CE309

Sustainable refurbishment

Towards an 80% reduction in CO_2 emissions, water efficiency, waste reduction, and climate change adaptation

energy saving trust®

Contents

1. Introduction 4
   - 1.1 The task ahead 4
   - 1.2 Minimum thermal standards for refurbishment 6
   - 1.3 Trigger points - opportunities for including improvements 7
   - 1.4 Carbon Emissions Reduction Target (CERT) 8
   - 1.5 Refurbish or demolish/rebuild? 8

2. House type base cases 9

3. Energy efficiency measures - insulation 11
   - 3.1 Walls 11
   - 3.2 Roofs 17
   - 3.3 Floors 20
   - 3.4 Windows and doors 22

4. Energy efficiency measures - airtightness and ventilation 24
   - 4.1 Reducing unwanted air leakage 24
   - 4.2 Providing adequate controlled ventilation 25

5. Energy efficiency measures - heating systems/control and hot water systems 28
   - 5.1 Fuel choice 28
   - 5.2 Recommended upgrade package 28
   - 5.3 Seasonal efficiency of boilers 29
   - 5.4 Heating and hot water systems 29
   - 5.5 Electric storage heating systems 30
   - 5.6 Smart meters 30

6. Energy efficiency measures - lighting and appliances 31
   - 6.1 Lighting 31
   - 6.2 Appliances 32

7. Installation of renewable energy 33
   - 7.1 Solar thermal hot water 33
   - 7.2 Solar photovoltaic 34
   - 7.3 Micro combined heat and power 34
   - 7.4 Ground source heat pump 35
   - 7.5 Air source heat pumps 35
   - 7.6 Biomass 35
   - 7.7 District heating and combined heat and power 36
   - 7.8 Wind 36
   - 7.9 The Low Carbon Buildings Programme 37

8. House types revisited 38

9. Water efficiency measures 40
   - 9.1 Legislation 40
   - 9.2 Trigger points for water efficiency measures 40
   - 9.3 Water metering 41
   - 9.4 Water efficiency fittings and appliances 41
   - 9.5 Rainwater harvesting and grey water recycling 43
   - 9.6 Water efficiency labelling 43

10. Recycling of waste and materials 44
10.2 Construction waste from domestic refurbishment 44
10.3 Domestic waste and provision of recycling facilities 45

11. Climate change adaptation 46
11.1 Summer overheating 46
11.2 Making use of existing thermal mass 46
11.3 Flooding 47
11.4 Storm 47
11.5 Future proofing 47
11.6 Trigger points for considering climate change adaptation measures 48

Appendix A – Glossary of technical terms 50

Appendix B – Relevant organisations and websites 52

Appendix C – Further information 53

1. Introduction

The Climate Change Act (2008) requires that by 2050, the UK's annual carbon dioxide (CO_2) emissions should be reduced by 80% compared to 1990 levels. Home energy use is responsible for over a quarter of UK CO_2 emissions which contribute to climate change. We must therefore aim to reduce CO_2 emissions from all dwellings by an average of 80% to help meet the UK's long term goal.

However this isn't a straightforward target to meet, especially since the UK has a high percentage of older homes with poor energy performance. What's more, because homes generally only have a major refurbishment every 50 years or so, the opportunity to improve energy performance before the 2050 deadline will be lost unless energy efficiency measures are incorporated next time an upgrade is done.

An 80% reduction in emissions from existing housing is nonetheless very achievable. The key is to take a whole house approach. This means taking into consideration the type of house, then looking at all appropriate energy efficiency measures, examining renewable energy options and including water and waste reduction measures. Whether roofing, central heating, re-plastering or a complete refurbishment, any upgrade work offers an opportunity to improve energy efficiency. The key is to do the maximum possible at each opportunity, and to consider each job in context within the whole house.

This guide, developed by the Energy Saving Trust Housing programme, provides an integrated package of measures that will enable builders, developers and householders to hit the demanding 80% target and make radical improvements to energy performance that go beyond current building regulations.

We start by presenting a base case scenario of the most common housing types. Then we introduce the energy, water, waste and climate change adaptation measures to be considered in a whole house approach to refurbishment. Finally, we revisit the base case scenarios to show what is possible in terms of energy performance.

Links to more in-depth reference materials are listed in Appendix C and provide more detailed technical information when it is needed.

1.1 The task ahead

In 1990 the level of CO_2 emissions from housing alone was in the region of 160 million tonnes per year (see figure 1). It has reduced very little since 1990 even though changes to the building regulations have made newly built dwellings more energy efficient. However, these new houses still emit significant amounts of CO_2 each year. Emissions from housing stock continues to increase as we attempt to meet the ever-growing demand for housing in the UK.

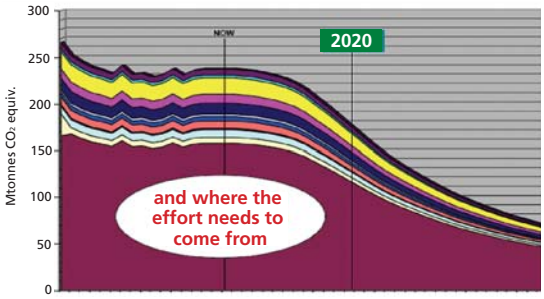


Figure 1: Built environment contribution to UK CO_2 emissions (CLG 2008)

The UK Government has signalled its intention that from 2016 all newly built dwellings should be net zero carbon, and therefore these should not add further to CO_2 emissions. This measure will stop the growth in CO_2 emissions. However only by significantly improving the existing housing stock can we achieve the required overall 80% cut in CO_2 emissions across the entire housing stock. So by 2050, CO_2 emissions from most existing dwelling will need to be no more than about 1.5 tonnes per year[1]. Emissions from dwellings vary because of their size, build form, number of occupants and their lifestyle. Larger family dwellings will emit more than 1.5 tonnes of CO_2 per year, while single-occupied flats will emit less.

The Government's approved methodology for determining emissions, Standard Assessment Procedure (SAP), predicts these emissions in terms of kilograms of CO_2 per square metre of floor area per year. Using this measure, and using an average dwelling size of between 75-100m^2, a reasonable CO_2 emissions target to aim for would be in the region of 15-20kg/m^2/yr for most existing dwellings. A note of caution though - these target figures include both the emissions that are currently

1. This is estimated from an 80% cut in emissions from 160 million tonnes per year to no more than 32 million tonnes per year, shared by all the dwellings that will still be emitting CO_2 in 2050.

considered in SAP, as well as those from appliances and cooking which are not[2].

Additionally, it has been estimated that about 24 million homes[3], that either exist now or are built before 2016, will still exist in 2050. This means that on average, some 600,000 homes will need to be refurbished to a high degree of thermal performance each year to reach the 80% target. Before embarking on a range of measures for improving the thermal performance of a dwelling, it is important to know where you are starting from.

1.1.1 Finding out how an existing dwelling performs

The Energy Performance Certificate (EPC) was introduced in August 2007 as a way of estimating the overall thermal performance of a dwelling (see figure 2). The rating system is similar to that of domestic appliances/boilers etc., with band G being the lowest (i.e. worst performing dwelling), and band A the highest.

Figure 3 shows the average performance of the housing stock is band E rated but there is a long tail of poorly performing housing that are only F or G rated, and it is here where significant CO_2 savings can be made.

Currently an up-to-date EPC is only required when a dwelling changes hands through a sale or a new letting. However there is no reason why an EPC cannot be obtained from a Domestic Energy Assessor (DEA) as part of the planning of a refurbishment project. The certificate's recommendations can be considered alongside the guidance in this publication.

Ultimately, if we are to reach our target of an overall 80% cut in CO_2 emissions across the housing stock by 2050, the majority of dwellings will need an energy performance rating no worse than band B.

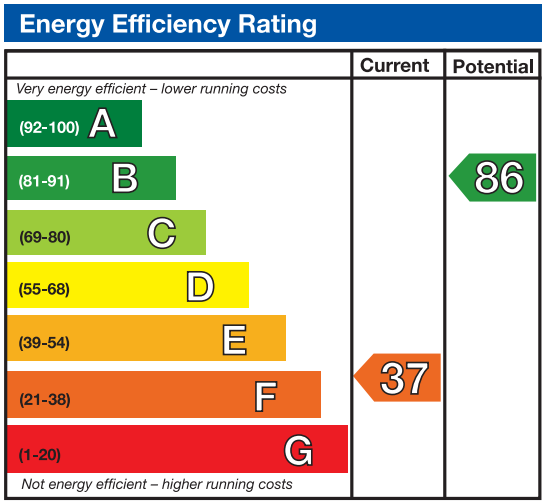


Figure 2: EPC ratings

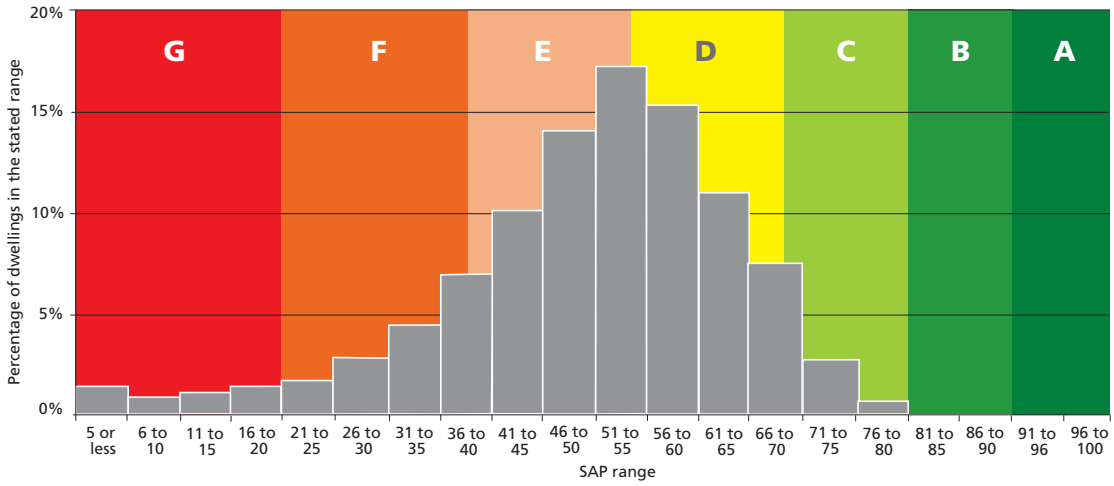


Figure 3: Performance of UK's housing stock

2. To estimate the CO_2 emissions from appliances/cooking we have used the calculation method contained in the Code for Sustainable Homes (CLG 2007).

3. This estimate is from the number of dwellings that exist now and emit CO_2, some 26 million, plus an estimated one million new homes that will be built between now and 2016, minus the potential number of existing dwellings that will be demolished before 2050, estimated to be up to three million (New Tricks with Old Bricks – Existing Homes Agency/Building and Social Housing Foundation 2008).

1.1.2 Achieving best practical level of refurbishment

Although some of the guidance presented here may be familiar, the levels of performance are significantly higher than has previously been recommended.

In order to achieve an overall 80% reduction in CO_2 emissions from dwellings, it will be necessary to take every opportunity, where practical, to achieve the best possible level of thermal upgrading during a refurbishment.

In most cases, national building regulations or local planning policies will already require a minimum level of thermal performance when refurbishing. However the only additional cost to improve thermal performance further is the cost of the extra insulation – in most cases, the installation and labour costs will be the same.

For up-to-date information regarding the costs of carrying out the measures presented in this guide, please refer to www.energysavingtrust.org.uk/housing/existing/housetypes

1.2 Minimum thermal standards for refurbishment

1.2.1 Building control

Anyone carrying out building work on a property controlled by building regulations is required by law to assess its performance with regards to the conservation of fuel and power.

The minimum standards set by building regulations vary across the UK. The following guidance should be consulted to determine the different technical performance requirements, definitions and procedures:

- Communities and Local Government (CLG) issues a series of 'Approved Documents' containing guidance on compliance in England and Wales. Approved Document L1B provides guidance as to the minimum level of thermal performance needed when carrying out building work on existing dwellings.
- The Scottish Building Standards Agency provides guidance on complying in Scotland through a system of technical handbooks - section 6 deals with energy use.
- In Northern Ireland, The Building Regulations Unit of the Department of Finance and Personnel provides guidance via a series of Technical Booklets - Technical Booklet F deals with energy use.
- In Wales, currently building regulations are the same as in England so again, refer to Approved Document L1B.

Building regulations place minimum standards, i.e. they control thermal elements, fixtures and fittings which are being worked on, added to, or replaced.

Items controlled by building regulations

- Alterations and renovations to building fabric, i.e. walls, roofs, and floors.
- Home conversions to lofts or garages, etc.
- Home extensions.
- Replacing windows, doors, and rooflights.
- Replacing or upgrading heating and hot water systems, including controls.
- Other building services, i.e. lighting and ventilation.

You are advised to check with the local building control team whether or not your proposal requires approval under the building regulations.

When working on, adding to, or replacing any of the above items, you must check what minimum building regulation requirements apply. At the same time, remember that building regulations are the minimum legal standard – so this is an ideal opportunity to consider specifying the best practical level of performance. Once refurbished, a dwelling is unlikely to be significantly altered again within the foreseeable future.

It should also be noted that work to improve the thermal performance of the fabric and services could be required when carrying out either a change of use or a material alteration. These may apply even if no work is actually proposed to be done to the fabric.

For more detailed guidance on how building regulations may require thermal upgrading of existing fabric and improved building services, please see www.energysavingtrust.org.uk/housing/buildingregulations or contact your local building control team.

1.2.2 Planning permission

Complying with the building regulations is a separate matter from obtaining planning permission for the work being undertaken. Planning permission is mainly required when carrying external alterations, such as adding external wall insulation, raising the roof line to accommodate over rafter insulation, or building some types of extension, etc. Planning authorities may also require improvements in the energy efficiency of an existing dwelling which is undergoing work that is subject to planning permission.

Although it is generally the case that internal work will not require planning permission, this may not be the case if the property is listed or situated in a conservation area. Where the existing dwelling is of historic or heritage value, it is essential to consult with English Heritage, Historic Scotland, Cadw or Northern Ireland Environment Agency, as to the best way to incorporate energy efficiency measures into the dwelling in a sympathetic way which will not cause long-term damage to its fabric and structure.

It is therefore essential to discuss your proposals with the local planning authority as early as possible in the design stage to ensure all planning legislation is also adhered to.

1.3 Trigger points - opportunities for including improvements

Home improvements often provide the opportunity to improve levels of energy efficiency. For example, when installing a new kitchen, you could also choose to upgrade the internal wall insulation, install low energy lighting and appliances, low flow rate taps, floor insulation, efficient ventilation with heat recovery and recycling facilities.

This guide can be used to determine the opportunities for sustainable refurbishment. It uses an elemental approach to refurbishment by following these trigger points and ensuring future opportunities for improvements are not missed. Table 1 illustrates some of the opportunities.

Table 1: Trigger points for energy efficiency

	Opportunity														
Measures to consider	Moving in or out	Extending	Loft conversion	Adding a conservatory	New kitchen	New bathroom	Re-roofing	Re-plastering	Replacing windows	Re-wiring	Re-flooring	New heating	Replacement boiler	Replacement hot water cylinder	Re-rendering
Wall insulation	Good	Good	Possible	Possible	Good	Good	Possible	Good	Possible	Good	Good	Good	Good		Good
Roof Insulation	Good	Good	Good	Possible	Possible	Possible	Good	Good	Good	Good	Possible	Good	Good	Good	Good
Floor insulation	Good	Good		Good	Good	Possible				Good	Good	Good	Good		
Heating controls	Good	Good	Good	Good	Good	Good		Possible		Possible		Good	Good	Good	
Cylinder/pipe insulation	Good	Good	Good	Possible	Good	Good	Good			Possible	Good	Good	Good	Good	
Airtightness improvements	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good		Good
Efficient ventilation	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good		Good
Windows	Good	Good	Good	Good	Good	Good	Possible	Good	Good			Good	Good	Good	Good
Low energy lighting	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Possible	Possible	Possible	Possible	Good
Energy efficient appliances	Good	Good		Good	Good	Possible		Possible		Good	Possible				

Key

Good opportunity ■ Possible opportunity ■

1.4 Carbon Emissions Reduction Target (CERT)

CERT requires certain gas and electricity suppliers to meet a carbon reduction target in domestic properties. It runs from 2008 until 2011 and is projected to reduce emissions by 154MtCO_2 over the lifetime of the measures, the equivalent of a year's worth of UK household CO_2 emissions. Funding of this scheme is estimated at about £3.3 billion over three years.

CERT is dominated by insulation measures with small contributions to high efficiency window replacements and microgeneration technologies producing electricity (e.g. solar photovoltaics (PV)) and heat (in particular solar hot water and ground source heat pumps). Cavity wall and loft insulations are the main contributors though, and between them they make up over 90% of the carbon savings attributable to insulation, however CERT funding is also available for solid wall insulation.

A further £350 million will also be contributed by the energy suppliers to a new Community Energy Saving Programme (CESP). This will involve local councils, voluntary organisations and energy suppliers visiting householders street-by-street to offer free and discounted central heating and other energy saving measures. The programme is designed to target those households most in need of energy efficiency improvements. It will operate in 100 localities and the Government estimates that some 90,000 homes will benefit over the next three years.

1.5 Refurbish or demolish/rebuild?

The UK has the oldest housing stock in the developed world with 8.5 million properties over 60 years old. One of the problems that local authorities, regional development agencies and private developers face when choosing whether to refurbish or rebuild is that the issues they need to consider are broad-ranging and complex. This has been explored and reported in recent major publications, such as 'New tricks with old bricks' by Empty Homes Alliance with Building and Social Housing Foundation, and 'Knock it down or do it up' (IHS BRE press). There are many factors which should be considered before a decision to demolish is made, such as the embodied energy of the replacement dwelling, local housing needs, Decent Homes requirements and structural condition. These issues are fully explored in these publications.

2. House type base cases

This section focuses on how typical house types perform, with sections 3, 4, 5 and 6 describing how to improve the energy efficiency.

Table 2 below summarises the performance of eight 'base case' house types that we have used.

It is not possible to demonstrate every different house type that exists, nor is it possible to show a selection of different scenarios for these house types. However, it is hoped that sufficient information is provided in order to understand that the upgrading of any type of existing dwelling in terms of energy efficiency, even those built recently, is relatively straightforward.

To illustrate the additional detail available, we have included the full performance information on one of the cases, a typical 1950s semi-detached (see figure 4) , built with a main wall of clear brick and brick cavity.

In section 8, we show how energy efficiency measures can improve the performance of this house from band E to band A, through fabric improvements and renewable technology.

Total CO_2 emissions for this house are 72kg/m²/yr. This equates to about 6.5 tonnes of CO_2 per year, putting the house in band E. As the dwelling is not well insulated, about 3.5 tonnes of the CO_2 emissions come from energy used to heat the home.

Table 2: The performance of some typical existing dwellings

House type	Floor area (m²)	Existing EPC Band	Existing total CO_2 emissions	
			Tonnes/yr	kg/m²/yr
Solid walled detached	104	F	13.7	132
Period end terrace	89	F	6.5	73
Period mid terrace	85	E	6.7	79
1950s semi-detached	90	E	6.5	72
1960s bungalow	64	E	6.2	98
1980s detached	111	E	7.7	69
1980s mid floor flat	61	E	4.2	68
Post 2002 mid terrace	79	C	3.4	43

House type base cases

The dwelling's total emissions are about average for all UK housing. However because this house type performs so poorly, the fabric and services improvements recommended in this guide offer significant savings in CO_2 emissions.

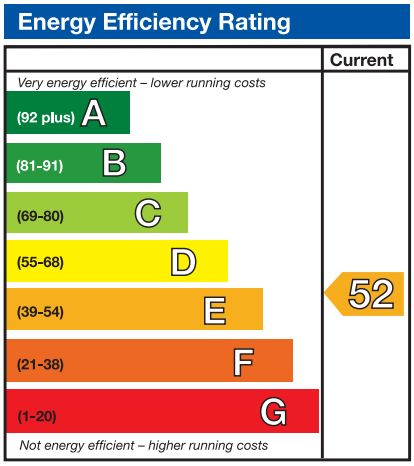


Figure 4: The EPC rating for this house type in current state would typically be rated at band E

1950s semi-detached house, floor area 90m²

Typical existing features

Element	Fabric U-value
Insulated roof, 100mm mineral wool.	0.41 W/m²K
Unfilled brick cavity walls.[4]	1.39 W/m²K
Uninsulated suspended timber floor.	0.57 W/m²K
Replacement UPVC double glazing.	3.10 W/m²K
Doors, half glazed solid timber.	3.70 W/m²K

Other features

- Natural ventilation.
- Typical envelope air leakage rate 12m³/m²/h @ 50 Pa.
- Regular boiler 78% efficiency, programmer and room thermostat, electric fire secondary room heating.
- Water storage cylinder 150 litre capacity, loose jacket on cylinder, no pipe insulation.
- No dedicated low energy light fittings.

Typical energy demand

Energy source	Total energy demand (kWh/yr)		Energy demand per m² (kWh/yr/m²)
Gas	Main heating and hot water	21,970	258
	Cooking	1,280	
Electric	Secondary heating, lights, fans and pumps	2,150	52
	Appliances	2,510	

CO_2 emissions (kg/m²/yr)

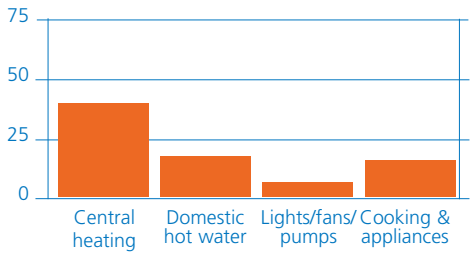


Table 3: CO_2 emissions for 1950s semi-detached house, floor area 90m² before improvements

4. RDSAP default U-value for age.

3. Energy efficiency measures – insulation

Insulating the major elements of dwellings is one of the most effective ways to improve the energy performance of the UK's existing housing stock.

3.1 Walls

Three types of wall construction dominate in the UK – solid wall, cavity wall and timber frame. Each of these is described briefly below before we go on to explore the insulation options available for each wall type.

Solid wall - approximately one in every five homes in the UK today has traditional 220mm solid brick walls. This was the main form of construction until the 1930s. Other types of solid wall construction can be found, for example systems using no-fines concrete or pre-cast concrete panels. These buildings suffer high fabric heat loss, which leads to high fuel bills. Unfortunately, they are often occupied by those least able to pay higher energy bills.

Solid walls can be thermally improved with either external or internal insulation.

Cavity wall - since the late 1920s, masonry cavity walls have been used in house construction throughout most of the UK (see table 4) – the cavity was originally used to counteract damp. Cavity-walled houses are relatively easy to improve thermally as the cavity can be filled with insulation. Where this is not appropriate, they can be insulated in a similar way to solid walls.

Even where cavity walls are insulated, their performance can be significantly enhanced with extra internal or external insulation.

'Modern' timber frame - for the past 30 years, timber-frame homes in the UK have been built with insulation filling the studwork frames. Houses built between 1920 – when 'modern' timber-frame construction was introduced in the UK, and the mid-1970s, when the building regulations first required a maximum wall U-value of 1.0 W/m^{2}K – will have had little or no insulation.

The construction system used in a particular property should be identified before refurbishment starts. While it is easy to recognise early examples of timber-frame housing, later designs such as those built in the 1960s and 1970s look very similar to buildings of conventional masonry construction.

Where insulation has been built into the timber frame walls, it is likely to be very thin (25 – 50mm) and it may now be in poor condition. This can cause high heat loss and condensation, reducing comfort for the occupants. Insulation can easily be added to timber frame walls, but the process can be very disruptive to householders and it is best carried out while the property is unoccupied.

Table 4: Evolution of cavity wall construction

Decade	Development of cavity walls	Cavity width
1920s	Solid walls still dominate, but cavity walls grow in popularity.	Typically between 50mm and 100mm
1930s	Cavity walls become main form of construction, but some solid walls still built.	Typically between 50mm and 100mm
1940s and 1950s	Cavity width becomes standardised.	50mm
1960s	Concrete blocks used to inner leaf.	50mm
1970s	Lightweight blocks are introduced.	50mm
1980s	Partial fill cavity wall insulation introduced, cavity widths increased.	60-70mm
1990s onwards	Full fill cavity wall insulation becomes dominant.	50-100mm

Energy efficiency measures – insulation

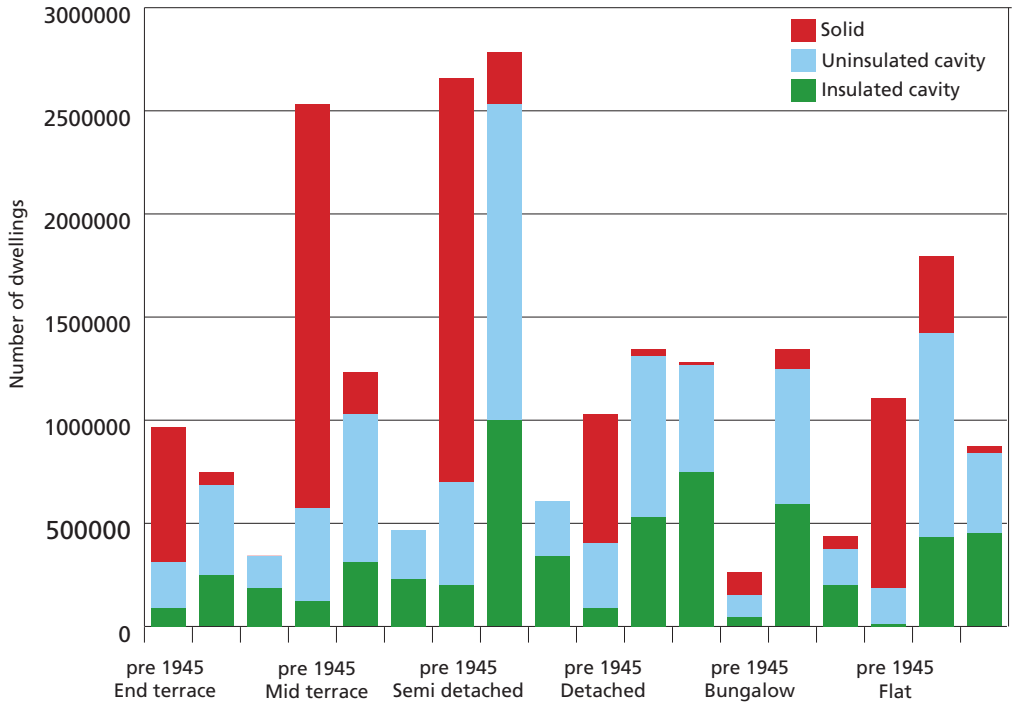


Figure 5: Evolution of masonry construction based in information gathered by English Housing Condition Survey (2008)

Two points immediately jump out from figure 5 – the number of solid-walled houses that exist today, and the number of cavity walls that remain to be filled. Since houses with uninsulated solid walls make up the majority of the existing stock, this seems a good place to start.

3.1.1 Solid wall insulation

The heat lost through an uninsulated solid wall is typically over 50% greater than through an uninsulated cavity wall. However refurbishing solid wall dwellings in an energy efficient way raises particular problems for specifiers. The first is deciding whether to use internal or external wall insulation. Both options offer advantages and disadvantages and the final decision often depends upon the scope of the work being planned. For example, if walls are to be re-rendered it clearly makes sense to add external insulation while this is being done. And the work can be carried out while the dwellings are occupied, although it may cause some disruption. On the other hand, if major work is being carried out inside the dwelling (which has to be vacant for this process) then internal insulation may be the better choice.

(i) Internal insulation

Internal insulation typically consists of either a built-up system with insulation between and across a studwork frame, or dry lining in the form of a laminated insulating plasterboard (known as rigid insulation board).

Insulated studwork

The insulation is held between a metal (or preferably timber) framing system and finished with a vapour control layer and plasterboard or thermal laminate plasterboard. This approach allows for a variety of insulation thicknesses.

For small dwellings where internal space cannot readily be sacrificed, a high-performance rigid insulation board or an in-situ applied closed-cell PUR/PIR insulation may be preferable, either in addition to internal studwork, or as a single-layer installation.

In-situ applied closed-cell insulation can be applied directly to the plaster, or if plaster is to be removed, directly onto the brickwork. This provides insulation and greatly reduced air leakage, in a single application.

Energy efficiency measures – insulation

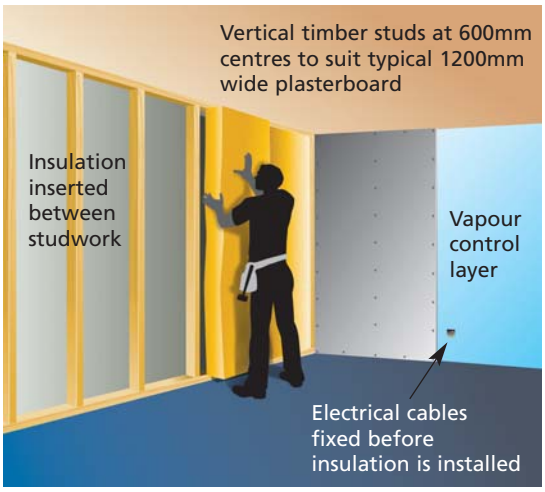


Figure 6: Insulation being inserted between studwork

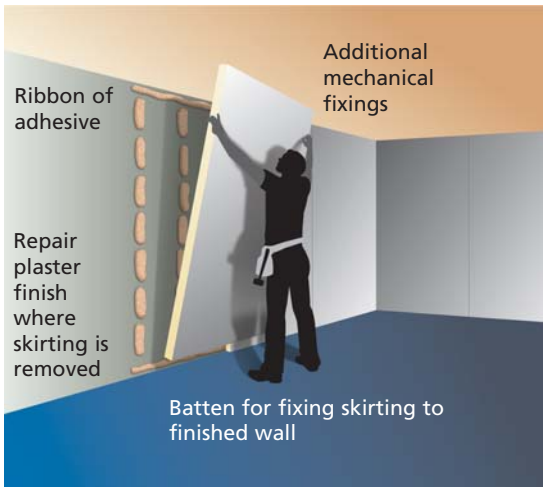


Figure 7: Thermal laminate plasterboard installation

Thermal laminate plasterboard

Thermal laminate plasterboard consists of plasterboard with a backing of insulation. The rigid insulation backing can be specified in a variety of types and thicknesses. Thermal laminate plasterboard is usually fixed to the wall surface using continuous ribbons of plaster or adhesive, plus additional mechanical fixings, or onto 25mm thick softwood battens. The joins between the boards should be taped and sealed to help prevent air leakage and interstitial condensation.

Most types of thermal laminate plasterboard provide better insulation than comparable thicknesses of fibre-based insulation (such as mineral wool). It is therefore possible to achieve the same thermal performance using thinner insulation (which can be a major asset for small dwellings).

Before thermal laminate plasterboard is installed, the surface of the wall must be carefully prepared. Where existing plaster is removed and the brick is uneven, the wall must be levelled using a suitable parge coat to provide an even surface for fixing of the thermal laminate plasterboard, whether it is to be fitted directly or on battens. The parge coat can also greatly reduce air leakage. The balance between airtightness and ventilation is discussed later in section 4 of this guide.

Table 5 shows how well a solid wall can be insulated. It also shows how thicker insulation (or insulation with lower thermal conductivity[5]) can achieve

Table 5: U-values of typical upgraded 220mm solid brick walls using thermal laminate plasterboard or in-situ applied closed cell insulation(W/m²K). N.B Uninsulated U-value of wall is 2.10W/m²K

Internal insulation thickness	Thermal conductivity of insulation λ (W/mK)		
	0.015 (advanced insulation)	0.025 (high performance insulation)	0.035 (typical insulation)
	U-values of insulated solid wall (W/m²K)		
25mm	0.42	0.59	0.71
50mm	0.25	0.37	0.47
75mm	0.18	0.27	0.35
100mm	0.14	0.21	0.28

5. Thermal conductivities of various types of insulation can be found in the Energy Saving Trust publication 'Insulation materials chart – thermal properties and environmental ratings (CE71)'. See www.energysavingtrust.org.uk/housing/publications

a really high level of thermal performance. The only extra cost of 100mm thickness compared to 25mm is the cost of the insulation. The labour and preparation costs and the time involved are about the same. But using 100mm of insulation instead of 25mm reduces heat loss through the wall by about two-thirds, and produces a finished wall with a U-value that is generally better than most current newbuild dwellings.

One disadvantage of internal insulation is that it can introduce numerous thermal bridges, for example at junctions where internal walls or floors meet the external wall. We are investigating the effects of these heat loss paths in existing dwellings, and plan to publish specific guidance on how to reduce the effects of thermal bridging shortly.

(ii) External wall insulation

External wall insulation is generally a more expensive way to insulate solid-walled dwellings. However for existing external elevations that are in need of periodic re-rendering, or where extensive remedial action is needed, for example to prevent rainwater penetration, then the only extra cost of the upgrade is the insulation itself. Re-roofing is another point at which external insulation may be cost effective.

Installing external wall insulation does have some advantages over using internal insulation. Occupants can remain in the dwelling during the work – there is less thermal bridging because the insulation layer is continuous, and it can both improve the dwelling's appearance and extend its lifespan.

External wall systems are made up of an insulation layer fixed to the existing wall (using adhesives and mechanical fixings depending on the type of insulation to be used) and a protective render or cladding finish. The system chosen should be approved by a suitable independent authority, and the Insulated Render and Cladding Association (INCA) holds a register of proven systems and installers. (See Appendix B for relevant organisations.)

Wet render systems

Most external render systems consist of either a thick sand/cement render applied over a wire mesh, or a thinner polymer based cement render applied to a glass reinforced plastic scrim see figure 8.

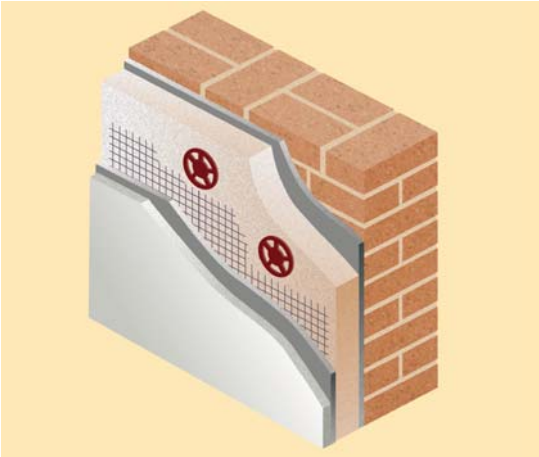


Figure 8: Wet render system

Dry-cladding systems

The use of dry-cladding systems allows for greater flexibility of external appearance and could allow for the design to meet local planning requirements using, for example:

- Timber panels.
- Stone or clay tiles.
- Brick slips (figure 9).
- Aluminium panels.

Figure 9: Brick slip cladding

The improvement in thermal performance mainly depends upon the thickness of insulation provided. Table 5 can also be used as a guide as to what U-values can be achieved using external wall insulation.

3.1.2 Cavity wall insulation

Unfilled cavity walls can be filled at any time, with heat loss through the walls being reduced significantly, by up to 60% in most instances. After loft insulation, providing cavity wall insulation is the most cost-effective insulation measure.

If the internal surface is being replaced, a thermal laminate plasterboard can further improve the thermal performance.

(i) Description

Installing cavity wall insulation usually takes less than half a day and the occupants can remain in the dwelling. The work should be carried out by a specialist contractor who can provide a Cavity Insulation Guarantee Agency (CIGA) guarantee, or in the case of injected polyurethane foam, a manufacturer's guarantee authorised through the British Urethane Foam Contractors Association (BUFCA). The National Insulation Association (NIA) holds a register of proven systems and installers, and the British Board of Agrément (BBA) provides a certification scheme for installers and products. An inspection is undertaken prior to installation to assess the wall's suitability which covers factors such as the exposure of wall to driving rain, the masonry materials used and pointing of the masonry. It is recommended that cavities of less than 50mm should only be filled with in-situ applied closed cell insulation. Any defects or dampness problems should be put right before work begins. If all is satisfactory, the installation process proceeds as follows:

- Injection holes are drilled through the mortar joints according to the drilling pattern specified in the BBA certificate, which is typically at 1m intervals.
- Cavity barriers are installed to prevent the fill entering the cavities of adjacent properties.
- Air ventilators that cross the cavity are sleeved (or sealed, if obsolete).
- Air bricks and balanced flues should be sleeved.
- The insulant is injected into the wall cavity.
- Quality checks are carried out on the fill material prior to making good the injection holes.
- Injection holes are filled with colour-matched mortar or render.

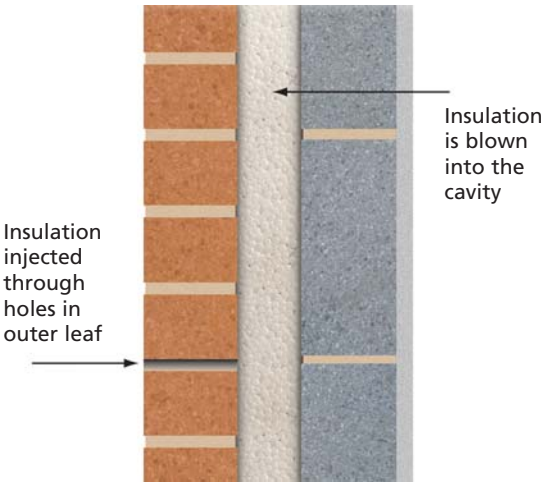


Figure 10: Insulation injected into the cavity

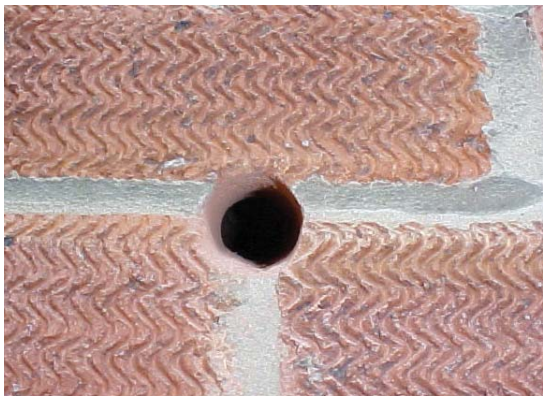


Figure 11: An injection hole prior to filling

Figure 12: Insulation being injected into the wall

N.B. Polystyrene cavity wall insulation should not be used if there are any unprotected PVC cables in the cavity, or if there are PVC cavity trays or damp proof courses.

Table 6: U-values of typical upgraded existing cavity walls

Existing brick/ cavity/brick wall	Thermal conductivity of insulation λ (W/mK)		
	0.025	0.035	0.045
Cavity width to be filled	U-value of filled cavity wall (W/m²K)		
50mm	0.46	0.58	0.67
75mm	0.35	0.44	0.52
100mm	0.22	0.29	0.36
Brick/50mm cavity/ lightweight block wall	0.42	0.51	0.58

(ii) Suitability

Most masonry cavity walls can be filled with insulation, especially those under 12 metres in height built after 1930. There are also systems available for buildings up to or over 25 metres in height and a few even taller buildings have been successfully cavity-filled following suitable assessment.

Almost all of the systems on the market are approved for use in all parts of the UK. However, they assume that the outer leaf is built for local exposure conditions so that rainwater penetration is minimal.

Where cavity walls are not suitable for cavity insulation, for example when there is only a partial cavity, they can be treated in the same way as solid walls and have internal insulation installed.

(iii) Benefits of cavity wall insulation

Cavity wall insulation can significantly reduce heat loss through the wall. Performance depends on the existing construction as well as the properties of the insulating material used. Table 6 shows the improved thermal performance achieved with various insulation materials.

Table 7: Improved U-values of further upgrading of filled cavity walls (W/m²K)

Existing cavity filled wall		Thermal conductivity of internal insulation λ (W/mK)		
		0.015	0.025	0.035
Year built	Existing U-value	U-value of upgraded wall (W/m²K) - with additional 20mm internal insulation		
1986 - 1995	0.60	0.36	0.44	0.48
1995 - 2002	0.45	0.30	0.35	0.38
2002 +	0.35	0.26	0.29	0.31
		with additional 40mm internal insulation		
1986 - 1995	0.60	0.25	0.33	0.38
1995 - 2002	0.45	0.23	0.28	0.32
2002 +	0.35	0.20	0.24	0.27
		with additional 60mm internal insulation		
1986 - 1995	0.60	0.20	0.27	0.32
1995 - 2002	0.45	0.18	0.24	0.28
2002 +	0.35	0.16	0.21	0.24

(iv) Upgrading existing cavity filled walls

Houses with cavity wall insulation can be further improved by internal or external insulation. Many houses have only 'partial fill' cavity insulation which cannot be topped up, so internal insulation would make a significant difference. Over the last decade or so, internal wall lining has changed from wet plaster finish to mainly plasterboard on dabs. There are no technical reasons why the walls of even recently built dwellings cannot be improved significantly. And it is likely that they will need refurbishment at some point before 2050. The potential improvements from adding internal insulation are detailed in table 7.

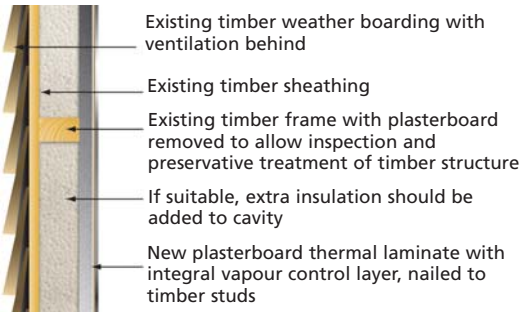
External wall insulation may not be suitable for cavity walls with a clear cavity, as convection of the air in the cavity may reduce the thermal performance of the wall.

3.1.3 Timber frame and other wall types

Other common wall constructions can also benefit from extra insulation. However specialist advice should be sought and each dwelling type treated on a case-by-case basis.

(i) Timber-framed dwellings

There are currently some 100,000 timber framed dwellings with little or no wall insulation. Even more recent timber framed dwellings, which will have a full fill of insulation, could still benefit from laminated insulated plasterboard when it is time to replace the existing wall lining (see figure 13 below). Extra plasterboard may however be required in this case to achieve the correct level of fire resistance. For this and other technical reasons, such as condensation control, professional guidance is needed before considering how best to thermally improve the walls of any timber framed dwelling.



Note: an extra layer of plasterboard may be required for fireproofing. This should be fitted directly to the studs.

Figure 13: Laminated plasterboard for timber framed dwellings

(ii) Other non-traditional methods of construction

There are many other non-traditional buildings that can benefit from wall insulation, such as:

- Wimpey no-fines (cast in-situ) concrete panels.
- Airey (pre-cast) concrete panels.
- BISF (steel framed).

For cast in-situ and pre-cast concrete walls (which are in sound condition), external insulation is better, as the concrete construction is particularly susceptible to thermal bridging.

Steel frame systems can be insulated internally or externally. However specialist knowledge is needed to prevent problems with condensation on the non-galvanised frame members. The construction consists of a steel frame of rolled steel angles and channels. For external insulation, the frame is clad with rendered expanded metal lathing up to first floor level, and vertically profiled galvanised steel sheet above. Internally, the walls are lined with a glass fibre insulation blanket, and plasterboard on a timber frame (see figure 14).

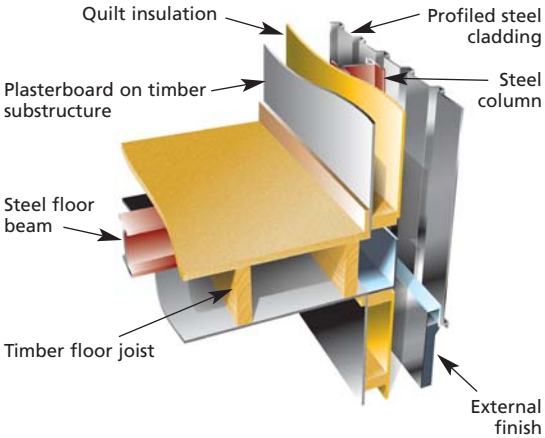


Figure 14: Steel frame system

3.2 Roofs

Loft spaces are generally the easiest part of a dwelling to insulate. Insulation can be placed at ceiling or rafter level at any time, without much disruption to the occupants. Attic rooms and flat roofs can also be insulated, but this work should only be done by professionals during a conversion or major renovation.

3.2.1 Insulation at ceiling level

Laying insulation at ceiling level is relatively straightforward. The first layer is placed between the ceiling joists and its thickness is determined by the depth of the joists and the presence of any existing insulation. The top of this layer of insulation should be no more than 25mm either above or below the top of the ceiling joists. Additional layers of insulation can then be placed on top, this time laid across the joists (see table 8).

There are three main technical issues to consider – condensation, storage and wiring.

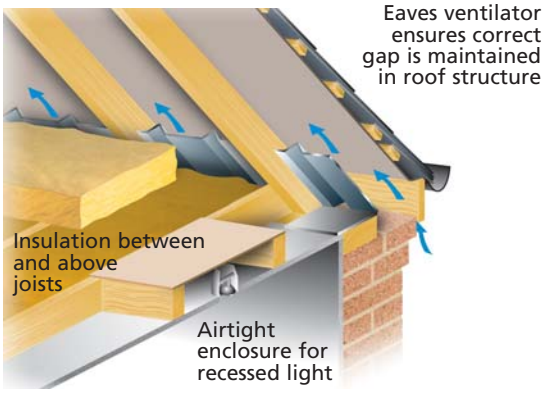


Figure 15: Insulation at ceiling level

Condensation

This is best avoided by preventing moist air from entering the roof void from within the dwelling. Sealing any service penetrations through the ceiling (such as recessed light fittings depicted in figure 15), draught-proofing loft hatches and pipes, and sealing and insulating water storage tanks (see figure 16) will help avoid condensation. To stop water tanks freezing, no insulation should be placed below them.

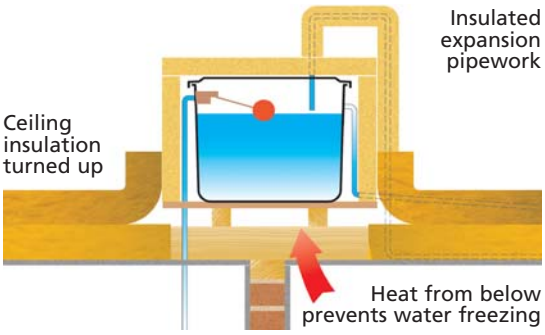


Figure 16: Water tank insulation

Adequate ventilation in 'wet' rooms such as kitchens, bathrooms and shower rooms will also reduce the risk of moist air entering the roof space.

It is also necessary to maintain or improve existing roof void ventilation. This is usually provided through gaps between the wall and soffit at eaves level, or through ventilator tiles positioned at a low level on the roof slope. Roof insulation must not block this ventilation. Some roofs may have no obvious means of ventilation (for example having no sarking felt, or using a breathable felt). In these cases, there is little risk of condensation. Here, it is recommended that insulation is placed as far as possible into the eaves to reduce thermal bridging.

Storage

If a small storage area is required in the roof void, then this should be located as close to the loft hatch as possible. A higher performance material should be used below the proposed storage area because the insulation will be thinner by necessity. The storage decking itself should be either laminated with 100mm of rigid insulation, or supported off 100mm deep cross timbers to spread the load between adjacent ceiling joists, again with insulation placed between. Any boxing over existing recessed lighting should also be insulated with higher performance materials to make up for the reduced thickness of insulation in this spot.

Wiring

It is most important that insulation is not laid over any existing cables, as this prevents them from dissipating heat when in use. Continued heating will damage the cables, which could in turn lead to a fire risk. If the cables have sufficient slack, they must be raised above the proposed insulation. If not, they may need to be replaced before the roof can be insulated.

When replacing the cables within the roof void, a dedicated service void below the existing ceiling should be considered. This could substantially improve the airtightness of the ceiling structure and becomes even more important if new recessed light fittings are to be provided.

Table 8: U-values of upgrading of ceiling insulation (W/m²K)

		Thermal conductivity of insulation λ (W/mK)		
		0.035	0.040	0.045
100mm insulation between joists		**U-values (W/m²K)**		
Thickness of insulation laid over joists	200mm	0.12	0.13	0.15
	250mm	0.10	0.12	0.13
	300mm	0.09	0.10	0.11
150mm insulation between joists				
Thickness of insulation laid over joists	150mm	0.12	0.14	0.15
	200mm	0.11	0.12	0.13
	250mm	0.09	0.10	0.12

3.2.2 Insulation at rafter level

Although it is possible to insulate at rafter level whether the loft is a habitable space or not, it should only be done where there is an existing room in the roof space, or when converting a loft into habitable space. When the loft is not used as habitable space, it clearly makes sense to insulate at ceiling level in order to minimise the heated volume of the dwelling.

If rafter level insulation accompanies re-roofing, consideration should be given to placing the insulation above and between the rafters. This will raise the roof level slightly and may need planning permission but will improve the fixing of the insulation.

When using internal insulation, it is important to maintain any existing cross ventilation. To achieve this, insulation between the rafters must provide a 50mm space between the insulation and the roof structure (see figure 17). Where a breathable sarking membrane exists or is provided, this gap can be reduced. The insulation must however not come into contact with the membrane, as this could impair its ability to breathe.

Extra insulation will need to be placed below the rafters to give a reasonable level of thermal resistance. Table 9 shows U-values that can be achieved using insulation placed between the rafters and thermal laminate plasterboard below them (assuming a spacing of 600mm).

Table 9: U-values of upgrading of rafter insulation (W/m²K)

		Thermal conductivity of insulation λ (W/mK)		
		0.025	0.030	0.035
50mm insulation between 100mm deep rafters		**U-values (W/m²K)**		
Thickness of insulation fixed below rafters	50mm	0.26	0.30	0.34
	75mm	0.20	0.24	0.28
	100mm	0.17	0.20	0.23
100mm insulation between 150mm deep rafters				
Thickness of insulation fixed below rafters	25mm	0.23	0.27	0.30
	50mm	0.19	0.22	0.25
	75mm	0.16	0.18	0.21

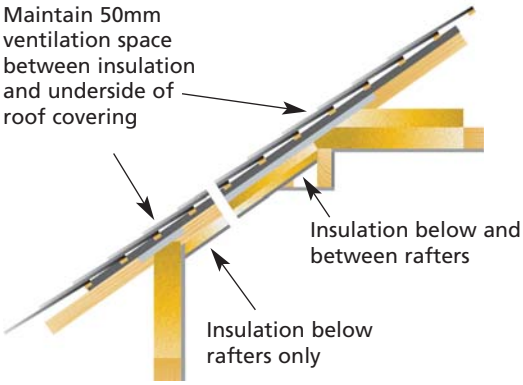


Figure 17: Insulation between the rafters

If there is a room in the roof space, its other areas will also need insulating. The lower stud walls can be insulated like the rafters, while any gable or party wall should also be insulated if the adjacent properties do not also have rooms in the roof voids. These can be considered in the same way as solid walls. The ceiling above the room in the roof can be treated in the same way as either a normal insulated ceiling, or if there is insufficient space, then insulation can be placed between and below the ceiling joists.

Again, it is crucial to stop moist air from within the room from entering any of the new voids formed beyond the insulation, as all of these will be colder, and condensation could easily form.

3.2.3 Insulation of flat roofs

If an existing flat roof is in need of re-roofing, the preferred option is to put the insulation above the new roof deck to avoid the risk of condensation. It can go below or above the weatherproofing membrane; the latter option is known as an inverted warm deck (see figure 18) which has the advantage of protecting the waterproofing membrane and prolonging its life. However it is possible for rainwater to penetrate the insulation layer and reduce its thermal performance. So the insulation should be of a type which is unaffected by moisture – and it is possible to include a water-shedding layer that reduces this effect. Additional insulation is usually needed to achieve the same thermal performance as a warm deck construction.

It may not be necessary to remove any existing insulation between the roof joists, as long as the entire existing roof deck is removed, any means of cross-ventilation sealed, and perimeter walls built up to the underside of the new roof structure.

Careful detailing is also required at abutment and parapet walls. Advice on preventing thermal bridging at these locations can be found in BR262 Thermal insulation: avoiding risks (BRE), and Accredited Construction Details (CLG).

3.3 Floors

The U-value for a ground floor is made up of the floors thermal resistance and its geometry, specifically the ratio of floor perimeter (of external walls) to floor area. So the U-value for an end-terrace property will be higher than for the mid-terrace property next door, even if the same thickness and type of insulation is provided to both. For that reason it makes more sense to think in terms of how much thermal resistance can be provided to a floor. When deciding what can be done to upgrade the thermal resistance of the floor, it is important to consider the type of existing floor and its condition.

3.3.1 Existing floor timbers

Suspended timber ground floors offer little thermal resistance. And because the sub-floor void is usually cross-ventilated, cold air readily leaks through the floor into the dwelling. The air leakage paths can be seen in figure 19.

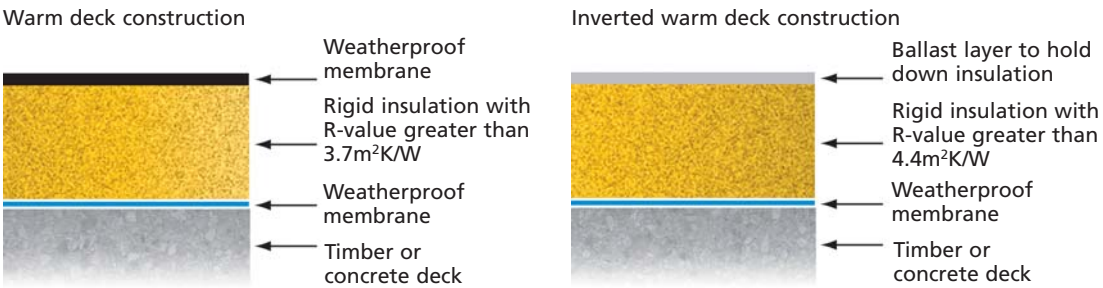


Figure 18: Insulation options for flat roofs

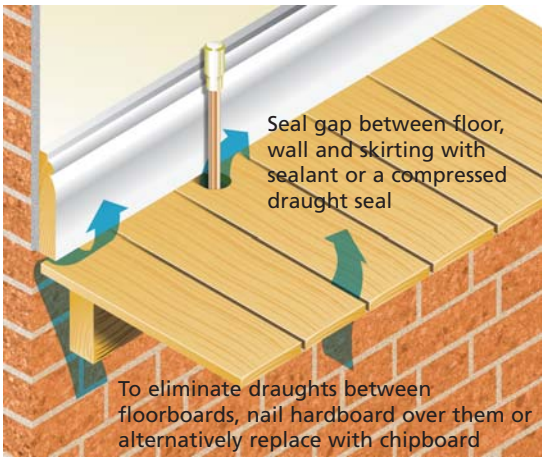


Figure 19: Air leakage paths into a suspended timber floor

If the existing joists are in good condition, and not showing any signs of wet or dry rot, then the easiest way to upgrade a suspended timber floor is to lift the existing floorboards and lay insulation between the joists supported by netting, which is shown in figure 20.

In most circumstances, it is only possible to fill the full depth of the joists with insulation. Extending insulation below the bottom of the joists could restrict the sub-floor ventilation which is needed to remove moisture and prevent wet or dry rot. It is also important to ensure that any gap between the wall and the first floor joist is also filled with insulation, whether the wall is internal or external, as this reduces thermal bridging in this location.

Figure 20: Insulating a suspended timber floor

When replacing the existing floorboards, it is essential to seal any gaps (such as service penetrations and between skirtings and the floor boards, etc.) to achieve a good level of draught-proofing and airtightness. If the existing floor joists are not in a good condition, consideration should be given to replacing the timber floor with an insulated concrete floor.

There is more scope to insulate an existing suspended timber floor if there is a basement below, and this could be less disruptive, as insulation can 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 - and rigid insulation could be fixed underneath the basement ceiling to improve the floor's thermal performance further. This also applies to suspended upper floors, such as those with rooms above garages, walkways and recesses, which are currently areas of large heat loss in many existing dwellings.

3.3.2 Replacement concrete floor

Replacing a timber floor with concrete, or indeed replacing an existing concrete floor presents an opportunity to install as much insulation as possible. It is most likely that replacing a floor with concrete will only be done once in the remaining lifetime of the dwelling, so it is important to achieve the highest thermal resistance possible.

The insulation can either be placed above or below the concrete. Either way, consideration should be given to how insulation continuity can be maintained. Figure 21 below shows solid wall with internal insulation together with floor insulation placed over the concrete. A damp proof membrane is lapped up the wall behind the wall insulation.

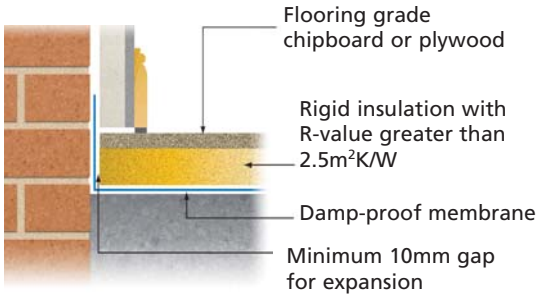


Figure 21: Solid wall with internal insulation

If the insulation is placed below the concrete, it will be necessary to provide an upstand of insulation to the entire perimeter of the floor. This can either be used to maintain the continuity of the solid wall insulation layer, or overlap any existing cavity wall insulation. Figure 22 below also shows the use of a damp proof membrane which is laid below the main insulation and lapped up the walls.

Figure 22: Damp proof membrane below the insulation layer

3.3.3 Existing concrete floors

If the existing concrete floor is in good condition, there is no real reason to replace it. In any case, suspended beam-and-block floors or raft slabs cannot be replaced. However it is always possible to add a layer of insulation on top of the existing floor. The use of a high performance material will allow for a reasonable improvement in thermal performance whilst minimising the effect of raising the floor level. Figure 23 shows how to accommodate insulation above an existing concrete floor.

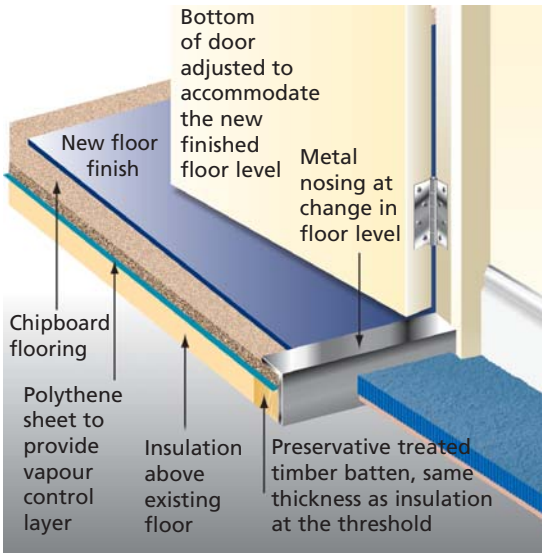


Figure 23: Insulating an existing concrete floor

Although the existing floor may be in good condition now, it may need to be replaced at some point in the future. This may influence the type of insulation that is chosen: it may make sense to use a type which can be re-used when the floor is replaced. Raising the floor does of course raise issues of accessibility, as well as requiring modifications: doors will need shortening; skirtings and low-level electrical sockets may need to be raised.

3.4 Windows and doors

3.4.1 Replacement and secondary double glazing

Windows and doors are a major source of heat loss from a dwelling. Energy efficient windows, when correctly selected and installed, will help to improve thermal comfort for the occupants as well as reducing fuel bills. Savings from high performance glazing are significant. It is important to recognise that windows are replaced very infrequently, so windows of the highest thermal performance should be installed when the opportunity arises. In cases where the original character of the dwelling needs to be maintained, as in listed buildings and conservation areas, then high performance secondary glazing or indeed high performance primary single glazing may offer significant reductions in heat loss.

Figure 24: High performance glazing

Energy efficiency measures – insulation

The performance of a window is not only determined by U-value of the glazing, but also the U-value of the frame, the proportion of the frame in the window, the solar transmittance of the glazing, i.e. its g-value, and also the airtightness of the unit as a whole. Together, these contribute to a window's energy rating as assessed under the British Fenestration Rating Council (BFRC) system (see figure 25).

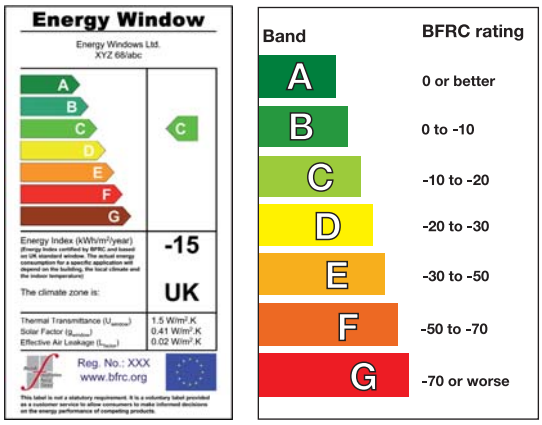


Figure 25: Window energy ratings

This system, set up in conjunction with European partners, compares the overall energy performance of windows based on the total annual energy flow through the window (kWh/m²/yr). Most windows have a negative rating, indicating a net loss of energy over the year, however a few have a positive rating, meaning that they create a net gain of energy.

Typical features of high performance glazing include (also see figure 26):

- The number of panes, i.e. two or three, with the width of the gap between each pane influencing overall performance.
- Low-e coatings on the inside of the inner pane, applied during manufacture, help to reflect radiant heat back into the room.
- Filling the gap with a gas like argon, krypton or xenon reduces the amount of heat lost through conduction.
- Low iron glass increases light and solar transmittance.
- Insulated window frames will also reduce the overall heat loss through the window.

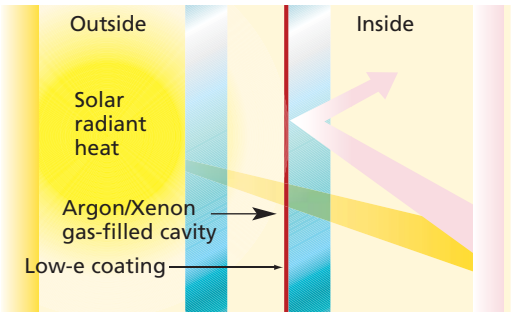


Figure 26: Typical features of high-performance glazing

More information on high performance windows can be found on the British Fenestration Rating Council website www.bfrc.org

3.4.2 Secondary replacement glazing

Replacement double glazing has been a major success story in terms of energy efficiency for many years and increases the market value of properties. Although the earliest examples of double glazing are much better than the single glazing they replaced, they are now well below even the minimum standard required by building regulations. Replacing glazing for a second time can therefore still provide a significant reduction in heat loss and CO_2 emissions.

3.4.3 Replacement doors

New and replacement doors, whether un-glazed or partially glazed, should have insulated cores, i.e. high performance insulation between the two outer surfaces. Insulated doors can currently achieve U-values as low as 0.8W/m²K, which is a significant improvement over solid timber doors, which achieve typically 3.0W/m²K.

4. Energy efficiency measures – airtightness and ventilation

A combined, consistent airtightness and ventilation strategy should be part of any refurbishment work. The objective is to provide a balance by minimising heat loss due to air leakage whilst maintaining indoor air quality.

Air leakage leads to heat loss as air warmed by the heating system leaks out through gaps and cracks in the fabric of the building. This warmed air is replaced by cold air from outside, causing draughts and discomfort. As this replacement air needs to be heated, it compromises the efficiency of the heating system and wastes energy as outside air is unnecessarily heated.

At the same time, adequate ventilation is required to remove pollutants (such as water vapour from cooking), provide fresh air for the occupants and to provide a means of cooling in summer.

This is why both issues have to be tackled at the same time. This can be summed up succinctly by 'build tight, but ventilate right', i.e. making sure that the external envelope is sufficiently airtight but provides adequate fresh air when and where it is needed.

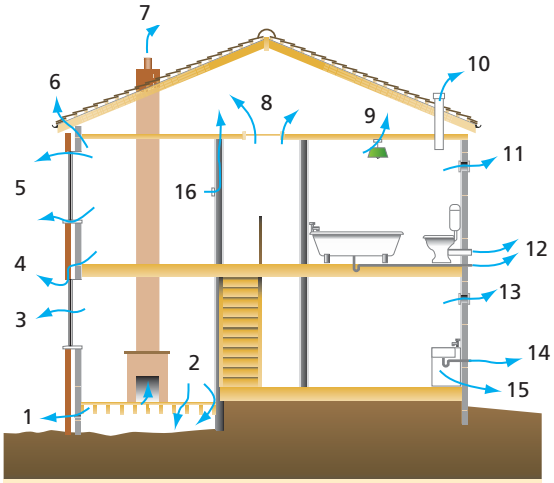
4.1 Reducing unwanted air leakage

The first stage of this strategy is therefore to improve the airtightness of the fabric. The principle air leakage pathways are illustrated in figure 27.

With so many potential air leakage paths available, the location of the final gap in the building envelope might be completely divorced from the original source. For example, a bath waste penetrates through the floorboards, the air then escapes into the wall cavity through a gap between a joist and the inner wall at the other end of the floor void. The air eventually leaks out through a gap between a window frame and the outer wall on the ground floor. All of these locations need to be sealed to prevent the unwanted air leakage.

It is therefore essential that as part of any major refurbishment works, air leakage paths should be identified, possibly using a pressure test, and minimised.

The potential to improve a dwelling's airtightness depends on the nature and construction of the existing building and the type of works being carried out. It is generally more difficult to improve the airtightness of existing dwellings than it is to build new, airtight ones, but low levels of air leakage are achievable in refurbishments.



1. Through air bricks which are required to ventilate sub-floor voids to prevent wet and dry rot.
2. Gaps between floor boards, at the floor edge, and around radiator pipes.
3. Leaking windows and doors.
4. Pathways into floor voids and then through to the cavity at poorly pointed in joist ends.
5. Gaps between window and door frames and external walls.
6. Gaps at the edges of ceilings below a roof void.
7. Open chimneys.
8. Gaps around loft hatches.
9. Service penetrations (light fitting and water pipes etc.) through ceiling into floor or roof void.
10. Vents passing through the roof void.
11. Permanently open bathroom extract vents.
12. Gaps around bathroom waste pipes.
13. Permanently open kitchen extract vents.
14. Gaps around kitchen waste pipes.
15. Gaps between wall-to-floor joints, particularly in timber framed construction.
16. Gaps in and around electrical fittings in hollow walls.

Figure 27: Air leakage pathways

The results of an airtightness test can be used to:

- Identify air leakage pathways and the overall air leakage rate.
- Assess the potential for reducing air leakage in the dwelling.
- Measure improvements achieved by remediation.
- Help decide on what type of ventilation system will be most energy efficient.

Please note that care must be taken when dealing with historic buildings.

Energy efficiency measures – airtightness and ventilation

Table 10: Basic information on how to reduce unwanted air leakage

Windows and doors	Seal gaps around windows and doors to prevent air leakage via the reveals and thresholds.
	Apply an external mastic seal to all window and door frames.
	Seal any internal gaps where the wall reveals/window boards abut window units or external doors with a bead of mastic.
	Repair any damage to window frames and ensure the casements, sashes and top-lights close firmly. It may be necessary to replace closing mechanisms.
	Apply draught-stipping to gaps around window casements, sashes and top-lights.
Walls	Air leakage behind dry-lining can be reduced by injecting continuous ribbons of expanding polyurethane foam between the plasterboard sheets and the inner leaf blockwork.
	Make good damage to mortar joints and fill holes in external walls.
Floor	Improve timber floors by laying hardboard sheeting over the top. Do not use plastic sheeting to cover timber floors as this may cause the timber to rot.
	Seal around the edges of the room and make good gaps around service pipes.
Roof	Ensure the loft hatch fits snugly into its aperture and apply draught-stripping between the hatch and the frame.
Services	Seal gaps around any service pipes and cables passing through external walls, ceilings and ground floors.

4.2 Providing adequate controlled ventilation

Having identified the dwelling's air leakage pathways and carried out the necessary remediation, the next stage is to provide adequate controlled ventilation which will remove pollutants from the inside of the dwelling, whilst at the same time providing the occupants with sufficient fresh air. Provision of ventilation is covered by national building regulations, so any system will need to comply with these minimum legal standards.

The main types of ventilation systems that can be used in dwellings are:

- Natural ventilation and local extract fans.
- Whole house passive stack ventilation systems.
- Continuous mechanical extract ventilation.
- Positive input ventilation.
- Whole house balanced mechanical ventilation with heat recovery.

Background ventilators, also know as trickle vents, are required to provide a minimum supply of fresh air for occupants, and disperse residual water vapour. Background ventilators provide continuous ventilation throughout the dwelling. These are an essential part of most ventilation strategies, as they provide the minimum level of replacement fresh air needed for the occupants.

Natural ventilation and local extract fans

This is probably the most widely used approach to achieving adequate ventilation for dwellings. Extract fans remove stale or polluted air from all wet rooms such as kitchens, bathrooms, drying spaces, and utility rooms, while fresh air is drawn into the building via background ventilators in these and other rooms.

Low power extract fans using DC motors are now readily available, typically saving up to 80% of the electricity required by conventional units. Ideally, all extract fans should be fitted with a humidistat controller to keep the room humidity at an acceptable level, and the duct should not be permanently open to the outside to reduce the level of uncontrolled air leakage through the vent.

Energy efficiency measures – airtightness and ventilation

For effective ventilation, extract fans should be located:

- In accordance with manufacturers recommendations.
- As high as possible in the room.
- As far as possible from the source of fresh air.
- Close to the source as possible, i.e. within a cooker hood.

Passive infra-red detectors can be used to activate this type of fan, or usage detection controls can turn on the extract system when a specific appliance (e.g. a shower) is used.

The single-room heat recovery ventilator is an extract fan which incorporates a heat exchanger. It recovers 60% or more of the heat from the outgoing air, using it to preheat the incoming replacement air (see figure 28).

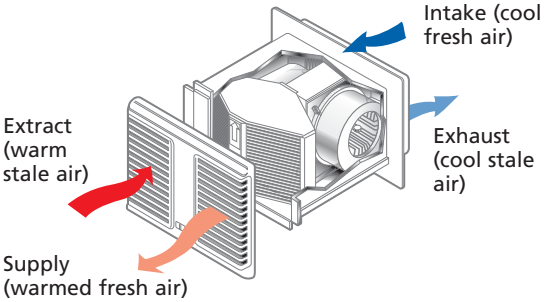


Figure 28: Heat recovery ventilator

Background ventilation will still be required in all other rooms, and the design considerations regarding location are similar to those for normal extract fans.

Whole house passive stack systems

The layout of existing dwellings may make passive ducted ventilation systems difficult to incorporate. However, adequate levels of ventilation can be achieved by this method.

A passive stack system consists of vertical, or near vertical, series of ducts that connect wet rooms directly with the outside, through the roof. Moist air is extracted by the stack effect – moist warm air is less dense than cold, dry air and so rises – as well as by the effect of the wind blowing over the roof. Fresh air is replenished through background ventilators in the normal way (see figure 29).

Passive stack systems do not require electricity, so do not directly cause any CO_2 emissions. However unless the ducts are fitted with self-closing valves when ventilation is not required, they can allow some warmed air to escape and slightly increase the demand on the heating system.

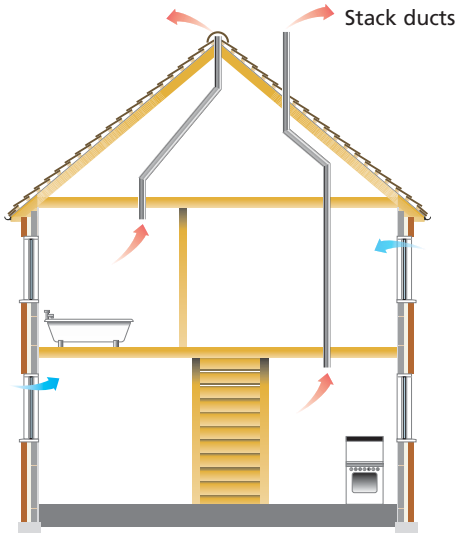


Figure 29: Passive stack system

Positive input ventilation systems

This system (also known as mechanical input ventilation) consists of a fan, typically mounted in the roof space, which supplies air into the dwelling via the central hallway or stairwell, creating a slight positive pressure in the dwelling. With these systems, excess water vapour is not directly removed from wet rooms, but instead is allowed to escape through the required background ventilators. Fans typically run continuously at low speeds with a manual or humidity controlled boost option.

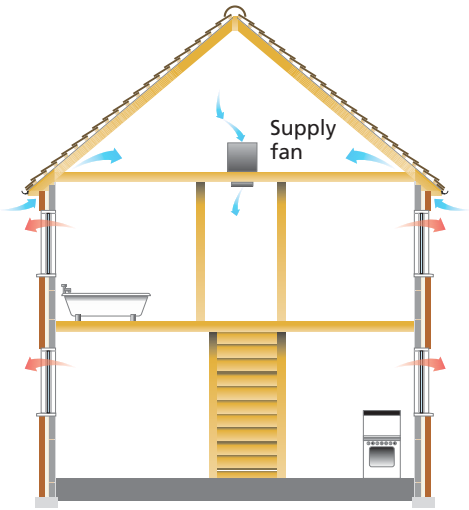


Figure 30: Positive input ventilation

Energy efficiency measures – airtightness and ventilation

If the fan draws air directly from the roof space (see figure 30), it will depressurise the roof space relative to the rest of the dwelling, and could cause significant recirculation of the air from the dwelling to the roof space and back into the dwelling again. This needs to be minimised by ensuring the uppermost ceiling (including access hatches) is as airtight as reasonably practical. Additionally, as the roof void needs to be adequately ventilated from outside, it may be more practical to use air ducted directly from the outside (and not through the roof void) if the roof is sealed and has breathable sarking felt.

Continuous mechanical extract ventilation

This type of system is a combined form of the previous two systems, and usually consists of a single central continuously running ventilation unit positioned in a cupboard or loft space, ducted through the dwelling to extract air from wet rooms. The replacement air can be from background ventilators (see figure 31).

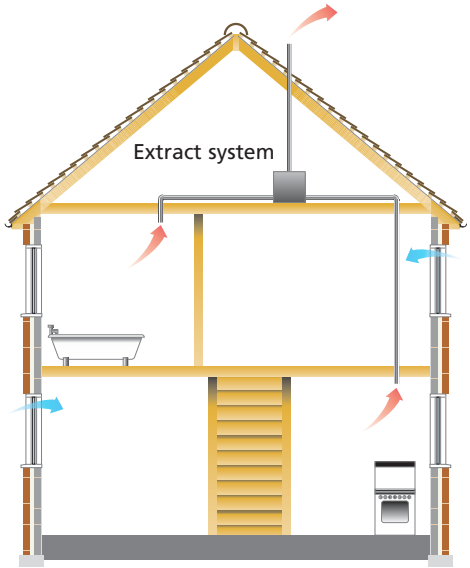


Figure 31: Continuous mechanical extract ventilation

The whole system should have a specific fan power of 0.6W/l/s or less when tested in the appropriate configuration via SAP Appendix Q. Appendix Q of the SAP document explains a procedure allowing the benefits of energy efficient technologies to be recognised in SAP. Further information on SAP Appendix Q, the test methodologies and test results of eligible systems can be found at www.sap-appendixq.org.uk

Whole house balanced mechanical ventilation with heat recovery

This system consists of extracting moist warm air from wet rooms and drawing in replacement air which is preheated by the outgoing air. As the rate of air intake matches the extract rate, there is no need to provide background ventilation when using this system (see figure 32).

These systems deliver the required ventilation rate almost independently of weather conditions. However, where the other systems discussed above provide similar levels of energy efficiency, the improved energy efficiency benefit of a whole house balanced mechanical ventilation system will only be realised in really airtight properties.

Following a pressure test, and subsequent remedial works, if the final air leakage rate is likely to be much less than 5m^3/m^2/h @ 50 Pa, then significant energy efficiencies are possible with this type of system if it has a specific fan power of 1.0 W/l/s or less and a heat recovery efficiency of 85% or more. Both should be tested in the appropriate configuration via SAP Appendix Q.

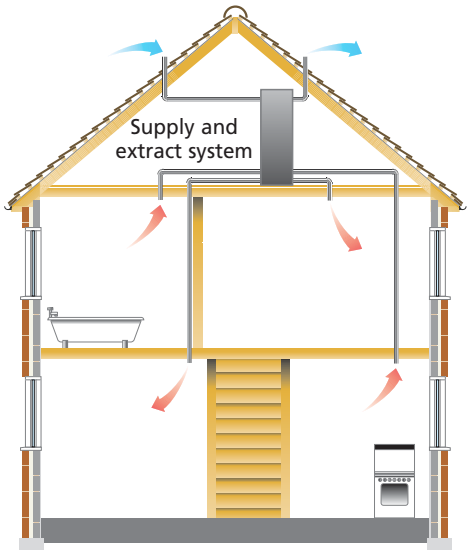


Figure 32: Whole house balanced mechanical ventilation with heat recovery

5. Energy efficiency resources – heating systems/controls and hot water systems

Space heating provides thermal comfort where and when required. Heat gains from the sun, hot water system, lighting, cooking and electrical appliances supplement the main heating source, while poor levels of insulation and airtightness increase heating demand.

An energy efficient heating system is one that:

- Is correctly sized to warm up the dwelling from cold within a reasonable time.
- Uses fuel as efficiently as possible.
- Can be accurately and easily controlled by the dwellings occupants.

An efficient system will have lower running costs and CO_2 emissions, and can also increase the value of a property.

A complete system replacement provides the best opportunity for improving energy efficiency. It also allows a reassessment of fuel choice, as this influences running costs and CO_2 emissions. A partial upgrade can give many of the same benefits, particularly when controls and insulation are improved, or the boiler replaced.

5.1 Fuel choice

The choice of fuel depends on availability and affects running costs and CO_2 emissions. Solid fuels such as coal/coke, and electric heating systems have significantly higher emissions than mains gas or oil, whereas wood pellets or chips (biomass) potentially have very low CO_2 emissions. Unfortunately there is no current labelling scheme for wood pellets or chips, which means that without verification of the source, levels of CO_2 emissions (and other forms of air pollution such as mono-nitrogen oxides (NO_X) cannot always be guaranteed.

Electric resistance heating should only be used when the heating demand is very low and all insulation measures have been carried out to the best achievable level.

5.2 Recommended upgrade package

The recommended heating upgrade packages are the best practice specification set out in CHeSS (2008) (table 11). Heating and hot water systems need to be correctly sized. A number of factors should be considered for new systems in dwellings where fabric insulation has been significantly upgraded, and levels of air leakage have been reduced:

- The size of the boiler will be increasingly determined by hot water demand for dwellings with lower heating demand.
- The system should be adequately controlled to avoid over-heating.
- The system needs to be easily controlled by the occupants, and also be responsive to environmental conditions.

It is vital that occupants are advised on how best to operate their new systems. For instance, thermostatic radiator valves (TRVs) are still relatively new, and it is widely believed that by turning these up to maximum will warm a room more quickly. This is not the case, as the speed of heating is solely down to the boiler output and the size of the radiator. Thermostatic radiator valves only moderate the room temperature by controlling the flow of hot water through the radiator. Further advice on heating system controls specifically written for dwelling occupants can be found at www.energysavingtrust.org.uk/Home-improvements/Heating-and-hot-water/Heating-controls

Table 11: CE51 – CHeSS specifications

Recommended best practice (2008)	
Reference	**CHeSS – HR8 (2008)**
Description	Domestic wet central heating system with regular boiler (natural gas, LPG, or oil) and separate hot water store.
Boiler (see notes 5 and 6)	• A regular boiler (not a combi) which has a SEDBUK efficiency of at least 90% (band A).
Hot water store	EITHER • High-performance hot water cylinder (see note 8). OR • High-performance thermal (primary) storage system (see note 9). In suitable buildings, consideration should be given to fitting a cylinder with an additional heat exchanger to allow for solar water heating.
Controls (see notes 10, 11 and 12)	• Programmable room thermostat, with additional timing capability for hot water • Cylinder thermostat • Boiler interlock (see note 13) • TRVs on all radiators, except in rooms with a room thermostat • Automatic bypass valve (see note 14) More advanced controls, such as weather compensation, may be considered, but at present cannot be confirmed as cost effective.
Installation	See notes 1, 2, 3 and 4.

Recommended best practice (2008)	
Reference	**CHeSS – HC8 (2008)**
Description	Domestic wet central heating system with combi or CPSU boiler (natural gas, LPG, or oil).
Boiler (see notes 5 and 6)	• A combi or CPSU boiler which has a SEDBUK efficiency of at least 90% (band A).
Hot water store	None, unless included within boiler.
Controls (see notes 10, 11 and 12)	• Programmable room thermostat • Boiler interlock (see note 13) • TRVs on all radiators, except in rooms with a room thermostat • Automatic bypass valve (see note 14) More advanced controls, such as weather compensation, may be considered, but at present cannot be confirmed as cost effective.
Installation	See notes 1, 2, 3 and 4

5.3 Seasonal efficiency of boilers

All gas and oil boilers, either newly provided or replacement, must now be of a condensing type with a SEDBUK efficiency of at least 90% unless there are exceptional circumstances as defined in the building regulations. The SEDBUK efficiency only applies to the boiler acting in heating mode. The actual efficiency in supplying domestic hot water can be significantly lower.

5.4 Heating and hot water systems

Efficient heating and hot water systems consist of many integrated components, all of which are required to maximise the efficiency of the system. These consist of a correctly sized boiler, the boiler type and its controls, the radiator size and its control, the performance location and level of insulation of the hot water storage cylinder, and the correct use of insulation to the system's pipework.

Type and size of boiler

The size of the boiler is determined by the overall demand for both space heating and hot water. For well-insulated dwellings, the demand will most likely be dominated by the need to provide adequate hot water. The whole house boiler sizing tool can be used to assist in determining the size of the boiler required to efficiently operate the system – see www.energysavingtrust.org.uk/Housing/Tools

Two types of boiler are available, either regular system or combination (combi):

- Regular system boilers provide space heating, and hot water using a storage cylinder.
- Combi boilers provide space heating and instant mains pressure hot water. They do not require a storage cylinder (or header tank). Some instantaneous combi boilers have a keep hot facility which keeps water within the boiler permanently hot to reduce response time at boiler start-up. This is particularly useful at reducing water usage.

It must be noted that combi boilers have minimum flow requirements to enable the heating of hot water to be activated. This is particularly applicable when considering the installation of flow regulation to showers and taps as discussed in section 9. Whilst newer boilers can activate with flows as low as three litres per minute, older combi boilers may require at least eight litres per minute or more.

Radiators

Radiators need to be adequately sized to provide the required level of heating to each room. It is very important to ensure that each radiator (except the one in the room containing the main thermostat) is fitted with a thermostatic radiator valve, and that the occupants are fully conversant with how the valves are to be used.

Controls

The central heating boiler and pump must turn off automatically when there is no demand for space heating or hot water. This is known as a boiler interlock.

Larger houses should be divided into zones with time and temperature controls for each zone. Generally the zones would be upstairs and downstairs, but in a building with significant solar gain and low overall heating demand, they may be north and south facing.

Seven day programmable room thermostats are recommended as they give the greatest choice of temperature and timing. It is important to choose one that is easy to operate or over-ride for departures from the normal occupancy hours (e.g. when going away for a few days). Some programmable thermostats incorporate hot water controls, but a separate hot water programmer is also acceptable.

Time and temperature controls that users find easy to use and understand will allow for the most efficient use of the heating system.

Other automatic heating system controls include load or weather compensators, which adjust the boiler's firing pattern to match the heating system's return temperature, and a delayed start feature which determines the time that will be required for the heating to reach the required temperature. This means that when it is warmer outside, the boiler will fire later as the heating system's response time will be reduced.

High performance hot water cylinders

Rapid-recovery coils in hot water cylinders increase the rate of heat transfer into the water within the cylinder and reduce recovery times. The principle advantages of high performance hot water cylinders are:

- Reduced operating time for the boiler.
- A thermostat prevents stored water overheating.

- A smaller hot water cylinder can be used, reducing standing losses. (N.B. This needs to be considered with regard to the potential use of a solar thermal hot water system to augment the hot water provided by the boiler.)
- The most important feature is the insulation. High performance hot water cylinders are supplied with factory-fitted insulation consisting of high performance foam. This is much better than fitting a loose insulating jacket to a standard hot water cylinder.

Pipework and system layout

All primary pipework to the hot water cylinder must be insulated. In addition, any pipework outside of the heated envelope of the dwelling must be insulated to save on heat loss and to prevent freezing, and it is also recommended that heating pipework in all floor voids is insulated. Additionally, any cold water supply pipes that are laid adjacent to hot water pipes should also be insulated to avoid wastage waiting for water to cool when it is drawn off.

The boiler should be positioned within the heated living space of the dwelling where possible, and the length of the primary pipework runs to the hot water cylinder minimised. Likewise, the hot water cylinder should be positioned close to the kitchen and bathroom in order to minimise pipe runs.

Passive flue gas heat recovery devices

These can be fitted to some combi boilers between the boiler and the flue outlet. They allow the flue gases to pass through a heat exchanger which absorbs the latent heat of the condensing flue gases. This additional heat is then used to preheat water used to supply domestic hot water, reducing the time needed for the boiler to run.

As the supply of domestic hot water is the dominant use of boilers in well insulated dwellings, this feature could offer savings not just in the energy used in heating the water, but also by reducing water use.

The energy saved in operating such a system can be determined through the methodology of SAP Appendix Q in a similar way for ventilation systems mentioned earlier. Further information on SAP Appendix Q, the test methodologies and test results of eligible systems can be found at www.sap-appendixq.org.uk

5.5 Electric storage heating systems

The CO_2 emissions and running costs of electric heating systems will be higher than those for gas. They should only be used in properties that have been insulated to a good standard, where the heating demand is very low, and where there are no other realistic fuel type options.

Recommended electric heating packages include:

- Fan-assisted off-peak storage heaters with top-up on-peak convectors in living rooms.
- Storage heaters in large bedrooms and large kitchens.
- On-peak fixed convector heaters with time switches and thermostats in small bedrooms.
- On-peak downflow heaters in bathrooms and small kitchens.
- Automatic charge control and thermostatically controlled damper outlet on all storage heaters.
- Dual-immersion hot water cylinder with factory applied insulation.
- Hot water controlled with one hour on-peak boost facility.

Hot water cylinders should be sized to allow most water heating to take place in off-peak hours, and cylinders with capacities of between 110 litres (for small dwellings) and 245 litres (for large dwellings) are recommended.

5.6 Smart meters

Smart meters offer the dwelling's occupants a real-time view of their energy usage, and so help eliminate unnecessary use, and reduce running costs and CO_2.

Figure 33: Smart meter

Installing smart meters while undergoing refurbishment removes the need for any future disturbance to the dwellings occupants.

6. Energy efficiency measure – lighting and appliances

Electricity for lights and appliances in our dwellings can account for a significant proportion of total energy demand, and hence CO_2 emissions. These can be reduced by:

- Using energy efficient bulbs in both fixed and movable lamps, for all light fittings internally or externally.
- Using gas cookers and hobs whenever gas is available.
- Installing Energy Saving Recommended (ESR) domestic appliances.
- Ensuring that all of these are used in an energy efficient manner.

6.1 Lighting

Low energy lighting can be installed at any time to any existing light fitting. When any major rewiring is being carried out, building regulations may require that at least 25% of any fixed light fittings should be dedicated energy efficient light fittings, only capable of taking low energy light bulbs. There is now an extensive range of such dedicated fittings to choose from, and therefore there is no reason why 100% of all fixed lighting cannot be dedicated energy efficient light fittings.

Energy inefficient tungsten filament light bulbs are to be phased out by 2012 throughout the entire European Union region.

Light-emitting diodes (LEDs) could become significant in providing low energy lighting in the near future. These extremely small semiconductors emit coloured light when energised by a low-voltage direct current. LEDs are usually too small to be used singly, and so are supplied in arrays or modules of differing shapes and sizes. They have very long life and their efficacy is improving fast (new generations are about 60–70 lumens per watt).

Three main types of energy efficient lighting are currently available.

Compact fluorescent lamps

The life expectancy for these is around twelve times longer than conventional tungsten filament light bulbs, and they use around a quarter of the energy to provide the same level of lighting. The efficacy of this type of lighting is generally in the range of 50–75 lumens per watt. Good quality compact fluorescent lamps with 'high-frequency ballasts' light up instantly, do not flicker, and produce full brightness quickly. Two or four pin lamps have light fittings designed for them, and are also cheaper to buy. Four pin lamps can also be dimmable.

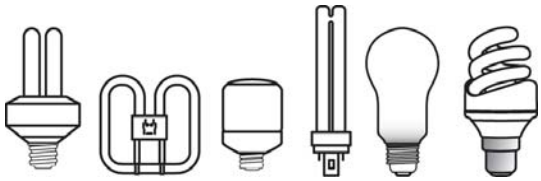


Figure 34: Compact fluorescent lamps

Fluorescent tubes

These contain high-frequency ballasts as standard which avoids flicker. Dimmable high-frequency ballasts are also available. Slimline 26mm diameter fluorescent tubes use about 10% less energy compared to older 38mm fluorescent tubes for the same colour rendering, and are cheaper to buy. The efficacy of this type of lighting is generally in the range of 50–100 lumens per watt.

Figure 35: Fluorescent tube

Tungsten halogen

These are only suitable for spotlighting or task lighting, and should not be used for general household lighting. They are at least 50% more efficient than tungsten filament light bulbs, and last about three times as long. The efficacy of this type of lighting is generally in the range of 15–30 lumens per watt, and thus cannot be used as low energy lighting in respect to current building regulations. They are often used for security lighting (which should also be fitted with daylight and movement sensors). Many tungsten halogen lights operate at 12 volts and hence require a small transformer.

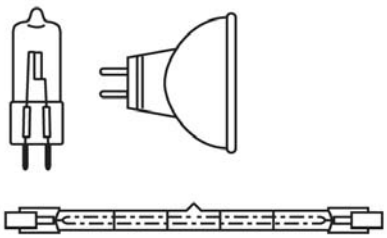


Figure 36: Tungsten halogen

6.2 Appliances

Domestic appliances account for a large proportion of total energy demand. As energy efficient appliances use less electricity, they are less expensive to operate and are responsible for lower CO_2 emissions.

While appliances may be increasingly efficient, our homes contain more and more of them. There is often very little different in purchase price, but a great difference in running costs since energy efficient appliances use less energy. Energy labelling schemes make it easier to choose energy efficient appliances.

In 1995, the European Union introduced a compulsory energy labelling scheme for domestic appliances, covering fridges, freezers and fridge-freezers. This scheme has since been extended to include washing machines, tumble dryers, washer-dryers, dishwashers and cookers. Energy labels are displayed on these products in shops and showrooms in order to allow potential purchasers to make an educated judgement on the relative energy efficiency of different appliances. The energy labels (figure 37) show estimated fuel consumption (based on standard tests) and an energy grading from A to G, although cold appliances can be graded up to A++.

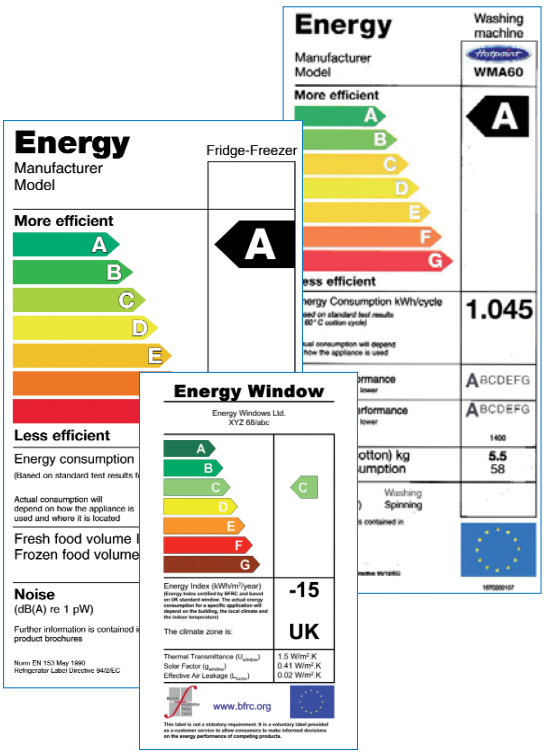


Figure 37: Energy labels for domestic appliances

However, the actual amount of electricity used will depend on how the appliance is used, and in some cases (e.g. fridges) where they are located. If they are positioned close to a cooker or a room heater, they will use more energy than if they were sited in a cooler location. Some energy labels now also provide information on other aspects of the performance of the appliance, such as water usage for washing machines etc.

The Energy Saving Trust manages the Energy Saving Recommended labelling scheme for products of proven energy efficiency. The scheme currently covers:

- Domestic appliances.
- Light bulbs and fittings.
- Gas and oil boilers.
- High performance hot water cylinders.
- Heating controls.
- Loft insulation.
- Cavity wall insulation.
- External wall and dry linings.
- Windows and doors.

These products carry the Energy Saving Recommended label, which marks the best 20% of products. Currently endorsed products can be found at www.energysavingtrust.org.uk/compare

energy saving recommended
www.energysavingtrust.org.uk

Certification mark

7. Installation and provision for renewable energy

Once energy efficiency measures have reduced the heat and electricity demand as far as is practicable in any given refurbishment project, low and zero carbon technologies are then required to reduce the dwellings energy use further. Indeed it will be highly unlikely that an 80% reduction in CO_2 emissions for a dwelling can be achieved without the use of some form of renewable energy generation.

The technologies available are broadly divided into the following low and zero carbon options, some of which deliver heat and some electricity. Table 12 clarifies how each technology is classified.

Some technologies are better suited to installation in refurbishment projects than others due to the infrastructure required. The basic principles, constraints and opportunities for each technology are discussed briefly below.

7.1 Solar thermal hot water

Solar thermal hot water systems capture heat energy directly from the sun and are used to provide domestic hot water rather than space heating. Flat plate or evacuated tube solar collectors (figure 38) absorb the incident solar radiation, which is transferred by a water or antifreeze loop to the domestic hot water supply through a second coil in the storage cylinder.

Evacuated tube collectors are more efficient than flat plate collectors, especially in overcast conditions, and are ideal in situations where the available unshaded south-facing roof is limited. Where suitable roof area or orientation is not a constraint, the additional expense of evacuated tubes puts both types of collectors roughly on a par in terms of cost effectiveness.

The yield depends on the collector size and type, angle of incidence, shading, size of tank and the geographic location (see figure 39).

Figure 38: A solar thermal system

Figure 39: Solar radiation in the UK
(PVGIS © European Communities, 2001-2008)

Table 12: Low and zero carbon technologies

	Heat output	Electrical output
Zero carbon	Solar Thermal Hot Water (PV pump or thermosyphon)	Solar PV Wind
Low carbon	Solar Thermal Hot Water Biomass Heat Pumps District Heating	
	Micro or Communal CHP	

During the summer months, solar thermal systems will typically provide over 80% of domestic hot water demand, and on average the householder can expect an annual reduction of about a third in the energy required for hot water heating.

An auxiliary heat source will be required to ensure that the water is heated to a sufficient temperature in order to eliminate the risk of legionella (please refer to Approved Code of Practice L8: Legionnaires' disease for further information). Therefore, solar thermal hot water systems need to be used in combination with a suitable heat producing appliance.

7.2 Solar photovoltaic

Solar photovoltaic (PV) panels consist of semi-conductor cells which convert sunlight directly to DC electricity. This can then be used directly, stored in batteries or (more commonly) converted to AC, using an inverter, for household use or exporting to the National Grid.

PV cells are commercially available in a range of different types – monocrystalline, polycrystalline, and hybrid amorphous mono. Hybrid is the most effective (and expensive) type. Monocrystalline is the second most expensive and efficient and works well in bright conditions. The least expensive is polycrystalline, and although not quite as efficient as monocrystalline, it is generally the most cost effective.

Solar PV should face close to due south, although any orientation between south west and south east should offer within 5% of the maximum output. Additionally, the output will depend upon the geographical location (see figure 39). Locating panels to minimise shading is critical for PV systems, even more so than solar thermal.

The installed cost of PV is still relatively high, although it can be offset if the PV is designed to be integral to the building, serving the same structural and weather-protection properties as traditional alternatives. As well as aluminium framed modules, which are fixed external to the existing roof, PV is available as roof tiles (figure 40) and semi-transparent atrium glass.

7.3 Micro combined heat and power

Micro combined heat and power (CHP) is an emerging technology which is expected to play a significant role in future domestic energy provision. Micro-CHP units are about the same size as a small fridge or floor-mounted boiler. They use a Sterling Engine to generate electricity as well as providing heating and hot water.

They are predominantly gas powered, delivering between 4-8kW of heat, and 1-3kW of electric power. They can therefore provide all of the dwelling's heating and hot water needs with the added benefit of providing some of its electricity.

In currently proposed systems, heat is delivered to radiators and hot water is supplied by a conventional storage cylinder. A micro-CHP unit can be connected into an existing wet heating system, often as a replacement for the existing boiler.

Micro-CHP systems must be selected carefully in accordance with a heating system design method. This will ensure the heat output is well matched to the dwellings heating and hot water demand, and in that way they will be capable of out performing a conventional gas boiler.

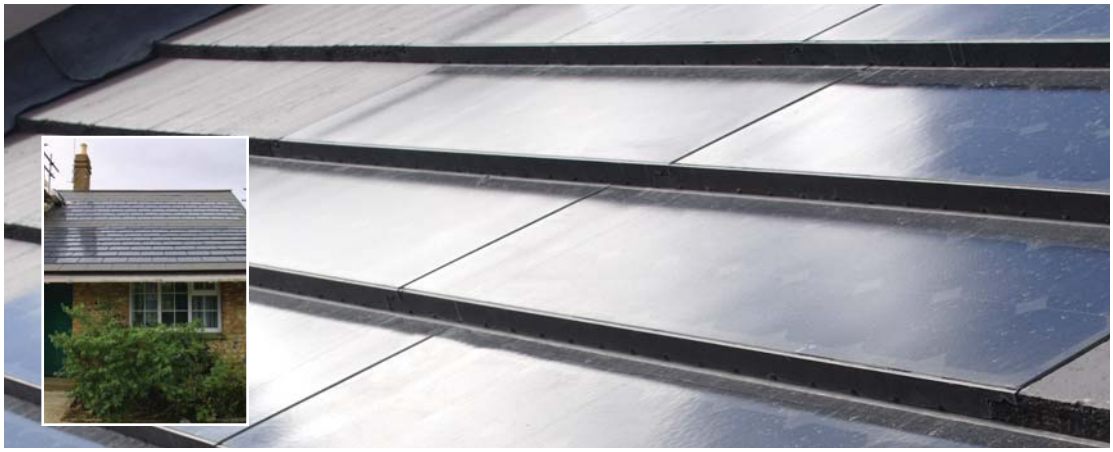


Figure 40: Solar PV roof tiles

7.4 Ground source heat pumps

This technology makes use of the solar energy which is stored as heat in the ground. Due to its high thermal mass, the ground under the first metre below the surface maintains a constant temperature of about 11-12˚C all year round. A ground source heat pump uses this stored solar heat by using electricity to move it from the ground to a dwelling.

A ground source heat pump (GSHP) consists of three key elements:

Ground heat exchanger – a water/antifreeze mixture circulating in a ground loop, which absorbs low-grade heat from the ground. The loop itself can be either vertical (figure 41), or horizontal (figure 42).

The heat pump – an electrically powered heat pump unit boosts the temperature by means of a compression and evaporation cycle in a similar way to a domestic refrigerator.

Heat distribution system – this can be either by some form of under floor heating system, or via conventional radiators, or a combination of these. When using radiators to supply heat, or when using a ground source heat pump to supply domestic hot water, a secondary heating source will be required to ensure the water is heated sufficiently as discussed earlier.

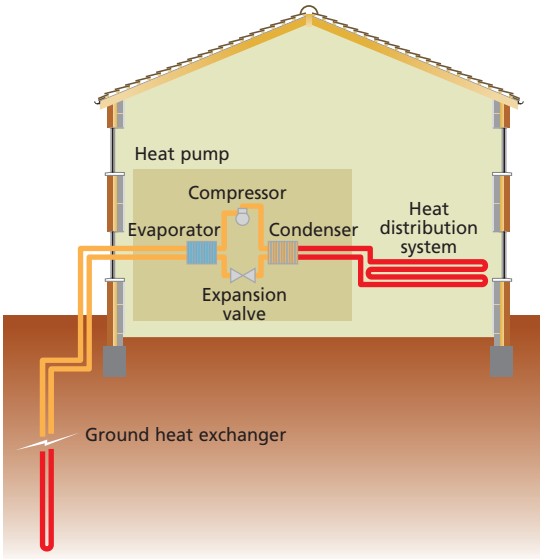


Figure 41: Vertical GSHP

Figure 42: Horizontal GSHP installation

The efficiency of a heat pump system is typically between 300 and 400% (i.e. three to four times more heat energy is output than the electrical energy used to drive the system). However, efficiencies can be up to 500% on more recent units – these efficiencies are in comparison to direct electric heating. The improvement compared to a highly efficient gas boiler will not be this high, because grid electricity is more carbon-intensive than gas. If the heat pump's power source is topped up by a low-carbon source like solar PV, then a further reduction in CO_2 emissions can be achieved. The difference in temperature between heat source and distribution system is key factor for efficiency. The smaller the difference, the higher the efficiency – so under-floor heating is better suited, as its lower distribution temperature maximises efficiency.

As for micro-CHP, its essential to ensure that heat pump systems are correctly designed/sized using a suitable method. In this way, they will be able to perform to their optimum potential.

7.5 Air source heat pumps

Where the installation of a GSHP is not practical, air source heat pumps (ASHP) – which concentrate the heat of the outside air, rather than the ground – offer an alternative. These can be air-to-air, or air-to-water and some units can also provide cooling in summer. Overall, ASHPs are not as efficient as ground source systems, and they do not perform as well as highly efficient gas boilers in terms of CO_2 emissions. However, as for GSHPs, an air source system that is in part powered by solar PV will provide a further overall reduction in CO_2 emissions.

7.6 Biomass

Burning biomass does release CO_2, however this is balanced by the CO_2 that was absorbed during the plant or tree's growth. So the process is close to being carbon neutral, with the only additional CO_2 emissions involved associated with planting/harvesting, processing and transportation. Even with these, the resulting emissions represent about a 90% reduction in emissions compared to the burning of fossil fuels.

However, the combustion process can be very inefficient if not properly controlled. Indeed the burning of logs in an open fire will result in around 85% of the heat generated being lost to the atmosphere. Controlling the air supply, selecting properly dried fuel and using an efficient appliance are the critical factors in achieving an efficient burn. Modern stoves and boilers have efficiencies in the range of 80–90%.

7.6.1 Fuel types

There are three main types of biomass fuel used for domestic heating – logs, woodchip and pellets. Disadvantages of biomass generally include the storage space required for the fuel, the removal/disposal of the ash residue, and the higher emissions of NO_X compared to gas.

7.6.2 Stoves

These can be log or pellet burning room heaters, and are ideal for smaller applications of between 2-12kW. They are most commonly used for space heating in conjunction with gas or oil central heating, however for well insulated dwellings they can provide the entire heating demand. They can also be fitted with back boilers to supply or augment the hot water supply. Many models have been approved for use in smokeless zones.

7.6.3 Boilers

Biomass boilers may be suitable for larger single dwellings, where a greater heating capacity is required. They can be fed by any of the above fuel types, and they work well in conjunction with a thermal store, allowing the boiler to burn fuel at a controlled and constant rate.

Figure 43: Biomass boiler

7.7 District heating and combined heat and power

District heating uses a large-scale central heat source along with a network of supply pipes in place of individual household boilers. Advantages include increased thermal efficiency, reduced investment in individual boilers and gas connections, ease of maintenance and the option of biomass as the fuel source in dwellings where gas may otherwise be inappropriate.

From a householder's point of view, district heating provides instant access to high pressure hot water, removing the need for their own hot water cylinder or any type of individual boiler and freeing up valuable space within the dwelling.

A further option is combined heat and power (CHP). In this arrangement, natural gas, biomass or bio-gas (derived from the gasification of wood chips) drives an engine to generate electricity. A large proportion of the low-grade heat that would otherwise be wasted (at a power station, for example) is captured for use in the district heating network. The combined efficiency of 75% compares with around 35% for grid electricity.

Systems range from a few kW electrical output (kWe) to several MWe, although they would typically be sized to match heat rather than electrical demand. As a rule of thumb, in order to achieve economical returns, CHP plants need to run for at least 13-14 hours per day on average, so are best suited to mixed-use developments where the demand profile is more consistent. For domestic only schemes, thermal storage is needed to match CHP heat output with the heat demand profile.

The scope of district heating and CHP systems in refurbishment situations is likely to be limited by the works required to install the distribution pipework. The most appropriate applications will be blocks of flats or high-density housing in urban areas.

7.8 Wind

A wind turbine converts power in a moving air mass (wind) into rotating shaft power and thus into electricity through a gearbox and generator. The UK is the windiest country in Europe, with 40% of the available resource. Wind speeds are typically greater during winter and during the day, matching demand patterns better than many of the other renewable options.

However, wind power on a domestic scale is limited by the potential size and location of turbines in an urban setting. Since the power that can be captured by a wind turbine increases by eight times if the windspeed is doubled, the slower and more turbulent wind resource in built-up areas greatly affects the potential output. Furthermore, the need for smaller, quieter and more unobtrusive turbines in urban areas also tends towards smaller rotor diameters.

As the hub height is raised further above the roof line, this turbulence is reduced and so the average windspeed and power output increases. Doubling the rotor diameter increases the power output by four times.

For these reasons, the most cost effective option for wind generation is a community-scale turbine. In rural areas, there may also be the opportunity to mount a 5-20kW turbine on a pole away from any surrounding obstructions, and this also may prove cost- and carbon-effective for detached homes with large gardens. A typical 5kW system can generate between 10,000-12,000 kWh per year, and reduce carbon emissions by 5-6 tonnes over the same period.

7.9 The Low Carbon Buildings Programme

The Low Carbon Buildings Programme (LCBP) was developed by the Department for Business, Enterprise and Regulatory Reform (BERR) and enables grant funding for microgeneration technologies. It is split into two phases – the first was restricted to householders, while the second phase is for community groups, public and non-profit sector organisations.

All applicants are encouraged to have first maximised the energy efficiency of the dwelling to get maximum benefit from their microgeneration installations. To be eligible to receive a grant, you must use an installer and a product certified under the Microgeneration Certification Scheme (MSC) – www.microgenerationcertification.org

This grant scheme is due to be replaced by a clean energy cashback scheme for electricity in 2010 and a Renewable Heat Incentive in 2011. These will subsidise the renewable generation, per unit, for the above technologies.

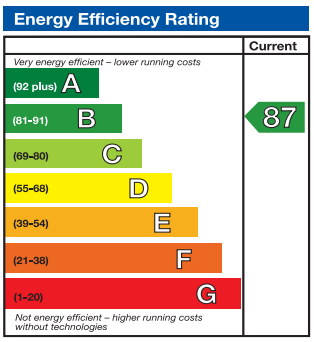
Figure 44: Wind turbine in-situ

8. House types revisited

In section 2 we introduced the base case scenario. In this section we provide examples of how dwellings can be upgraded to achieve an EPC band A rating, and significantly reduce their CO_2 emissions. This is done by improving the thermal performance of the fabric, improving services, and finally using some form of renewable energy generation. It is always possible to go further with fabric improvements than those demonstrated here. Table 15 indicates the improved performance and reductions in CO_2 emissions which can be achieved by fabric and services improvements to the various house types.

1950's Semi-detached, floor area 90m²

In this section, using fabric and services improvements, we show how this dwelling can be upgraded to an EPC band B, and then following the addition of some renewable energy generation, the dwelling can achieve an EPC band A.



Total CO_2 emissions for this house have now been reduced from around 72 kg/m²/yr to about 29 kg/m²/yr which is slightly below 2.6 tonnes of CO_2 emitted each year and is a 60% reduction. So with only fabric and services improvements, this upgraded dwelling now has an EPC band B rating and its CO_2 emissions have reduced by 3.9 tonnes/yr.

The energy used for both gas (heating/hot water and cooking) and electricity use (appliances, lights etc.) for this upgraded dwelling are shown in table 13.

1950s semi-detached house

Typical improved (or upgraded) features

Element	Fabric U-value
Insulated roof.	0.10W/m²K
Insulated cavity walls, internal insulation.	0.18W/m²K
Insulated replacement concrete floor.	0.12W/m²K
Windows, double glazed, timber frames.	1.50W/m²K (BFRC g-value of glazing - 0.45W/m²K)
Doors, insulated panel.	1.00 W/m²K

Other improvements

- Mechanical ventilation with heat recovery 85% efficiency, specific fan power 1W/l/s, air leakage rate 3m³/m²/h @ 50 Pa.
- Regular condensing boiler 91% efficiency, load compensation and delayed start, programmer, room thermostat and thermostatic radiator values (no secondary room heating needed).
- Water storage cylinder 110 litre capacity, 80mm factory cylinder insulation, all pipework insulated.
- 100% dedicated low energy efficient fixed light fittings.

Typical energy demand

Energy source	Total energy demand (kWh/yr)		Energy demand per m² (kWh/yr/m²)
Gas	Heating and hot water	4,800	68
	Cooking	1,280	
Electric	Lights, fans and pumps	865	38
	Appliances	2,510	

CO_2 emissions (kg/m²/yr)

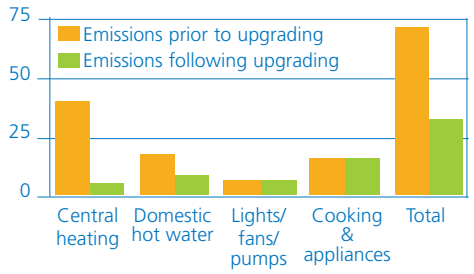


Table 13: CO_2 emissions for a 1950s semi-detached house, floor area 90m² following fabric and service improvements

House types revisited

However, this dwelling's CO_2 emissions are still substantially above the suggested target emissions of 15-20kg/m²/yr. Although various renewable energy generating strategies could be added to a dwelling, depending upon location and orientation, the method selected here is to use 4m² of solar thermal (including the use of a 200 litre twin coiled hot water vessel), and 2.2kWp of solar photovoltaic panels (approx. 13m²). Additionally, if the appliances are replaced with Energy Saving Recommended models following the refurbishment, then the energy demand for these will be typically reduced by a further 10%.

With these additional improvements, the CO_2 emissions from the heating and hot water reduce by nearly 3kg/m²/yr, while the solar photovoltaic panels provide a CO_2 emissions offset of about 11kg/m²/yr, which can be used to further offset electricity demand from the lights, pumps, fans and appliances. Overall the dwelling's emissions have now reduced to about 15kg/m²/yr, or about 1.4 tonnes per year, and the dwelling now has an EPC rating of band A. The overall reduction in CO_2 emissions is 80%.

Table 14: Typical energy demand, including use of renewables

Typical energy demand

Energy source	Total energy demand (kWh/yr)	energy demand per m² (kWh/yr/m²)
Gas	4,710	52
Electric	1,290	14

For further information and scenarios on improving all eight house types from their existing EPC band to an improved EPC, please see www.energysavingtrust.org.uk/housing/housetypes

Table 15: Summary of dwelling types following fabric and services improvements

House type	Floor area (m²)	Existing EPC Band	Existing total CO_2 emissions		Upgraded EPC Band	Upgraded total CO_2 emissions		Upgraded total annual energy demand (kWh/m²/yr)
			Tonnes/yr	kg/m²/yr		Tonnes/yr	kg/m²/yr	
Solid walled detached	104	F	13.7	132	B	3.0	29	109
Period end terrace	89	F	6.5	73	B	2.8	32	110
Period mid terrace	85	E	6.7	79	B	2.6	30	108
1950s semi-detached	90	E	6.5	72	B	2.6	29	106
1960s bungalow	64	E	6.2	98	B	2.1	33	127
1980s detached	111	E	7.7	69	B	3.3	30	78
1980s mid floor flat	61	E	4.2	68	B	2.1	35	83
Post 2002 mid terrace	79	C	3.4	43	B	2.4	30	99

9. Water efficiency measures

Currently, over half of all the water used in England and Wales is consumed in homes (7.7 billion litres a day) and each person uses about one tonne of water every week. The average consumption in the UK, as calculated from water company returns, is approximately 150 litres per person per day. Figure 45 shows the current uses of water in our homes, with toilets and showers using the majority of household water.

Over the past 30 years household water consumption has risen by 70%. Household consumption has remained relatively stable over the past 10 years. Some appliances and fixtures have been broadly similar over this time period, however WC flush volumes have reduced, while personal bathing, predominantly showers, have increased. Lifestyle issues are beyond the scope of this guide, but when specifying appliances and fixtures, any opportunity to reduce overall consumption, especially hot water, should be taken.

The benefits of reducing water usage do have an effect on CO_2 emissions. Approximately 23% of domestic CO_2 emissions are from hot water usage[6]. This means that integrating water efficiency into refurbishment projects will save water, money and carbon.

Against this backdrop of water usage and increased knowledge about climate change, carbon emission reduction targets, water stress and increasing household utility costs, our efforts to reduce domestic water consumption are more important than ever.

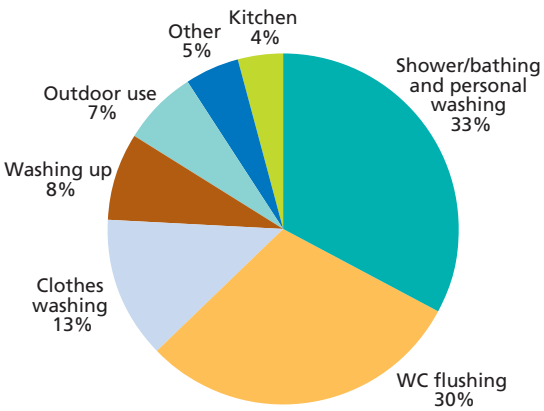


Figure 45: Water usage in UK homes

9.1 Legislation

Reducing future water usage in households from its current level will be a challenge. The UK Government has issued a number of reports looking at how attitudes and practices can be changed and has put into place a number of policies to influence water consumption. The sections below give details on the main policies and their relevance to refurbishment.

9.1.1 Revision to Building Regulation Part G (newbuild and change of use)

From October 2009, changes to Building Regulations Part G include a maximum water consumption target for all new dwellings (either new build or those formed by a change of use) of 125 litres per person per day, which includes five litres per person per day for outside use. It is not proposed to require any water efficiency measures when replacing kitchens and bathrooms, although this would be a reasonable target to aim for while refurbishing a dwelling. To achieve a target below 100 litres per person per day with standard fittings are likely to need some form of rainwater harvesting or greywater recycling. The proposed maximum of five litres per person per day for outside water use is a substantial reduction from standard usage, and will need the use of water butts to help achieve this reduction.

9.1.2 The Water Supply (Water Fittings) Regulations 1999 (currently under review)

Water Fittings Regulations are applicable to all buildings when any plumbing or water fitting-related work is carried out. Currently they include limits on water use for certain fittings. For example, they were amended so any newly installed WC has a maximum permissible flush volume of six litres. Water Fittings Regulations are being revised, and may include extending the range of maximum water use standards to a wider range of fittings and appliances.

9.2 Trigger points for water efficiency measures

For existing buildings, the impacts of changing users behaviour is similar to that for newbuild, but the opportunities to install water efficient appliances can be less due to the plumbing, structure of the building, and the types of existing appliances

Table 16 provides an indication when these measures may be appropriate.

6. Quantifying the energy and carbon effects of water saving (July 2009) Energy Saving Trust and Environment Agency.

Water efficiency measures

Generally, the installation of a lower-flush WC and water efficient shower heads are the easiest ways of reducing water consumption. Where a shower is provided, a low-flow showerhead is a simple option to improve water and energy efficiency.

If mains-pressure plumbing is available, reduced flow taps could be used, or flow regulators installed on existing models.

If provision can be made to accommodate additional water storage, a form of water reuse system can be considered. Whenever water-using white goods are replaced, water and energy efficient models, with capacities appropriate to the household, should be selected.

9.3 Water metering

About two-thirds of UK homes do not have water meters. Installing them after construction tends to be expensive, but many water companies will offer this service free of charge, and are legally obliged to install meters if customers ask for them. Some modern meters do not have to be read visually, so subsequent access to the property is no longer an issue. Many meter installations are outside the property, as this is more cost-effective.

Many private house owners may not want water meters because of the potential change in tariff. However, the majority of domestic customers now accept that metering is the fairest method of paying for their water use. Current water charges are based upon the rateable value of the home. This benefits high-volume users like large families and those with many inefficient water using appliances. However metered charging is likely to be cheaper after improving the water efficiency of a dwelling.

Where water metering is not possible or practicable at the current time, a water audit could measure likely consumption. Even if the property has a water meter, a pre-refurbishment audit could identify inefficient appliances or practices and help prioritise actions to reduce consumption.

9.4 Water efficient fittings and appliances

Reducing the amount of water used in fixtures and fittings can be achieved in a number of ways. The most appropriate choices will vary from household to household. The options are outlined briefly below. Reducing hot water consumption will also save the householder energy. The water efficiency of many products can be found on the Bathroom

Table 16: Trigger points to improve water usage efficiency

	Opportunity														
Measures to consider	Moving in or out	Extending	Loft conversion	Adding a conservatory	New kitchen	New bathroom	Re-roofing	Re-plastering	Replacing windows	Re-wiring	Re-flooring	New heating	Replacement boiler	Replacement hot water cylinder	Re-rendering
Water metering	Possible	Good	Possible		Good	Good						Good	Good	Good	
Low flush WCs	Good	Good	Good		Possible	Good						Possible	Possible	Possible	
Low flow taps	Possible	Good	Good		Good	Good						Possible	Possible	Possible	
Low flow shower	Possible	Good	Good		Possible	Good						Possible	Possible	Possible	
Flow restrictors	Possible	Good	Good		Good	Good					Possible	Possible	Possible	Possible	
Reduced capacity baths	Possible	Good	Good		Possible	Good						Possible	Possible	Possible	
Low water use appliances	Possible	Good	Possible		Good	Possible					Good	Possible	Possible	Possible	
Reducing water pipe length and/or insulating pipework	Possible	Good	Possible	Possible	Good	Possible	Possible				Good	Good	Good	Good	
Rainwater harvesting	Possible	Good	Good	Good	Possible	Possible	Good				Possible				Possible
Greywater recycling	Possible	Possible	Possible		Good	Good					Possible				

Key

Good opportunity ■ Possible opportunity ■

Manufacturers Association website (water-efficiency.org.uk) or additionally through the Green Building Store (greenbuildingstore.co.uk/es4-about.php).

Low flush WCs

As mentioned above, about 30% of all potable water used in dwellings is flushed down the toilet every day. Low-flush WCs are specifically designed to reduce the volume of water used during flushing. There are various systems that can be specified to achieve a reduction in flush volume – low single-flush cisterns, delayed action water inlet valves (which prevent the cistern refilling until it has completely emptied), and dual-flush cisterns which provide a part flush and a full flush (figure 46). It is also possible to install an interruptible flush device to an existing WC.

Figure 46: Dual flush WC

Low flow taps

Taps with a low flow rate can be fitted to wash hand basins and kitchen sinks. However, these fittings are the most susceptible to differing usage patterns, and therefore need to be considered on a case-by-case basis. For example a tap with a flow rate below five litres per minute might be acceptable for a wash hand basin, but not filling the kitchen sink or even a kettle. For kitchen sink taps, a click point tap is better. These use a click point (sometimes known as a break point or dual action) which limits the opening action to reduce the flow through the tap. Beyond the click point, the tap allows a full flow. The mains pressure should also be considered as it affects the water flow rate.

Low flow showers

It is possible to obtain showers with quite low flow rates. However, the perception of high pressure or flow showers are preferred. There is a possible compromise, as new technology showerheads can now produce water flows that feel to be of a far higher flow than they actually are. Water efficient shower heads have the greatest potential to save both water and energy with one simple device.

Flow regulators

Where wash hand basin and sink taps or shower units are not being replaced, it is still possible to reduce water use by fitting a suitable flow regulator either to the inlet pipework of taps or showers, or to the outlets. Flow regulators contain precision made holes or filters to regulate flow.

Reduced capacity baths

A standard bath has a capacity to its overflow of about 225 litres. Even less than half full, it uses a substantial amount of water. Baths with a much lower capacity to overflow are now available.

Figure 47: Reduced capacity bath in-situ

Waterwise was set up by the government to promote water efficiency, provide advice and develop the evidence base for large-scale water efficiency. It also maintains a website that ranks washing machines and dishwashers in order of water efficiency. See www.waterwise.org.uk/reducing_water_wastage_in_the_uk/

Water efficiency measures

9.5 Rainwater harvesting and greywater recycling

There is a limit to how much water usage can be reduced with water efficient fixtures, fittings and white goods. However it is possible to reuse some of the waste water, capture rainfall, and to reduce the overall mains water usage of a household further.

When considering alternative water supplies, it is important to assess the suitability of the technology on a case by case basis. Factors to consider include local average rainfall, size of roof catchment area and the likely increase to energy consumption and carbon emissions if a pump is required. Areas of very low rainfall may not be suitable for some rainwater capture refurbishment options.

9.5.1 Rainwater harvesting (RWH)

Rain from roofs and hard external surfaces can be used instead of mains water in WCs and washing machines, and also for outdoor uses. Rainwater is usually collected in a tank placed into the ground that needs electrical power to pump the water back into the dwelling, requiring additional energy use.

If sufficient space is available on the upper floor level of the dwelling, in a cupboard or above the stairwell perhaps, then a header tank can be installed to store rainwater collected off the roof via the guttering and drain pipe. The tank will need an overflow at high level (which can be discharged to an external rainwater butt for use in a garden) and a back-up mains feed to the top of the tank that is activated when the water level is low (such as a ball cock inlet valve at low level) to ensure a constant water supply. As long as the header tank is situated above the level of the highest WC cistern, then gravity will ensure that the cistern is filled when required. All systems must conform to the recently published British Standard BS 8515:2009 Rainwater harvesting systems – Code of practice and the Water Supply (Water Fittings) Regulations 1999.

9.5.2 Greywater recycling (GWR)

Greywater (waste water from showers/baths and bathroom wash basins) can be collected, treated and stored for re-use in place of mains water for WC flushing. Again this requires electricity to treat and pump the water to either a tank or direct to a cistern.

9.6 Water efficiency labelling

To assist refurbishment and retrofitting programmes, the Bathroom Manufacturers Association has recently released the Water Efficiency Products Labelling Scheme (WEPS). This label will help inform the purchase and installation of water efficient products within domestic and commercial markets (figure 48).

Figure 48: Water Efficiency Labelling

10. Recycling of materials and waste

Two aspects of managing waste in the context of domestic refurbishment are considered here – reducing the quantity of construction waste that is generated during refurbishment, and providing waste collection facilities to increase recycling rates.

10.1 Construction waste from domestic refurbishment

10.1.1 Background

Construction waste is growing in importance as an issue, with rising costs and environmental impacts. In the UK it is estimated that over 120 million tonnes of construction, demolition and excavation waste is produced annually. It is estimated five million cubic metres may be produced each year from the domestic refurbishment sector, roughly equivalent to over 350,000 tonnes of waste. For comparison, the amount of waste (excluding excavation) from newbuild housing is thought to be around ten million tonnes per year. About half of the inert waste is known to be recycled, the rest is used for covering and backfilling, or is disposed to landfill as waste and spread on land, e.g. for levelling, landscaping etc.

Government policy is starting to target construction waste as part of the wider sustainability agenda, with a recent joint government/industry target set to halve the amount sent to landfill by 2012 based on 2008 figures. Additionally, the construction industry has recently seen the introduction of compulsory Site Waste Management Plan (SWMP) Regulations for projects costing over £300,000 in England.

10.1.2 Measuring and managing construction waste

Typical waste from building projects includes bricks, soils, timber, packaging, metals, plasterboard and plastics. However, the type and amount of waste will vary depending on the process creating it.

Waste from domestic refurbishment is likely to have a high percentage of timber, plastics, furniture, plasterboard and floor coverings, which is of low recovery value and is unlikely to be segregated at source because of the low volumes generated and the smaller scale of the projects undertaken. The builder may prefer to pay a premium for a mixed waste skip rather than using segregated skips. Most of this waste will go to a transfer station where some of it will be sorted and sent for recovery.

The rate of recovery depends on the quality and quantity of that particular waste stream. Waste from domestic refurbishment can often be contaminated (e.g. plasterboard covered with paint) which makes it difficult to recover. Re-use is more common for materials that have a salvage value, e.g. timber floorboards and slate tiles.

10.1.3 Policies and legislation

Much legislation covers waste management in the UK, the main aim of which is to protect the environment. Increasingly this legislation is making the waste producer responsible for better management of the waste they produce. The EU Landfill Directive bans the co-disposal of certain wastes in landfill and requires the pre-treatment of most waste, including hazardous waste.

Fiscal drivers are important to encourage businesses to recycle waste rather than dispose of it in landfill. In the UK, the Landfill Tax is set at £32 per tonne for active waste (i.e. waste that can biodegrade) and is increasing by £8 per tonne per year – inert waste is set at £2.50 tonne. Additionally, a charge of £2.00 is made on the use of a tonne of primary aggregates (known as the Aggregates Levy) which therefore encourages the use of recycled and secondary aggregates.

Site waste management plans (SWMPs)

SWMPs aim to reduce waste crime – it is estimated that up to 31% of serious fly-tipping events involve construction related waste – and to encourage resource efficiency. Such plans must include an assessment of the type and amount of waste that is likely to be produced and how it will be managed and any decisions related to waste minimisation. This should then be recorded throughout the project. The SWMP also requires that all legal obligations for waste management are complied with, particularly in relation to the Duty of Care legislation and ensuring that waste management carriers and facilities are properly licensed. The threshold project value for a SWMP is set at £300,000 and the Government has indicated that the proportion of projects covered is 30% by number and 89% by value. However an increasing number of Local Authorities require a SWMP as part of the planning consent for a lower threshold. The government has committed to reviewing its threshold within three years.

Voluntary codes of practice and initiatives

More housing associations and local authorities are starting to address the issue of refurbishment waste and are working closely with their framework contractors. Some technical guidance is given in Fit for the Future (see Appendix C).

A key requirement is to develop partnerships with the waste management industry and be able to predict the amount and types of waste that are likely to be produced through refurbishment activities. Larger contracts will now have to consider refurbishment waste as part of the SWMP requirements.

There has been much support for businesses in the area of waste management in recent years which has resulted in a number of initiatives:

- Envirowise is a Government funded programme that gives advice to businesses to help them reduce waste and save money. A number of guides have been produced for the construction industry. See www.envirowise.gov.uk
- The Waste Resources Action Programme (WRAP) is a Government programme that focuses on promoting greater resource efficiency. Guidance and advice on construction waste can be found on the WRAP website. See www.wrap.org.uk
- Other organisations in this area include the National Industrial Symbiosis Programme (NISP) which acts as broker for unwanted materials.

There are no financial incentives to encourage the householder to manage the waste coming from their refurbishment/DIY facilities more effectively, and there is a low level of awareness of the relevant issues. However, householders can take their construction waste to local household waste recycling centres, usually at no cost (though this may vary depending upon the local authority).

10.1.4 Opportunities for reducing waste

Waste produced during the strip-out phase of the refurbishment can be reduced by considering some of the following issues:

- Carry out a pre-refurbishment audit of waste likely to arise.
- Determine amounts and likely waste management routes, which is in line with SWMP requirements for larger projects.
- Consider waste segregation on-site if possible.
- Liaise with local waste management contractors to ensure waste is recycled as much as possible.
- Re-use, then recycle. Look for opportunities to re-use in the local community.

Waste produced during the installation phase can be reduced by considering the following:

- Avoid the use of over-packaged products.
- Look for opportunities to return excess products/packaging to the supplier.
- Stockpile excess materials for later use.
- Avoid large off-cuts, look for opportunities at the design stage.
- Avoid over-ordering.

10.2 Domestic waste and provision of recycling facilities

Domestic waste has received much government and political attention in recent years. It is estimated that 29.1 million tonnes of municipal waste (waste arising from households and other similar waste) was generated in 2006/07 in England, which is a 1.4% increase from 2005/06. It is also estimated that only 31% of this waste was recycled in 2006/07. Although this has increased by 4% from 2005/06, the figure is still significantly lower than in comparable European countries.

One of the reasons for an increase in recycling levels is that it is now easier for people to recycle, with 94% of households receiving a doorstep or kerbside collection service from their local authority. The management of domestic waste is driven by national and European targets which are largely related to reducing the amount of biodegradable municipal waste that is landfilled. The EU Waste Framework Directive requires that at least 50% of household waste must be recycled by 2020.

A key issue is that biodegradable waste deposited in landfill can decompose to generate methane and other gases which contribute to climate change. It is possible that such waste could be sorted and either allowed to decompose in a controlled manner to produce green gas that could then be added to the gas supply, or the waste could be formed into a suitable fuel for use as biomass burning.

So when refurbishing dwellings, consideration should be given to the storage (i.e. space, location and accessibility) of both recyclable and non-recyclable household waste and the provision (if appropriate) of facilities to compost green waste. Guidance is given in EcoHomes XB. An understanding of the current local authority waste collection scheme will provide an indication of storage requirements. Refurbishment of dwellings should seek to make it easier for householders to recycle their household waste. When refurbishing a number of dwellings, opportunities exist to develop communal facilities (such as communal composting), and to bring in collection systems for recyclables that may not be collected by the local authority.

11. Climate change adaptation

Given that the frequency of refurbishment is typically up to 50 years, such action should include consideration of future climate change impacts. The hazards and associated remedial measures are described below.

11.1 Summer overheating

Hotter, drier summers will potentially lead to a variety of negative impacts, one of the worst will be the risk of homes overheating during summer. Dwelling overheating takes place via several mechanisms:

- Solar gain via glazed areas.
- Solar heating of the building fabric itself.
- Warm external air entering the internal living space.
- Heat gains from occupants, appliances and cooking.

To reduce the risk of overheating, heat gains from each of these areas must be controlled.

There are two strategies for cooling dwellings – passive and active. Passive cooling describes measures such as solar shades, which require little or no energy to operate, and may even rely on occupant intervention to operate effectively. Active cooling means processes such as air conditioning, which use mechanical systems to deliver cooled air to the interior of the dwelling. Whilst air conditioning is a simple 'fit and forget' solution, it causes other knock-on effects such as waste heat, increased CO_2 emissions and noise. For these reasons, passive techniques are preferable, providing they can achieve a suitable level of protection. The following techniques are some typical options that can be used in the existing housing stock:

Insulating walls and lofts - as well as reducing heat loss in cold periods, insulating walls and lofts will help to prevent heat ingress during hot weather. Painting external walls with reflective paint also reduces the warming effect on the building fabric.

Solar shading or shutters - solar gain via glazed areas can be beneficial during cold periods, but during warmer weather this can lead to uncomfortable and potentially dangerous internal temperatures. External awnings, shades or window shutters can be effective in maintaining cool internal temperatures.

Cross ventilation - providing that external air is cooler than internal air, this can be a good way of purging heat from the dwelling. Cross ventilation is often difficult to achieve due to internal partitions and doors. A solution to this problem is to use louvers above internal doors, to permit the passage of air whilst maintaining privacy.

Night ventilation - this is a very effective technique for purging heat from the internal environment, as the external temperature is typically much lower during the night. This technique is particularly useful for houses with high thermal mass, as heat absorbed during the day can be released to the external environment. Any potential security issues should be considered carefully before choosing this approach.

Pre-cooling air - where the ventilation is via either continuous mechanical extract ventilation, or balanced mechanical ventilation with heat recovery, it becomes possible to make use of the ground's almost constant temperature. If the inlet ducting for mechanical systems can be switched in summer, then a duct laid below ground level, either around the building or below an insulated floor will pre-cool incoming replacement air to the same temperature as the ground, i.e. about 11-12°C.

11.2 Making use of existing thermal mass

Thermal mass can be defined as the ability of parts of a dwelling with a high specific heat capacity to store excess heat within a building and release it at a later time. Air has a very low specific heat capacity so even a small heat gain can lead to a large temperature increase. However, if the surplus heat can be absorbed by parts of the building's fabric and then released again when air temperature falls, it will increase comfort for occupants.

In the preceding section we looked at ways of limiting heat gains during summer to prevent overheating. However, during winter periods we can use the existing thermal mass of dwellings to supplement the space heating needs. For this to be possible, dwellings need to have a significant proportion of glazing that faces the sun at some point during the short winter day.

Therefore when it comes to refurbishment and improving the overall levels of insulation, consideration should also be given to allowing materials with high specific heat capacity to remain in contact with the air inside the dwelling.

Although this becomes more difficult where internal insulation is to be provided to solid or cavity external walls, it should still be possible to retain solid plastered internal walls, and if possible provide concrete replacement floors which are not isolated from the internal air by insulating layers such as carpets, but instead finished with stone or clay tiles. Additionally, allowing for the movement of air between rooms, such as cross ventilation, can also be beneficial. This will allow air warmed by the sun during winter in a south-facing room to flow to cooler, north-facing rooms.

Although it is inherently more difficult to provide thermal mass to existing dwellings, opportunities to make use of existing thermal mass should be considered whenever these are possible.

11.3 Flooding

More intense rainfall is expected, particularly in winter, with an increased risk of surface water flooding. And with more and more paving in urban areas, drainage systems built in Victorian times can easily become overwhelmed, leading to water backing up and causing flooding from within dwellings.

To guard against water damage, the following two broad strategies may be used:

Resistance – resistance strategy involves limiting or preventing water ingress into the dwelling by physical barriers, e.g. door covers, waterproof render or membranes.

- A resistance strategy may not be suitable for dwellings at risk of deep flooding (0.9m or more), due to the pressure of the external hydrostatic head on the structure of the dwelling.
- A resistance strategy requires a large one-off investment, and will only be effective if all potential points of water ingress have been made safe.
- Post-flood costs are likely to be low, as the dwelling is essentially sealed off and remains dry.

Resilience – this involves choosing materials which are not damaged by immersion in water, and configuring the dwelling to minimise damage to areas likely to become immersed in the event of a flood. For example, having solid ground floors instead of suspended timber, replacing carpets with tiling, installing closed cell rigid polyurethane (PUR)/ polyisocyanurate (PIR) insulation in cavities, and relocating meters and wiring above the expected water level.

- Resilience measures are cumulative, and can be added gradually rather than requiring a large single investment.
- Even when a resilience strategy is in place, post-flood costs are still likely to occur; however a well-designed strategy can be expected to reduce costs by between 50% and 80%.

In general, external measures such as green roofs, porous paving and drainage pathways away from the dwelling are also essential parts of a robust flooding strategy.

Materials used in refurbishment should be carefully considered and only those with demonstrably robust performance selected. Materials which suffer irreversible damage from water should not be incorporated into a refurbishment if flooding is a possibility. For further information see www.floodprotectionassoc.co.uk

11.4 Storm

Climate change is expected to bring an increase in winter rainfall and wind speeds, leading to potential negative impacts on existing dwellings. Roofs are at risk from higher suction forces created by strong winds. Low-level damage, for example tile loss, can be minimised by using more robust roof tile fixings, e.g. holding straps.

Due to greater understanding of the risks that wind loading can pose, new design codes have in some cases been tripled in stringency. Protecting against more serious damage may require strengthening of the roof structure itself.

Gable walls can also be at risk, and again may require structural bolstering to minimise any risk of collapse.

Driving rain will potentially have a major impact on the suitability of cavity fill in affected areas and give a higher risk of damp problems in dwellings. Cladding or waterproof render may be required to minimise risks.

11.5 Future proofing

Whilst the decision to install microgeneration technologies may not be taken at the time a dwelling is refurbished, consideration should be given to the potential of future inclusion and, wherever possible, the infrastructure required can be installed where there is little additional cost. This may well save costs in the long term and accelerate the future integration of such technologies. Possible actions include:

Twin-coil hot water cylinder - these cylinders are required for solar thermal systems and do not cost much more than standard cylinders. Suitable cylinders are often slightly larger capacity than normal to allow more of the sun's energy to be usefully captured in summer months. Further, depending on the location of the hot water cylinder, pipework connecting the additional coil to the roof space may facilitate future connection of solar thermal systems.

Thermal store - these are beneficial for biomass boilers and solar thermal systems. They allow boilers to work for longer periods at full capacity (higher efficiency). And during summer months, thermal stores mean water can be heated to a greater temperature (e.g. 80°C) than would be acceptable for a domestic hot water supply due to scalding.

Reasonable sized loft hatch - this will provide access to the roof space for installation of any roof-based microgeneration technologies, e.g. solar thermal, solar PV, and to upgrade roof insulation at a later date.

Over-sized fuse board - this should have sufficient space for inverters, etc.

Underfloor heating system - where central heating is being installed or renewed, an underfloor heat delivery system would in most cases be preferable to radiators, since the heating circuit must be at a greater temperature for radiators. The efficiency of a GSHP unit increases significantly as the delivery temperature drops.

Boiler position in house - this should be close to appropriate external wall to allow space for biomass storage hopper, or to facilitate easy connection of ground loops.

Suitability of roof - issues to consider are:

- Maximise south-facing roof space and minimise shading (e.g. from dormer windows and disused chimneys).
- If older existing dwellings are to be re-roofed, strengthening of the roof structure may be appropriate to ensure that the additional weight and aerodynamic stresses of any solar thermal hot water or solar PV panels could be accommodated in future. In the UK, optimum roof pitch for solar PV collectors is approximately 37°; low pitch roofs are less suitable. Installing an electrical inverter in the roof void would also be appropriate.
- Consideration may also be given to selecting tiles that will be of appropriate dimensions to be compatible with currently available solar tiles, so these could be easily retrofitted into the building fabric.

11.6 Trigger points for considering climate change adaptation measures

Table 17 indicates when it may be possible to consider and incorporate measures that can mitigate the effects of climate change.

Further information can be found in Your home in a changing climate - Retrofitting existing homes for Climate Change Impacts (2008) - Three Regions Climate Change Group (see Appendix C).

Climate change adaptation

Table 17: Trigger points for considering climate change adaptation measures

	Opportunity														
Measures to consider	Moving in or out	Extending	Loft conversion	Adding a conservatory	New kitchen	New bathroom	Re-roofing	Re-plastering	Replacing windows	Re-wiring	Re-flooring	New heating	Replacement boiler	Replacement hot water cylinder	Re-rendering
Summer overheating	Possible	Good	Possible	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good		Good
Using existing thermal mass	Possible	Good		Good	Possible			Good	Good	Possible	Good	Possible	Possible	Possible	Good
Flooding	Possible	Good		Good	Good						Good				Possible
Storm	Possible	Good	Good	Good			Good								
Future proofing:															
Twin coil water cylinder	Possible	Good	Good	Possible	Good	Good	Good				Good	Good	Good	Good	
Thermal store	Possible	Good	Good	Good	Possible	Possible	Possible				Good	Good	Good	Good	
Access to roof void	Possible	Good	Good	Good	Good	Good	Good				Good	Good	Good	Good	
Use of roof structure	Possible	Good	Good	Good	Good	Good	Good			Good					
Underfloor heating	Possible	Good		Possible	Good	Possible		Possible			Good	Good	Good	Good	

Key

Good opportunity ■ Possible opportunity ■

Appendix A – Glossary of technical terms

Technical term	Description
Air barrier	The layer in the building fabric whose primary function is to restrict air flow through the construction. Examples of this include a plaster finish to a wall or a vapour control layer to a ceiling.
Air leakage rate	This is a measure of how much air leaks through the building fabric, and excludes air movement through intended ventilation measures. This is uncontrolled ventilation, which leads to additional energy use as heated air is lost, while the replacement air also needs to be heated. It can be measured during a pressurisation test and is expressed as the volume of air that leaks through every square metre of the fabric each hour when the dwelling is subject to an internal/external pressure difference of 50 Pascals (N.B. Atmospheric pressure is approximately 100,000 Pascals)
Low-e coatings	Low emissivity coatings are applied to one or more of the internal glass surfaces of double/triple glazing units. The coating reduces the heat flow from the inside of the dwelling through the glazing.
NO_x	There a variety of oxides of nitrogen which are formed during combustion process, and these are collectively known as NO_X. These are also a more powerful greenhouse gas than CO_2 although they exist in significantly lower concentrations.
Reduced Data SAP	Also known as RD SAP, this is the version of SAP that is used to determine the cost efficiency rating on an EPC for existing dwellings. Although the data inputs are either estimated or defaults, it still provides a reasonably accurate SAP rating for a dwelling that has not undergone thermal upgrading.
SAP	SAP is the Standard Assessment Procedure which is favoured by the UK Government to determine the cost efficiency of the energy use in a dwelling for space heating, domestic hot water and lighting, and the amount of CO_2 this energy use produces.
SAP Appendix Q	A procedure within SAP that allows for the calculation of reduced CO_2 emissions from a dwelling through the use of suitably tested energy efficient services and low and zero carbon technologies.
SEDBUK	The Seasonal Efficiency Database for Boilers in the UK, allows for manufacturers data for boiler efficiencies and controls to be entered directly into SAP.
Solar transmittance of the glazing	This is the proportion of the incident solar radiation reaching the external glazed surface of a window that penetrates through to the inside of the dwelling. The higher the solar transmittance (known as the g-value) the more sunlight penetration is allowed and the greater the solar gains which can be used to offset the need to heat the dwelling with the central heating system.
Specific heat capacity	A building material with a high specific heat capacity can be used to store excess heat within a building and release it at a later time. Air has very low specific heat capacity so a small energy input will result in a large temperature increase. If the surplus heat in the air can be temporarily stored in the structure and then released when air temperatures fall, occupant comfort will be increased.
Thermal bridges	A region within the building fabric where the transfer of heat is higher than in other adjacent parts of the structure. A severe thermal bridge could lead to mould growth or condensation. A thermal bridge can also refer to a junction between two building elements where the transfer of heat is higher than in neighbouring elements.

Appendix A – Glossary of technical terms

Technical term	Description
Thermal conductivity	This is the ability of a material to allow heat energy to be transferred through conduction. The lower the value, the higher the thermal resistance per unit thickness, and consequently the lower the amount of heat transfer through the fabric.
U-value	The rate of heat transfer through the fabric of the building. It is expressed in W/m^2K. A lower U-value represents a reduction in heat transfer and an improved thermal performance.
Vapour control layer	A layer in the building fabric which reduces the ability of water vapour to penetrate it.
Water audit	A water audit would typically involve checking all existing fittings to establish that any form of excessive water use is eliminated. This means, for example, checking taps are not leaking, ensuring well fitting plugs are provided, or the WC cistern is not overflowing.

Appendix B – Relevant organisations and websites

Accredited Construction Details (CLG)
www.planningportal.gov.uk/england/professionals/en/1115314255826.html

Bathroom Manufacturers Association
water-efficiency.org.uk

British Board of Agrément (BBA)
www.bbacerts.co.uk

British Fenestration Rating Council website
www.bfrc.org

British Urethane Foam Contractors Association (BUFCA)
www.bufca.co.uk

Cavity Insulation Guarantee Agency (CIGA)
www.ciga.co.uk

Envirowise
www.envirowise.gov.uk

Federation of Environmental Trades Association
www.feta.co.uk

Heat Pump Association
www.heatpumps.org.uk

Insulated Render and Cladding Association (INCA)
www.inca-ltd.org.uk

Microgeneration Certification Scheme
www.microgenerationcertification.org

National Insulation Association (NIA)
www.nationalinsulationassociation.org.uk

Renewable Energy Association
www.r-e-a.net

SAP Appendix Q
www.sap-appendixq.org.uk

The UK Rainwater Harvesting Association
www.ukrha.org

Waterwise
www.waterwise.org.uk

Waste and Resources Action Programme
www.wrap.org.uk

Appendix C – Further information

The Energy Saving Trust provides free technical guidance and solutions to help UK housing professionals design, build and refurbish to high levels of energy efficiency. These cover all aspects of energy efficiency in domestic new build and renovation. They are made available through training seminars, downloadable guides, online tools and a dedicated helpline.

A complete list of guidance categorised by subject area can be found in 'Energy Efficiency is best practice' (CE279). To download this, and to browse all available Energy Saving Trust publications, please visit www.energysavingtrust.org.uk/housing/publications

The following publications may also be of interest:

General

- Energy efficient refurbishment of non-traditional houses – case studies (CE193)
- The effect of Building Regulations Part L1 (2006) on existing dwellings – Information for installers and builders in England and Wales (CE53)

Airtightness and efficient ventilation

- Energy efficient historic homes – case studies (CE138)
- Energy efficient ventilation in housing (CE124/GPG268)
- Improving airtightness in dwellings (CE137/GPG224)

Heating systems

- Central Heating System Specification (CHeSS) Year 2008 (CE51/GIL59)
- Domestic heating by gas boiler systems (CE30)
- Domestic heating by oil boiler systems (CE29)
- Whole house boiler sizing method (CE54)

Insulation

- Cavity wall insulation in existing housing (CE16)
- Cavity wall insulation: unlocking the potential in existing dwellings (GIL23)
- External wall insulation for dwellings (CE118)
- Insulation materials chart – thermal properties and environmental ratings (CE71)
- Internal wall insulation in existing housing – a guide for specifiers and contractors (CE17)

Lighting

- Energy efficient lighting (CE61)
- Low-energy domestic lighting (GIL20)

Renewables

- Domestic low and zero carbon technologies guide (CE310) - in development, to be published mid-2010.

Windows

- Windows for new and existing housing (CE66)

Other publications listed in this guidance

The Climate Change Act (2008)
www.opsi.gov.uk/acts/acts2008/ukpga_20080027_en_1

Code for Sustainable Homes
www.planningportal.gov.uk/england/professionals/en/1115316369681.html

New Tricks with Old Bricks
www.emptyhomes.com/documents/publications/reports/New%20Tricks%20With%20Old%20Bricks%20-%20final%2012-03-081.pdf

Knock it down or do it up
www.bre.co.uk/newsdetails.jsp?id=522

English Housing Condition Survey
www.statistics.gov.uk/ssd/surveys/english_house_condition_survey.asp

BR 262 Thermal insulation: avoiding risks
www.brebookshop.com/details.jsp?id=556

Approved Code of Practice L8: Legionella' Disease
www.accepta.com/industry_water_treatment/hse-acop-l8-part1.asp

Fit for the Future
www.housingcorp.gov.uk/server/show/ConWebDoc.14312/changeNav/440

Your home in a changing climate - Retrofitting existing homes for Climate Change Impacts (2008) – Three Regions Climate Change Group.
www.london.gov.uk/trccg

ACT ON CO2

energy saving trust®

Energy Saving Trust, 21 Dartmouth Street, London SW1H 9BP Tel 0845 120 7799 Fax 0845 120 7789
bestpractice@est.org.uk www.energysavingtrust.org.uk/housing

CE309 © Energy Saving Trust February 2010. E&OE
The Energy Saving Trust Housing programme is grant aided by the Department of Energy and Climate Change.

This publication (including any drawings forming part of it) is intended for general guidance only and not as a substitute for the application of professional expertise. Any figures used are indicative only. The Energy Saving Trust gives no guarantee as to reduction of carbon emissions, energy savings or otherwise. Anyone using this publication (including any drawings forming part of it) must make their own assessment of the suitability of its content (whether for their own purposes or those of any client or customer), and the Energy Saving Trust cannot accept responsibility for any loss, damage or other liability resulting from such use.

So far as the Energy Saving Trust is aware, the information presented in this publication was correct and current at the time of the last revision. To ensure you have the most up to date version, please visit our website: www.energysavingtrust.org.uk/housing The contents of this publication may be superseded by statutory requirements or technical advances which arise after the date of publication. It is your responsibility to check latest developments.