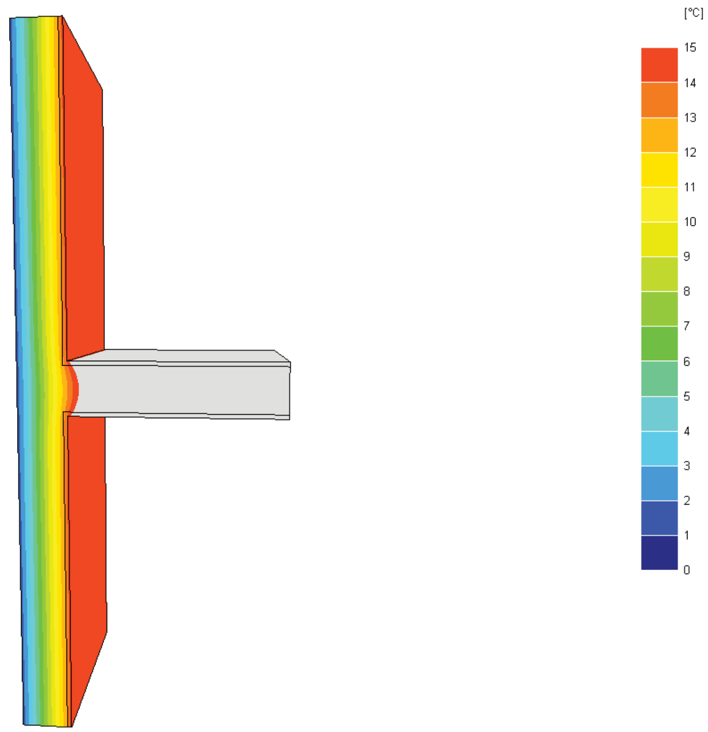


Figure G.8 - External wall junction with party wall (plan view): Thermal image of TRISCO output showing existing walls below 15 °C

All of the previous thermal images show that when EWI is installed the internal surface temperature of the external wall increases significantly. This will also be the case across a party wall line where the EWI continues on the adjacent dwellings. However, in many instances, EWI will only be installed up to the party wall line as shown Figure G.9.

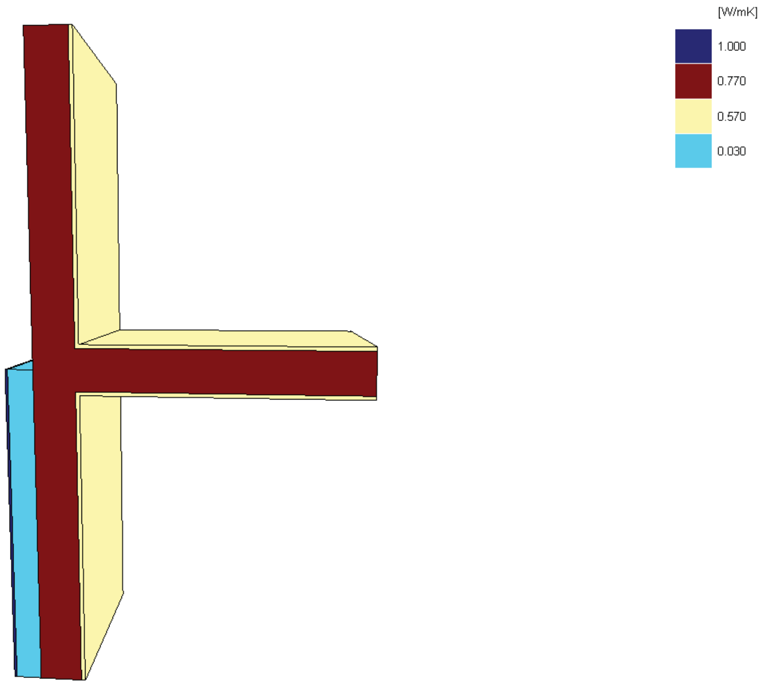


Figure G.9 - EWI up to party wall line (plan view): Thermal image of TRISCO output showing party wall is above 15 °C

Figure G.10 shows the thermal image of the TRISCO output. Here the party wall to external wall of the property receiving EWI is clearly above 15 °C, as is the corner of the wall in the adjacent property, although the remainder of the adjacent external wall not benefiting from EWI remains below 15 °C. This is because the presence of EWI on one side of the party wall has slightly improved the temperature factor to 0,78 at the corner of the uninsulated dwelling at the party wall.

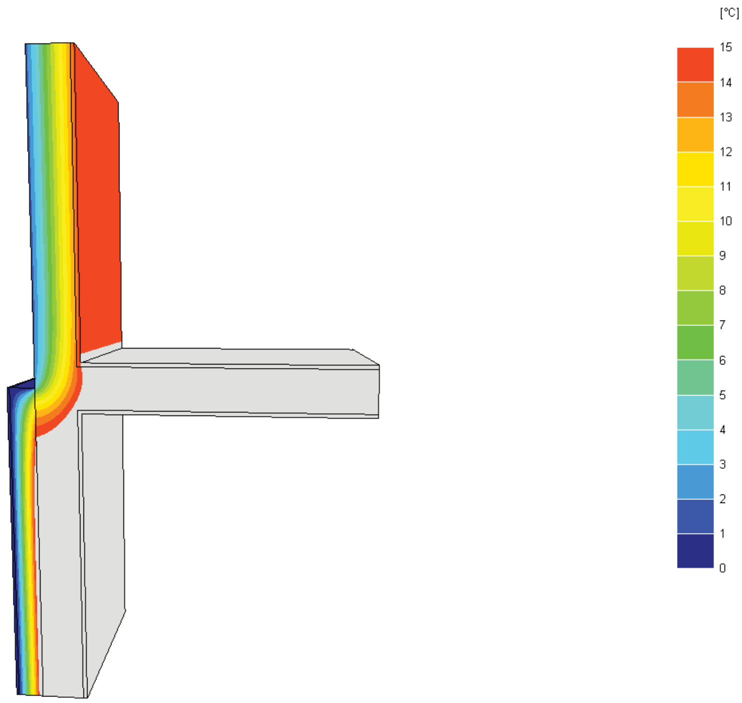


Figure G.10 - EWI up to party wall line (plan view): Thermal image of TRISCO output showing party wall is above 15 °C

G.2.1.3 Concrete/stone sill with EWI

In the Clause 7 Walls of this S.R. there is a recommendation to cut back an overhang of a concrete/stone sill when providing EWI. This is the only practical method to ensure insulation continuity in this location.

The presence of a concrete/stone sill provides a significant thermal bridge in an uninsulated external wall as shown in Figure G.11 and Figure G.12.

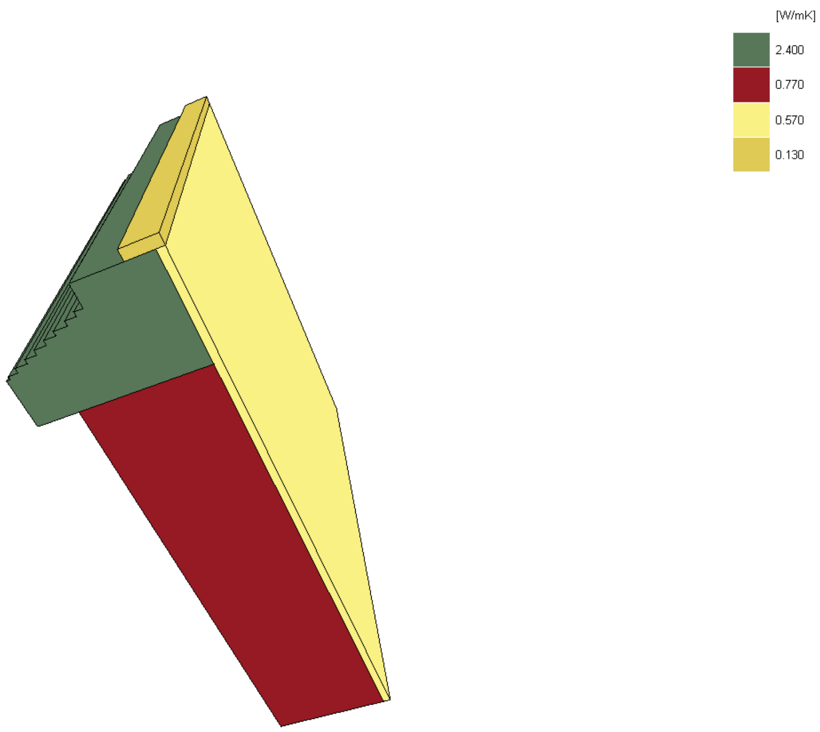


Figure G.11 - Concrete/stone sill: Materials modelled in TRISCO

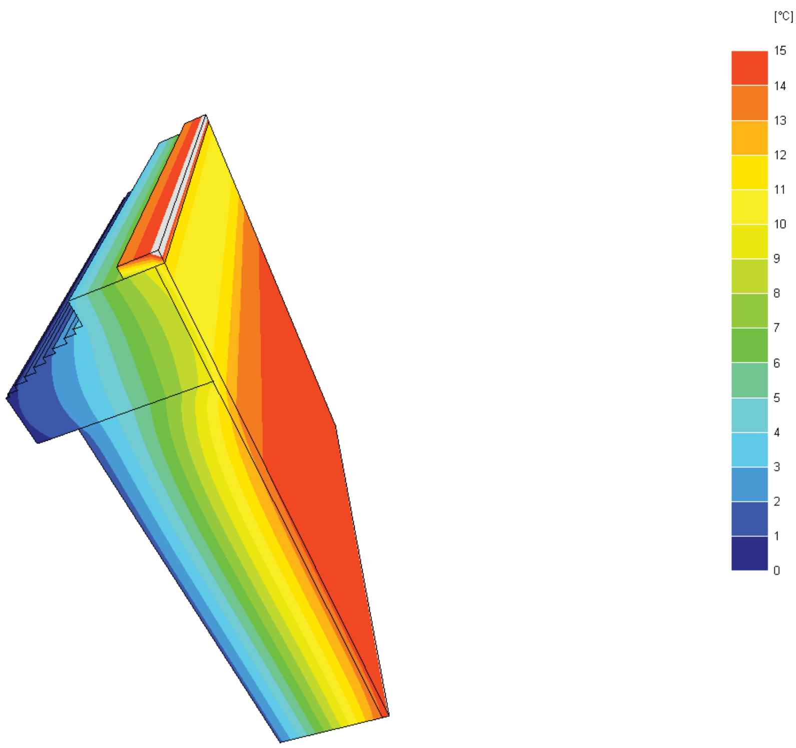


Figure G.12 - Concrete/Stone sill: Thermal image of TRISCO output showing the internal surface to the rear of sill is significantly below 15°C

The lowest surface temperature present is 10,7 °C (a temperature factor of 0,535) meaning this location will suffer significantly from surface condensation.

Although it is constructionally possible to provide EWI below the under sill (by inserting a suitable flashing beneath the under sill and over the top of the insulation) this will not eliminate the risk of surface condensation, as the minimum surface temperature only increases slightly to 11,5 °C. See Figure G.13 and Figure G.14.

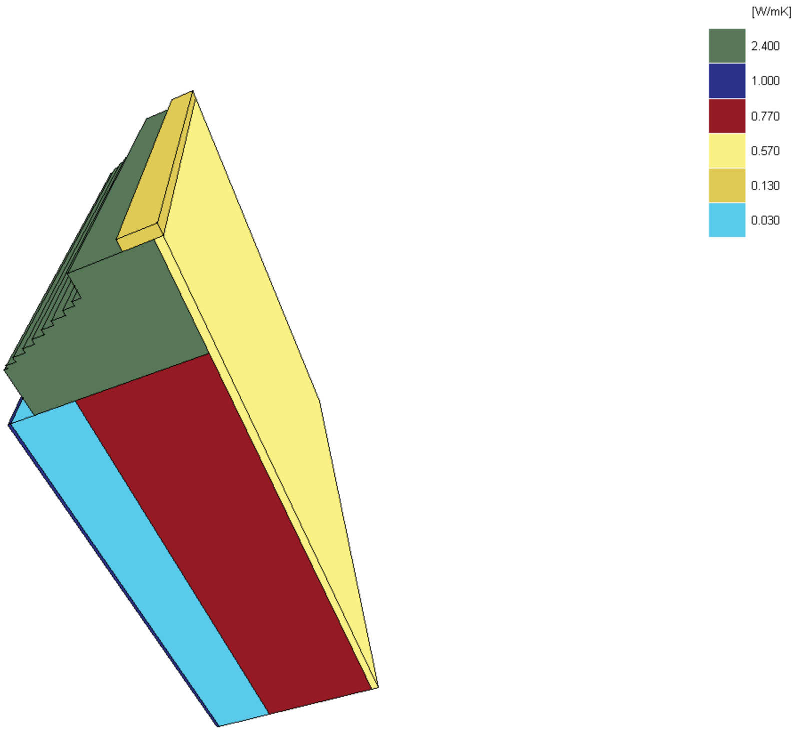


Figure G.13 - Materials modelled in TRISCO showing EWI terminated below the sill

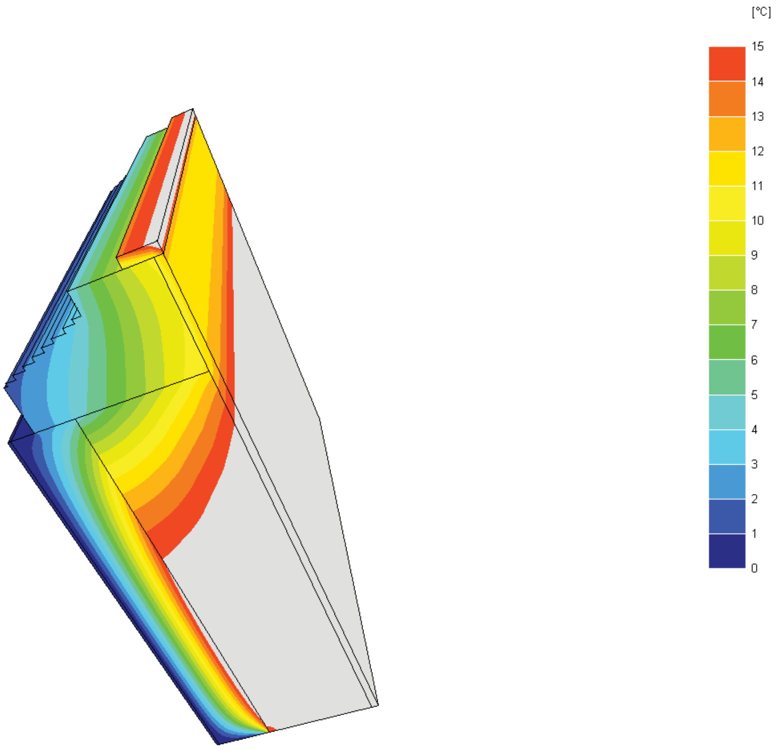


Figure G.14 - Thermal image of TRISCO output showing the internal surface to the rear of the sill is still significantly below 15 °C

However, by cutting back the sill, and lapping insulation to the window frame (see Figure H.4 in Annex H of this S.R.), ensures insulation continuity and eliminates the risk of surface condensation. See Figure G.15 and Figure G.16.

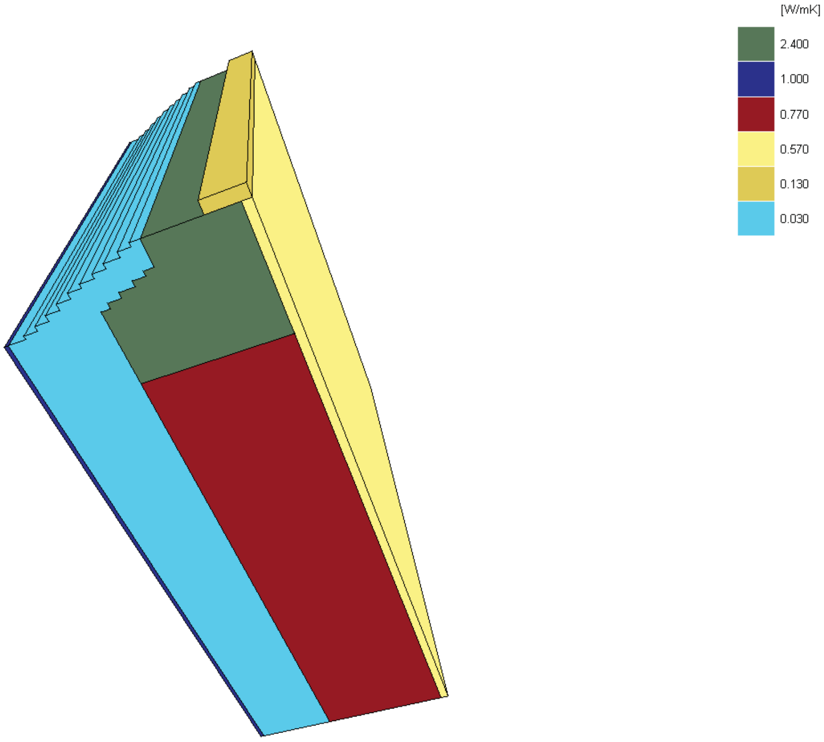


Figure G.15 - Materials modelled in TRISCO showing cut back sill

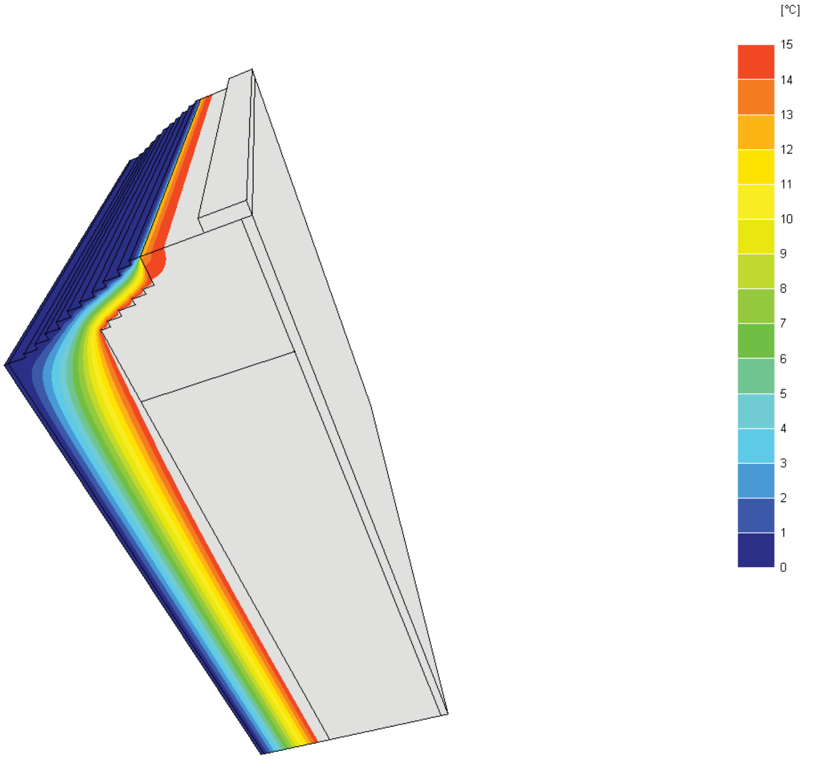


Figure G.16 - Thermal image of TRISCO output showing the internal surface to the rear of the cut back sill is significantly above 15 °C

G.2.2 Hollow block wall with IWI

The poor U-value of a hollow block wall (2,09 W/m^{2}K) means that the internal surface temperature of the entire wall surface is below 15 °C with a temperature factor of only 0,70. However, when IWI is applied to this wall its surface temperature increases, and this section shows how this affects other flanking thermal elements.

G.2.2.1 Junction with a flat warm roof and parapet

For a flat roof with a parapet, where new insulation is provided as IWI and where a warm roof is either formed, or already exists, there will be a discontinuity of the insulation within the unventilated roof void. Where an existing roof joist is located adjacent and parallel to the parapet wall, this offers some thermal resistance. However, where the roof joists are perpendicular to the parapet wall, the surface temperature of the wall/ceiling junction falls to about 15 °C; see Figure G.17 and Figure G.18.

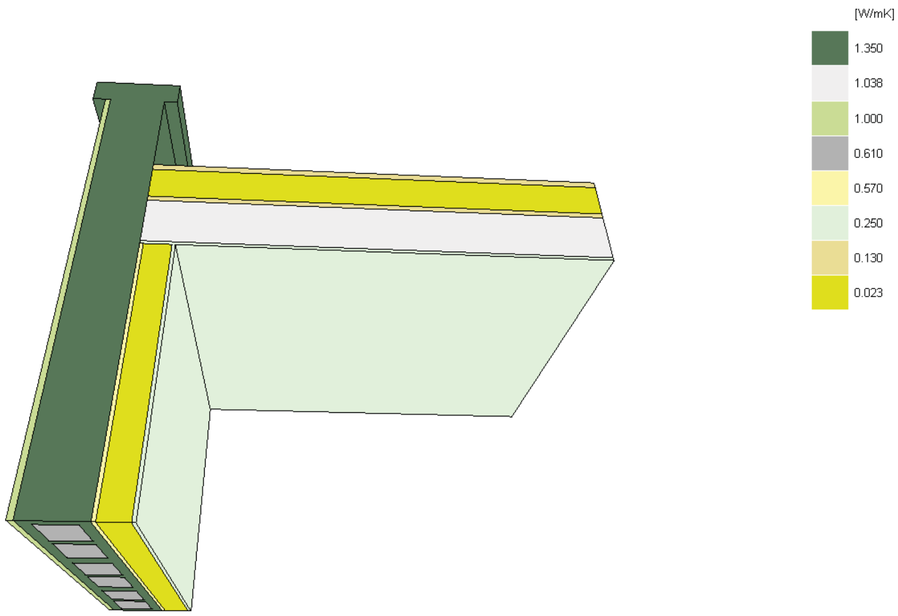


Figure G.17 - Hollow block wall with IWI, junction with flat warm roof and parapet: Materials modelled in TRISCO

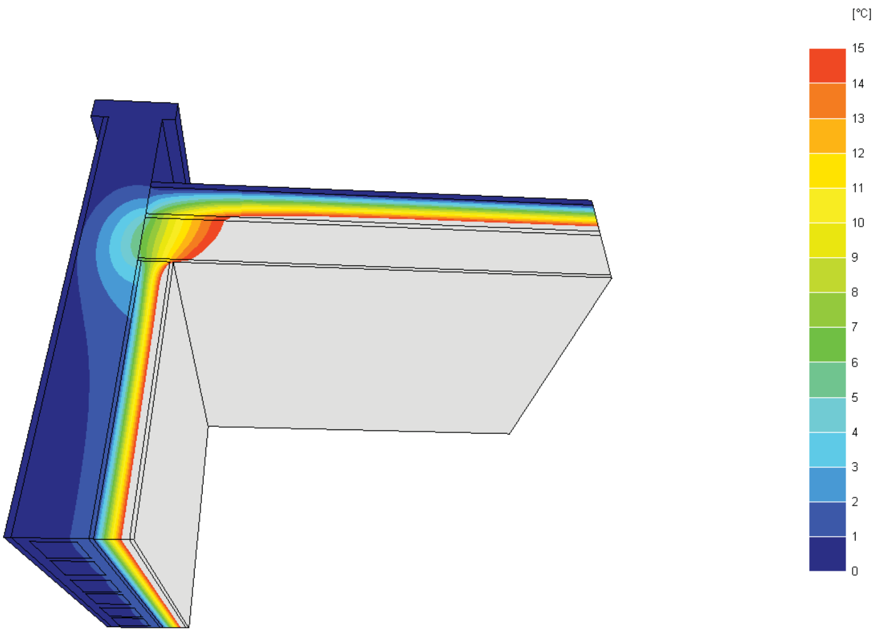


Figure G.18 - Hollow block wall with IWI, junction with flat warm roof and parapet: Thermal image of TRISCO output showing internal surface temperatures just above 15°C at ceiling/wall junction

With a temperature factor of 0,76, this junction is very close to the point where surface condensation could still occur following the installation of IWI. The surface temperature of the wall within the roof void will be significantly below 15 °C. It is essential therefore that all penetrations through the ceiling (for services etc.) are adequately sealed.

G.2.2.2 Junction with an uninsulated solid ground floor

Clearly, installing IWI to an external wall where the ground floor is either suspended timber insulated between the joists, or where a solid floor has insulation above the slab, provides a significant level of continuity of insulation.

However, where the floor slab is not insulated, this leads to thermal bridging at the junction between the floor and wall. Figure G.19 and Figure G.20 show the situation prior to installing IWI.

As shown in Figure G.20, close to the junction of the wall and floor slab, the surface temperature

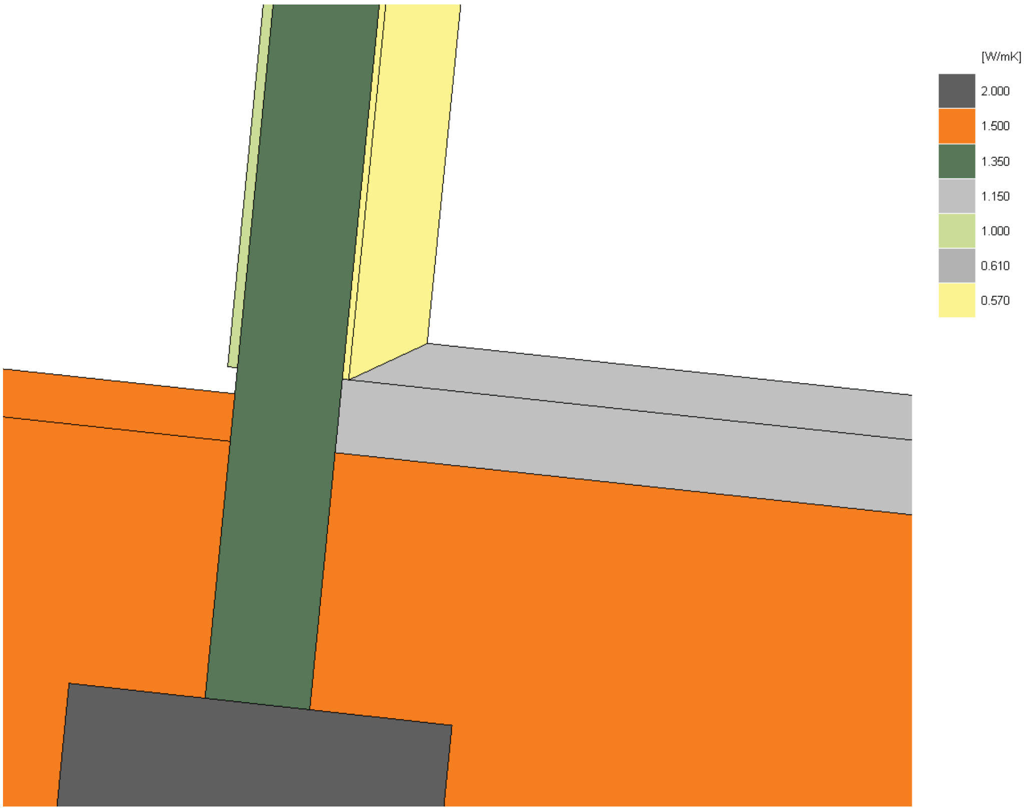


Figure G.19 - Hollow block wall, junction with uninsulated solid ground floor: Materials modelled in TRISCO

drops rapidly, and the temperature factor at the junction is 0,61.

However, installing IWI increases the wall surface temperature, but only slightly increases the floor

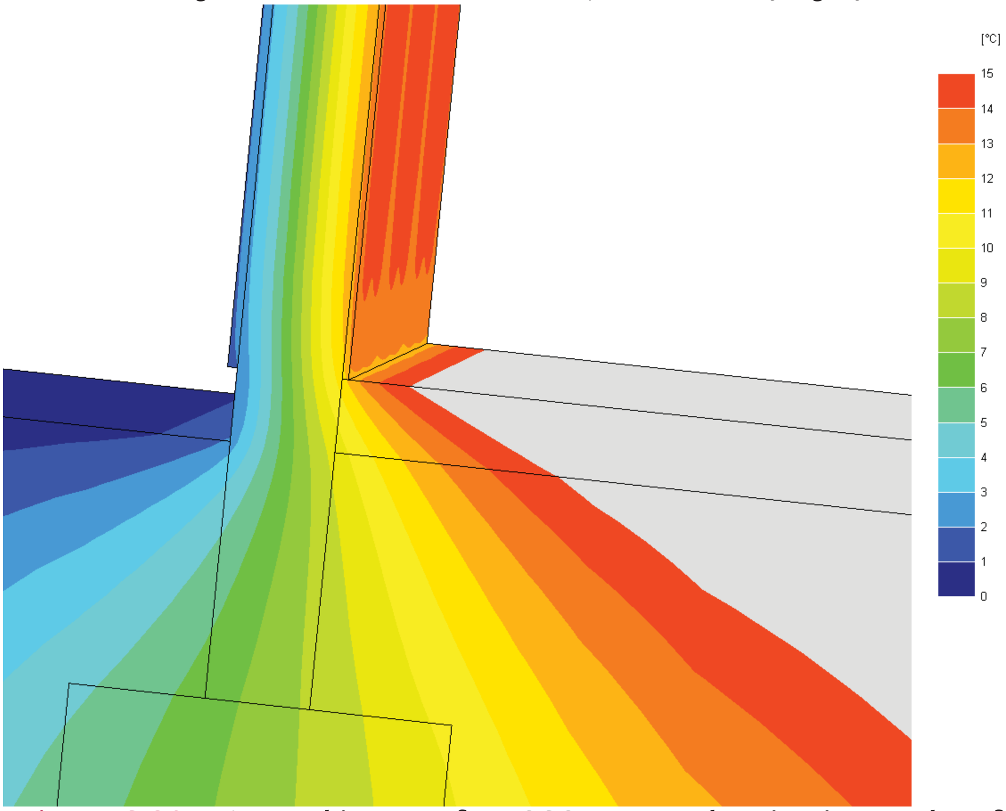


Figure G.20 - Thermal image of TRISCO output showing internal surface temperatures are below 15°C on wall surface and for first section of floor slab

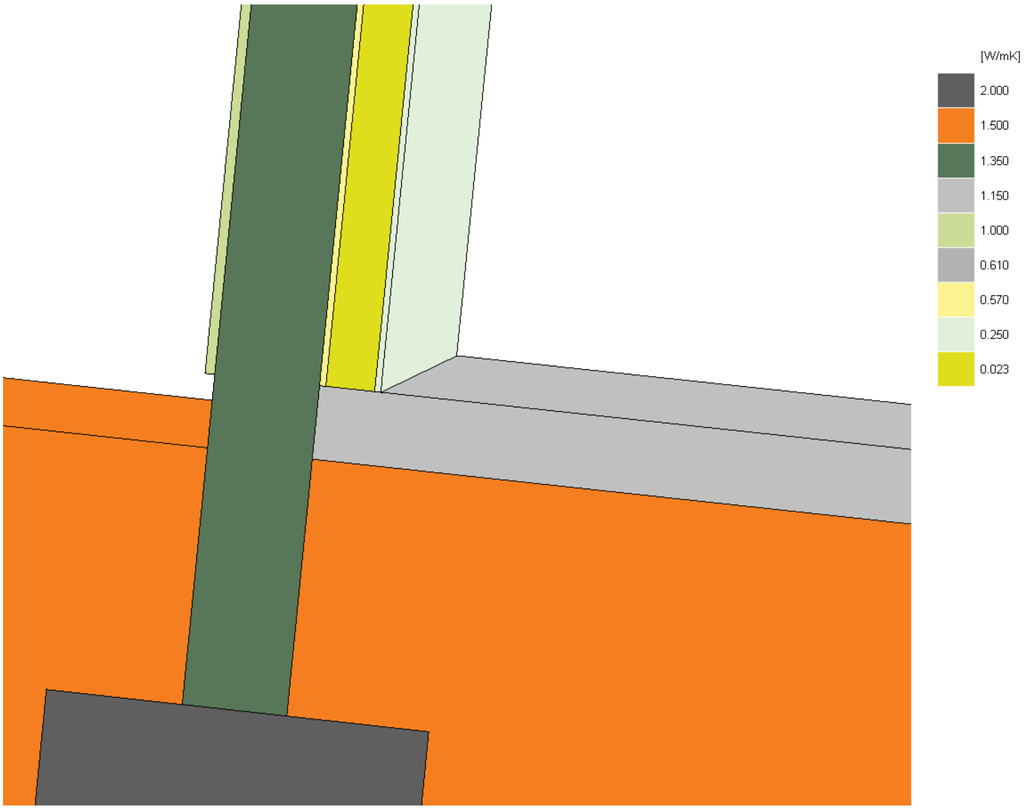


Figure G.21 - Hollow block wall with IWI, junction with uninsulated solid ground floor: Materials modelled in TRISCO

surface temperature. See Figure G.21 and Figure G.22.

The temperature factor of the floor/wall junction has risen slightly to 0,63, and has not changed the surface condensation risk. but there is still a section of floor slab that is below 15 °C. Therefore to

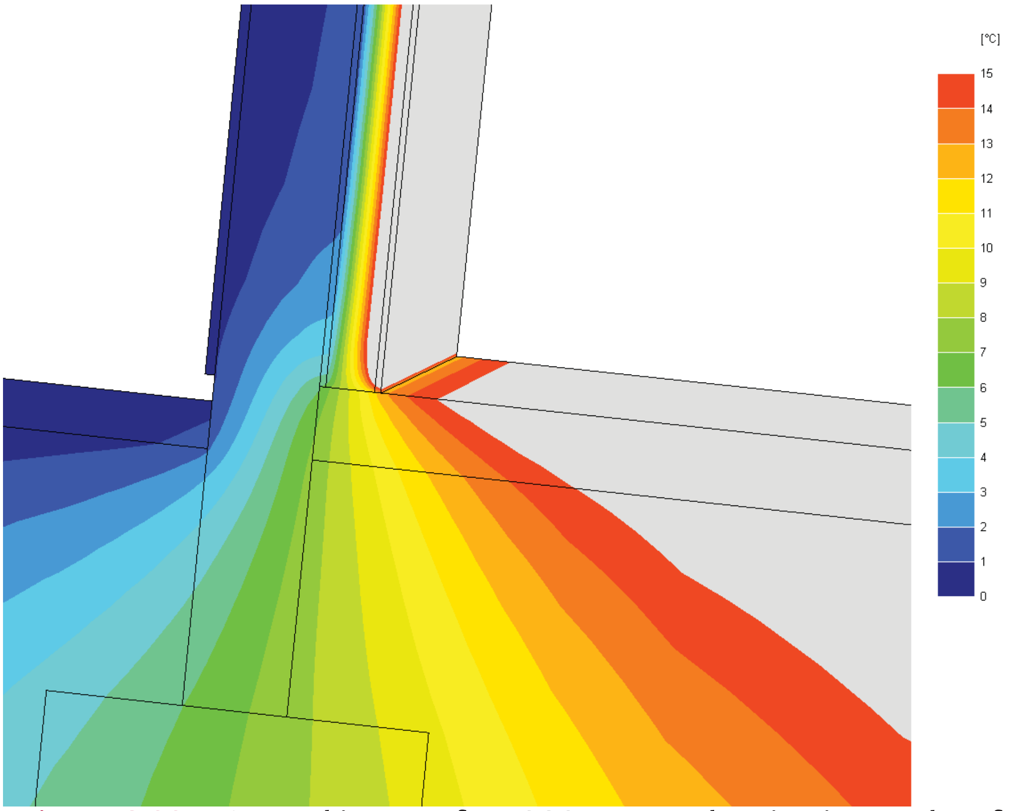


Figure G.22 - Thermal image of TRISCO output showing internal surface temperatures are still below 15°C on first section of floor slab

eliminate surface condensation on the floor, either the existing floor is provided with over-slab insulation or the floor replaced and below slab and perimeter insulation should be installed.

G.2.2.3 Junction with an intermediate floor

The junction of an intermediate floor is similar to the flat roof parapet junction shown in figure G.17. Again, it is important to ensure that all penetrations through the ceiling below and the floor above are sealed as adequately as is possible. However, sealing a floor can be potentially more difficult, and if this is the case then continuity of insulation should be provided between the joists where the joists are perpendicular. The situation where IWI is not provided between the joist is shown in Figure G.23 and Figure G.24; where insulation is provided is shown in Figure G. 25 and Figure G.26 .

It should be noted here, that thermal bridging software is not capable of determining the dew-point at which condensation within a structure will occur. However, the surface temperature

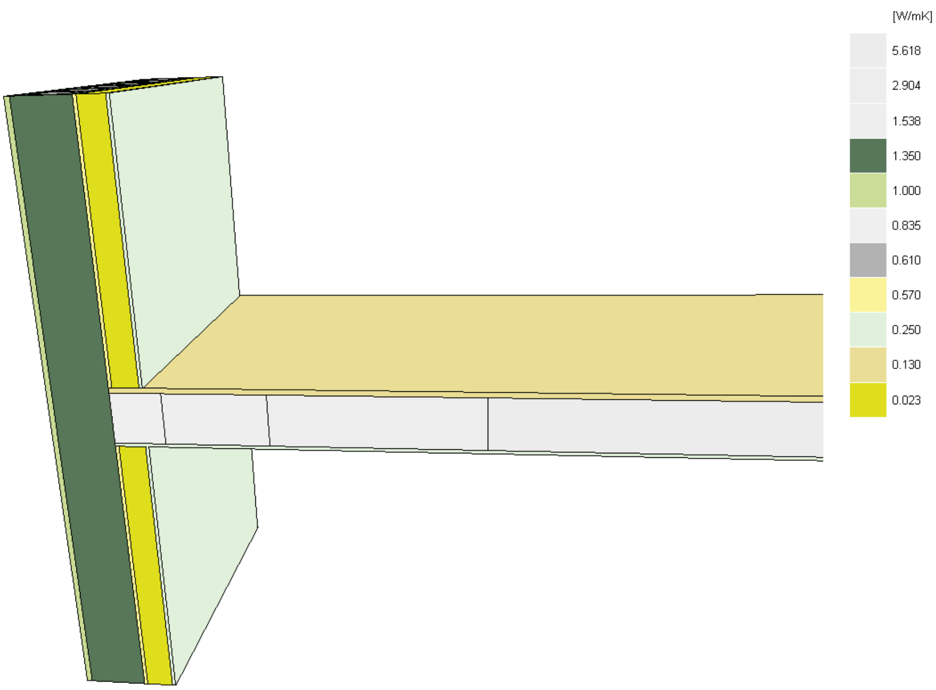


Figure G.23 - Hollow block wall with IWI, junction with intermediate floor: Materials modelled in TRISCO with no insulation between joists

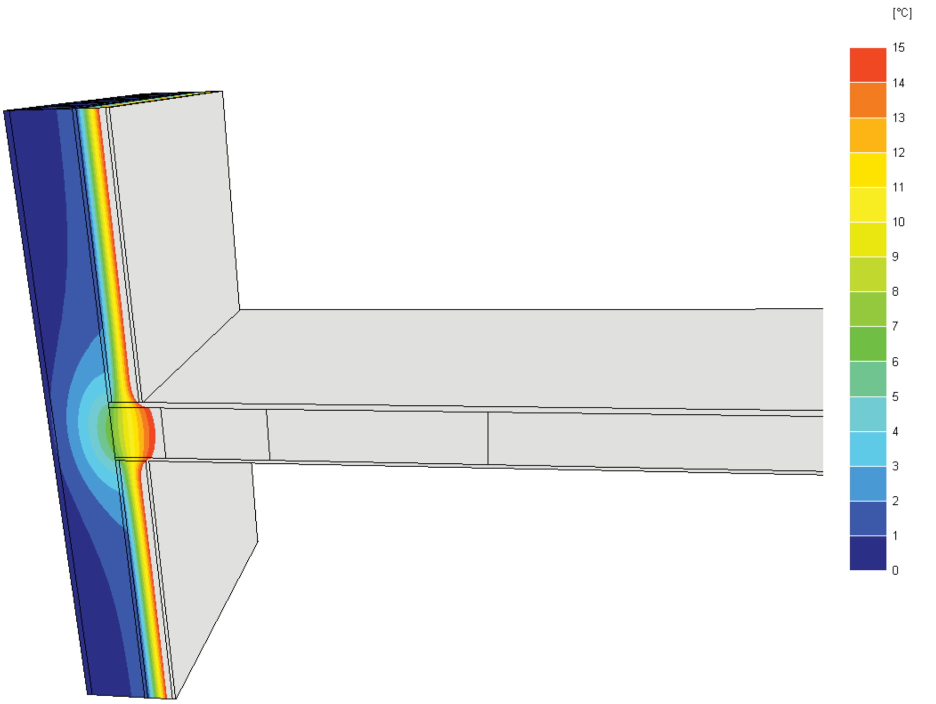


Figure G.24 - Thermal image of TRISCO output showing internal wall surface temperatures within floor structure are significantly below 15°C

of the wall in this location is between 6 °C and 7 °C, which clearly represent a risk of interstitial condensation where warm moist air from within the rooms of the dwelling could enter the floor void.

By insulatng between the joists the floor void surface temperatures are not below 15 °C and this

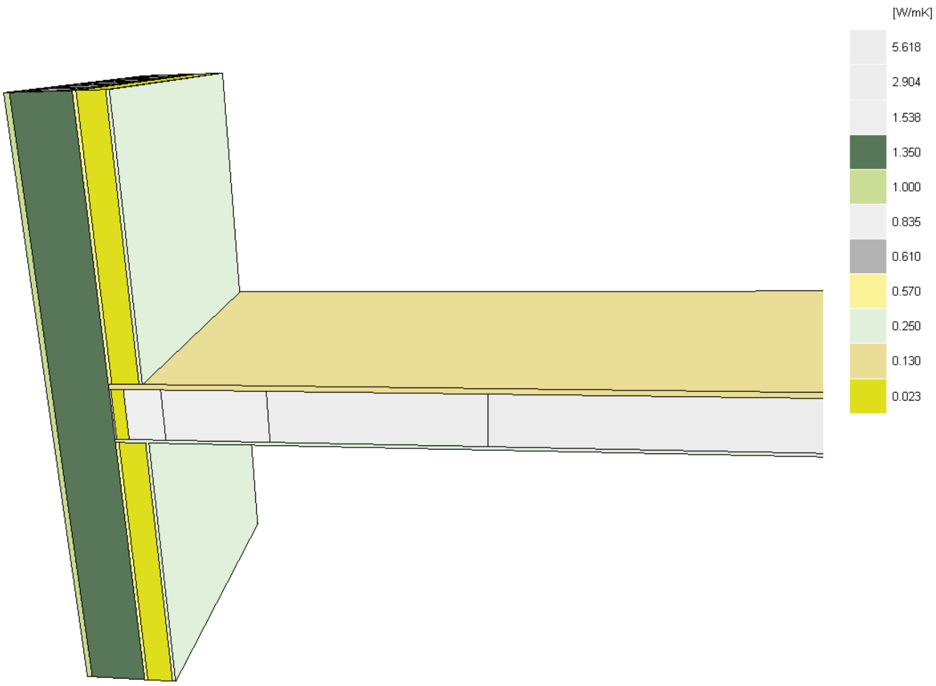


Figure G.25 - Hollow block wall with IWI, junction with intermediate floor: Materials modelled in TRISCO with insulation between joists

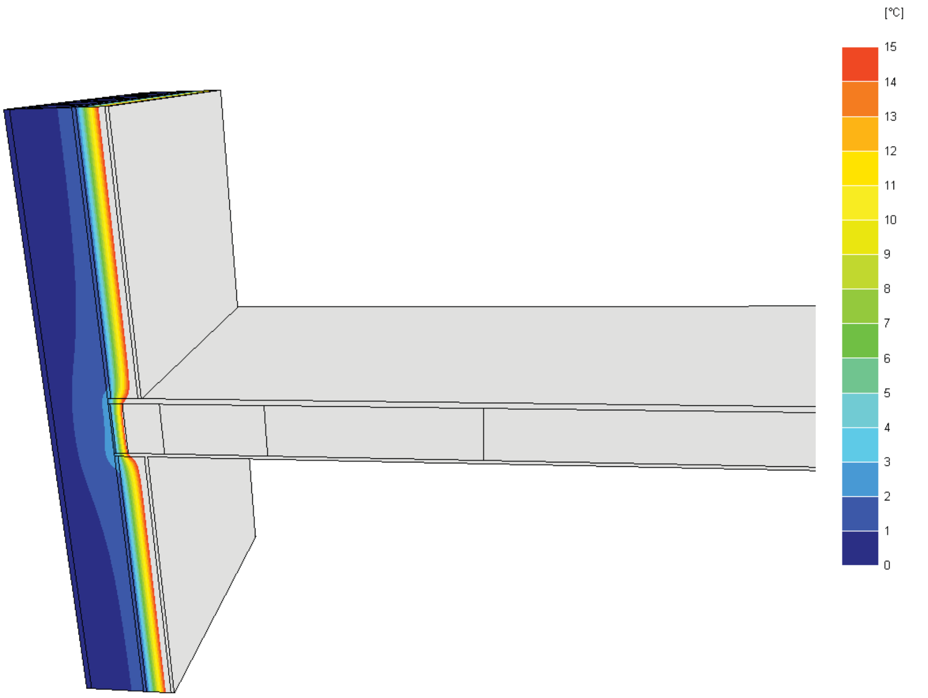


Figure G.26 - Thermal image of TRISCO output showing internal surface temperatures within floor structure are not below 15 °C

ensures interstitial condensation cannot occur, as the relative humidity within the floor cannot exceed that within the rooms. However, it is essential also that all edges of the insulation between the floor joists are adequately sealed.

G.2.2.4 Junction with a solid party wall

The focus here again is what happens within an adjacent property when one property is provided with IWI. It has been shown above that the provision of IWI increases the surface temperature of the wall that is upgraded. This has the potential to reduce the heat flow from that room into a party wall. The uninsulated situation is shown in Figure G.27 and Figure G.28.

Figure G.29 and Figure G.30 show the effect of providing IWI to one side of the party wall only.

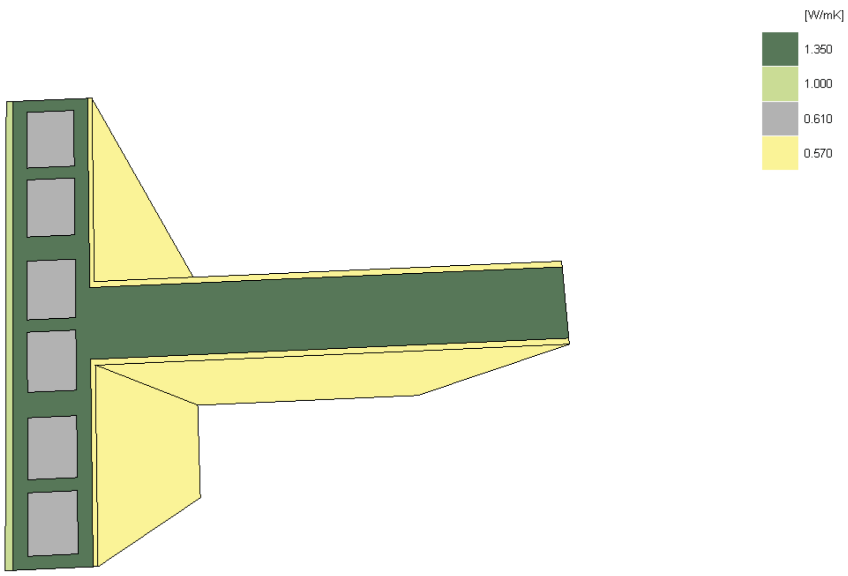


Figure G.27 - Uninsulated hollow block wall junction with solid party wall (plan view) : Materials modelled in TRISCO

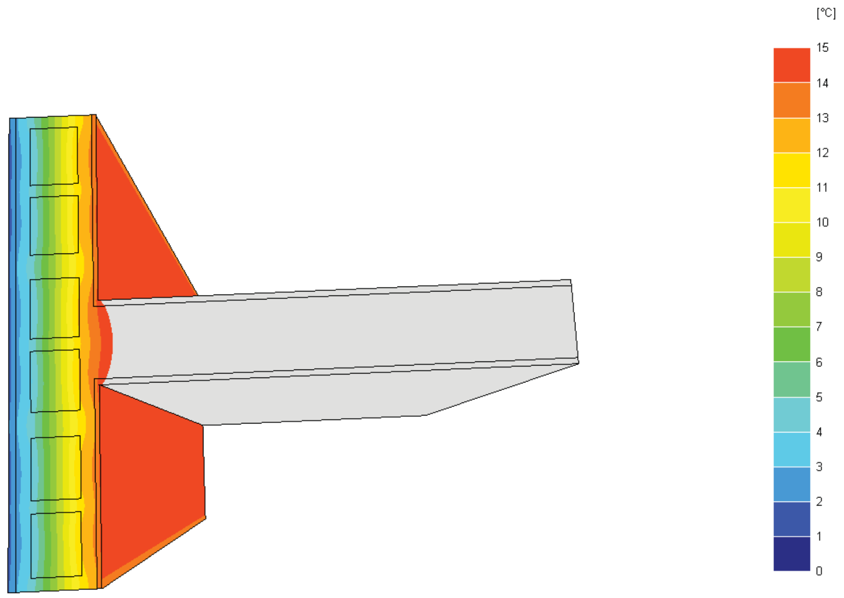


Figure G.28 - Thermal image of TRISCO output showing internal surface temperatures are below 15 °C and temperature factor of external wall is 0,692

The temperature factor within the adjacent property reduces from 0,692 to 0,686 which is 0,69 to

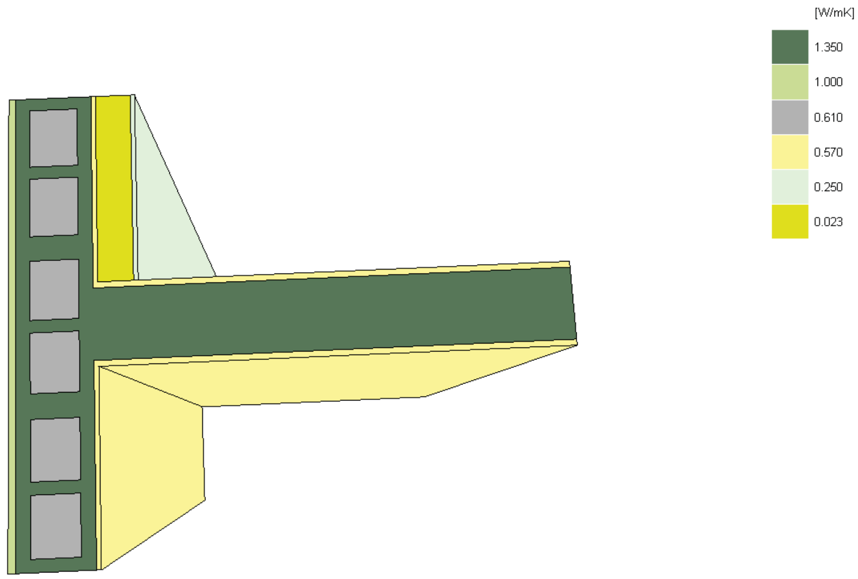


Figure G.29 - Insulated hollow block wall junction with solid party wall (plan view): Materials modelled in TRISCO with IWI one side only

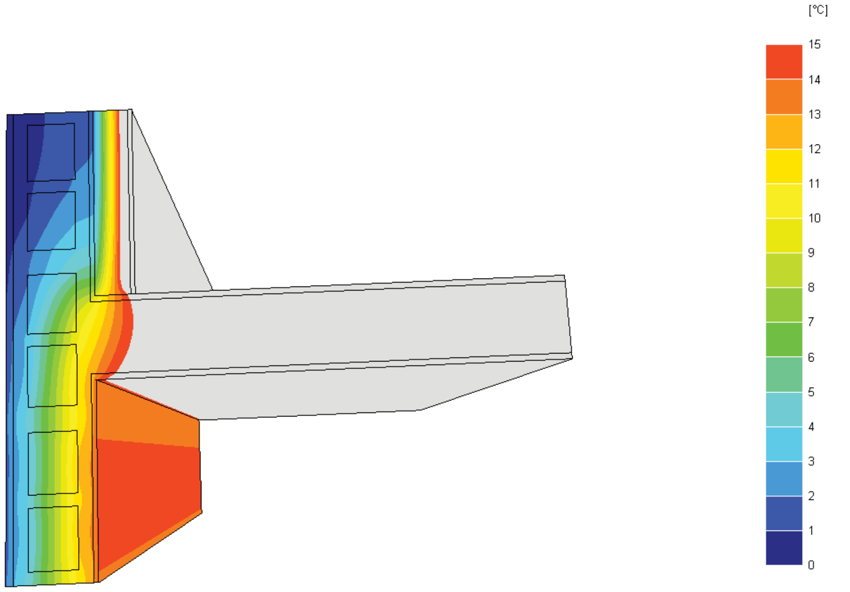


Figure G.30 - Thermal image of TRISCO output showing internal surface temperature of adjacent property is still below 15°C, and temperature factor here is 0,686

two decimal places, so this indicates that providing IWI to a room on one side of a party wall will not adversely affect the adjacent property.

G.2.2.5 Junction with a sills

The sill location for IWI offers a risk of surface condensation when no insulation is provided directly below the sill board. If surface condensation were to occur in this location, it could be misidentified as condensate forming on the glazing and running down onto the sill board, or that the window is leaking. See Figure G.31 and Figure G.32.

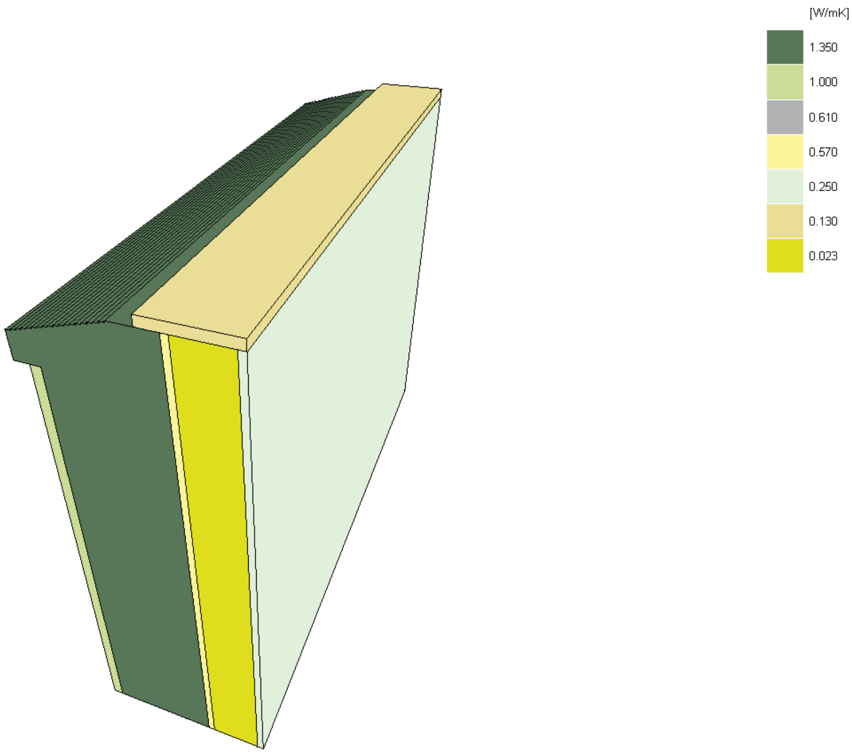


Figure G.31 - Materials modelled in TRISCO with no insulation below sill

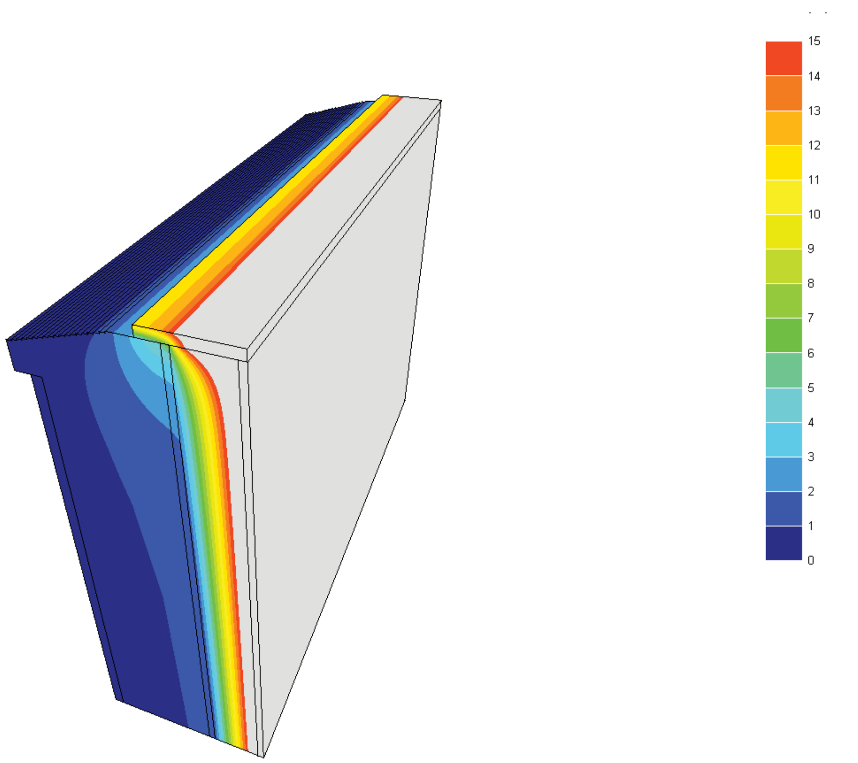


Figure G.32 - Thermal image of TRISCO output showing internal surface temperature of sill adjacent to window frame is below 15°C

Figure G.33 and Figure G.34 show that providing a layer of rigid insulation with minimal thickness directly under the sill board reduces the risk of surface condensation.

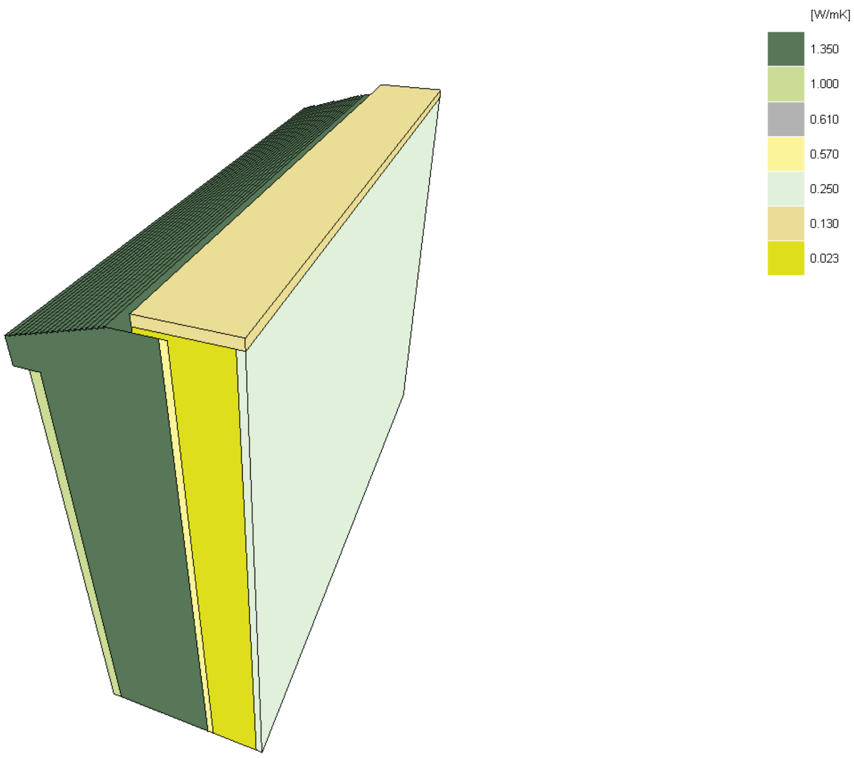


Figure G.33 - Materials modelled in TRISCO with insulation below sill

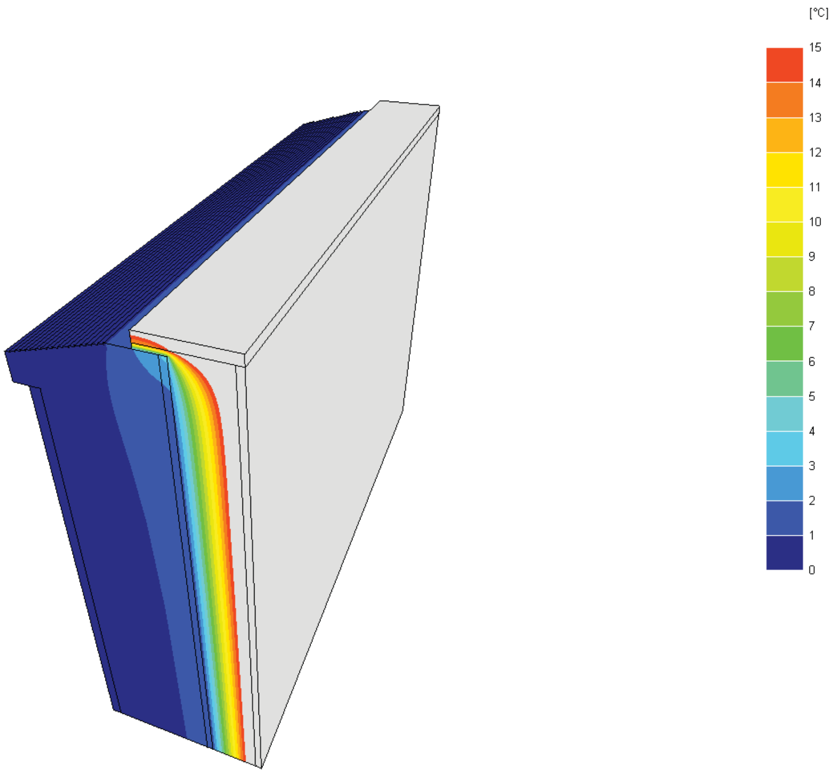


Figure G.34 - Thermal image of TRISCO output showing internal surface temperature of sill adjacent to window frame is now above 15°C

G.2.3 Cavity wall insulation (CWI)

G.2.3.1 Junction with a sill

The sill location for cavity walls offers a risk of surface condensation when the cavity is closed. If surface condensation were to occur in this location, it could be misidentified as condensate forming on the glazing and running down onto the sill board, or that the window is leaking. Figure G.35 and Figure G.36 show the existing situation with an unfilled cavity. The temperature factor

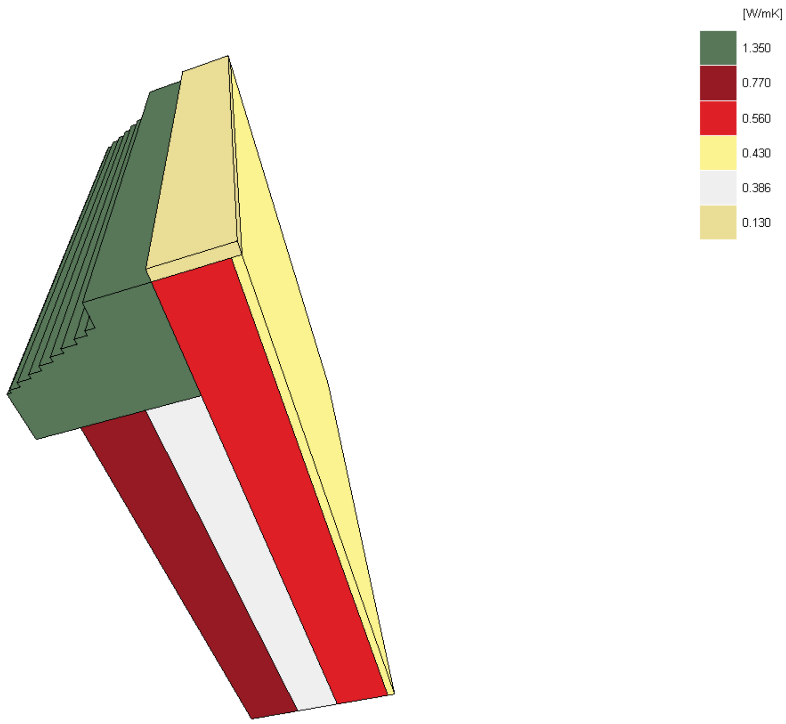


Figure G.35 - Uninsulated cavity wall, junction with sill: Materials modelled in TRISCO

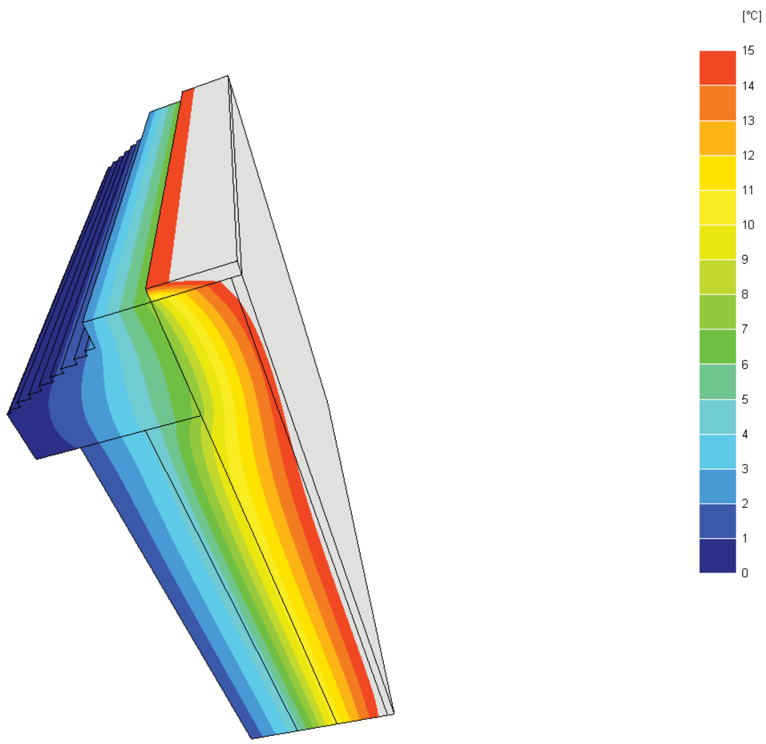


Figure G.36 - Thermal image of TRISCO output showing internal surface temperature of sill adjacent to window frame is just below 15 °C

here is actually 0,700.

If new windows are being provided, then it may be possible to provide a layer of rigid insulation with minimal thickness directly under the sill board which will eliminate the risk of surface condensation. However, where existing windows are being retained, as in Figure G.37 and Figure G.38, these show that with a filled cavity the temperature factor increases slightly to 0,704.

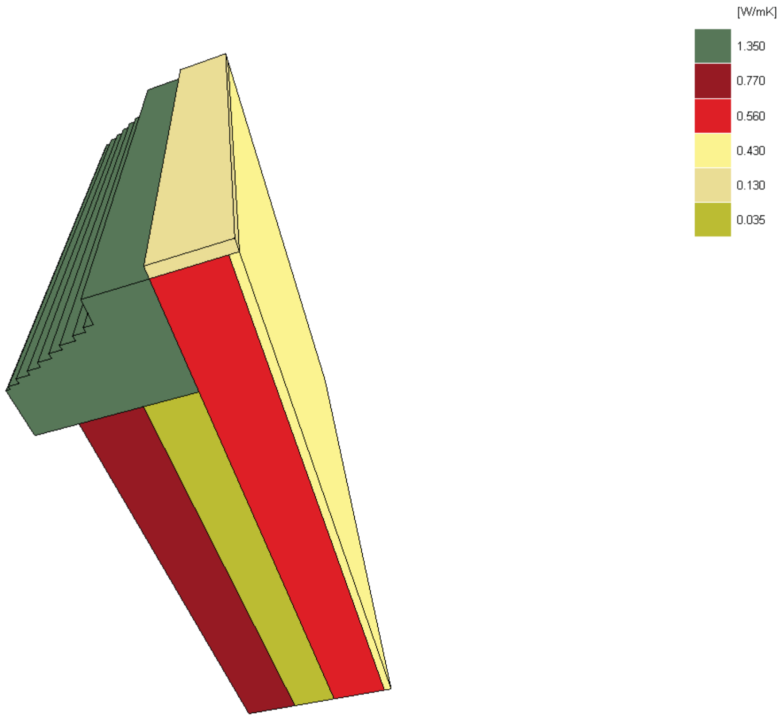


Figure G.37 - Insulated cavity wall, junction with sill: Materials modelled in TRISCO

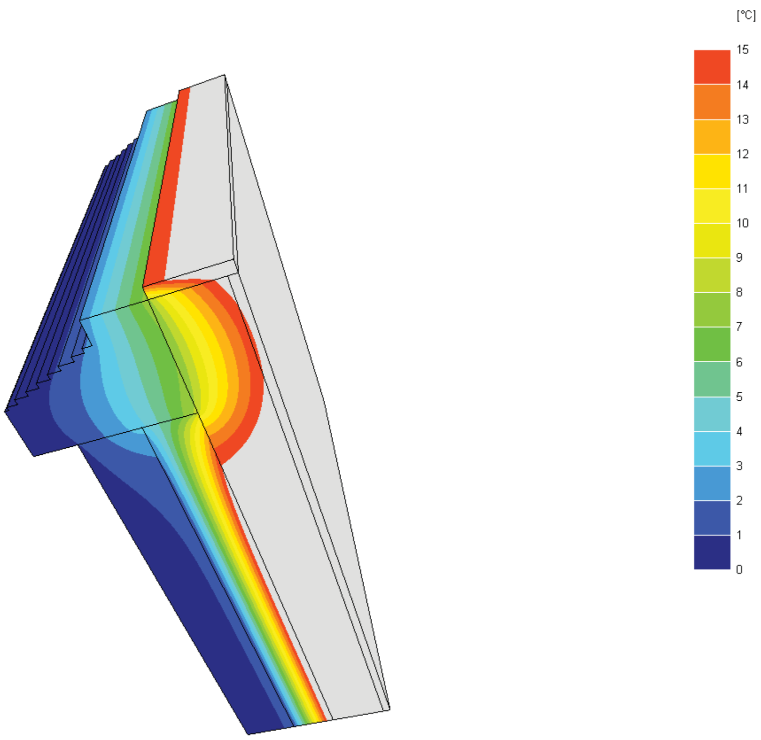


Figure G.38 - Thermal image of TRISCO output showing internal surface temperature of sill adjacent to window frame is still just below 15 °C

Annex H
(informative)

Thermal bridging details

H.1 External wall insulation for retrofit

The following details from Section 2 of 2008 *Acceptable Construction Details* (ACDs) may be applied in retrofit works as described in Table H.1.

Table H.1 identifies the appropriate details for retrofit works to avoid surface condensation. Where the detail is not necessary to avoid surface condensation but is recommended in order to reduce heat loss this is identified as an improved heat loss detail.

Detail 2.02 and 2.03 are not suitable for retrofit works and a revised version of this detail for retrofit application is shown in Figure H.1 and Figure H.2. Figure H.4 has also been provided for a sill.

Table H.1 - ACDs for External Wall Insulation

Detail No.	Description	Detail required to avoid Surface Condensation	Improved heat loss detail	Comment
2.01	Ground floor - insulation above slab	NA		
2.01a	Ground floor - insulation above slab	N	Y	
2.02	Ground floor - insulation below slab	NA		See Figure H.1
2.02a	Ground floor - insulation below slab	N	Y	
2.03	Timber suspended ground floor	NA		See Figure H.2
2.03a	Timber suspended ground floor	N	Y	
2.04	Concrete intermediate floor	Y		
2.05	Masonry separating wall - plan	Y		
2.06	Masonry partition wall - plan	Y		
2.07	Stud partition wall - plan	Y		
2.08	Eaves - ventilated roof space	Y		See Figure H.3 for additional guidance
2.09	Eaves - unventilated roof space	NA		
2.10	Eaves - ventilated - insulation between and under rafters - dormer	Y		
2.11	Eaves - unventilated - insulation between and under rafters - dormer	Y		
2.12	Eaves - ventilated - insulation between and under rafters - pitched ceiling	Y		
2.13	Eaves - unventilated - insulation between and over rafters	Y		

Detail No.	Description	Detail required to avoid Surface Condensation	Improved heat loss detail	Comment
2.14	Ventilated Roof - Attic Floor Level	Y		
2.15	Gable - Insulation between and under rafters - Ventilated Rafter Void	Y		
2.16	Gable - Insulation between and under rafters - Unventilated Rafter Void	Y		
2.17	Gable - Insulation between and over rafters - Unventilated Rafter Void	Y		
2.18	Flat Roof - Eaves	Y		
2.20	Ope - Lintel	Y		
2.21	Ope - Jamb	Y		
-	Cill detail	See Figure H.4		
NOTE	NA = detail not applicable for retrofit			

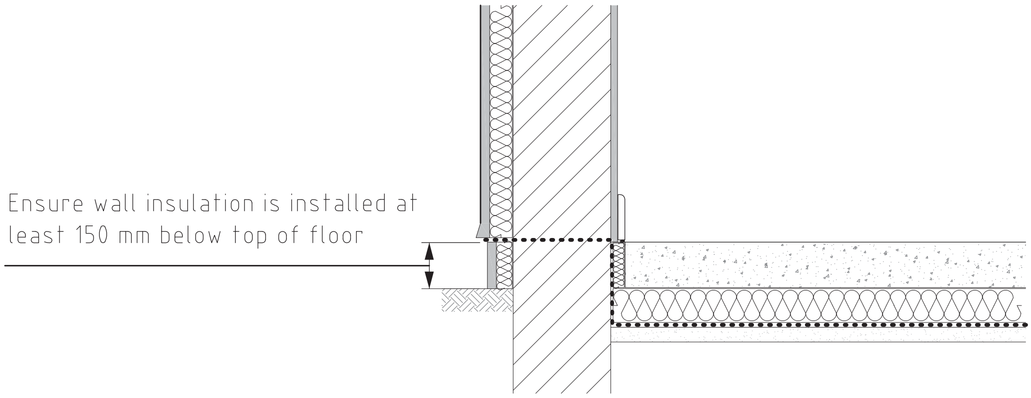


Figure H.1 - Ground Floor - Insulation below slab

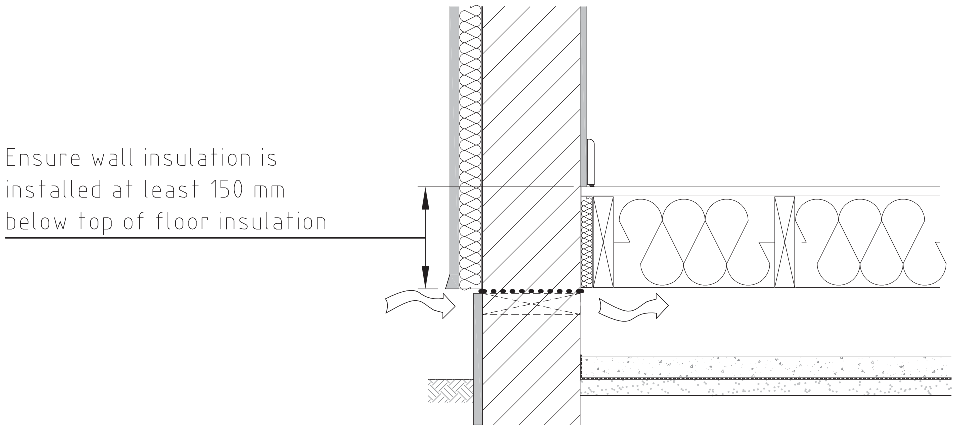


Figure H.2 - Timber suspended ground floor

H.1.1 Floors

Providing a minimum depth of external perimeter insulation, which extends down 150 mm from the finished floor level removes the risk of surface condensation.

H.1.2 Eaves

The method described in Figure H.3 allows for the EWI to join the roof insulation but care should be taken to ensure ventilation is maintained to the cold roof space. If packing insulation into the eaves, then a clear ventilation path should be maintained. This is facilitated by soffit ventilators and eaves ventilators. See Figure H.3 .

Where a clear path cannot be established then roof vents can be fitted no greater than 300 mm above the level of the top of the loft insulation, in a manner similar to Figure H.8.

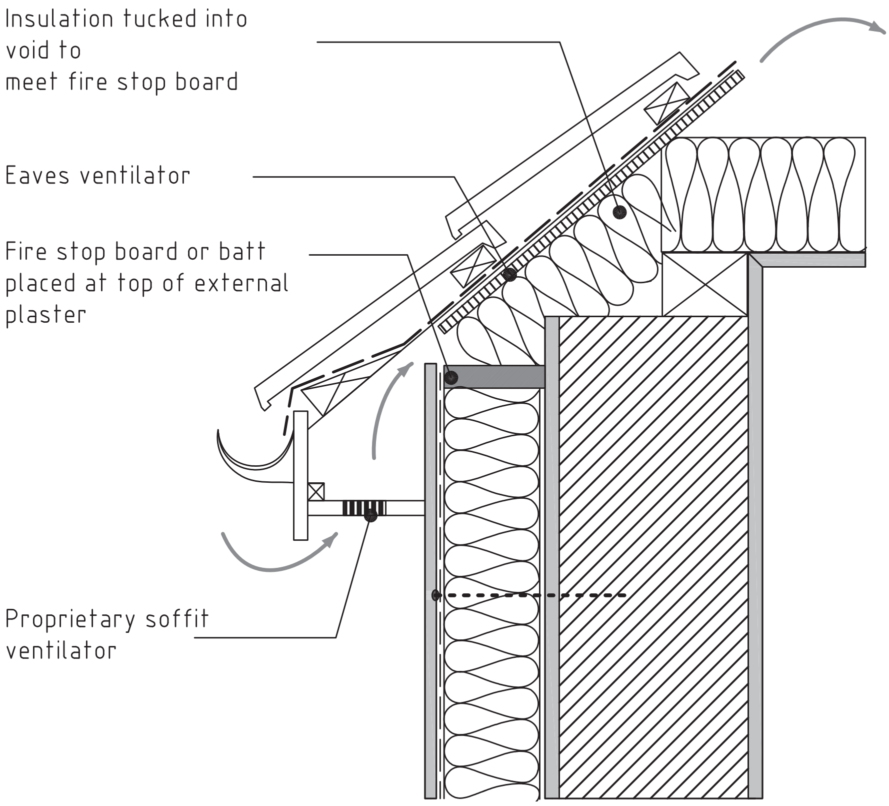


Figure H.3 - Junction of external insulation and roof insulation at ceiling level

H.1.3 Windows and openings

Measures to prevent thermal bridging at sill location as shown in Figure H.4 are as follows:

- the stone or concrete sill is cut back to give a smooth finish;
- a wind bracket can be fitted prior to the insulation, which will provide extra rigidity to new over sill and also prevent driven rain or moisture through capillary action to infiltrate behind the render layer;
- insulation is placed into the void under the over-sill, and this allows the thermal envelope to meet the window. The over-sill is fixed according to the certificate instructions, and seals or gaskets maintain the water resistance;
- any drain holes in the window frame should be allowed for and kept clear.

To prevent thermal bridging at window and door jamb locations external insulation should be returned into the window frame/jamb. See Figure H.5.

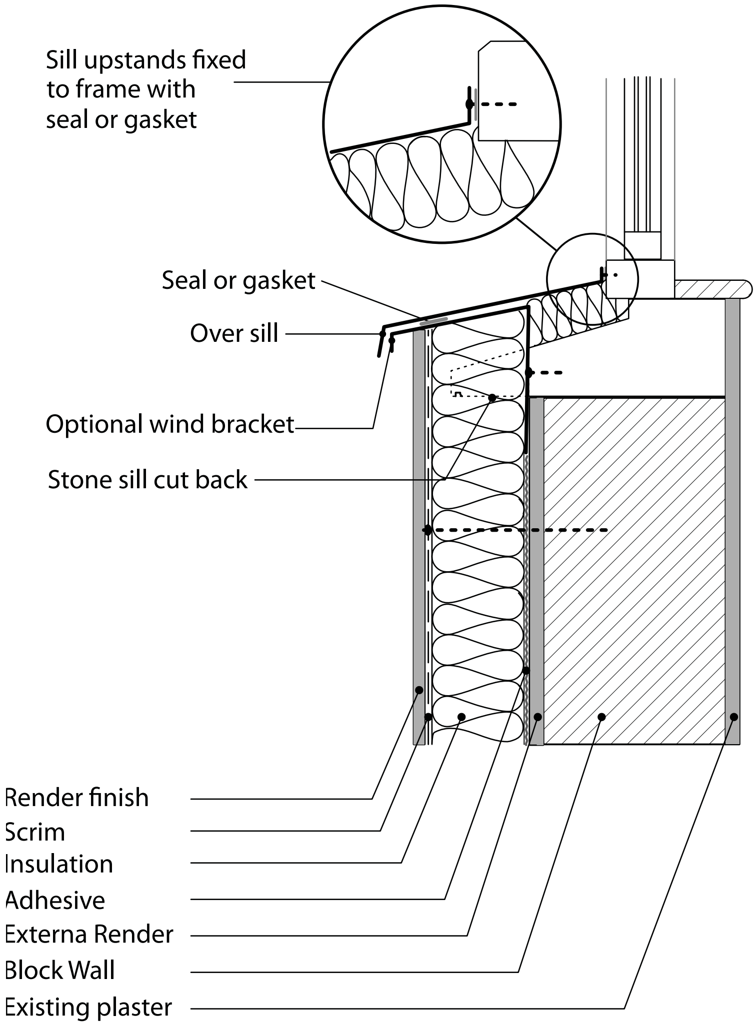


Figure H.4 - Sill detail for external insulation

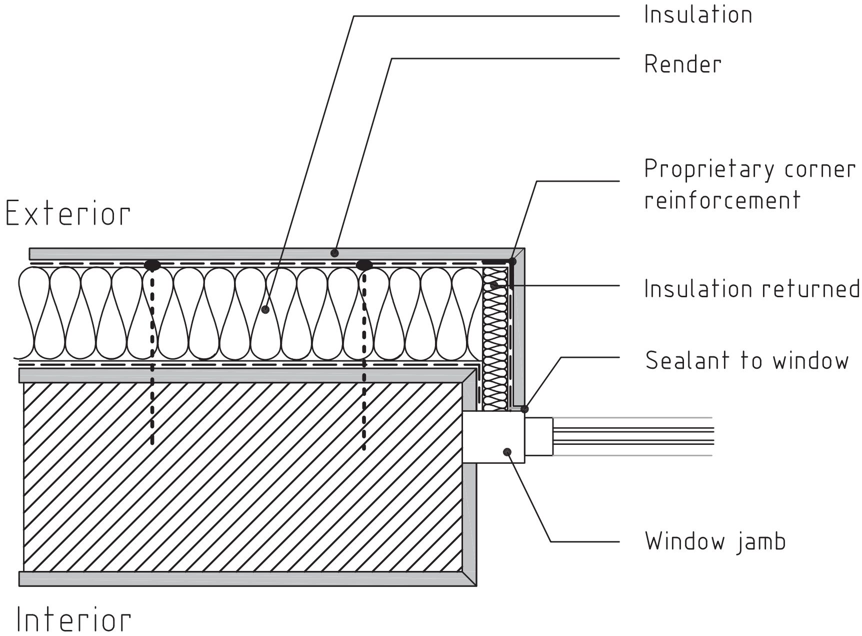


Figure H.5 - Jamb detail for external insulation

To prevent thermal bridging at window and door head locations external insulation should be returned into the window frame. See Figure H.6.

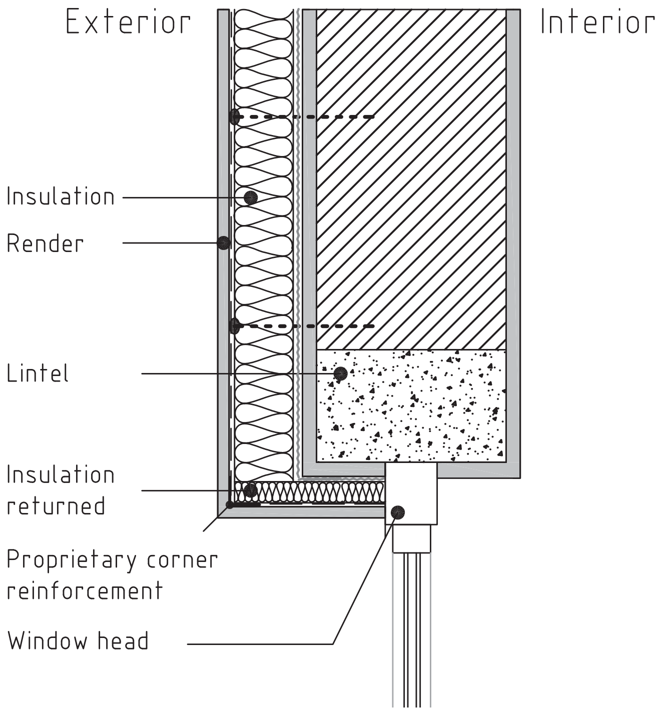


Figure H.6 - Head detail for external insulation

H.2 Internal wall insulation details for retrofit

The following details from Section 6 of 2008 Acceptable Construction Details (ACDs) produced by the Department of Environment, Community and Local Government may be applied as detailed in Table H.2.

The following table identifies where the detail is required to avoid surface condensation. Where the detail is not necessary to avoid surface condensation, but is recommended in order to reduce heat loss, this is identified as an improved heat loss detail.

Detail 6.04, detail 6.09 and detail 6.21 are not suitable for retrofit works and revised versions of these details for retrofit application are provided in Figures H.7, H.8 and H.9.

Table H.2 - ACDs for Internal Wall Insulation

Detail No.	Description	Detail required to avoid Surface Condensation	Improved heat loss detail	Comment
6.01	Ground Floor - Insulation above slab	Y		Where perimeter floor insulation does not exist the provision of IWI creates no greater surface condensation
6.02	Ground Floor - Insulation below slab	Y		As for comment in 6.01
6.03	Timber Suspended Ground Floor	Y		As for comment in 6.01
6.04	Timber Intermediate Floor		Y	See Figure H.7 for detail of joist running perpendicular to wall
6.0.5	Masonry Separating Wall - plan	N	Y	

Detail No.	Description	Detail required to avoid Surface Condensation	Improved heat loss detail	Comment
6.06	Masonry Partition Wall - plan	N	Y	
6.07	Stud Partition Wall - plan	NA	NA	
6.08	Eaves - Ventilated roof space	Y		See Figure H.8
6.09	Eaves - Unventilated roof space	N		See Figure H.8
6.10	Eaves - Ventilated - Insulation between and under rafters - Dormer	Y		
6.11	Eaves - Ventilated - Insulation between and under rafters - Pitched ceiling	Y		
6.12	Eaves - Unventilated - Insulation between and over rafters - Dormer	Y		
6.13	Ventilated Roof - Attic Floor Level	Y		
6.14	Gable - Insulation between and under rafters - Ventilated Rafter Void	N	Y	
6.15	Gable - Insulation between and under rafters - Unventilated Rafter Void	N	Y	
6.16	Gable - Insulation between and over rafters - Unventilated Rafter Void	Y		
6.17	Flat Roof - Eaves	Y		.
6.18	Flat Roof - Parapet	N	Y	
6.19	Ope - Lintel	Y		
6.20	Ope - Jamb	Y		
6.21	Ope - Sill	N/A	N/A	See Figure H.9
NOTE	NA = detail not applicable for retrofit			

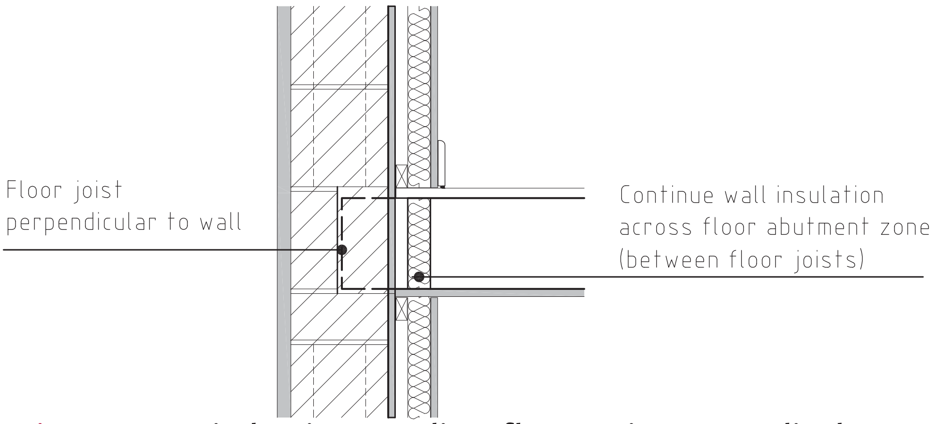


Figure H.7 - Timber intermediate floor - Joist perpendicular to wall

(INFORMATIVE) THERMAL BRIDGING DETAILS

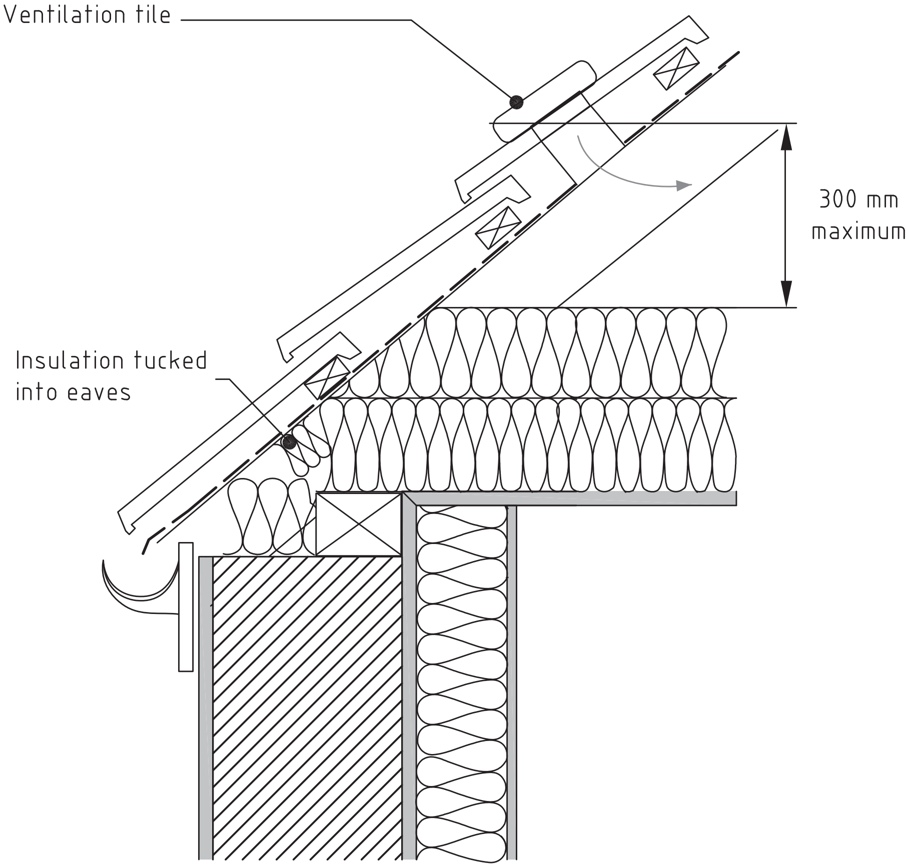


Figure H.8 - Correct location for fitting of roof vent

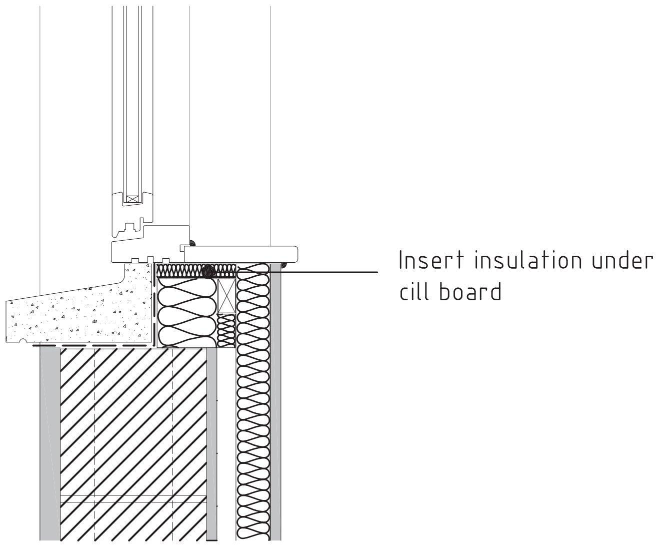


Figure H.9 - Internal wall insulation - Cill detail

H.3 Cavity wall insulation for retrofit

The following details from Section 1 of 2008 ACDs may be applied in retrofit works. It is assumed that all cavities are to be full filled.

Table H.3 identifies where the detail is required to avoid surface condensation. Where the detail is not necessary to avoid surface condensation but is recommended in order to reduce heat loss this is identified as an improved heat loss detail.

Where internal insulation is being applied to cavity walls Section 3 of ACDs may be used as appropriate.

Table H.3 - ACDs for Cavity wall insulation

Detail No.	Description	Detail required to avoid Surface Condensation	Improved heat loss detail	Comment
1.01a	Ground Floor - Insulation above slab	Y		
1.01b	Ground Floor - Insulation above slab	NA		
1.02a	Ground Floor - Insulation below slab	Y		
1.02b	Ground Floor - Insulation below slab	NA		
1.03	Timber Suspended Ground Floor	Y		
1.04	Concrete Intermediate Floor	Y		
1.05	Timber Intermediate Floor	Y		
1.06	Masonry Separating Wall (plan)	N	Y	Only applies where both houses are having cavities filled
1.07	Masonry Partition Wall (plan)	Y		
1.08	Stud Partition Wall (plan)	Y		
1.09	Eaves - Ventilated roof space	NA		See Figure H.10
1.10	Eaves - Unventilated roof space	NA		Principle is the same as for 1.09
1.11	Eaves - Ventilated - Insulation between and under rafters - Dormer	NA		Principle is the same as for 1.09
1.12	Eaves - Unventilated - Insulation between and under rafters - Dormer	NA		Principle is the same as for 1.09
1.13	Eaves - Ventilated - Insulation between and under rafters - Pitched ceiling	NA		Principle is the same as for 1.09
1.14	Eaves - Ventilated - Insulation between and over rafters - Dormer	NA		Principle is the same as for 1.09
1.15	Ventilated Roof - Attic Floor Level	N	Y	
1.16	Gable - Insulation between and under rafters - Ventilated Rafter Void	N	Y	
1.17	Gable - Insulation between and under rafters - Unventilated Rafter Void	N	Y	
1.18	Gable - Insulation between and over rafters - Unventilated Rafter Void	N	Y	
1.19	Flat Roof - Eaves	Y		
1.20	Flat Roof - Parapet	NA		See Figure H.11

Detail No.	Description	Detail required to avoid Surface Condensation	Improved heat loss detail	Comment
1.21	Ope - steel lintel	N	Y	Can be performed when replacing windows
1.22	Ope - perforated steel lintel	NA		
1.23.1	Ope - prestressed concrete lintels	N	Y	Can be performed when replacing windows
1.23.2		NA		
1.24	Ope - jamb with closer block	N	Y	Can be performed when replacing windows
1.25	Ope -jamb with proprietary cavity closer	NA		
1.26	Ope - concrete forward sill	NA		

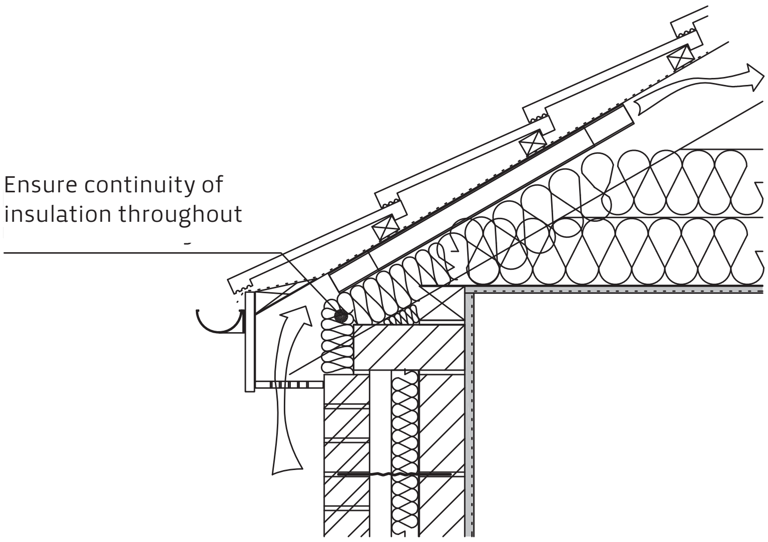


Figure H.10 - Cavity wall insulation - Eaves detail (Ventilated roof space)

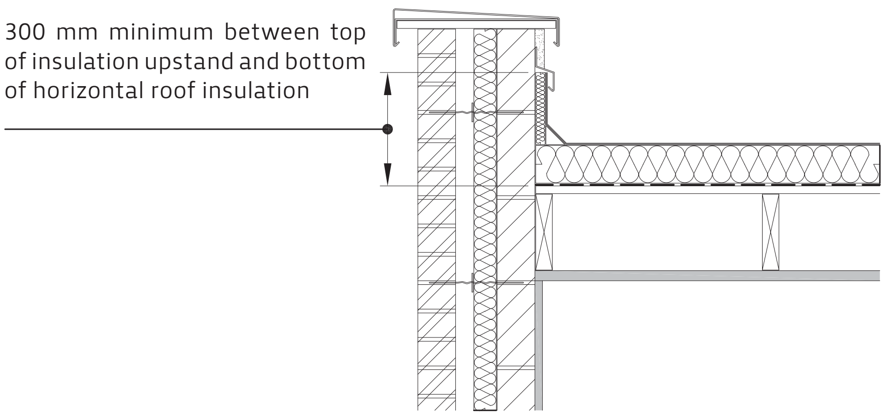


Figure H.11 - Cavity wall insulation - Flat roof - Parapet

H.4 Retrofit measures for timber frame

All of the details in Section 4 of 2008 ACDs may be applied where an existing void between studs has been filled.

At the junction between the timber frame wall and ceiling, Detail Numbers (ACDs) 4.09 to 4.14, the attic insulation should be extended across the external surface of the frame to meet the cavity fire barrier. This will reduce the thermal bridge of the timber head plates.

Where internal insulation is used in timber frame construction the following details provided in Table H.4 (Section 3 of 2008 ACDs) should be referred to, to minimise thermal bridging at reveals in so far as is practicable. Where this approach is being adopted the inner leaf should be assumed to be a timber frame leaf.

Table H.4 - ACDs for Timber frame

Detail No.	Description
3.09	Eaves - ventilated roof space
3.22	Ope - prestressed concrete lintels
3.23	Ope - iamb with proprietary cavity closer
3.24	Ope - concrete forward sill

H.5 Steel frame

All of the details in Section 5 of 2008 ACDs may be applied where an existing void between studs has been filled.

Where internal insulation is used in steel frame construction the details provided in Table H.5 (Section 3 of 2008 ACDs) should be referred to, to minimise thermal bridging at reveals in so far as is practicable. Where this approach is being adopted the inner leaf should be assumed to be a full filled light steel frame structure.

Table H.5 - ACDs for Steel frame

Detail No.	Description
3.09	Eaves - Ventilated roof space
3.22	Ope - Prestressed concrete lintels
3.23	Ope - Jamb with proprietary cavity closer
3.24	Ope - Concrete Forward Sill

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