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an introduction to low carbon domestic refurbishment

construction products association

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Foreword

The UK has made a commitment to reduce its carbon emissions by 80% by 2050 and the built environment is expected to account for about half of this reduction. Programmes are in place to ensure that the new buildings we create in the future meet the highest practical and cost effective standards for energy efficiency, but impressive as we expect this achievement to be, it will barely scratch the surface in terms of meeting the contribution that the built environment has to make to the overall carbon reduction target.

The real challenge is to improve the energy efficiency of the buildings that exist today, the vast majority of which will continue to exist in 2050. This will involve some form of refurbishment to each of the 26 million homes and two million non-domestic buildings – a programme that it is estimated will cost £400bn over the next 40 years. The scale of such a programme is unprecedented in both the challenge and opportunity it provides for the construction industry.

This Introduction to Low Carbon Domestic Refurbishment is a first step in setting out the various ways in which homes can be upgraded. It begins from first principles and highlights what needs to be done before work starts and then focuses on the main elements of the home – the floor, walls, windows, roof, heating and hot water. It concludes with a series of case studies which show the different scale of activity that can be undertaken, ranging from low cost work on walls, lofts and floors, through to radical renovations of the whole structure.

The information is presented in a way that will be of value to a wide audience – the informed householder trying to decide where to start on their property, the builder looking to advise their clients on the most cost effective solution for them, as well as regulators and politicians, who need to understand the challenges ahead.

Every household in the country needs to be engaged in this programme at some point over the next 40 years and it is imperative that the work undertaken is carried out in a cost effective and efficient manner, with least inconvenience to the owners and occupiers. Success will require everyone to play their part and understand the balance between costs and benefits. This publication provides the first step in the long road to a more carbon efficient future.

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1. Introduction

The aim of this guide

This guide is intended for builders who are carrying out refurbishment of existing houses and flats. It will also be of interest to householders who are planning to refurbish their homes and to their professional advisers (architects, surveyors and energy consultants) politicians and regulators. The aim of the guide is to provide clear information about how to refurbish in a way that improves the energy efficiency of the building and therefore reduces carbon dioxide emissions from energy use for heating, hot water, lighting and domestic appliances. We deal first with basic principles and the preliminary considerations associated with planning a refurbishment project and then with each of the elements of a house (floors, walls, heating system) in turn. Each section of the guide includes references and links to sources for more detailed information. The case studies at the end of the guide provide examples of a variety of low carbon refurbishment projects.

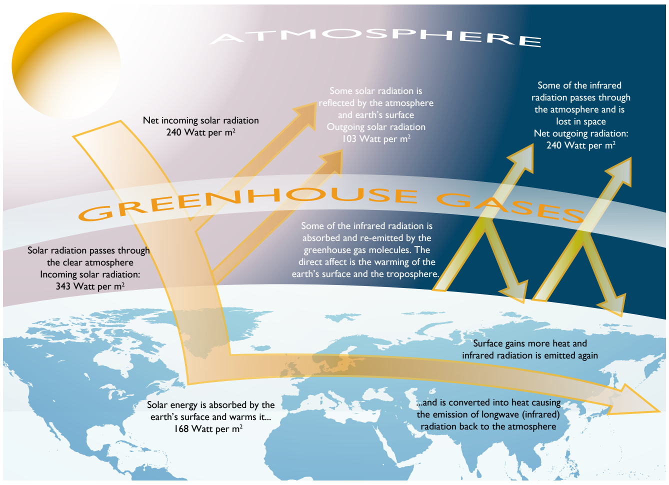

Figure 1.1 The process of global warming caused by greenhouse gases in the atmosphere

Fuel	Carbon dioxide emissions factor $kgCO_2/kWh$	Emissions factor relative to mains gas
Mains gas	0.198	1.00
LPG (bulk)	0.245	1.24
Oil	0.274	1.38
House coal	0.301	1.52
Grid electricity	0.517	2.61
Wood chips	0.009	0.05
Wood pellets	0.028	0.14
Wood logs	0.008	0.04

Table 1.1 Carbon dioxide emissions factors for domestic fuels used in the UK (source: SAP 2009, Table 12)

Climate change

Climate change brought about by man-made emissions of greenhouse gases has been identified as the greatest challenge facing human society at the beginning of the twenty-first century. In the UK, each person's share of our national greenhouse gas emissions is around ten tonnes per year. Stabilising global emissions at a sustainable level will involve reducing emissions to two tonnes per person per year. Every individual, every industry and every profession will have a part to play in meeting the challenge.

The complex mechanisms of climate change involve the balance of greenhouse gases in the atmosphere, in the oceans and in all living things. The main mechanism is the greenhouse effect, by which levels of greenhouse gases in the atmosphere affect the heat balance of the earth. The process is summarised in Figure 1.1.

The principal greenhouse gas is carbon dioxide, which is emitted when we burn fossil fuels. This includes gas, solid fuel (such as coal) and electricity (which is currently generated mostly by burning gas and coal). Table 1.1 shows the carbon dioxide emissions factors for fuels used in the UK, i.e. the amount of carbon dioxide emitted (including power station emissions and emissions associated with processing and distribution) per unit of energy delivered to the building. The third column of the Table indicates the relative size of the emissions factors, compared to mains gas. Note that the carbon dioxide emissions associated with the use of grid electricity are nearly three times greater than the emissions associated with the use of the same amount of energy in the form of gas.

The European Union has adopted a policy to reduce carbon dioxide emissions by 20% and to obtain 20% of energy from renewable sources such as wind power and solar power, throughout the EU, by 2020. The UK government has set a target of reducing carbon dioxide emissions by 80% by 2050, with intermediate targets to be met during the next twenty years. As part of the process of meeting these targets, the government has announced the Warm Homes Greener Homes

Household Energy Management strategy, which aims to cut the carbon dioxide emissions associated with the use of energy in our homes significantly. The government has also introduced a Feed-in Tariff (FIT) to provide a financial incentive for the local generation of electricity from renewable sources such as photovoltaics and plans to introduce a Renewable Heat Incentive (RHI) to provide a financial incentive for the local generation of heat and hot water from renewable sources such as solar energy and biomass.

Energy use in our homes

Carbon dioxide emissions associated with all energy use in the UK amount to more than 500 million tonnes each year (the exact amount depends on the weather). Almost half of these emissions are associated with energy use in buildings. Energy use in housing accounts for slightly more than half of the emissions associated with energy use in all buildings, amounting to 27% of the UK total – typically between 135 million and 150 million tonnes per year. Despite measures to improve the energy efficiency of dwellings, carbon dioxide emissions are rising, mostly because of a significant increase in the numbers of electrical appliances in homes. Increasing household numbers and a tendency to heat our properties to higher temperatures are also contributing to rising emissions.

There are approximately 25 million homes in the UK. The stock has grown from 18 million in 1976 and is expected to reach 27 million by 2020 – 50% growth in less than fifty years. From 2016 new dwellings will have to be 'zero carbon', but few new dwellings will replace existing ones; the average replacement rate of the housing stock, during the last fifty years, has been less than 1% per year. This means that, in any one year, only 0.03% of carbon dioxide emissions are associated with the new homes built that year and 99.7% of emissions are associated with dwellings built in previous years. Over 80% of the current stock of homes will still be standing and occupied in 2050. Therefore the required 80% reduction in emissions associated with energy use in housing cannot be achieved without significant improvement in the energy efficiency of existing homes.

Since we refurbish our homes only rarely (at intervals of twenty or thirty years), it is important to seize every opportunity to improve energy efficiency. If you are improving your home you should incorporate measures to improve its energy efficiency and reduce the carbon dioxide emissions associated with energy use. If you are advising homeowners on refurbishment projects you should advise them to improve energy efficiency as much as possible. In an era of rising fuel prices this is sound advice, irrespective of the argument for reducing emissions. Benefits for homeowners include lower fuel bills and improved comfort, as well as helping to meet the challenge of climate change.

The energy efficiency of existing dwellings and their potential for improvement, depends largely on their age. Before the 1930s, most buildings were built with solid masonry walls, which are relatively expensive to insulate, and with single-glazed windows and solid fuel heating. Since the 1930s most domestic buildings have been built with cavity walls, which are easy to insulate by filling the cavities; to date, approximately 40% of the originally empty cavity walls have been insulated. Roofs have been progressively improved since the 1970s by the installation of loft insulation. Since the 1960s, single-glazed windows have slowly been replaced by new double-glazed windows.

Gas-fired central heating is installed in 87% of dwellings, but a significant number of dwellings has no gas supply. Boilers are replaced at 10-20 year intervals; boiler efficiencies have increased, from 65% or less in the 1970s to around 90% for new condensing boilers today.

From 1976, regular improvements in the energy efficiency of new dwellings have been driven by the Building Regulations. Insulation standards were increased in 1982 and 1990; overall energy efficiency standards for dwellings were first introduced in 1995 and increased in 2002 and 2006. Further changes are planned for 2010, 2013 and 2016.

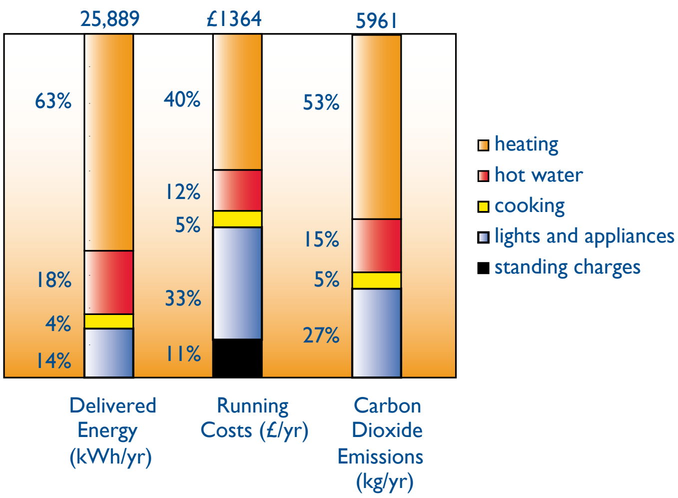

Figure 1.2 The breakdown of annual fuel use, fuel costs and carbon dioxide emissions for a typical 1930s semi-detached house of 90 m^2 floor area

Today, an average 1930s semi-detached house of 90 m^2 floor area, with some insulation and gas-fired central heating, uses approximately 25,900 kWh of energy per year for heating, hot water, cooking, lighting and appliances. Fuel costs are approximately £1400 per year (including 5% VAT) and carbon dioxide emissions are approximately six tonnes per year, of which 70% are associated with fossil fuel use (mostly for heating and hot water) and 30% are associated with electricity use. Figure 1.2 shows the breakdown of annual fuel use, fuel costs and carbon dioxide emissions for this typical house.[1]

Energy standards for refurbishment

In this guide, we have adopted two energy standards for housing refurbishment: a current 'best practice' standard, and an 'advanced' or 'low carbon' standard. These standards may be applied to individual elements (e.g. exposed floors, walls and roofs, heating systems) and to the dwelling as a whole:

- The best practice standard exceeds the current minimum standards required by the Building Regulations[2], and is consistent with the guidance published by the Energy Saving Trust[3]. This standard is readily achievable using widely available materials and products with which builders and installers are familiar

- The advanced standard identifies the improvements to each element of the building that would be required in order to reduce overall carbon dioxide emissions by 60% or more. Refurbishing a home to the advanced standard will be more complicated and expensive, but will often be a more appropriate response to the challenge of climate change, especially if another improvement opportunity may not arise (or may not be affordable) for some time

1 All of the figures quoted in this paragraph and presented in Figure 1.2 were calculated under SAP standard occupancy using BREDEM-12 based NHER Plan Assessor (SAP 2005) version 4.5 software.

2 See Building Regulations Approved Document L1B Conservation of fuel and power in existing dwellings (2006 edition), NBS; a new edition comes into force in October 2010.

3 For the Energy Saving Trust's Housing Energy Programme guides, see www.est.org.uk.

Refurbishment strategies: the three-step approach

There are two common approaches to improving the energy efficiency of a home during refurbishment: the 'measures-based' approach and the 'whole-house' approach:

- The measures-based approach involves the installation of individual improvement measures one-by-one at different times. Measures such as cavity wall insulation, loft insulation, new windows or a more efficient boiler are chosen because opportunities arise – for example, the offer of grant funding or the need to replace worn out window frames or a broken boiler

- The whole-house approach involves installing a 'package' of improvement measures embracing the building fabric (exposed floors, walls and roofs), the building services (heating, hot water, ventilation and lighting) and often renewable energy systems (e.g. solar water heating) at the same time

The measures-based approach has been adopted for many government-funded programmes such as Warm Front (aimed at tackling fuel poverty in low income households) and the Carbon Emissions Reduction Target (CERT) programme that obliges energy suppliers to reduce emissions associated with energy use by their customers. This approach is straightforward and affordable and minimises disruption of the household during installation, but it takes a long time and a lot of projects to achieve significant reductions in carbon dioxide emissions.

When a major refurbishment is being carried out, the whole-house approach should be adopted. This approach is often more expensive and disruptive, but it allows all the work to be completed at once so that significant fuel cost savings and emissions reductions are obtained immediately.

In reality, few households can afford to adopt the whole-house approach, and many are unwilling to undertake work that may involve them moving out of their home while improvements such as internal wall insulation, floor insulation or whole-house ventilation are installed. Nevertheless, the challenge of climate change is to significantly improve the energy efficiency of most of our homes within the next forty years and there are at least twenty million dwellings to improve.

Therefore in this guide we recommend a three-step approach, which involves having a plan for the dwelling (see Chapter 2) and implementing it progressively, as opportunities arise and funding becomes available, perhaps over many years. The three stages are as follows:

1 **Make 'quick fixes':** Improvement measures that are affordable, achievable with readily available materials and products by existing installers and not too disruptive

2 **Exploit and preserve opportunities:** Options for improvement often arise while other work is being carried out. It is essential to exploit these opportunities because they may not arise again for some time. It is also important not to close down options for making improvements in the future. For example, it makes sense to insulate the roof when re-roofing and to replace windows when installing wall insulation. If external wall insulation is planned as a future improvement, it may be appropriate to allow for it by extending the eaves when re-roofing. If a hot water cylinder is replaced, it may be appropriate to specify a twin-coil cylinder ready for the later installation of solar water heating

The Building Regulations require us to exploit some improvement opportunities: for example there are minimum efficiencies for replacement boilers and if you re-plaster or re-render more than a certain percentage of any external wall you must insulate the whole wall.[4] The Building Regulations are dealt with in more detail in Chapter 3

3 **Implement major projects:** Eventually, if we are to meet our national emissions reduction targets, major improvements to most homes are likely to be required. These are often best implemented when carrying out other work (replacing a kitchen or bathroom or having a loft converted), when funding becomes available, or before moving into a house for the first time

We will return to this three-step process in Chapter 3.

The capital cost of a refurbishment project designed to reduce carbon dioxide emissions increases exponentially with the percentage by which emissions are to be reduced, as shown in Figure 1.3. The average capital cost of reducing emissions by 80% or more may be as much as £50,000. A more practical target of reducing emissions by between 50% and 60% may cost much less. 'Quick fixes' (step 1) lie along the left-hand end of the curve. Exploiting and preserving opportunities (step 2) reduces the cost and disruption associated with some projects, making them more affordable. Major projects (step 3) lie at the middle and towards the top of the curve.

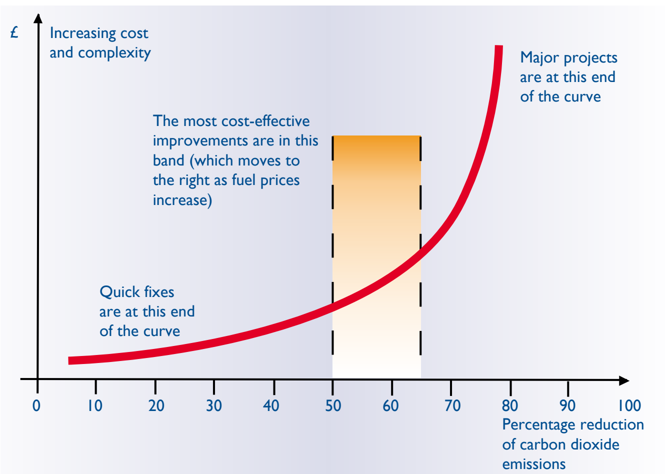

Figure 1.3 How the cost and complexity of refurbishment varies with emissions reduction

4 See the guidance in Building Regulations Approved Document L1B, Conservation of fuel and power in existing dwellings (2006 edition), NBS; a new edition comes into force in October 2010.

2. First principles

Energy use and carbon dioxide emissions for a typical house

Figure 2.1 shows an average UK dwelling: a semi-detached house built in the 1930s, with average floor area of 90 m^2, some insulation, gas-fired central heating and average carbon dioxide emissions of just under six tonnes per year.

Figure 2.2[5] shows the breakdown of carbon dioxide emissions associated with fuel use in this average dwelling; the arrows represent the emissions associated with heat losses through the various elements of the building fabric, those incurred because of the inefficiency of the heating system and controls and those incurred as a consequence of electricity use for lighting and appliances. The breakdown of emissions varies a little for dwellings of other types, e.g. larger detached houses and smaller flats. However, the approximate improvement costs and carbon dioxide figures quoted in this chapter always refer to the average house shown in Figure 2.1.

The biggest source of carbon dioxide emissions is space heating, which accounts for 54% of emissions. The heat losses through the building fabric (including windows and doors) make up 30% of the total emissions and these must be satisfied by the heating system. A further 15% of emissions are attributed to the inefficiency and poor control of the heating system (which uses more fuel than it would if more efficient) and 9% of emissions are attributed to infiltration and ventilation. Improved insulation and air tightness (including better windows) and efficient heating and controls, are important components of any refurbishment.

The next largest source of carbon dioxide emissions is electricity use for lighting and appliances (26%). Fixed lighting accounts for 6% of emissions and portable lighting and appliances account for 20%. Using electricity makes a lot of carbon dioxide – nearly three times as much as using the equivalent amount of gas[6]. This is why it is important to consider the efficiency of lighting and domestic appliances in a refurbishment project. Low energy compact fluorescent lamps (CFLs) use approximately a quarter of the electricity used by old-fashioned tungsten lamps and the latest LED[7] lighting is even more efficient.

At least 15% of carbon dioxide emissions can be attributed to water heating; these depend on the efficiency of the boiler, how well the hot water system is controlled and how well the hot water cylinder is insulated. Finally, 5% of carbon dioxide emissions are attributed to cooking – this can be reduced by the use of a microwave oven and induction hob.

Figure 2.1 A typical semi-detached house. Picture: John Willoughby.

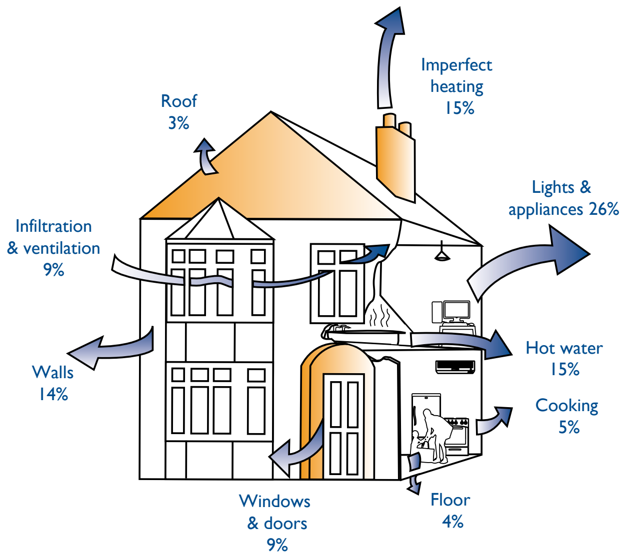

Figure 2.2 Breakdown of carbon dioxide emissions for a typical house[5]

5 The percentages in Figure 2.2 have been calculated under SAP standard occupancy using BREDEM-12 based NHER Plan Assessor (SAP 2005) version 4.5 software.

6 The emissions factors (taken from SAP 2009) are 0.206 $kgCO_2/kWh$ for mains gas, and 0.591 $kgCO_2/kWh$ for grid electricity.

7 LED stands for light emitting diode.

The building fabric is dealt with in Chapters 4 to 8 of this guide. Ventilation is dealt with in chapter 9. Heating and hot water are dealt with in Chapters 10 and 11. Electric power is dealt with in Chapter 12. This guide does not deal with the energy used for cooking.

Insulation

Insulation of the building fabric is a key component of any domestic refurbishment project. Insulating materials are built into the building fabric to impede the flow of heat from the warm interior to the cold exterior (during the heating season). The most important property of an insulating material is its thermal conductivity, which is measured in W/mK – that is, the rate of heat conduction through one metre of the material per K (or degree C) temperature difference across it. The lower the conductivity is, the better, but insulation material must be suited to its application.

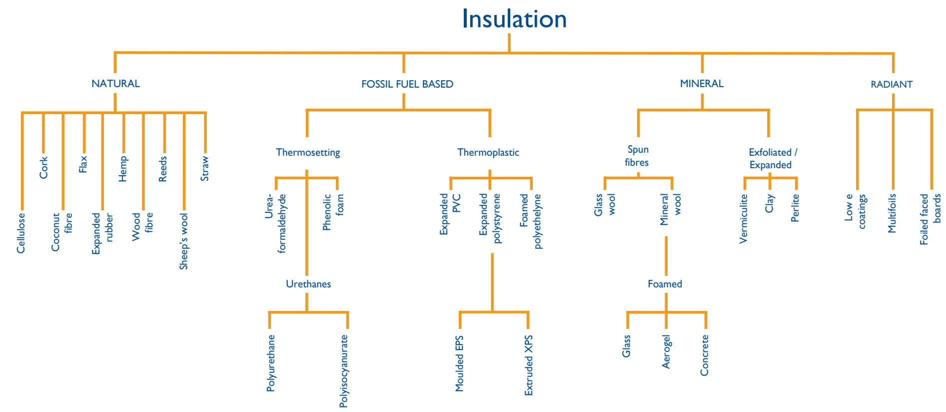

Figure 2.3 The family tree of insulation materials used in buildings

There are many types of insulation: Some are natural materials, some are highly processed and many of those with the best thermal performance are derived from oil. Figure 2.3 shows the 'family tree' of insulating materials. Table 2.1 shows the approximate thermal conductivities of some common insulating materials. Figure 2.3 and Table 2.1 do not show the latest vacuum insulation panels (because a vacuum is not strictly a material!), which have thermal conductivity of approximately 0.01 W/m²K.

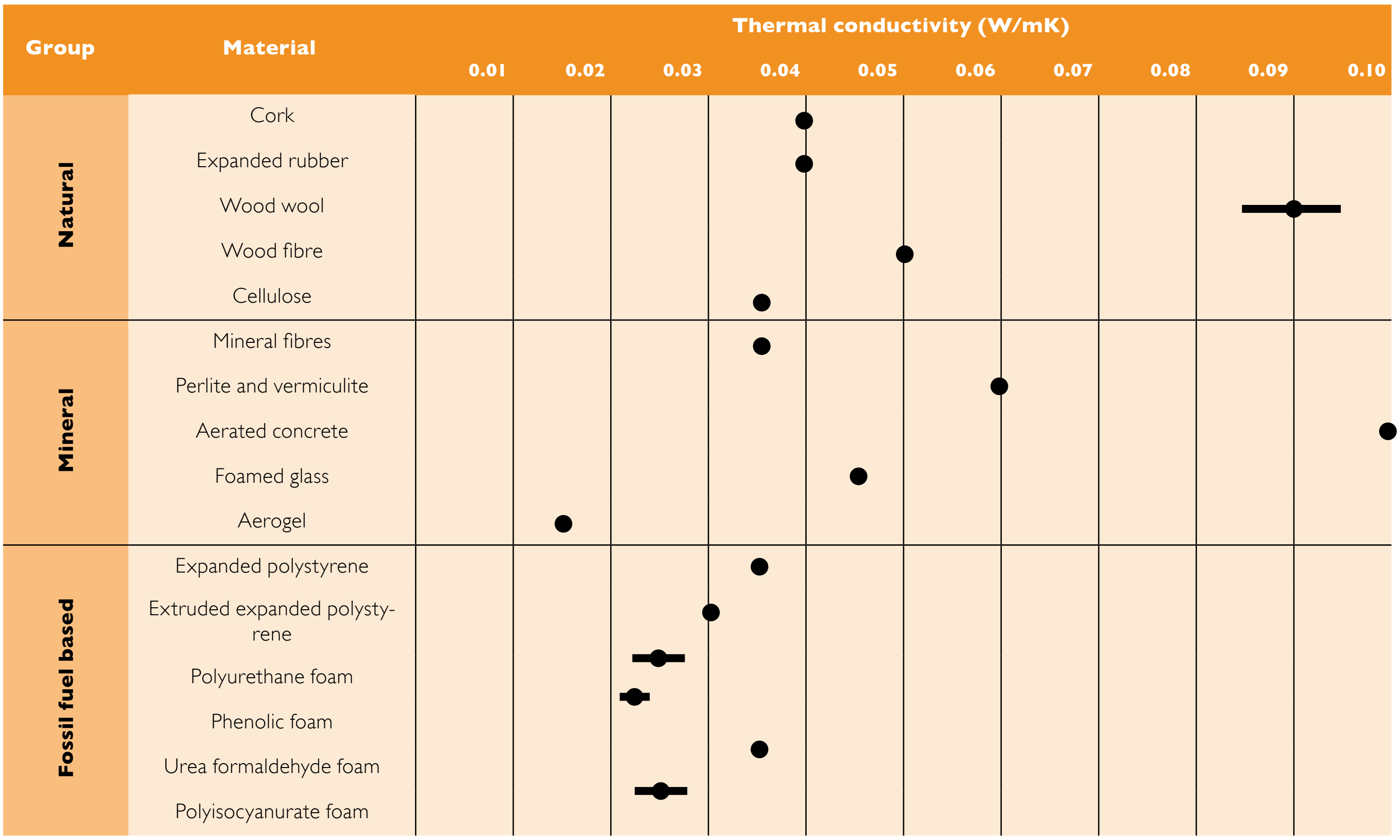

Table 2.1 Thermal conductivities of common insulating materials

U values

When it is incorporated in a building, an insulating material inhibits the thermal transmittance, or 'U value', of the building element (a floor, wall or roof). U values are measured in W/m^2K, that is, the rate of heat transfer through one square metre of the element per K (or degree C) temperature difference across it. Again, the lower the U value is, the better. Table 2.2 presents the approximate U values of some common domestic constructions for walls, roofs and floors, in dwellings of various ages.

For windows and doors, U values are usually quoted for the complete unit – glazing and frame. Table 2.3 presents the approximate U values of some common timber-framed window and door types. Also presented in Table 2.3[8] are approximate solar energy transmittances, or g values; note that the transmission of solar energy is reduced as more panes or low emissivity coatings are added.

When all the heat losses through the various building elements are added together, the overall heat loss will typically be between 2 kW for a modern, well-insulated house and 20 kW for a large, uninsulated house. The average semi-detached house shown in Figure 2.1 has an overall heat loss of approximately 7.5 kW.

Improvement costs and 'carbon cost effectiveness'

The capital costs of improvement measures vary considerably, from almost nothing for a compact fluorescent lamp to several thousand pounds for wall insulation and up to ten thousand pounds for a ground source heat pump. In this chapter, the approximate capital costs of improvement measures are shown by £ symbols, as shown in Table 2.4 and these figures apply to the average house shown in Figure 2.1. Actual improvement costs may be more or less than those shown, according to the house type.

Improvement measures also have different effects; some may reduce the carbon dioxide emissions associated with energy use in a dwelling only slightly, while others may deliver large reductions of many tonnes over their lifetimes. To complicate matters further, measures have different lifetimes – a low energy lamp may last five years, a new boiler may last fifteen years and insulation may last sixty years or more. It is helpful to know which measures represent the best investment, so when planning a refurbishment project we need to consider not only the capital costs of the improvement options but also by how much each measure is likely to reduce both fuel costs and carbon dioxide emissions over its life.

Construction	U value (W/m^2K)
Walls	
Solid brickwork (225 mm uninsulated)	2.30
Cavity (brick + dense block, unfilled)	1.60
Cavity (brick + lightweight block unfilled)	1.00
Cavity (brick + dense block filled)	0.52
Cavity (brick + lightweight block filled)	0.30
Modern timber frame or masonry wall	0.25
Superinsulated wall	0.15
Roofs	
No insulation	2.30
100 mm loft insulation	0.40
150 mm loft insulation	0.29
200 mm loft insulation	0.20
250 mm loft insulation	0.16
Floors	
Solid ground floor (uninsulated)	1.00
Suspended timber ground floor (uninsulated)	1.30
Modern insulated ground floor	0.18

Table 2.2 Approximate U values for typical domestic construction

Opening type	U value (W/m^2K)	g value
Single glazed window	4.8	0.85
Single glazed window with secondary glazing	2.4	0.76
Double glazed window	2.7-3.1	0.76
Double glazed window with low-e coating	2.1-2.7	0.63-0.72
Double glazed window with low-e and argon fill	2.0-2.5	0.63-0.72
Triple glazed window with low-e and argon fill	1.5-1.9	0.68
Modern high performance window	0.7	0.55
Solid timber external door	3.0	-
Modern insulated external door	1.0	-

Table 2.3 Approximate U values and g values for timber framed windows and doors from SAP2009 Table 6e

8 The U values in Table 2.3 have been taken from SAP (2009), Table 6e

Capital cost band	Symbol
Up to £100	**£**
£100 - £1000	**££**
£1000 - £5000	**£££**
£5000 - £10,000	**££££**
Over £10,000	**£££££**

Table 2.4 Capital cost bands used in Table 2.7

Carbon cost effectiveness	Symbol
Pays for itself	☺☺☺☺☺
0 – 10 £/tonne CO_2	☺☺☺☺
10 – 100 £/tonne CO_2	☺☺☺
100 – 500 £/tonne CO_2	☺☺
> 500 £/tonne CO_2	☺

Table 2.5 Carbon cost effectiveness bands used in Table 2.7

The 'carbon cost effectiveness' of an improvement measures is the capital cost of the measure minus the fuel cost savings that it will deliver, per tonne of carbon dioxide emission saved, during the lifetime of the measure. We have calculated the carbon cost effectiveness of improvement measures, using current average prices and fuel costs, for the typical semi-detached house shown in Figure 2.1.

Some measures may be said to 'pay for themselves' – they reduce fuel costs over their lifetimes by more than their initial capital costs. Other measures involve substantial costs and deliver significant carbon dioxide emissions reduction. The least carbon cost effective measures may cost several thousand pounds per lifetime tonne of carbon dioxide saved. In this guide we have indicated the carbon cost effectiveness of various improvement measures in bands, indicated by ☺ symbols, as shown in Table 2.5.

How did we calculate carbon cost effectiveness?

These simplified carbon cost effectiveness calculations were developed for the Technology Strategy Board's 'Retrofit for the Future' competition.

Example A

Insulation Measure A costs £5000 and has a lifetime of 60 years. It saves £50 in fuel bills and 400 kg (0.4 tonnes) of carbon dioxide each year.

Over the 60 year lifetime:		
Fuel cost savings are: 60 years x £50	=	**£3000**
The net cost of the measure is: £5000 cost - £3000 saving	=	**£2000**
Carbon dioxide emissions are reduced by: 0.4 tonnes x 60 years	=	**24 tonnes**
The £s spent for every lifetime tonne of CO_2 saved is 24 tonnes ÷ £2000	=	**£83 per tonne**

Example B

Insulation Measure B costs £2000 and has a lifetime of 60 years. It saves £50 in fuel bills and 400 kg (0.4 tonnes) of carbon dioxide each year.

Over the 60 year lifetime:		
Fuel cost savings are: 60 years x £50	=	**£3000**
The net cost of the measure is: £2000 cost - £3000 saving	=	**-£1000**
Carbon dioxide emissions are reduced by: 0.4 tonnes x 60 years	=	**24 tonnes**
The £s spent for every lifetime tonne of CO_2 saved is 24 tonnes ÷ -£1000	=	**£-42 per tonne**

Example C

Heating Measure C costs £250 and has a lifetime of ten years. It saves £10 in fuel bills and 100 kg (0.1 tonnes) of carbon dioxide each year.

To enable comparison with the insulation measures, we must compare them over similar periods of time. If we use the 60 year lifetime of the insulation measures, we will need to assume that Heating Measure C is replaced every ten years. This means that the cost of the measure is £250 x 6 = £1500.

Over the 60 year period:		
Fuel cost savings are: 60 years x £10	=	**£600**
The net cost of the measure is: £1500 cost - £600 saving	=	**£900**
Carbon dioxide emissions are reduced by: 0.1 tonnes x 60 years	=	**6 tonnes**
The £s spent for every lifetime tonne of CO_2 saved is 6 tonnes ÷ £900	=	**£150 per tonne**

This simple analysis shows us that Measure B is the most cost effective as it saves more money over its life than it costs to install and the cost per tonne of carbon dioxide saved is negative. The next most cost effective is Measure A, which costs £83 per tonne of carbon dioxide saved, and then Measure C, which costs £150 per tonne of carbon dioxide saved.

Disruptiveness

Another attribute of improvement measures is that installing them may disrupt the life of the household. For simple measures such as low energy lamps, disruption is negligible, but more complicated measures such as the installation of internal wall insulation, ground floor insulation or whole-house ventilation are much more disruptive, often involving loss of use of some rooms or even having to move out of the house while the work is carried out. In Table 2.7 we have indicated the level of disruption likely to be experienced with each measure by 🛠 symbols, as shown in Table 2.6.

Disruption	Band	Examples	Description
Minimal	🛠	Low energy lamps, energy efficient appliances	You hardly notice it happening
Low	🛠🛠	Heating controls, cavity wall insulation, draught-stripping, loft insulation	It's noisy or intrusive for a short while, but you can live with it
Moderate	🛠🛠🛠	Replacement boiler, solar water heating	This takes a little longer, but you can still live with it – make tea
High	🛠🛠🛠🛠	Replacement windows, whole house ventilation, external wall insulation	The installers will be everywhere – make lots of tea
Significant	🛠🛠🛠🛠🛠	Ground floor insulation, internal wall insulation, new heating system	You'll want to move out while this is happening

Table 2.6 Disruption bands used in this guide

An overview of improvement measures

Table 2.7 provides an overview of the most important domestic improvement measures that are dealt with in this guide. For each measure there is an indication of its capital cost, carbon cost effectiveness and level of disruption. The final column of the Table identifies the chapter of this guide in which more information can be found. The indicators in the Table have been worked out for the average house in Figure 2.1, so capital costs may be less for smaller properties and more for larger houses.

Measure	Capital cost	Carbon cost effectiveness	Disruption	Chapter
Floors				
Floor insulation	££	☺☺☺☺☺	⚒⚒⚒⚒⚒	4
Walls				
Internal wall insulation	££££	☺☺☺☺☺	⚒⚒⚒⚒⚒	5
Cavity wall insulation	££	☺☺☺☺☺	⚒⚒	
External wall insulation	££££/£	☺☺☺☺/☺	⚒⚒⚒	
Roofs				
Loft insulation	££	☺☺☺☺☺	⚒⚒	6
Rafter insulation (only when reroofing)	£££	☺☺	⚒⚒⚒	
Windows and doors				
Replacement windows and doors (U value 1.8)	£££	☺☺	⚒⚒⚒	7
Replacement windows and doors (U value 0.8)	£££££	☺☺	⚒⚒⚒	
Air tightness and ventilation				
Draught-stripping	£	☺☺☺☺☺	⚒⚒⚒	8
Major air-tightness measures	££	☺☺☺☺☺	⚒⚒⚒	8
Air-tightness measures with MVHR	£££	☺☺	⚒⚒⚒⚒	9
Lighting and appliances				
Low energy lights	£	☺☺☺☺☺	⚒	12
Low energy appliances (marginal cost of replacement)	£££	☺☺	⚒	
Heating				
Replacement gas boiler	£££	☺☺	⚒⚒⚒	10
Upgrading heating controls	££	☺☺☺	⚒⚒	
Micro CHP	££££	☺	⚒⚒⚒	
Ground source heat pump	£££££	☺	⚒⚒⚒⚒⚒	
Air source heat pump	££££	☺	⚒⚒⚒⚒	
Wood pellet boiler	££££	☺☺	⚒⚒⚒⚒	
Renewable energy systems				
Solar hot water heating	£££	☺	⚒⚒	11
1 kW solar photovoltaic panels	££££	☺	⚒⚒	12
Micro wind turbine	£££	☺	⚒⚒	12

Table 2.7 An overview of improvement measures for the average house shown in Figure 2.1

Note: costs are approximate and will vary depending on many factors, including detailed specification, actual home being upgraded and local conditions. Lower cost will improve carbon cost efficiencies

3. Before you start

There are several issues to consider before you start refurbishing a house. There may be statutory approvals (Planning and Building Regulations) to obtain, funding to seek and put in place and professional advisors to consult. It is also important to establish a plan for the refurbishment – for a programme of work that may extend, intermittently, over many years. See government Planning Portal www.planningportal.gov.uk

Statutory approvals

The planning system seeks to guide the way our towns, cities and countryside develop. One part of the system is 'development control', or the need to obtain approval from the local planning authority (usually the local council) before some types of building work can commence. If the improvements you propose involve an extension to the house, a 'change of use' of any part of the house (the addition of a granny flat) or a change to the external character or appearance of the building, then Planning Approval may be required. You should seek guidance from a planning officer at your local planning authority. Applications for Planning Approval must be submitted to the local planning authority and usually take approximately eight weeks to be determined; the process can take much longer if the proposals are considered contentious or a neighbour objects. Applications can be approved (usually with conditions) or refused (in which case reasonable grounds for refusal must be given). There is a right of appeal to the Secretary of State against refusal; appeals must be submitted within twelve months and are determined on the advice of a Planning Inspector appointed by the Secretary of State.

The installation of some types of renewable energy systems (solar collectors) has been exempted from the requirement for Planning Approval but there are strict conditions, so the local planning authority should always be consulted.

If the house is 'Listed' as of special architectural or historic interest, then Listed Building Consent will usually be required for any work within the curtilage, except the most minor repairs. You should seek guidance from the local Historic Buildings Officer before submitting an application for Listed Building Consent to your local planning authority. Applications for Listed Building Consent usually take approximately eight weeks to be determined, but can take much longer if the house is of exceptional architectural merit or the proposals are contentious. Some applications are referred to English Heritage, prior to determination. Similar constraints and procedures apply if the house is located in a Conservation Area or an Area of Outstanding Natural Beauty, or in or near a World Heritage Site.

Building Regulations set standards for the design and construction of buildings to ensure the health and safety of people in or near them. They include requirements to ensure that fuel and power are conserved and to limit the carbon dioxide emissions associated with energy use in buildings. Most work to existing buildings is controlled, other than minor repairs. Applications for approval under the Building Regulations may be submitted to any Building Control Body and they are usually determined within eight weeks. Applications may be approved (usually with conditions) or refused (in which case the details of non-compliance must be identified). Work can be started without approval under the Building Regulations, provided that a Building Notice is submitted to the local Building Control Body, who may then require information to demonstrate compliance.

Each local authority in England and Wales (Unitary, District and London Boroughs in England; County and County Borough Councils in Wales) has a Building Control section, which is the local Building Control Body. It is their duty to ensure that building work complies with the Building Regulations except where it is formally under the control of an Approved Inspector (a private sector Building Control Body). Individual local authorities coordinate their Building Control services regionally and nationally via Local Authority Building Control (LABC – see www.labc.uk.com). LABC has developed an online service for creating and submitting applications for approval under the Building Regulations; homeowners can use this service via www.submit-a-plan.com.

Part L of the Building Regulations deals with the conservation of fuel and power. Building Regulations Approved Document L1B and the Domestic Services Compliance Guide provide guidance on how work to existing dwellings may comply. The guidance covers 'thermal elements' (i.e. heat loss floors, walls and roofs), 'controlled fittings' (i.e. windows, roof windows and external doors) and 'controlled services' (i.e. heating, hot water, ventilation and fixed internal and external lighting). Minimum insulation standards (i.e. maximum U values) apply if any thermal element is provided new (e.g. in an extension), replaced, retained through a change of use or renovated. A thermal element is 'renovated' if any layer of its construction is added or replaced and the scope of the work includes more than 25% of the area of the element for Part L 2006 and 50% for Part L 2010, although there is an overall limit of 25% of the area of total building envelope in Part L 2010. Maximum U values apply to new and replacement controlled fittings (windows and external doors). Minimum efficiency and control standards apply if any controlled service (e.g. a heating system) is provided new or is wholly or partially replaced. In most cases approval for controlled work should be obtained via an application to a Building Control Body (see above), but the compliance of new or replacement windows can be 'self certified' by installers who are registered with FENSA[9]. Similarly, the compliance of work to heating systems can be self-certified by a 'competent person', i.e. a registered Gas Safe, HETAS or OFTEC fitter.

9 FENSA is the Fenestration Self-Assessment scheme operated by the Glass & Glazing Federation.

Funding

There are many sources of funding for domestic improvement measures that reduce carbon dioxide emissions. The Energy Saving Trust's online funding database[10] is a good starting point for identifying and accessing national and local funding schemes. Potential sources of funding include:

- The Warm Front scheme operated by Eaga Ltd on behalf of the government, which offers insulation and heating upgrades to qualifying households (those in which at least one person is in receipt of certain state benefits)

- The Carbon Emissions Reduction Target (CERT) scheme operated by the energy suppliers, which can help fund many basic energy efficiency measures such as cavity wall insulation, loft insulation, low energy lamps and heating controls upgrades

- The Community Energy Saving Programme (CESP), which targets all households in selected areas across Britain to improve energy efficiency and permanently reduce fuel bills. The scheme promotes a whole-house approach and is delivered through community partnerships involving local authorities and energy suppliers

- The Low Carbon Buildings Programme operated for the government by the Energy Saving Trust, which subsidises the installation of sustainable energy systems

- The Feed-in Tariff, which provides an advantageous rate for selling electricity generated from renewable sources (i.e. micro-CHP or PV – see Chapters 10 and 12) to the electricity grid

- The Renewable Heat Incentive, which (from 1 April 2011 - subject to confirmation) will provide a financial incentive for generating heat locally (via solar water heating, biomass boilers or heat pumps), in the form of a quarterly or annual payment related to the amount of heat generated (see Chapter 10)

Many local authorities also operate grant schemes or have links with one or more of the above programmes.

The government is currently piloting a scheme called 'Pay As You Save' (PAYS), under which a loan to finance a package of improvements that significantly reduce carbon dioxide emissions can be attached to the house (rather than to the current occupants) and repaid via the energy supplier by means a levy on bills. In principle, the amount of the levy should not exceed the theoretical fuel cost savings resulting from the improvements.

10 See www.energysavingtrust.org.uk/housingbuildings/funding/database; the EST's online funding guide is continuously updated.

Establishing an overall improvement plan

Most households do not have the opportunity to carry out a whole-house refurbishment of their home as a single project. More commonly, opportunities arise at intervals according to family circumstances, funding and the need to replace worn out building elements or services. Therefore it is a good idea to consider all aspects of the house at an early stage and to make an improvement plan, even though it may only be implemented in stages, over several years or even decades. Such a plan may assist with programming and funding of the work. The plan should also identify improvement opportunities that are likely to arise, and improvement options that should be preserved for implementation in the future. A starting point for an improvement plan might be the recommendations which form part of the Energy Performance Certificate for the house, if you have one. The T-Zero website (www.tzero.org.uk) provides a tool for identifying and comparing the options for your house and a 'marketplace' of green home improvement products and services.[11]

Opportunities for improving our homes arise for many different reasons. We may need to extend to accommodate a growing family or an ageing relative, or we may need to replace something (e.g. worn out window frames or boiler), or we may just decide to invest some spare money in reducing our 'carbon footprints'. When improvement opportunities arise, there are two ways in which we may respond: we can exploit them by carrying out the work, or we can preserve them for later. Preserving opportunities is often a good policy, in the context of a long-term plan to improve a home.

Examples of exploiting opportunities include:

- Adding internal wall insulation when re-plastering
- Adding roof insulation when re-roofing
- Installing high performance windows when replacing worn out windows
- Installing high performance windows when installing external wall insulation
- Installing a very efficient gas boiler when replacing a worn-out boiler

Examples of preserving opportunities include:

- Extending the eaves while re-roofing to allow for external wall insulation to be added later (see Figure 3.1)
- Installing a dual-coil hot water cylinder when upgrading a heating system, to allow for solar heating to be added later
- Postponing window replacement until wall insulation can also be afforded, for installation at the same time

11 T-Zero is a partnership of leading UK organisations in the fields of housing and energy efficiency, including the Construction Products Association.

Figure 3.1 Extended roof verge to accommodate future external wall insulation. Picture courtesy of Gil Schalom.

Figure 3.2 Door replaced by a window to accommodate future flat roof insulation. Pictures: John Willoughby.

These examples show that making an improvement plan can be a sophisticated process, which involves more than identifying the obvious improvements. Some improvements are difficult unless prior enabling work is carried out. An architect, surveyor or energy consultant should be able to assist you in making an improvement plan. This plan should differentiate between 'quick fixes' and 'major projects', as well as identifying improvement opportunities that are to be exploited or preserved for the future.

Using specialists and professional consultants

Simple refurbishment works such as loft insulation can be carried out by local installers or builders and there should be no need to engage specialists or professional consultants. Cavity wall insulation is best carried out by a specialist installer, who should be a member of the Cavity Insulation Guarantee Agency (CIGA). There are approximately 160 specialist cavity wall insulation installers who will assess the property before starting work to ensure that the walls are suitable for filling and will provide an independent 25-year CIGA Guarantee.

Because of its complexity, external solid wall insulation should either be purpose-designed by an architect or installed by a specialist contractor who complies with a professional code of practice such as that operated by the National Insulation Association (NIA). The NIA can provide advice and details of local contractors (see www.nationalinsulationassociation.org.uk/). It is important that work is carried out in accordance with the relevant technical approvals and guidance and is covered by a Solid Wall Insulation Guarantee Agency (SWIGA, www.swiga.co.uk) or equivalent guarantee. SWIGA also accredits contractors and provides an arbitration service to consumers in the event of any dispute.

Replacement windows should be supplied and installed by a company registered with Fenestration Self Assessment (FENSA www.fensa.org.uk), who will be able to 'self-certify' the compliance of their products with the guidance in Building Regulations Approved Document L1B. Boiler replacement and heating control upgrades should be carried out by qualified heating installation specialists who again should certify and guarantee their work and uphold the manufacturers' guarantees of the products that they supply and install.

For most properties, a detailed energy survey carried out by an experienced energy consultant will provide an invaluable insight into current energy use and help to identify the most appropriate improvement options. Surveys should embrace the building fabric and the building services and should include a performance assessment using energy rating software. The survey report should identify appropriate improvement options from among those dealt with in this guide. Energy consultants should be accredited through one of the domestic energy rating schemes. You can find an energy consultant via the Landmark database of accredited energy assessors at www.hcrregister.com/searchAssessor.html.

Where the refurbishment work is complex, perhaps involving several improvement measures that must be coordinated (e.g. external wall insulation combined with re-roofing and/or window replacement), it is advisable to engage an architect or surveyor who will be able to assist by providing some or all of the following services:

- Advising on the feasibility and approximate cost of your proposals and identifying related opportunities for future improvements
- Consulting the local planning authority about the need for Planning Approval and/or Listed Building Consent, preparing and submitting application(s) on your behalf and negotiating with the planning authority
- Preparing drawings, schedules of works and specifications for a builder to price and work from and to support an application for approval under the Building Regulations
- Preparing and submitting an application for approval under the Building Regulations on your behalf and negotiating with the Building Control Body
- Inviting quotations or tenders from an agreed list of suitable builders or installers, advising on the tenders submitted and arranging a contract with a builder chosen to carry out the work
- Administering the terms of the building contract, visiting regularly to inspect progress and quality of the work, advising on any problems that arise during the course of the work and issuing instructions, payment certificates, etc, required by the contract, on your behalf
- Inspecting the work at the end of a 'defects liability period' (usually six months) and arranging for the builder to repair any defects that have arisen

You can find an architect via the Royal Institute of British Architects at www.architecture.com/UseAnArchitect/Home.aspx

Most houses built before the 1950s will have suspended timber floors. Those built after that date are more likely to have concrete floors, either slab on ground or suspended. Suspended timber floors are often leaky and cold but, unlike concrete floors, are relatively easy to upgrade.

Quick fixes

A cheap and relatively easy measure for suspended timber floors is to eliminate draughts (see below).

If suspended timber floors are over a cellar, an effective first fix is to insulate and draught proof from below.

Opportunities

Rotten floor boards or damp penetration sometimes mean that floors need to be lifted. This gives an ideal opportunity to add insulation to the new work.

Major projects

When major works are being carried out, floor insulation should be added and the floor made draught proof.

Floor U values

Table 4.1 presents recommended maximum U values for exposed floors according to various standards.

Building Regulations 2006 & 2010	Best Practice	Advanced
Below 0.25	Below 0.25	Below 0.15

Table 4.1 U values for exposed floors (W/m²K)

Timber floors

Draught-proofing floors

Suspended timber floors are notoriously leaky. With old square edged floorboards, laying hardboard over the whole floor will eliminate draughts from between the boards. The hardboard should be taped at the joints and sealed at the edges. Alternatively the gaps can be sealed with a sealant, combined if necessary with timber beads. Gaps and holes in the floor where pipes or cables rise from below should be sealed with tightly-packed mineral fibre or expanding foam. It is important to maintain the ventilation under the floor void.

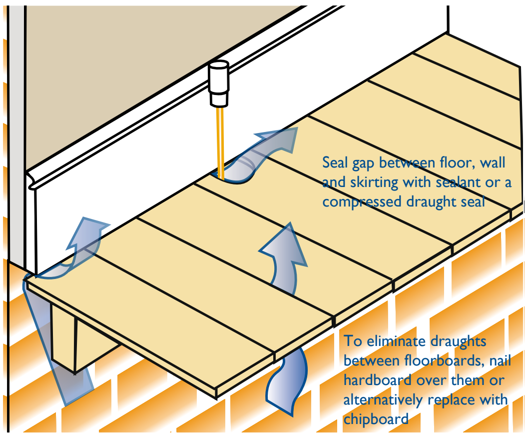

Figure 4.1 Air infiltration through a suspended timber floor[12]

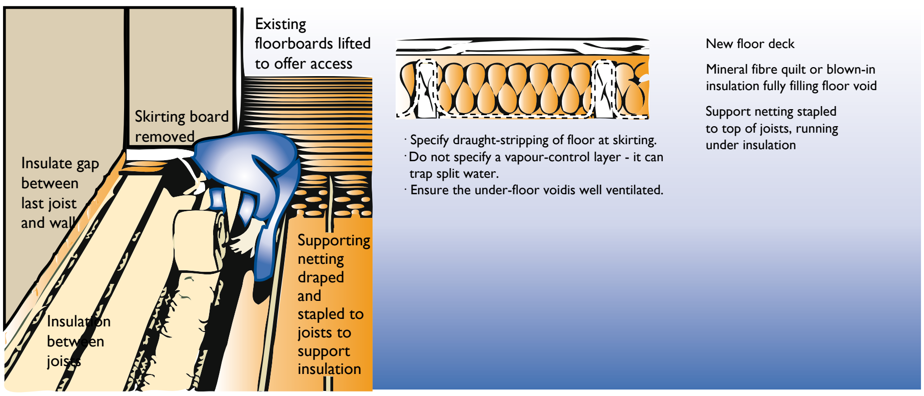

Figure 4.2 insulating a timber floor[13]

12 Figure 4.1 redrawn from Practical refurbishment of solid-walled houses, Energy Saving Trust (CE184).

13 Figure 4.2 redrawn from Energy efficient refurbishment of existing housing, Energy Saving Trust (CE83).

Insulating timber floors

Timber floorboards can be lifted and insulation fitted between the joists. A Building Control Officer should be consulted to ensure the correct fire performance is achieved. The most common technique is to use mineral fibre supported on plastic netting; rigid insulation can also be wedged or cut to fit tightly between the joists (although this is less reliable) or supported on timber battens fixed to the joists. It is important to fill the space between the netting and the floorboards. Air tightness measures should be applied. A membrane under the boards, sealed to the wall or skirtings, is recommended. To reduce the risk of condensation in the floor void, it is important to maintain under-floor ventilation.

Advanced insulation

At the Nottingham EcoHome, insulation was added to the suspended timber floor in two layers from the cellar below. First sheep's wool insulation was fitted between the joists. Then a 'breathable' air barrier was installed to make the floor airtight. Finally a rigid insulation board was fixed to the joists. These boards were also returned down the cellar wall to reduce the thermal bridge. The resulting U-value was around 0.16 W/m²K.

Although niche products were used in this instance, mainstream products such as mineral fibre and rigid insulation boards are equally applicable.

At a traditional back-to-back house in Todmorden, the kitchen floor was insulated and draught-proofed from the cellar below in a single operation using proprietary spray-applied polyurethane (PUR) insulation. The insulation was applied between the floor joists and all gaps, cracks and voids were sealed during the two-minute curing process. The application took less than three hours to complete and a thickness of 195 mm insulation achieved a U Value of 0.15 W/m²K.

Figure 4.3 Insulating a suspended floor from beneath, at the Nottingham Ecohome. Picture courtesy of Gil Schalom.

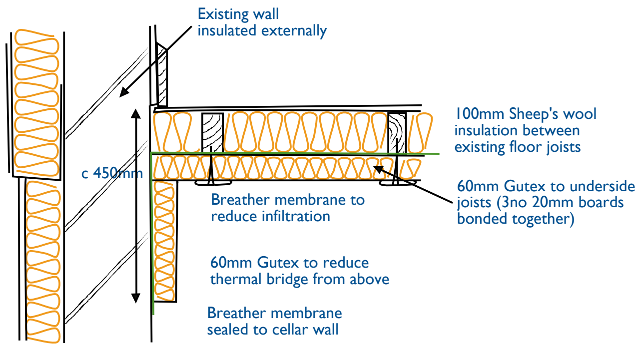

Figure 4.4 Cellar insulation at the Nottingham EcoHome

Figure 4.5 The floor seen from the cellar, before and after the installation of spray-applied polyurethane insulation. Pictures: Isothane.

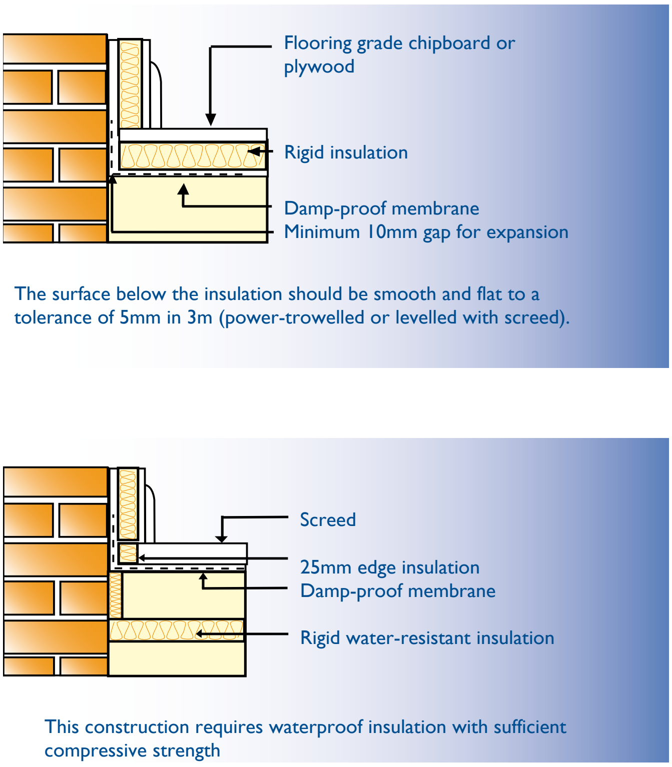

Figure 4.6 Insulating above and below concrete floors[14]

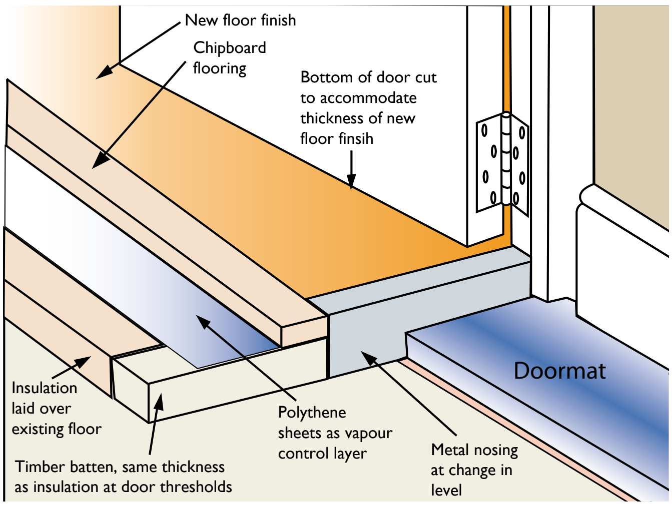

Figure 4.7 Incorporating a well in insulation above a concrete floor[15]

Concrete floors

If solid floors are to be taken up and re-laid then there is an opportunity to add insulation to the new concrete floor slab. The construction is the same as a new-build floor. Insulation can be added above or below the slab.

If solid floors are not taken up then the only way to add insulation is to lay it on top of the existing floor. This can cause problems with room heights, door thresholds and at the bottom of the stairs. In some cases thin layers of insulation (e.g. 50 mm) can be added with an uninsulated well formed at the foot of the stairs as shown in Figure 4.7.

14 Figure 4.6 redrawn from Energy efficient refurbishment of existing housing, Energy Saving Trust (CE83).

15 Figure 4.7 redrawn from Refurbishment site guidance for solid-walled houses – ground floors, Energy Saving Trust (GPG 294).

Advanced insulation

At another house in Nottingham, a new concrete floor was laid on 200 mm of expanded polystyrene (EPS) insulation to give a U value of approximately 0.14 W/m^{2}K.

In a refurbishment of an old Police House in Kent, the existing solid floors were overlaid with 70 mm of PU insulation and a new screed and floor finish, giving a U value of about 0.21 W/m^{2}K. Lintels over internal ground floor doors were lifted and a landing built at the bottom of the stairs to even out the risers.

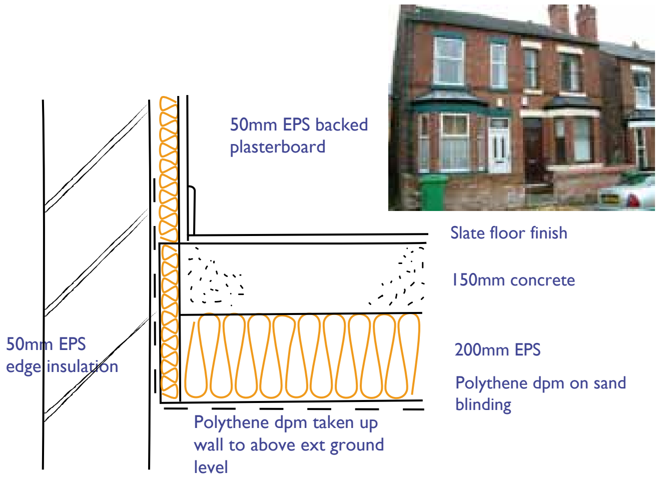

Figure 4.8 200 mm of insulation added under new concrete floor

Figure 4.9 A landing built at the bottom of stairs to even out the risers. Pictures: Tony Clelford.

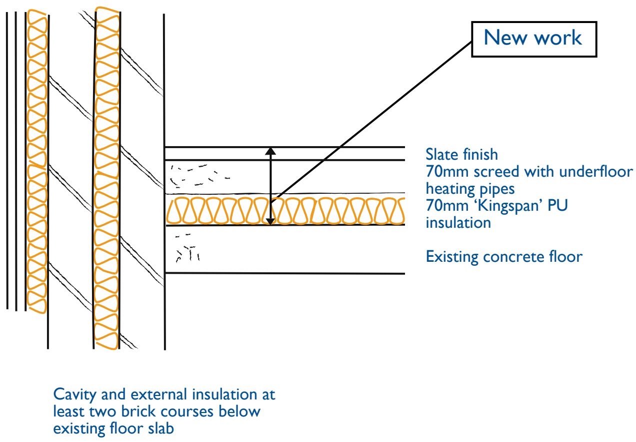

Figure 4.10 Additional insulation laid over an existing concrete floor

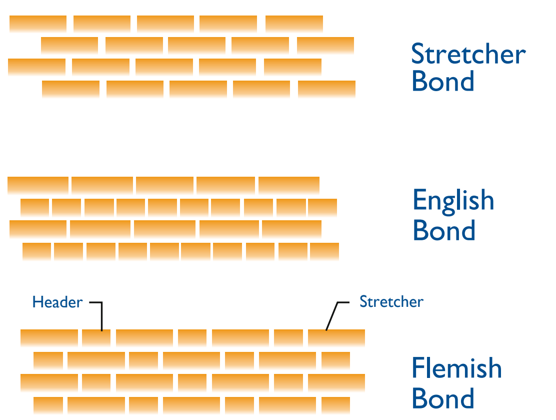

Figure 5.1 Brick bonds: the lower two examples are likely to be solid walls

In detached and semi-detached houses, heat lost through walls is often the largest contribution to fabric heat losses. Cavity walls are easy to insulate but solid walls are more difficult and expensive to treat.

Most houses built before the 1930s will have solid walls. Those built after that date are more likely to have cavity walls. Solid brick walls can usually be identified by the brick pattern: bricks laid across the wall show up as 'headers'. Cavity walls are built with 'stretcher' bond (see Figure 5.1). Note that modern timber frame houses are often also finished with brickwork in stretcher bond, and people sometimes mistake these walls for masonry cavity walls.

Quick fixes

If the walls are of cavity construction, cavity insulation is one of the most cost effective measures.

Opportunities

If internal plastering work has to be carried out, this presents an ideal opportunity to add internal wall insulation. Similarly if external render has to be replaced or extensive pointing of brickwork is needed, there is an opportunity to insulate externally.

Major projects

Because heat losses through walls are often large, internal or external insulation can have a dramatic effect on fuel use and carbon dioxide emissions as well as improving comfort conditions in the house. Adding 100 mm or more of wall insulation should always be considered during a major refurbishment.

Wall U Values

Table 5.1 presents recommended maximum U values for exposed walls according to various standards.

Building Regulations 2006 & 2010	Best Practice	Advanced
Cavity walls below 0.55 Solid walls below 0.3	Below 0.3	Below 0.2

Table 5.1 U values for exposed walls (W/m²K)

Cavity walls

Cavity wall insulation (CWI) is one of the most cost-effective energy saving measures. A typical installation costs around £500 with the investment being paid back in two to three years. Not only will CWI save energy and reduce carbon dioxide emissions, but it will make the house more comfortable. An unfilled cavity will have cold air circulating in it. This cold air will enter the house via cracks and services penetrations and will cause draughts and heat losses. Cavity insulation will inhibit this air movement, reducing draughts and heat losses. Another benefit of CWI is that the internal surface temperature of the walls will be higher; the rooms will feel more comfortable as a result.

People are sometimes reluctant to fill cavity walls as they fear it will lead to damp penetration. But a survey carried out by the Building Research Establishment in the early 1990s showed that there was no evidence that filling the cavities resulted in any greater incidence of damp problems than in walls with empty cavities. The study showed that the structural condition of the cavity wall is the critical factor in avoiding damp penetration. Typically there are 600,000 cavity wall installations each year.

Cavity wall insulation is a specialist job that should be carried out by an approved contractor who complies with an appropriate code of professional practice such as that operated by the National Insulation Association and can offer a Cavity Insulation Guarantee Agency (CIGA) guarantee. The first job the contractor will do is to check that the wall is suitable for filling. Having carried out the inspection, the contractor will submit on your behalf a Building Control Notice to the local Building Control Body. The wall will then be drilled in a defined pattern and the insulation pumped in under pressure. The holes will be made good and checks and tests completed.

The most common materials used for CWI are mineral wool or polystyrene beads. All CWI systems are tested and approved by independent bodies. When the work is complete the contractor will ask the Cavity Insulation Guarantee Agency (CIGA, www.ciga.co.uk) to issue an independent 25-year Guarantee covering defects in materials and workmanship.

There are many properties with cavity widths less than 50 mm, which cannot be insulated using the method described above. High-rise tower blocks in Edinburgh, where cavity widths varied between 28 mm and 120 mm, were insulated with proprietary polyurethane (PUR) cavity wall insulation. Carbon dioxide emissions were reduced by 590 kg/year per flat and heating bills were reduced by 77%. The installation was completed in four weeks with no tenant disruption. At present this insulation technique is not guaranteed by CIGA and reference should be made to the manufacturer and installer about suitability and warranties on a case by case basis.

Advanced insulation

To achieve radical reductions in emissions, it is likely that cavity wall insulation will need to be augmented with an extra layer of internal or external insulation. In Gloucestershire problems with external render prompted one filled cavity wall to be insulated externally with 110 mm of phenolic foam. The DIY system used horizontal battens fixed to the wall for the first 55 mm layer, followed by vertical battens containing another layer of insulation. This was then covered with 'breathable' sarking felt and two coats of cement render on stainless steel expanded metal. The U value of the wall was improved from 0.65 to 0.21 W/m²K.


CAVITY INSULATION GUARANTEE AGENCY

25 Year Guarantee Certificate

The Guarantee

Period of Guarantee - 25 years from date of installation

Your Route to Total Satisfaction

Conditions

CIGA

Figure 5.2 CIGA guarantee certificate

Figure 5.3 A high-rise block in Edinburgh insulated with proprietary polyurethane cavity wall insulation. Picture: Isothane.

Figure 5.4 Two layers of insulation allow timber battens to support the extended roof verge. Picture: John Willoughby.

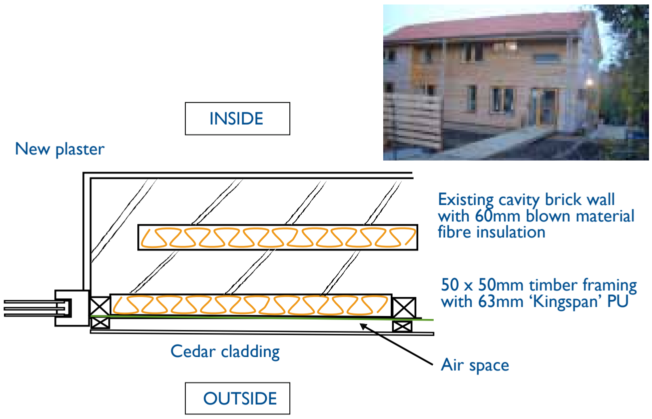

Figure 5.5 Insulated timber cladding to a cavity wall house. Picture: Tony Clelford.

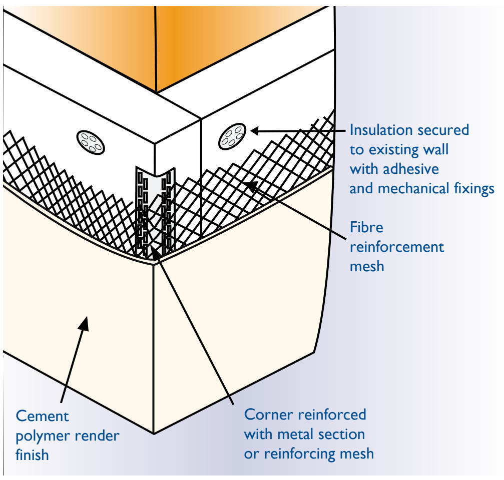

Figure 5.6 Typical external wall insulation system[16]

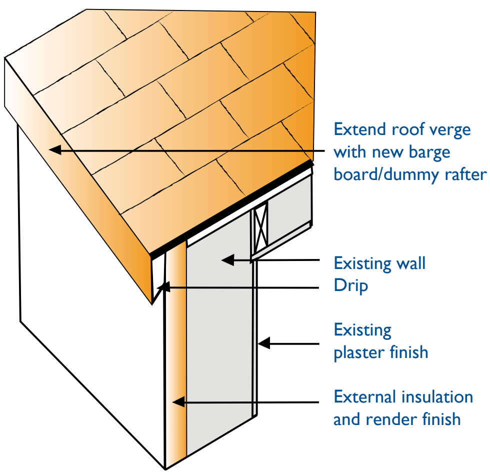

Figure 5.7 Refurbishment verge detail[17]

In Kent, a 1950s house with cavity walls had its cavities filled and was covered with 60 mm of polyurethane insulation and weatherboarding to give a U value of 0.26 W/m^{2}K.

External wall insulation

External wall insulation (EWI) can be installed as a one-off job using local builders, but is more often installed using a proprietary external wall insulation system. External insulation has many advantages. The insulation layer is more complete than with internal wall insulation which is interrupted at every internal partition. There is no loss of floor space. It causes less disruption to occupants and in some cases can enhance the external appearance of the home.

There are three generic types of EWI

- Wet render systems
- Dry cladding systems
- Bespoke systems

The most common systems use wet render. This can be a traditional thick cement-sand render but is more often a thin coat polymeric coating. These polymeric render coats give exceptional strength with a very thin coat, typically just 10 to 15 mm thick.

A typical system is shown in Figure 5.6. Usually, board insulation (mineral fibre or foamed plastic) is glued and mechanically fixed to the existing wall. The insulation is covered with a reinforcing mesh before the render is applied in two coats.

Insulation thicknesses vary typically between 50 and 140 mm, although systems using 250 mm thick insulation have recently become available (see Figure 5.8). Applied to a solid brick wall, 50 – 140 mm gives U values in the range 0.5 to 0.17 W/m^{2}K, depending on the material used.

The main problem with EWI systems is the detailing, particularly at the wall to roof junction. If the eaves are flush with the existing wall, it may make sense to install the wall insulation when re-roofing is being carried out. Although there are cappings available to cover the top of the insulation, their use means that a large thermal bridge at the eaves is inevitable. The verge detail is usually easier to deal with. A ladder system or a dummy barge board fixed through the insulation can be used (see Figure 5.7). Detailing at the base of the wall and around windows also requires careful attention.

16 Figure 5.6 redrawn from Practical refurbishment of solid-walled houses, Energy Saving Trust (CE 184).

17 Figure 5.7 redrawn from External insulation systems for walls of dwellings, Energy Saving Trust (CE 118 / GPG 293).

Another issue with EWI is that of external pipes. Rainwater down pipes need to be moved and re-fixed, external lights, satellite dishes, all need to be moved. These issues, and the need for scaffolding, make EWI the most expensive solution for wall insulation.

Advanced Insulation

A refurbishment to near Passivhaus standards in Hereford uses 250 mm thick grey polystyrene to achieve a wall U value of 0.12 W/m²K. The system is carefully tied into the new roof insulation to provide a continuous layer of insulation over the outside of the building. New windows are sealed to the wall before the insulation is installed. There are other insulation materials that are equally applicable.

Figure 5.8 The gap between 250 mm thick grey polystyrene insulation and a window frame being sealed with expanding foam prior to rendering at Grove Cottage, Hereford. Pictures: Simmonds Mills Architects.

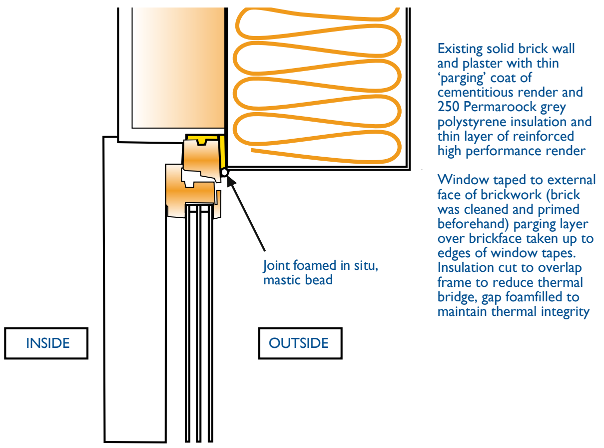

Figure 5.9 Window detail at Grove Cottage, Hereford. Image courtesy of Simmonds Mills Architects.

Internal wall insulation

In many cases it is not possible to externally insulate a property; it may have beautiful external features, there may be other planning issues, or the detailing may be prohibitive. In these cases internal wall insulation (IWI) is the next best thing. IWI is cheaper than EWI but it has some disadvantages: there is a loss of floor space, there are thermal bridge problems at internal wall junctions and intermediate floors, and there is a danger of interstitial condensation on the existing wall if water vapour penetrates (see Figure 5.10).

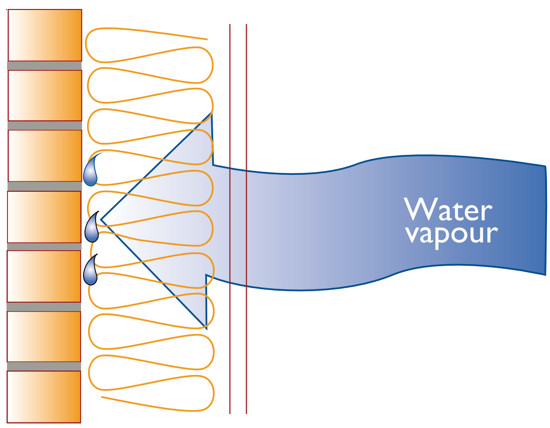

Figure 5.10 If water vapour passes through the insulation it can condense on the cold wall

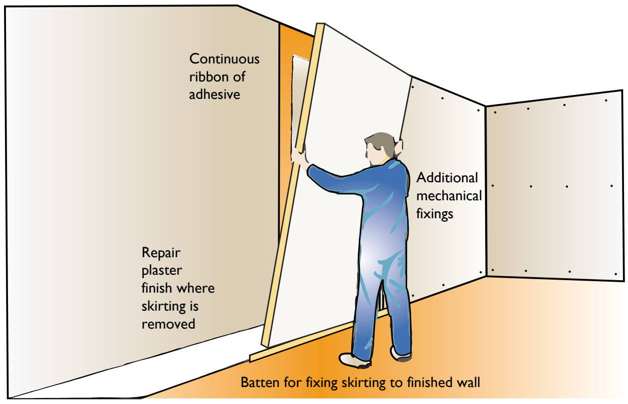

Figure 5.11 Insulated plasterboard[18]

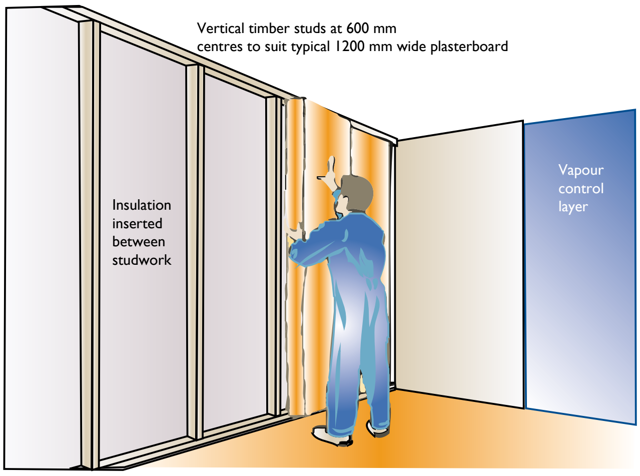

Figure 5.12 Insulation in a timber frame. The thermal bridge from the timber studs can be reduced by using insulated plasterboard[18]

Interstitial condensation

When a solid wall is internally insulated, the internal surface will be cold. If water vapour comes in contact with this surface it will condense. The condensation can become problematic, wetting the insulation and causing mould growth, rust and timber decay.

It is important to understand that water vapour can pass through to the wall in two ways: by diffusion through the insulation layer and (more significantly) by the movement of warm, moist air through any cracks or gaps. Vapour diffusion can be controlled by the use of a vapour barrier on the warm side of the insulation. Controlling air movement is much more difficult and necessitates that great care is taken with the installation, to ensure that the vapour barrier is continuous.

Internal wall insulation options

Insulated plasterboard (Figure 5.11) is a very common and useful material for IWI. The alternative is to build up insulation within a framing system (Figure 5.12). To meet the best practice standard U value of 0.3 W/m^{2}K requires an insulation thickness of between 80 and 120 mm, depending on the conductivity of the insulation. The effectiveness of the insulation depends on both the thickness and the area of wall covered, so it is important to remember to insulate in the intermediate floor voids and other 'hard-to-reach' areas.

Insulated plasterboard can be fixed on to existing plastered walls using drywall adhesive or plasterboard sealant. Framing systems can consist of timber or metal studs, or 'polystuds' made of insulating material bonded to timber or oriented stand board. If metal studs are used, they introduce a significant thermal bridge; this can be reduced by covering the studs with another layer of insulation.

18 Figures 5.11, 5.12 and 5.13 have been redrawn from Practical refurbishment of solid-walled houses, Energy Saving Trust (CE184).

Thermal bridges

Thermal bridges can occur at the reveals, cills and heads of windows and external doors. The insulated lining should be run into the window and door surrounds as shown in Figure 5.13, and under the cill boards. If the window frames are not thick enough to accommodate the thickness of the insulation, thinner pieces of insulation with lower conductivity can be used; in some cases it may be necessary to replace the windows.

Thermal bridges also occur where internal or party walls meet external walls. There is a concentration of heat flux at this point as heat is conducted through the internal wall as well as the external wall. When the external wall is insulated, this thermal bridge is exaggerated; temperatures on the party wall can fall, resulting in excessive heat loss and condensation. To reduce this problem it is worth returning the insulation along the internal wall, as shown in Figure 5.14. The thermal bridge can never be eradicated but if the insulation is returned between 400 and 600 mm along the internal wall, the bridge will be much reduced.

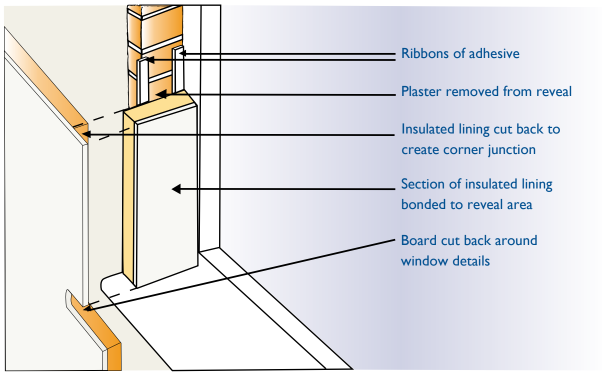

Figure 5.13 To avoid condensation on the cold window reveals, they should be insulated as well[18]

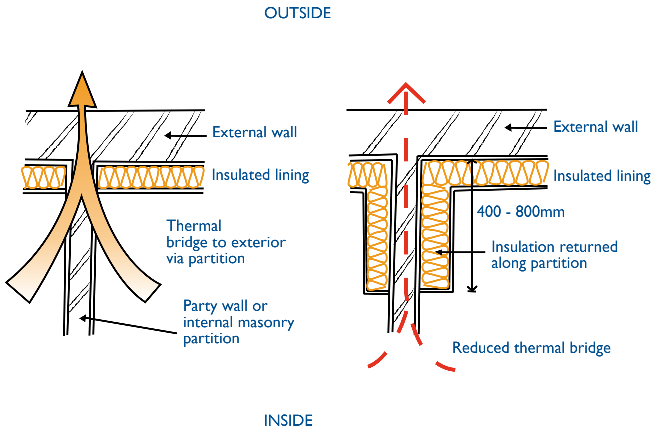

Figure 5.14 Internal partitions cause a thermal bridge (top). Returning the insulation along the partition reduces the problem (bottom)

Figure 5.15 Internal insulation at the Nottingham EcoHome. Pictures: Gil Schalom.

Advanced insulation

At the Nottingham EcoHome, internal wall insulation was used on the front wall. At the time of refurbishment the maximum available thickness of insulated plasterboard was 52.5 mm, so two layers of phenolic foam backed plasterboard were used to achieve a U value of 0.23 W/m²K. Today, this U value could be achieved with a single, thicker layer of insulated plasterboard. The insulation was taken into the first floor void and returned at the internal partition.

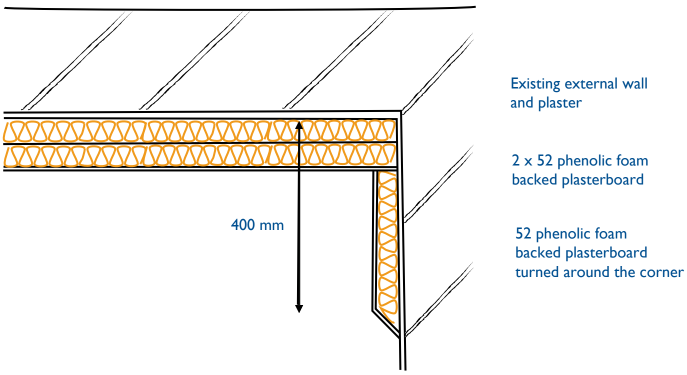

Figure 5.16 Internal insulation at the Nottingham EcoHome

Figure 5.17 Internal insulation at the Nottingham EcoHome – note the reinstated coving and the insulation returned along the party wall. Picture: Gil Schalom.

6. Roofs

Roof insulation comprises two main types; loft insulation at joist level, typically mineral or rock wool, but can be boards on top of ceiling; and rafter insulation, on, under, or between the rafters, that support the external roof covering. This can consist of any of the main types of insulation.

Loft insulation is the most common thermal improvement to the fabric of British homes. But this seemingly simple measure is not without its challenges. If reroofing work is being carried out then it may make more sense to insulate at rafter level. Insulating at rafter level creates a warm roof space and makes it easier to connect the roof insulation to external wall insulation.

Flat roofs are often poorly insulated and often difficult to upgrade. When the waterproof covering has failed, it is an ideal time to take radical steps to improve the insulation.

Quick fixes

Loft insulation is an improvement that can be made at almost any time. It is cheap and cost effective to top up loft insulation to between 250 and 300 mm thickness.

Opportunities

When reroofing, the opportunity to improve insulation levels should be taken.

If modifications are being made to the heating system, it is a good idea to remove all wet services from the loft space, which can then be insulated more thoroughly without the fear of freezing pipes.

Major projects

Insulating the roof at rafter level and connecting that insulation to external wall insulation is a strategy well worth considering during a major refurbishment.

Roof U Values

Table 6.1 presents recommended maximum U values for roofs according to various standards.

Building Regulations	Best Practice	Advanced
2006: Below 0.16 2010: 0.16 - 0.18	Lofts: below 0.16 Flat roofs: below 0.25	Below 0.1

Table 6.1 U values for roofs (W/m^{2}K)

Loft insulation

In an insulated loft space, condensation will almost always form on the underside of the roof covering. This is usually impervious bituminised sarking felt and it is important to provide the loft space with sufficient ventilation to remove the condensation when the weather gets warmer. The ventilation is often introduced at the eaves which makes it difficult to insulate the loft successfully. Figure 6.1 shows an insulated loft space looking towards the eaves. The thermograph, from below, Figure 6.2 shows a window and the ceiling below the eaves. Electric cables can just be seen disappearing under the insulation. Cold air from the eaves vent is passing under the insulation nullifying its effect. There is little between the inside and outside air except for a sheet of plasterboard.

Figure 6.1 Mineral wool quilt insulation in a loft

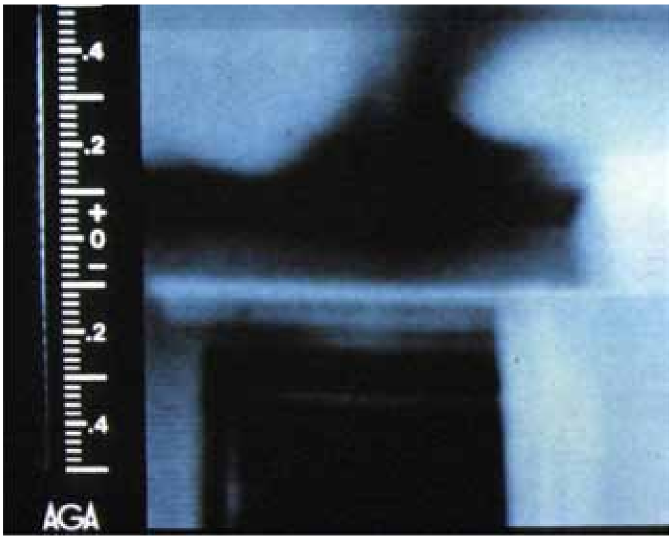

Figure 6.2 Thermograph showing how loft quilt lying on top of an electric cable allows air to get underneath creating a cold area in the room below.

Eaves vents are a problem. If they are blocked up then the loft will suffer from condensation. If they are left open ventilation air can find its way beneath the insulation. Getting round this problem takes quite a bit of care. First a sealed void should be created to channel the ventilation air into the loft above the insulation. This channel can be formed with a board. It should be cut round and sealed to the ceiling joists. The loft insulation can then be pushed into the eaves and as far as possible connected to the wall insulation. There are also some compressible board systems on the market.

Mineral fibre quilt is the most common loft insulation material. However, using blown insulation can help to force the insulation into corners and areas which are difficult to reach with quilt. Blown insulation is also a useful technique for insulating lofts where there are trussed rafters; it is virtually impossible to insulate properly between and over trussed rafters using quilt.

Services in loft spaces

It is difficult to insulate a loft thoroughly if there are tanks and pipes above the insulation. The strategy should be to remove the services from the roof space. Unless this is done, insulation will have to be left out under the tanks to stop them freezing. Not only will insulation be missing but there will be inevitable air leakage around the pipes which passes through the ceiling. Using combi boilers, heat stores or unvented cylinders allows tanks and pipes to be removed from the cold loft space.

Electric cables should be kept on the cold side of the insulation. Burying cables under the insulation can cause overheating. This is most likely to be a problem with cables supplying large loads like electric showers, cookers or storage heaters. Cabling may need to be upgraded.

Recessed down-lighters cause another problem with loft insulation. Insulation must be removed around light fittings (or they must be boxed) to stop them overheating. This results in thermal bridges, and the hot light fittings promote air leakage. If recessed light fittings must be used, then they should be fitted in a false ceiling so that the integrity of the insulation and air-tightness can be maintained.

Rafter insulation

In dwellings without loft spaces, where the ceiling follows the line of the roof, insulation needs to be applied at rafter level. Insulating in the depth of the rafter (typically 100 mm) is insufficient to meet best practice standards. Generally there needs to be an additional layer of insulation across the rafters. This can be added on the inside or outside of the roof.

External rafter insulation

If the roof finish is being replaced then there is sometimes the opportunity to insulate between and over the rafters. Board material is laid over the rafters and covered with 'breathable' sarking felt; counterbattens can be fixed through the insulation to form a ventilated air space. The roof finish is then fixed on battens.

Advanced external rafter insulation

A refurbishment to near Passivhaus standards at Grove Cottage in Hereford uses 400 mm of insulation between engineered timber 'I beams' in a new roof structure to achieve a roof U value of 0.09 W/m^{2}K. The detail connects the roof insulation to 250 mm thick external wall insulation at the eaves, as shown in Figures 6.4 and 6.5.

Figure 6.3 400 mm deep engineered timber 'I beams' with the first layer of roof insulation over the existing roof structure.
Picture: Simmonds Mills Architects.

Figure 6.4 The 250 mm thick external wall insulation, with a block shaped to fit at the eaves. Picture: Simmonds Mills Architects.

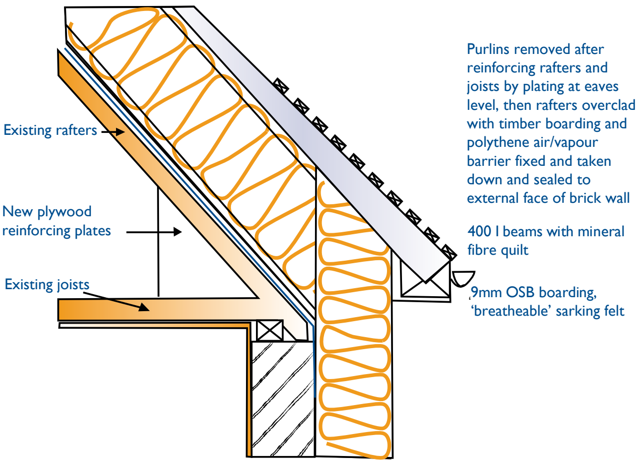

Figure 6.5 At Grove Cottage, the 400 mm thick roof insulation connects at the eaves to 250 mm thick external wall insulation.
Image courtesy of Simmonds Mills Architects.

Figure 6.6 Z rafters were set out using a jig to ensure the spacings matched the rigid insulation board. Picture: Ray Exton.

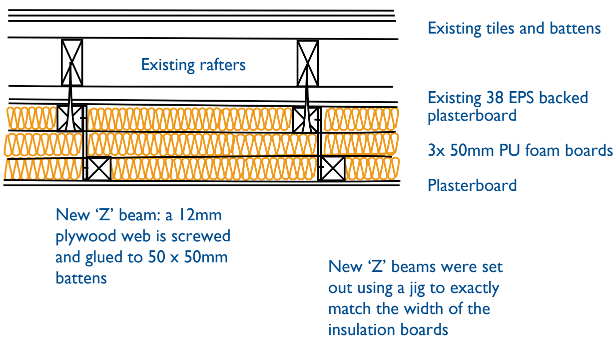

Figure 6.7 Z rafters fixed beneath the existing roof to support the insulation

Figure 6.8 Recess for rooflight in 300 mm deep extension rafters with air/ vapour barrier and plasterboard. Picture: Gil Schalom.

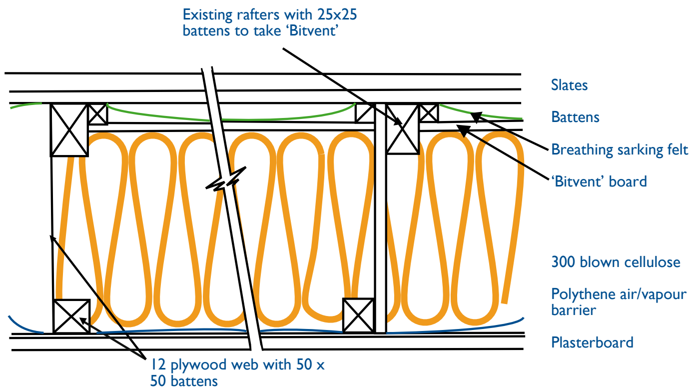

Figure 6.9 Plan section through the roof showing the new 'L' beams added to existing roof structure

Internal rafter insulation

Where the roof finish is not being replaced or cannot be extended outwards (e.g. in semi-detached properties), insulation must be added internally. If the rafters are exposed, insulation can be added between and under the rafters. If an impervious sarking felt is to be left in place, then it is important to create a ventilated air space below it. The difficulty is in stopping this cold ventilation air from leaking around the insulation. A board material glued or foamed in place is probably the best way to solve this difficult detail. Sealing along the rafter is fairly easy but sealing at the eaves is more difficult.

Where the ceiling is to remain in place, space considerations usually determine the thickness of additional insulation. Insulated plasterboard applied to the underside of a sloping ceiling can be quite effective but the resulting U value is unlikely to be as good as the best practice standard of 0.16 W/m^{2}K. A good technique for adding thicker levels of insulation is to use spaced 'C' or 'Z' section extension rafters.

This technique was used on a house in Gloucestershire where a Z beam was made up and insulated with three 50 mm thick layers of PU insulation. The existing roof had a 38 mm insulated plasterboard ceiling with a U value of around 1.0 W/m^{2}K. Adding the Z beams reduced the U value to 0.16 W/m^{2}K.

Advanced internal rafter insulation

The Nottingham EcoHome is a semi-detached house so it was not possible to extend the roof outwards when reroofing. 300 mm deep extension rafters were added before the roof was stripped. Bitumen impregnated fibreboard was used to create a void below the new roof slates. A polythene vapour barrier was installed behind the plasterboard on the warm side of the insulation.The void was pumped full with cellulose fibre. The resulting U value is 0.12 W/m^{2}K.

Loft Conversions

Loft conversions provide an excellent opportunity to incorporate high levels of insulation and air-tightness. Many of the techniques mentioned above can be used when new rooms are added to a loft space.
Loft conversions are dealt with in another Construction Products Association publication Loft Conversion Project Guide CPA/RIBA Publishing 2010 ISBN 978 1 85946 357 4, downloadable from www.constructionproducts.org.uk/publications/page.aspx?Id=509.

Flat roof insulation

Flat roofs are often poorly insulated. They can be upgraded internally using the techniques described above, but very often there is insufficient room to add very much insulation. External insulation is the preferred upgrade option. It can be added on top of the existing roof finish and there are two common systems: Warm deck and inverted warm deck. In the warm deck, the insulation is placed on top of the existing roof finish and another waterproof layer is added. The inverted warm deck uses the existing membrane as the waterproof layer and adds loose fitting waterproof insulation above it. Extruded expanded polystyrene is often used and held down with ballast or paving slabs. The disadvantages of the inverted warm roof are that the roof loading is increased and the cold rain can get on the warm side of the insulation.

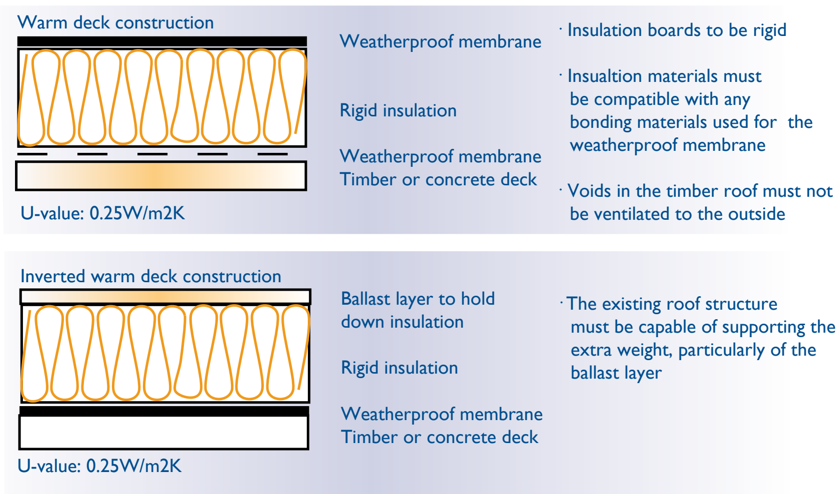

Figure 6.10 Warm deck constructions for upgrading flat roofs

7. Windows and external doors

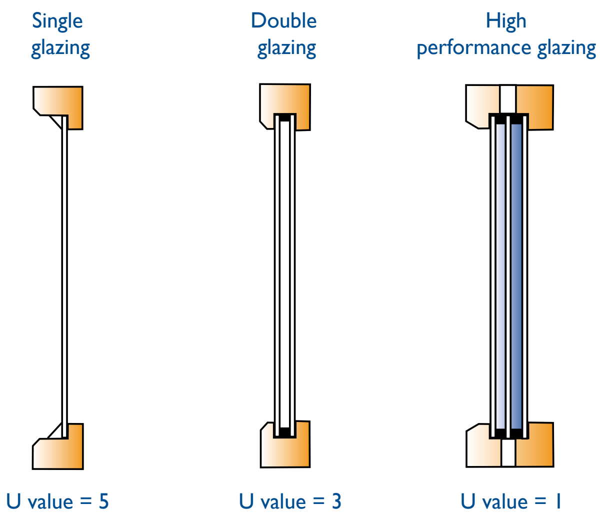

Figure 7.1 Improvements in U value of windows

Around two million windows are installed in the UK every year. The majority of these are replacement windows in existing homes. Many of these replacement windows replace old single glazed windows with double glazed ones. Such has the advance in glazing technology over the past few years that now it is possible to upgrade double glazing with a modern high performance window and get a similar improvement in performance as going from single to double glazing. Figure 7.1 indicates this improvement in performance – thermal transmittance is reduced by about 2 $W/m^2/K$ at each step.

A number of innovations have led to this improved performance.

- Low emissivity coatings reduce radiative heat loss across the glazing cavity. These soft coatings now have very low emissivities below 0.05, compared to 0.15 for hard coatings. At the same time as improving insulation levels, low E coatings have been made more transparent
- Gas filling reduces the convective heat transfer across the glazing cavity. Argon gas is most common but krypton gas will give the same performance for a narrower cavity and this is often useful in refurbishment (see Figure 7.4)
- Insulated spacers reduce the thermal bridge due to the high conductivity of the aluminium or steel usually used for edge spacers. These insulated spacers are often referred to as 'warm edge'
- These improvements in glazing technology have resulted in the glazing performing better than the frame. So insulated frames are now available (see Figure 7.5) which result in U values for whole windows as low as 0.6 W/m^2K

Figure 7.2 DIY secondary glazing film

Quick fixes

If windows are not being replaced, a simple DIY job can be used to improve performance. This involves sticking a thin transparent film over the window which is then stretched using a hair dryer (see Figure 7.2).

Properly fitting curtains with 'thermal' (low emissivity) linings can make a significant improvement to the performance of single or double glazed windows.

Opportunities

When windows, rooflights or doors are being replaced, high performance replacements should be considered. Good quality windows will last for 50 years so it makes sense to choose the best that can be afforded.

Major projects

When windows are being replaced as part of a major refurbishment, they can be tied in with wall insulation and air-tightness measures.

Windows and doors are defined as 'controlled fittings' under Part L of the Building Regulations. This means that a Building Regulations application must be made when windows are replaced. In England and Wales, if a FENSA (Fenestration Self-Assessment scheme) registered installer is used, the work will be 'self certified' by the installer and no application is required.

The performance of a window depends on many factors; heat losses through the glass, spacers and frame, heat gains through the glazing and infiltration through any cracks or gaps. To assess the effect of these factors, a European Window Energy Rating (WER) has been developed. In the UK the WER is administered by the British Fenestration Rating Council (BFRC). Windows are modelled or hot-box tested and a rating (A to G) is awarded depending on the U value, solar transmission (g value) and the effective air leakage (see Figure 7.3).

Figure 7.3 Windows are rated on an A to G scale. Picture: BRE.

U Values for windows and doors

Table 7.1 presents recommended maximum U values or minimum energy ratings for windows and rooflights, according to various standards.

Note that WER Band A windows can have U values as high as 1.6 W/m²K, so for advanced applications it is important to check the U value. Glass with low emissivity tends to have a lower g value; this may be significant if solar gains through southerly oriented windows are important to the refurbishment energy strategy.

Table 7.2 presents recommended maximum U values for doors, according to various standards.

Building Regulations (2010 edition)	Best Practice	Advanced
WER band C or better or U-value below 1.6	WER band B or better	U value below 0.8 W/m²K

Table 7.1 U values and energy ratings for windows and rooflights

Building Regulations (2010 edition)	Best Practice	Advanced
Below 1.8	Below 1.8	Below 0.8

Table 7.2 U values for doors (W/m²K)

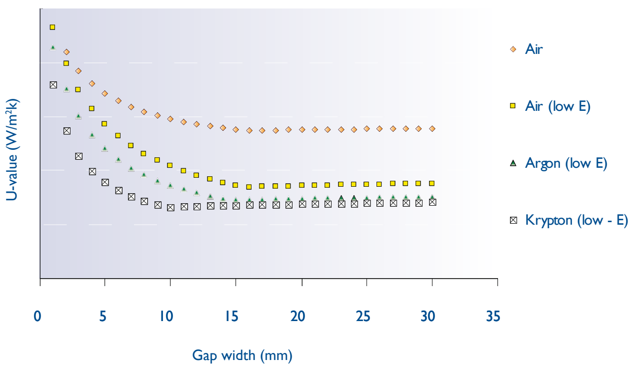

Figure 7.4 The graph shows that the most significant improvement in U value comes from low E coatings. Note that the U value given by krypton gas filling with a gap of around 10 mm is similar to argon filling with a 16 mm gap.

Figure 7.5 Triple glazed low emissivity gas filled glazing with insulated spacers in insulated timber frame, giving a whole window U value of around 0.75 W/m²K (Green Building Store)

Figure 7.6 Using 4/6/4 mm low emissivity krypton filled glazing gives a high performance for this handmade secondary window. The overall U value is about 1.2 W/m²K. Picture: John Willoughby.

Window installation

When high performance windows are installed in existing dwellings, there is a danger of excessive heat loss around the edge of the window. This can be due to infiltration and to thermal bridging at the head, cill and reveals. Infiltration can be dealt with by using expanding foam and special sealing tapes. The thermal bridge is often caused by a lack of insulation around the window. Steel lintels and masonry returns often result in excessive thermal bridging. If internal or external wall insulation is being used, a thin layer can be returned into the window reveal. More information may be found in BS8213-4, which is the Code of Practice for window installation.

Replacing windows usually necessitates some repairs to plaster window reveals. Even if wall insulation is not being carried out at the same time, using insulated plasterboard in the reveals helps to reduce the thermal bridges.

Secondary windows

If glazing is to be replaced within existing frames (e.g. in a Conservation Area) then vacuum insulated glazing provides high performance with minimum thickness. However, in most situations where windows are not being replaced, secondary windows will be a good alternative. The secondary glazing can often be tied into internal wall insulation. Using krypton filled low emissivity double glazing with a 6 to 8 mm gap can result in a slim window frame with a good thermal performance (see Figure 7.6).

Doors

Insulated doors reduce fabric heat losses but the main energy saving feature, when compared to the usual UK door, is in the reduction of air leakage. This is often achieved by the use of multi-point locks to ensure that the door seals are properly compressed. The graph in Figure 7.7 shows how reductions in air leakage dominate the energy savings. An energy rating scheme is being developed for external doors.

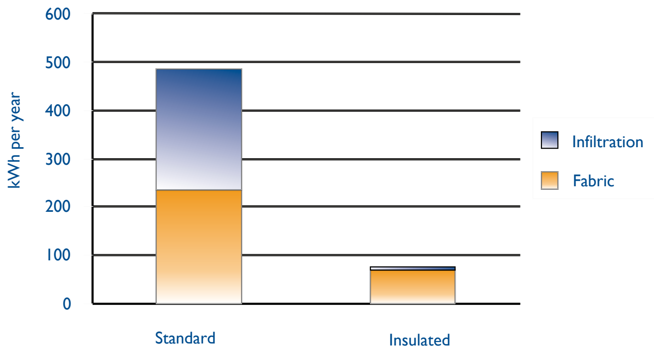

Figure 7.7 The greater savings from using an insulated door are from reductions in air leakage rather than in fabric heat losses. Graph courtesy of Peter Warm.

Air-tightness and ventilation

It is important to ensure that replacement windows and doors are well sealed at the wall joint and are well draught-proofed. This work needs to be part of an overall strategy for air-tightness and ventilation. Windows may well need to be specified with trickle vents if an adjustable air supply is required in the room. When existing windows that have trickle ventilators are replaced, the new windows must have trickle vents sized in accordance with the guidance in the Approved Document to Part F of the Building Regulations. Air-tightness and ventilation issues are dealt with in the next two Chapters of this guide.

8. Air tightness

British homes are notoriously leaky. In a typical house, the infiltration of external air causes the air in the dwelling to be changed about once every hour. This rate of air change is far more than is needed for ventilation and results in excessive heat losses as well as discomfort.

Air infiltration is caused by the wind and by the 'stack effect'. Wind causes positive and negative pressures on the building which forces cold air in and warm air out, through cracks and gaps in the structure. The stack effect causes warm air to rise and leak out through gaps in ceilings.

Generally UK homes rely on this infiltration to provide ventilation air. Ventilation is needed to maintain a good air quality and to remove pollutants, particularly water vapour. The problem is that the infiltration is more than is required for ventilation and infiltration occurs all the time, even when the house is unoccupied. What is needed is a controllable supply of ventilation air in the right place at the right time. The maxim is 'build tight and ventilate right'.

Quick fixes

Draught-proofing is a simple measure that can be carried out at any time. Windows, doors and loft hatches can be draughtstripped and letterbox covers can be fitted. Suspended floors can be sealed as described in Chapter 4. Gaps around services pipes can be sealed with mastic or expanding foam.

Opportunities

When practically any improvements are being made, there is an opportunity to improve air-tightness. Caulking can be carried out when decorating; air-tightness measures should accompany an insulation work. If plumbing work is being done, sealing should be carried out around services penetrations.

Major projects

Simple draught-proofing will not result in very low levels of infiltration because of all the unseen leaks, in floor voids for instance. So when a major refurbishment is being carried out, it is important to take a strategic approach to air-tightness and use pressure testing to check performance.

Air permeability

Table 8.1 presents maximum recommended air permeabilities of dwellings, according to various standards. Air permeability is a measure of the air-tightness of a dwelling, as discussed in the section about pressure testing.

Building Regulations	Best Practice	Advanced
Reduce unwanted air leakage	5 m^3/hm^2 @ 50 Pa	1 m^3/hm^2 @ 50 Pa

Table 8.1 Maximum recommended air permeabilities for existing dwellings

Air leakage routes

Obvious air leakage paths, such as windows, doors and letter boxes, can be dealt with fairly easily. But these only account for a small part of the infiltration in a typical dwelling. Figure 8.1 identifies some air leakage paths that need to be considered.

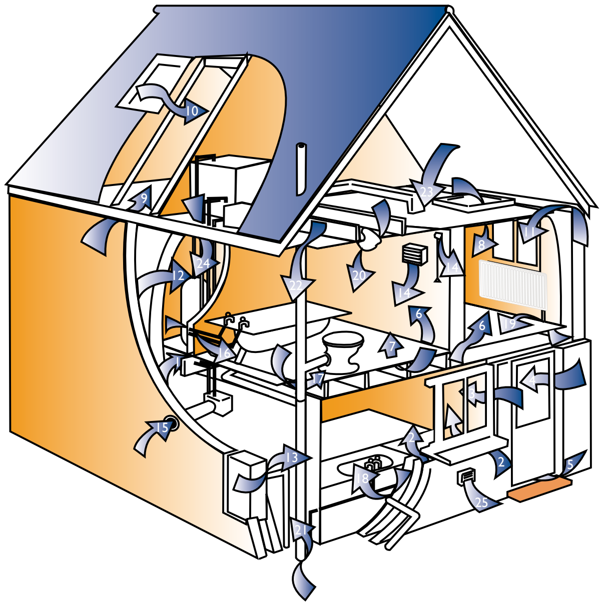

Figure 8.1 Common air leakage paths – see key below. Diagram courtesy of Paul Jennings, ALDAS, www.aldas.co.uk.

Key to air leakage paths in Figure 8.1	
1	Around the ends of floor joists or joist hangers; through poor quality masonry between joists
2	Beneath inner window sills and around window frames
3	Through windows and/or hollow window frames
4	Through and around doors – particularly double doors
5	Beneath doors and doorframes
6	Along the top and bottom edges of skirting boards
7	Between and around sections of suspended floors, usually timber floorboards
8	Around loft hatches
9	Through the eaves
10	Around rooflights
11	Through gaps behind plasterboard on dabs or hollow studwork walls
12	Cracks or holes through a masonry inner leaf
13	Around supplies from external meter boxes
14	Around wall mounted fan or radiant heaters; around and through fused spurs and pull switches
15	Around boiler flues
16	Around water and heating pipes that penetrate into hollow floor voids and partition walls
17	Around waste pipes passing into floor voids or boxed in soil stacks
18	Around waste pipes passing through walls
19	Gaps around heating pipes
20	Around and through recessed spotlights
21	Around waste pipes, gas and water supplies, cables, which penetrate the lower floor
22	Hole around the top of a soil stack
23	Through MVHR or warm air heating systems; around terminals
24	Gaps around pipes to cold water and/or heating header tanks
25	Around and through wall-mounted extract fans, cooker hood vents, tumble dryer vents

Not on the diagram, but also:	
26	Around and through ceiling roses
27	Through room thermostats and heating controllers
28	Behind polystyrene coving along wall to roof joints
29	Through key holes and where locks and bolts prevent effective draught-proofing
30	Around internal timber joists that penetrate plaster walls
31	Through subfloor air supplies to solid fuel heaters
32	Through gaps in the casings of MVHR units
33	Up chimneys, particularly where flue dampers are not fitted
34	Through airbricks and partially closable hit-and-miss vents
35	Through window spinner vents
36	Around and through closed trickle vents

Figure 8.2 Pressure testing equipment. Picture: Rickaby Thompson Associates.

Figure 8.3 A smoke pencil (or 'puffer') being used to show air leakage through services penetrations. Picture courtesy of Kingspan.

Strategic planning

A strategy for reducing air leakage needs to be part of any major refurbishment work. The most important part of this strategy is to identify how air-tightness is to be achieved in each element (walls, floors, roofs) and how the elements are sealed to one another. For instance new wall insulation may incorporate an air / vapour barrier which should be sealed to air / vapour barriers in the roof and floor; services are then kept within the air / vapour barrier envelope (see Advanced air-tightness).

Pressure testing

Pressure testing involves fitting a fan in an external door opening (see Figure 8.2), raising the pressure in the house and measuring the airflow. This is a very useful technique to identify air leaks, which can be seen with a smoke pencil (Figure 8.3), and to check on the standard of air-tightness.

The volume of air passing through the door fan is recorded at various pressure differences. The results are used to assess the volume (m^3/h) at a standard pressure difference of 50 Pa. Dividing this volume by the internal surface area gives the 'air permeability', which has the units $m^3/h/m^2$ or m/h. Average air permeabilities in UK houses are around 18 $m^3/h/m^2$ @ 50 Pa; this can be compared with a new-build maximum allowable air permeability of 10, the best practice refurbishment standard of 5, the best practice new-build standard of 3 and the Passivhaus standard of less than 1.

Registered pressure testers can be found at http://www.attma.org/member_list.htm and http://www.bindt.org/downloads/Approved_Air_Tightness_Testers.pdf.

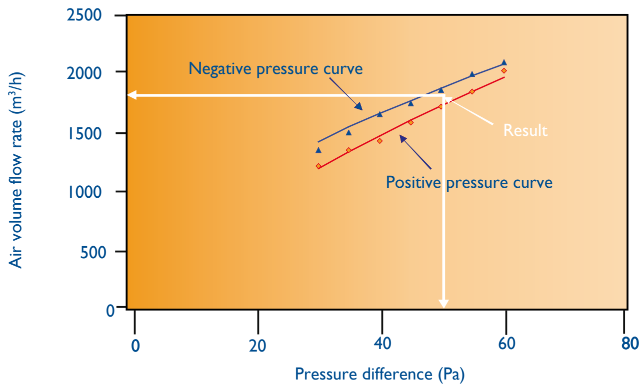

Figure 8.4 A results chart from a pressure test. Chart courtesy of Rickaby Thompson Associates.

Advanced air-tightness

Two recent refurbishment schemes have attained air permeability standards of near to 1.0 $m^3/h/m^2$ @ 50 Pa. In Hackney, London, a Victorian terrace house has been refurbished. The main air-tightness feature is orientated strand board (OSB) included in the internally insulated front walls. The OSB was carefully taped at the board joints and to the window boxes. Four different types of proprietary tapes were used to seal the OSB to the OSB in the insulated party walls, which in turn were taped to new masonry rear walls. Other tapes were used for the wall to roof and floor. See Figures 8.5 and 8.6.

Figure 8.5 Exceptional levels of air-tightness have been achieved at this refurbishment project in Hackney. New draught-proof windows have been carefully sealed to new internal wall insulation. Pictures: John Willoughby.

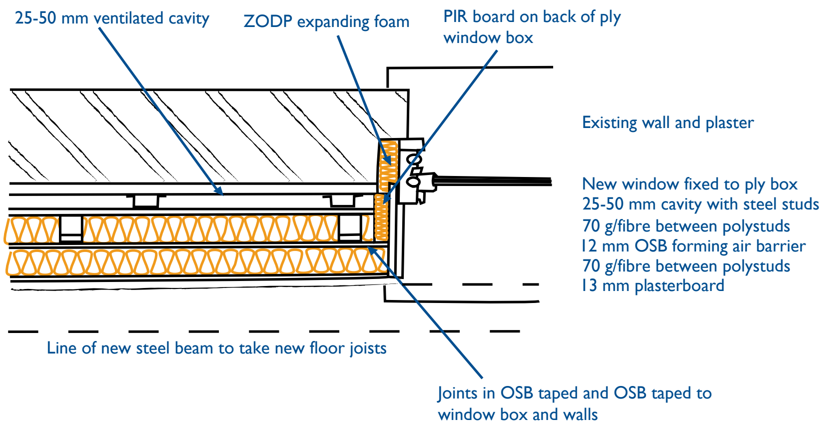

Figure 8.6 The second layer of OSB formed the air-tightness layer. This was taped to window boxes and the other walls. Image courtesy of Prewett Bizley Architects.

Figure 8.7 Windows taped to walls before they were rendered and covered with 250 of insulation. Pictures: Simmonds Mills Architects.

In Hereford, air-tightness was achieved by a render coat applied to the brickwork before the EWI was applied. New windows were sealed to the wall to eliminate infiltration (see Figure 8.7).

In both the Hackney and Hereford projects, ventilation air is supplied via an advanced MVHR system.

9. Ventilation

We spend a great deal of time indoors in the company of many indoor pollutants (see Figure 9.1). Ventilation has a key role to play in diluting and removing these pollutants. If a house is made airtight without an adequate ventilation system, it can be an unhealthy place to live. Conversely, installing ventilation systems in leaky houses can add to heat losses and carbon emissions. It is important to build tight and ventilate right.

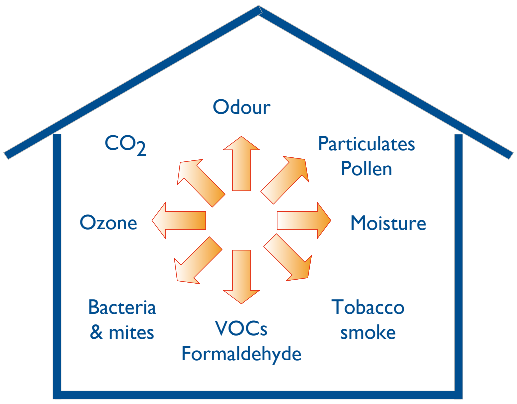

Figure 9.1 Typical indoor pollutants (based on AIVC Guide to Ventilation)

Quick fixes

Ensure that extract ventilation fans and trickle ventilators are clean and clear.

Opportunities

When extract fans need replacing, there is an opportunity to use low wattage replacements. In some cases it may be appropriate to change the extract fan for a heat recovery room ventilator.

Major projects

Major refurbishment work will allow a fresh look to be taken at the ventilation provision. If exceptional levels of air-tightness can be achieved, whole house heat recovery ventilation may be worth considering.

Ventilation standards

Table 9.1 presents various ventilation standards.

Building Regulations	Best Practice	Advanced
Existing ventilation systems may be retained, replaced or improved	A purpose-provided ventilation system should be installed	Whole house ventilation with heat recovery (MVHR)

Table 9.1 Ventilation standards

Ventilation heat losses

The graph in Figure 9.2 shows the proportions of heat loss via the fabric (floors, walls, roofs and openings) and via infiltration and ventilation. In the unimproved three bedroom semi-detached house discussed in Chapter 2, nearly 80% of heat loss is through the building fabric. Infiltration and ventilation is a minor issue. However, if the building fabric is insulated to best practice standards, then infiltration and ventilation losses become much more significant. With further improvements in fabric performance, infiltration and ventilation losses can dominate, at nearly 60% of the total. At the advanced insulation standard, with air permeability down to 1.0 $m^3/h/m^2$ @ 50 Pa and a whole house extract ventilation system, ventilation losses are still a significant part of the total. At this point using an advanced heat recovery ventilation system can reduce ventilation losses to a minor fraction of the total.

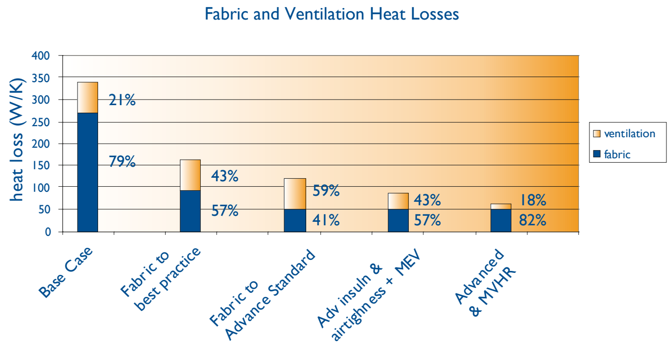

Figure 9.2 If building fabric improvements are made without attention to infiltration and ventilation, ventilation heat losses can dominate

It is clear that to make significant reductions in heat losses requires attention to the fabric insulation, infiltration heat losses and the ventilation system.

Ventilation options

Most UK homes rely on uncontrolled infiltration for background ventilation. Windows are opened or extract fans are used for intermittent purge ventilation. When air-tightness issues have been addressed, a more controllable ventilation system should be considered. Options include extract fans and trickle vents, whole-house extract, passive stack ventilation, heat recovery room ventilators and whole-house heat recovery ventilation systems.

Extract fans and trickle vents

Extract fans in bathrooms and kitchens are good for purge ventilation to remove odours and water vapour. Energy savings can be made by selecting low wattage fans. DC motors and improved fan design can reduce electricity use by as much as 80%. However in airtight houses, with air permeability of 3 $m^3/h/m^2$ or less, there is a danger that air quality will be poor.

Mechanical extract ventilation (MEV)

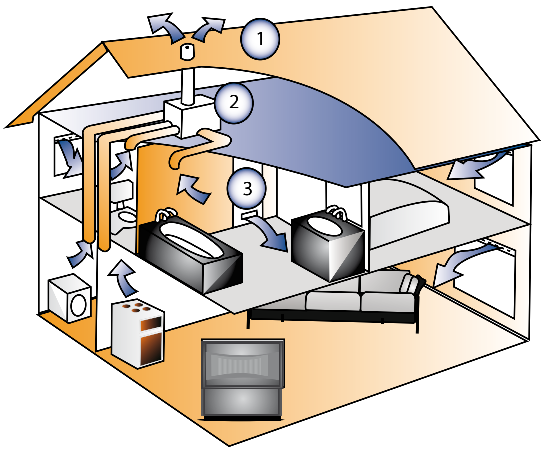

Figure 9.3 Whole house mechanical extract ventilation
Image courtesy of www.orcon.nl

In airtight houses air quality can be improved by using a continuous extract system. Air is taken from the wet rooms and trickle vents are used to admit fresh air into living rooms and bedrooms (see Figure 9.3). Extract rates can be boosted with switches or presence detectors. Further improvements can be made by using low watt fans and humidity-controlled trickle vents. The preferred option is a single central extract fan unit with ducts to the wet rooms. But a new range of fans have become available which are intended to be installed in each wet room and to run continuously.

If the air-tightness of the house is being improved, it is important to provide sufficient trickle ventilators for fresh air supply – one in each window head may not be enough - and it may be necessary to fit some ventilators in walls. Good quality humidity-controlled trickle ventilators should be used; poor quality ones often leak air even when they are closed.

Passive stack ventilation (PSV)

Passive stack ventilation has the ability to ventilate the house without the use of electric fans. Ducts link the bathrooms and kitchens to terminals on the ridge of the roof. Humidity-controlled inlet vents in these wet rooms control the extract rate; while humidity-controlled vents in living rooms and bedrooms control the fresh air supply (see Figure 9.4). In refurbishment schemes, using PSV will require a considerable amount of careful planning to accommodate the passive stacks.

All the above ventilation systems throw away expensive warm air. Heat recovery systems help to address this issue by recovering some of the heat in the exhaust air. This can be done on a room-by-room basis or with a whole house system.

Room ventilators with heat recovery

These systems combine supply and extract ventilation with heat recovery in compact through-the-wall units (see Figure 9.5). Heat recovery efficiency can be as high as 80% with fan power as low as 2 W.

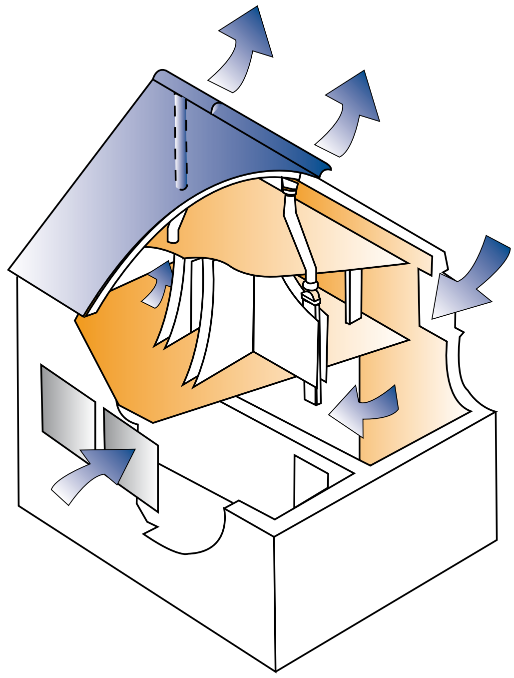

Figure 9.4 Passive stack ventilation. Diagram courtesy of Passivent.

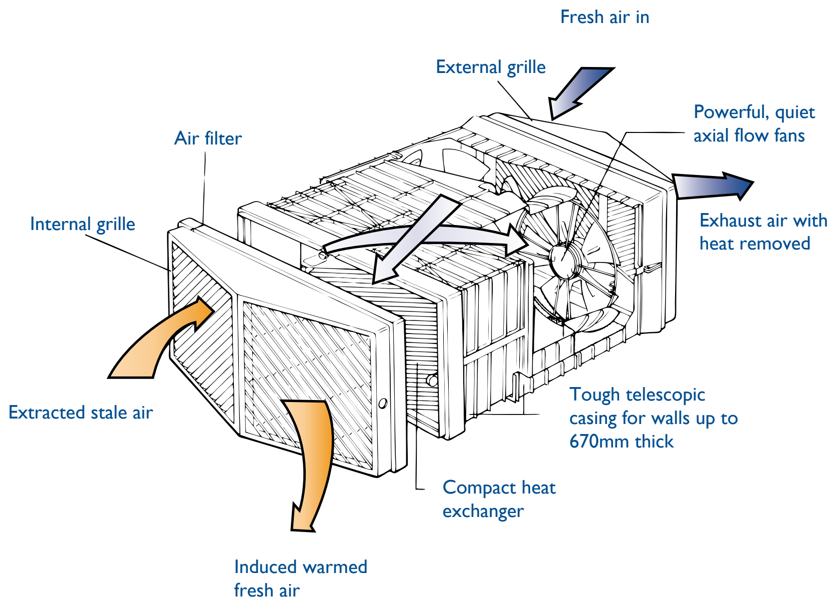

Figure 9.5 Room ventilator with heat recovery

Figure 9.6 Whole house heat recovery ventilation. Warm air from wet rooms (3) passes through a fan and over a heat exchanger (1) where it heatsincoming air delivered by another fan to living rooms and bedrooms (2).[19]

Mechanical ventilation with heat recovery (MVHR)

Whole house MVHR systems extract from wet rooms and supply to other rooms (see Figure 9.6). Typically, half an air change per hour is supplied, which is sufficient to give good air quality. Carefully designed heat exchangers can recover up to 90% of the heat in the extract air. It is important to select systems with high efficiencies because some systems only recover 60% of the heat. The other essential consideration in the selection of an MVHR unit is the fan power. If high wattage fans are used the fuel costs and emissions associated with running them continuously can outweigh the heat recovery savings. The fan power is expressed in terms of the total wattage per litre per second of extract air (W/(l/s)). Some systems use as much as 1.5 others as low as 0.5 W/(l/s).

Fan power and heat exchange efficiency are not the only issues needing careful specification. With low fan powers, it is essential that ducts are large diameter (150 mm), smooth bore and rigid, with very few bends. Flexible ducts should only be used for the final terminations to air diffusers.

It is clear that using MVHR systems in refurbishment requires a lot of careful planning. The fan unit and all the ductwork must be within the insulated airtight envelope. This is where insulating the roof at rafter level can come into its own - a warm loft space can accommodate the MVHR unit and the ductwork.

Figure 9.7 Heat recovery ventilation in a refurbishment project in Hackney (note the conglomeration of ducts and also the extensive use of sealing tape). Picture: John Willoughby.

Advanced ventilation

At Hackney, an MVHR unit has been accommodated in cupboards on the top floor of the house. A services distribution zone has been created in the middle of the house adjacent to the insulated party wall (see Figure 9.7).

19 Picture from http://www.greenfoot.ie/images/Ventilation/HouseDiagram.gif.

10. Heating

91% of British homes have central heating; 87% have gas central heating. This is in marked contrast to 1970, when only 31% of homes had central heating. Another interesting statistic is that around 40% of boilers are now combination types, or 'combis', providing heating and 'instant' hot water from the same boiler (without a hot water storage cylinder). This chapter concentrates on wet central heating systems but also mentions alternative solutions, which may prove to be viable low carbon solutions in the future.

Heating systems are defined as a 'controlled service' under Part L1B of the Building Regulations. Work on heating systems should comply with the Domestic Heating Compliance Guide and a Building Control Body should be notified of the work. This can be done by an application for approval under the Building Regulations before work starts or by a Building Notice. Alternatively the work can be 'self certified' by a 'competent person' (i.e. a registered Gas Safe, OFTEC or HETAS fitter).

Quick fixes

Regular servicing of heating equipment will ensure that high efficiencies are maintained. All central heating systems should be controlled with a time switch or programmer, thermostatic radiator valves (TRVs) and a room thermostat that switches the boiler off when the house is up to temperature. Upgrading controls is a fairly cheap and cost effective measure.

Opportunities

When a boiler breaks down, is more than 10 – 15 years old, or when the heating system is being modified, the opportunity to install an efficient 'A' rated boiler and advanced controls should be taken. The hot water system should be upgraded at the same time (see Chapter 11).

Major projects

Major refurbishment work should include a review of heating options, with the possibility of installing low carbon alternatives in combination with improved time and temperature zoning and controls.

Building Regulations	Best Practice	Advanced
Work should comply with the Domestic Heating Compliance Guide	Work should comply with the EST's Central Heating System Specification (CHeSS), or with EST guide CE185 for electric heating	Internal heat gains recovered by an MVHR system supplemented by low carbon room heaters

Table 10.1 Standards for heating systems

Heating standards

Table 10.1 presents various standards for heating systems.

Fuel choice

The choice of fuel affects running costs and carbon dioxide emissions. Figure 10.1 shows running costs and carbon dioxide emissions for the typical three bed house discussed in Chapter 2, with various heating fuels.

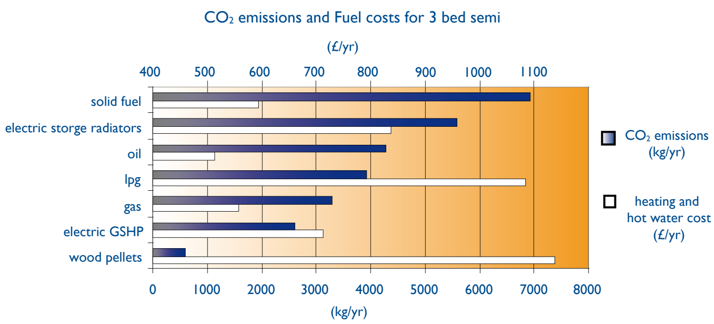

Figure 10.1 Carbon dioxide emissions and annual fuel costs for typical three-bedroom semi-detached house

The chart is arranged in order of carbon dioxide emissions. Solid fuel (anthracite) is the most polluting, while a wood pellet boiler is the least. In terms of fuel costs, oil, solid fuel and gas are cheapest, while wood pellets and LPG are the most expensive.

Gas-fired central heating

A gas-fired central heating system should have the following components:

- An 'A-rated' boiler with an efficiency of over 90%, which is sized to meet the heat load of the dwelling
- A programmer or time switch capable of controlling at least two heating periods during the day
- A room thermostat that switches the boiler off when the house has reached the desired temperature
- Thermostatic radiator valves (TRVs) to give temperature control in each room (the TRV should be omitted from the radiator in the space with the thermostat)

The system can be enhanced by using a more sophisticated programmer or programmable thermostat, which gives options for at least five different temperatures at different times of the day. But these controls also need a sophisticated user. In addition, it is often advantageous to split the dwelling into more than one control zone so that different areas can be heated to different temperatures at different times of the day.

It is always worth reassessing the heat loss of the dwelling before installing a replacement boiler. The existing boiler is likely to be oversized and very often energy efficiency measures will have reduced the load so that a smaller boiler will suffice.

Gas-fired heating systems have relatively low carbon dioxide emissions and are relatively cheap to run, but it may well be worth considering alternatives that have the potential to reduce emissions further.

Alternatives to gas central heating

The Renewable Heat Incentive

The government's Renewable Heat Incentive (RHI) is expected to be introduced in 2011. The RHI will provide a financial incentive for the local generation of heat from renewable sources, probably in the form of quarterly or annual payments based on the capacity of the installed system. Qualifying systems are expected to include solar water heating (see Chapter 11), biofuel boilers and heat pumps (see below). A minimum level of energy efficiency (of the house) is expected to be required, and assessments will be carried out before RHI funding is made available; the form of assessment has not yet been determined.

Heat pumps

Heat pumps use refrigeration technology to provide heat from a condensing unit. The evaporator side of the heat pump absorbs energy from outside the house. The evaporator typically uses outside air or the ground as the source of heat. Air source heat pumps (ASHP) are cheaper and easier to install than ground source heat pumps (GSHP) which use horizontal coils or vertical boreholes as the source. Figure 10.2 illustrates the basic components of a heat pump.

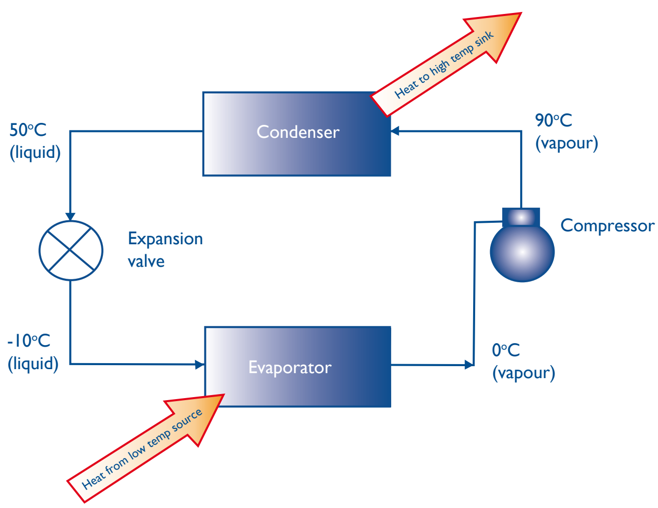

Figure 10.2 The basic components of a heat pump

The efficiency of a heat pump is denoted by its 'coefficient of performance' (CoP). This is the ratio of the amount of energy extracted from the ground or air source (in the form of heat) to the amount of energy used by the heat pump itself (in the form of electricity). Typically, the CoP of a GSHP is approximately 3.0, and the CoP of an AHSP is approximately 2.5, but well designed and installed systems can achieve CoPs of 3.5 or more. Whether the heat produced has lower carbon dioxide emissions than other forms of heating depends on the emissions from electricity production. With the current mix of fuels for electricity production, heat pumps result in slightly lower emissions than heating with gas.

All heat pumps require specialist installation. In the case of ground source heat pumps, the evaporator can be carefully installed in a deep borehole, which must be drilled by a specialist. The depth of the borehole will depend on the ground conditions. If 'ground loops' (see Figure 10.3) are used instead of a borehole, the loops must not be too tightly coiled and the trenches in which they are placed must not be too close together. This avoids freezing the surrounding ground, which significantly reduces the CoP of the heat pump.

Figure 10.3 Ground loops for ground source heat pumps

In the case of air source heat pumps, the external evaporator units (see Figure 10.4) must be adequately sized and sited away from obstacles that may obstruct air flow. If the evaporator is inadequately sized, or air flow is restricted, the unit may freeze, causing it to go into 'defrost' mode: reversing the heat pump and using electrical energy to melt the ice.

Figure 10.4 An evaporator unit for an air source heat pump. Picture: John Willoughby.

Figure 10.5 A domestic wood pellet boiler

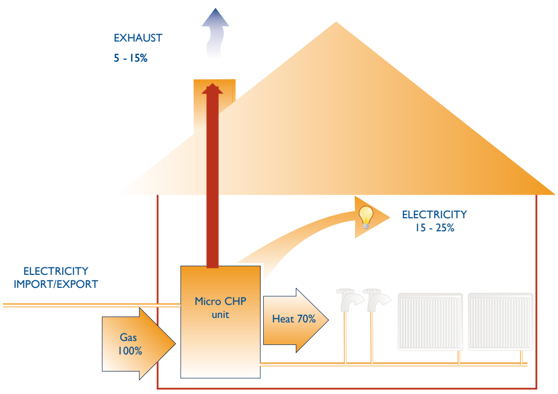

Figure 10.6 The micro-CHP concept. Diagram courtesy of EA Technology.

Figure 10.7 Domestic micro-CHP unit. Picture courtesy of Baxi Group UK.

Biomass heating

In the domestic setting, biomass heating usually involves burning wood logs or pellets in stoves or boilers. Other biomass crops include wood chip, miscanthus grass or coppiced willow, which are usually burnt in larger heating appliances, perhaps serving several dwellings. 'Processed' fuels such as wood chips and wood pellets involve slightly more carbon dioxide emissions than logs, but they are often easier to manage and store.

Provided that the tree is replaced, using wood for heating can be seen as a low carbon solution. In burning, the tree releases the same amount of carbon dioxide as it absorbed during its growth. A small amount of carbon dioxide is emitted in felling and transporting the fuel, but overall burning wood emits a fraction of the emissions released by burning fossil fuels. Where supplies are plentiful, wood heating represents a viable low carbon solution. However, it can only be a niche market since there is not enough land available to grow sufficient wood to heat all UK homes.

A wide range of wood-burning domestic appliances is available, including log-burning, chip-burning and pellet-burning boilers and stoves. Some stoves are capable of supplying hot water to radiators in other rooms and of supplying domestic hot water. Figure 10.5 shows a domestic wood pellet boiler.

Micro-CHP

A domestic combined heat and power (CHP) unit generates heat and electricity in one unit (see Figure 10.6). The heat can be used for heating the house and the electricity can be used in the house or exported to the grid. Micro-CHP units are usually based on gas-fired Sterling engines and typically produce 6 – 10 kW of heat and 1 kW of electricity. The electricity is a by-product of the heating so if micro-CHP is to be effective in reducing costs and emissions, there needs to be a large heating load for long periods of the day and long periods of the year. Thus micro-CHP units are best suited to large dwellings with high demand for hot water throughout the year. Small hotels or guesthouses are ideal situations to exploit this technology. The latest micro-CHP systems such as the one shown in Figure 10.7 are of a similar size to a conventional domestic boiler. They can be installed in kitchens, as shown in the picture, but some manufacturers suggest that utility rooms may be more suitable.

11. Hot and cold water

Domestic water use in the UK is around 150 litres per person per day. Taking water from the environment, treating it, distributing it to households, using it in the home, collecting it when it has become sewage and then treating it before discharging it back into the environment are all processes requiring energy and therefore result in carbon dioxide emissions. There is a national target to reduce water use to 130 litres per person per day by 2030. For new dwellings, the Building Regulations and the Code for Sustainable Homes set lower standards of water use, which are to be met by means of water conservation measures.

Simple measures

Regular servicing of heating equipment will ensure that high efficiencies are maintained. If the hot water system is gravity fed, then it may be possible to convert to a fully pumped system with the advantage of independent time and temperature control of hot water.

Opportunities

When a cylinder needs replacing, or is more than 10 – 15 years old, or when the heating system is being modified, the opportunity to install an efficient hot water system with good controls should be taken. The new 'high performance' hot water cylinder should be 'solar ready', i.e. have twin heat exchanger coils.

When modifications are being made to the heating system or work is being carried out on the roof, it may be a good opportunity to install solar hot water heating.

When taps or showers are being replaced, there is an opportunity to fit low flow alternatives.

Major projects

Major refurbishment work should include a review heating and hot water systems with the possibility of installing low carbon alternatives.

Hot water standards

Table 11.1 presents various standards for domestic hot water.

Building Regulations	Best Practice	Advanced
Work must comply with the Domestic Heating Compliance Guide	Work should comply with the EST's Central Heating System Specification (CHeSS) or with guide CE185 for electric heating	Use solar water heating and/or a low carbon heating source

Table 11.1 Standards for domestic hot water

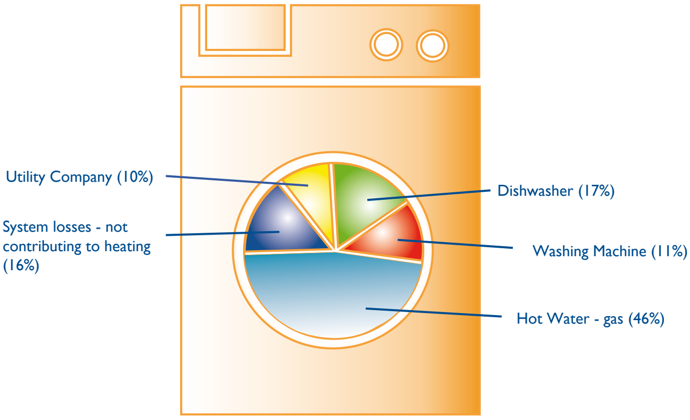

Figure 11.1 Water related carbon dioxide emissions[20]

Reducing demand

Figure 11.1 shows that the largest proportion of the carbon dioxide emissions relating to water use in the home is for heating hot water for use in the kitchen sink and bathrooms. The emissions associated with the washing machine and dishwasher are large because water in these appliances is often heated with electricity. 'Hot fill' washing machines (which use hot water from the domestic supply) are becoming increasingly difficult to obtain. 10% of the emissions are in treating, supplying mains water and disposing of waste water by the utility company.

Reducing water use in the home can be achieved by:

- Good housekeeping, including: taking showers instead of baths; taking short showers (using a shower timer); washing up with a bowl rather than under a running tap; mending leaking taps; not leaving taps running unnecessarily
- Installing low volume dual flush WC cisterns
- Fitting spray taps or aerators to taps on wash basins
- Fitting low flow showers with a maximum flow rate of six litres per minute
- Installing baths with a volume as small as is possible for its intended use

These simple measures can reduce water use by as much as a half.

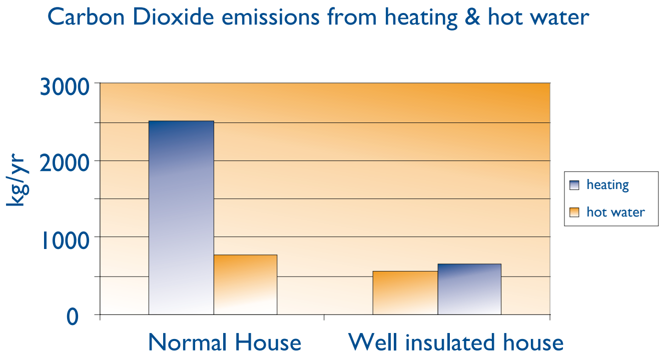

Figure 11.2 Carbon dioxide emissions from heating and hot water, for a typical 3-bedroom semi-detached house

Reducing fuel used for hot water

The main use for gas in UK houses is to provide heating and hot water. In our typical 3-bedroom semi-detached house (see Chapter2), carbon dioxide emissions from heating are much greater than those from hot water – emissions from hot water production are only 30% of the total from gas use. However, as shown in Figure 11.2, if the house is insulated to best practice standards, the emissions from hot water supply become dominant.

The importance of installing an efficient hot water system is clear; even if it is a minor heat source at present it may become the dominant thermal load in the future. The amount of hot water used can first be dramatically reduced by installing efficient appliances; then the hot water must be produced in the most efficient way possible.

Hot water is most commonly produced by either a combination boiler (supplying 'instant' hot water directly to the taps) or a regular boiler supplying a hot water storage cylinder. When using a combi boiler there is much that can be done to reduce fuel use.

- Ensure that the boiler is of a type that condenses in hot water mode; the efficiency of many combi boilers is low when producing hot water only

20 Diagram taken from 'Quantifying the energy and carbon effects of water saving', Environment Agency / Energy Saving Trust, 2009.

- Make sure the combi is positioned near to the water using appliances, particularly the shower and the kitchen sink
- Micro bore pipework serving each appliance separately can be used to reduce the 'dead leg' between the boiler and the appliance
- Keep-hot facilities on combi boilers keep the hot water heat exchanger hot so that hot water is supplied quickly when a tap is turned on. Make sure that the combi either does not have a keep hot facility or, if it does, make sure that it can be switched off. A keep-hot facility can significantly reduce the efficiency of the boiler

When using a regular boiler and cylinder fuel use can be reduced as follows:

- Make sure that the cylinder is well insulated. More insulation can be added to existing cylinders and new cylinders can be supplied with high performance foam insulation. It is important also to make sure that the pipework connected to the cylinder is insulated for at least a metre. Primary pipework between the boiler and cylinder should also be insulated
- Use a 'high performance' cylinder that contains a heat exchanger with larger surface than normal. This reduces the time taken to heat the water and may reduce boiler cycling. It gives a valuable reduction in recovery time between large draw-offs (such as baths) and helps to increase system efficiency (especially with older boilers). High performance cylinders often have improved factory-applied insulation as well
- Avoid the use of secondary hot water circulation around the building. This is sometimes included to avoid long dead legs but, because it runs continuously, it carries a large energy penalty. It is better to use cylinders local to appliances and, if there is sufficient water pressure, use micro bore pipework to each appliance

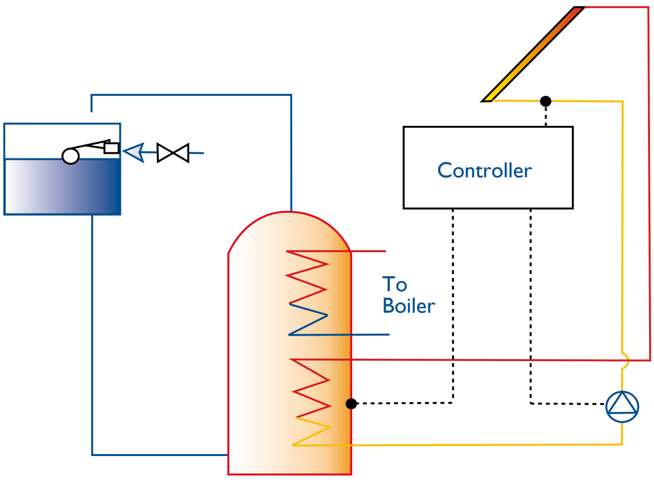

Figure 11.3 A typical solar water heating system[21]

Solar water heating

Solar hot water systems can make a significant contribution to reducing carbon dioxide emissions. In summer most of the hot water can be supplied and over the year a well designed system should reduce the emissions associated with water heating by approximately half. Solar water heating will qualify for financial support from the government's Renewable Heat Incentive (RHI) from April 2011.

Flat plate panels or evacuated tube arrays can be connected to a dedicated solar cylinder or to the lower coil of a dual coil 'combined' cylinder. Figure 11.3 shows a typical open vented system with a large combined cylinder containing an additional solar heat exchanger, usually referred to as twin-coil. Sealed solar primary systems (i.e. to collectors) are commonly used and unvented 'twin-coil' cylinders are also available. When the solar panel is hotter than the cylinder, the pump is used to deliver solar heated water. The system is thermostatically controlled, so the boiler only fires to produce hot water when the solar system has not raised the cylinder temperature to the required temperature; this will happen only rarely in summer, but more often in winter.

A good rule of thumb for solar water heating systems is to allow 1 square metre of solar collector per occupant of the house, and 40 litres of dedicated solar storage per occupant (70 litres if evacuated tube collectors are used.) Collectors work best if they are oriented to the south, but they work quite well when oriented between south-east and south-west; poor orientation may involve using a larger collector.

21 Figure 11.3 redrawn from Domestic heating by gas: boiler systems, Energy Saving Trust (CE30).

12. Electric power

Using a unit of electricity in the home produces about three times as much carbon dioxide emissions as using a unit of gas (see Table 1.1). A unit of electricity is also about four times more expensive than a unit of gas. Therefore energy saving electrical appliances and good housekeeping can make a significant impact on household fuel costs and emissions. Figure 12.1 shows that as more is done to reduce fuel used for heating, the more significant are emissions from electricity use.

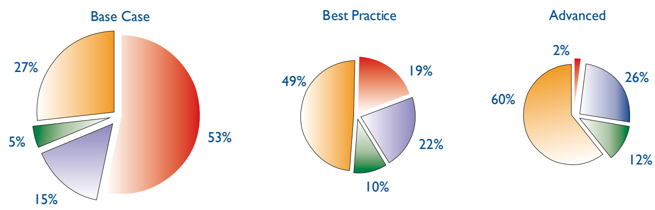

Figure 12.1 Carbon dioxide emissions by end use, for different standards of thermal performance

Simple measures

Low energy lamps can be installed at any time. They are extremely cost effective. Good housekeeping can substantially reduce electricity use.

Opportunities

When appliances are being replaced, choosing the most efficient can halve electricity use.

Major projects

Major refurbishment work should include a review of lighting and electrical appliances. Low energy lamps should be planned throughout. The position and switching of lamps should be carefully considered in relation to tasks and daylighting. It is an ideal opportunity to invest in the best possible electrical appliances.

Lights and appliances standards

Table 12.1 presents various standards for energy efficient lighting and appliances.

Building Regulations	Best Practice	Advanced
2006: Minimum number of energy efficient lamps in extensions and changes of use (1 low energy lamp per 25 m² of floorspace or per 4 fittings) 2010: work must comply with Domestic Services Compliance Guide	75% of all fixed lamps should be in dedicated low energy fittings. Low energy appliances should be specified	Low energy lamps and A++ appliances throughout

Table 12.1 Standards for energy efficient lighting and appliances

Low energy lamps

Low energy lamps are a very cost effective investment. The extra cost of the lamp is paid for many times over during its life (see Figure 12.2)

Figure 12.2 Even at a cost of £10 the compact fluorescent lamp saves seven times its cost over its life

Figure 12.3 CFLs are available in many different shapes and sizes. Picture sourced from Renovation Headquarters

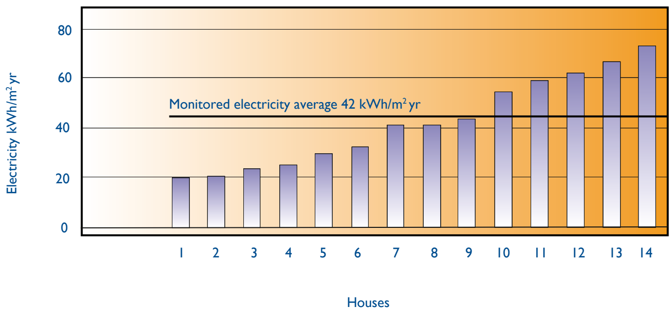

Figure 12.4 Monitored electricity use per square metre of floorspace, in similar houses

Now that 100 W and 60 W tungsten lamps are more difficult to find, the wider range of compact fluorescent lamps (CFLs) will become more readily available (see Figure 12.3). The range of light fittings is also developing to accommodate CFLs.

Luminous efficacy and colour temperature

The light output of a lamp, measured in lumens, can be compared with the power (Watts) used to run it in a measure called the 'luminous efficacy' (lumens/watt). Tungsten lamps have a poor luminous efficacy of around 12 lm/W. CFL lamps are much better at around 46 – 72 lm/W; fluorescent tubes are better again at 70 – 100 lm/W; light emitting diodes (LEDs) have an efficacy of 70 – 90 lm/W with recent claims of over 100 lm/W.

Colour temperature is important in a domestic setting: some lamps produce a very white light which is too harsh. CFLs with the 'Energy Efficiency Recommended' label have minimum efficacies and specific colour temperatures.

Domestic appliances

Energy labelling of electrical appliances has been a major success in promoting energy efficiency over the past two decades. Awareness among consumers has increased but the main success has resulted from manufacturers vying for pole position in the electrical retailers. Such has been the success that many electrical goods are now on an A++ to G scale. Consumers now need to be aware that buying an 'A-rated' appliance doesn't necessarily mean that it is the best available.

Electricity use in similar houses with different occupants can vary enormously. Figure 12.4 shows a range of over 3 to 1 in electricity use in similar houses. This suggests that there is a large potential for cutting electricity use by lifestyle changes.

Generating electricity

Electricity can be generated by photovoltaic panels (PV), CHP systems (see Chapter 10) and wind turbines.

Photovoltaics

PV panels use silicon cells (or other materials) to generate electricity from sunlight. The DC electricity produced by the PV array is converted to AC by an inverter and can then be used in the house or exported to the electricity grid. Electricity generated by domestic PV installations and exported to the grid qualifies for the 'feed-in tariff' (FIT), i.e. for payments significantly greater than the tariff the householder pays for electricity purchased from the grid.

As a general rule of thumb, a PV installation of 1 kW peak power will require an 8 m^2 array and generate approximately 750 kWh/year. PV cells are very sensitive to shading and orientation, so it is often difficult to identify sufficient well-oriented, unshaded roof (or another site adjacent to the house). To offset the electricity use in our three-bedroom semi-detached house would require a PV array with an area of about 24 m^2 costing around £15,000. However, upgrading the house to energy efficient lighting and appliances throughout would halve the electricity use and thus halve the size and cost of the required PV installation, making this a more attractive and practical improvement measure.

Wind turbines

Small wind turbines attached to individual dwellings have been heavily promoted in recent years. However, the important thing to understand about wind power is that the power output from a wind turbine is proportional to the cube of the wind speed. So a halving of wind speed will result in a reduction of output by a factor of eight. A typical 'micro' wind turbine might be rated at 1600 kWh/yr at an average wind speed of 12 m/s; however, the average wind speed in most of England is nearer 4 m/s, and in urban areas it is often less than 3 m/s. Halving the average wind speed to 6 m/s reduces the output of the turbine to 200 kWh/yr; halving it again to 3 m/s reduces the output to 25 kWh/yr (worth about £12). This illustrates why small, building-mounted wind turbines are not a cost effective improvement measure and are very unlikely to significantly offset the electricity demand of our homes.

However, large wind turbines on windy sites are an extremely cost effective way of producing low carbon electricity. Linking the house to a community wind turbine or to an off-site wind farm might be a very good way to reduce carbon emissions.

Green tariffs

Green tariffs offer the householder a convenient way of supporting suppliers of green electricity. However, not all green tariffs are the same. Some suppliers use only electricity from wind turbines and other zero carbon sources, while other green tariffs use the premium to augment development funds for green technologies. Care should be taken when selecting a green tariff, to ensure that the electricity to be purchased really will come from a low or zero carbon source. The energy regulator, Ofgem, has recently launched an independent certification scheme to make green tariffs more transparent and to provide consumers with confidence that their green tariff is delivering positive environmental outcomes (see www.greenenergyscheme.org).

13. Other issues

If you make and implement a low carbon improvement plan for your home, there are some related issues that deserve consideration. These include the way the improved house is used and other aspects of the lifestyles of the occupants.

Using a low carbon home efficiently

There is little point in investing in expensive low carbon improvement measures if the house is not used in an efficient way. The intended carbon dioxide emissions savings will not be realised. Living in a low carbon home includes 'good housekeeping' as well as using heating and hot water systems and domestic appliances efficiently. For example:

- Turning off lights in rooms that are unoccupied or where there is enough daylight
- Not leaving appliances such as televisions, computers and printers switched on, even in 'stand by' mode
- Not leaving chargers for mobile and cordless telephones, games consoles, etc, plugged in when they are not in use
- Ensuring that appliances such as washing machines have 'hot fill' connections and are not run part-loaded
- Reducing the duration of showers (perhaps by using a shower timer)
- Avoiding leaving taps running when washing up, shaving or cleaning teeth
- Setting the heating programmer to ensure that the heating is only on when it is needed
- Lowering the heating thermostat setting by one or two degrees and wearing warmer clothes

Modifying behaviour in this way may involve a culture change for some members of the household – particularly older persons who have become set in their ways and young people whose enthusiasms may lie elsewhere.

Display energy meters

It may be helpful to have a 'display energy meter' installed, to inform members of the household how much energy they are using. This is a device that is connected wirelessly to the incoming electricity supply and displays the amount of electricity that is being used in real time, as well as the amount and cost of electricity used to date. There are also display energy meters that monitor gas use, and some also display carbon dioxide emissions.

Beyond the home

UK carbon dioxide emissions amount to approximately 10 tonnes per person per year, approximately one quarter of which are associated with energy use in the home. To set these emissions in context, Table 13.1 sets out typical levels of carbon dioxide emissions for an average family of four (two adults and two children).

These figures suggest that other aspects of our lives can become 'low carbon' to complement our low carbon homes (and indeed that having a low carbon home would be a little pointless without them). For example:

- Using a car that is as energy efficient as possible and driving it in an economical manner
- Reducing car mileage by walking, cycling, or taking public transport instead and by making multi-purpose trips
- Reducing or eliminating flying and taking holidays in places that are accessible without the need to fly
- Growing some of our own food, obtaining other food from local sources and avoiding foods that have been imported from distant places
- Eating seasonal foods (fruits, vegetables and salad) as far as possible and avoiding foods that have been highly processed, chilled or frozen for long periods, or excessively packaged
- Reducing waste, reusing it wherever possible, then recycling as much as possible, to provide fuel (in some areas) and to minimise the carbon dioxide emissions associated with manufacturing new products

These changes in behaviour are likely to become much more commonplace, in the coming years, alongside our low carbon homes, as our communities begin to meet the twin challenges of fossil fuel depletion and climate change.

Activity	Carbon Dioxide Emissions (tonnes/yr)
Home energy use	**6**
Family car (average size and mileage)	**4**
Second car (smaller, lower mileage)	**2**
Mediterranean holiday (by air)	**4**
Food (cultivation, harvesting, processing and distribution)	**7**

Table 13.1 Annual carbon dioxide emissions for a typical household

Appendices

Case Study 1: **Baxi Group**
Every Street, Whitefield

Case Study 2: **Hanson**
Pagefield Renewal Area:
Upper St Stephen's Street, Wigan

Case Study 3: **Kingspan**
Low Energy Victorian House

Case Study 4: **Knauf**
Low energy whole house refurbishment in Doncaster

Case Study 5: **Lafarge**
Greening the Box

Case Study 6: **Rockwool Limited**
Edward Woods Estate,
White City, London

Case Study 7: **SIG Sustainable Solutions**
The E.ON 2016 Low Carbon house

Case Study 8: **Travis Perkins and E.ON**
Adopting a whole house approach to energy efficiency

Case Study 9: **Worcester/Wolseley**
Energy Homes

Case study 1

Baxi Group
Every Street, Whitefield

Refurbishment of 12 Victorian terrace properties including a number of two-into-one conversions and the installation of solar thermal technology.

About the project:

The project targeted 12 properties in two terraces that were in a very poor state; some had wood rot, which needed immediate treatment. Most properties had no central heating and the homes were smaller than the national average.

To address this, three two-into-one conversations were carried out, making good sized, four-bedroom homes, one with en-suite bathroom. There are now eight modern, spacious and eco-friendly homes, which still have their distinctive external appearance.

The following measures were installed:

Hot water:

A solar thermal hot water system was specified for the project. Potterton Solar in-roof flat plate collector panels were installed on the south-facing roofs in conjunction with Santon Premier Plus twin coil solar hot water storage cylinders.

Potterton Solar can generate up to 100% of a household's hot water during summer and around 55% annually, resulting in up to a 55% reduction in hot water costs. CO_2 emissions can be reduced by around 400kg per square metre of collector panel.

Heating:

Central heating and additional hot water are provided by Potterton Promax HE Plus heat-only boilers.

Deceptively small, but very powerful, the Potterton Promax HE Plus is a SEDBUK Band 'A' wall mounted boiler, available in a choice of outputs (15kW, 24kW and 30kW) to suit different sizes of home. According to heat demand, the boiler is capable of full modulation within a range of 9.14kW to 30kW.

Additional measures:

Roof insulation and external render were added to the properties. Lime mortar re-pointing was carried out in keeping with the requirements of the conservation area.

Sash windows and traditional four-panelled wood front doors have been installed along with light pipes to channel light into darker areas of the properties.

Project successes:

The integration of renewable technologies and heritage buildings was achieved seamlessly. Pendle Borough Council's Senior Regeneration Officer commented that the area has been "completely transformed".

Project partners:

Owner:	Pendle Borough Council
Equipment provider:	Baxi Group
Contractors:	Thornton Contractors
Project managers:	Liberata

Objectives:

The aim of the project was to help meet the town's housing needs whilst achieving long-term sustainability and satisfying the heritage requirements of a conservation area.

What was done:

Installation of solar thermal hot water systems and new 'A' rated boilers.

Properties after works

Rear of properties prior to works

Properties after works

The houses have been designed and developed to meet 'Lifetime Homes Standard' wherever possible.

The renewable technology installed meets the needs of all the properties, providing low carbon hot water which will reduce fuel bills and cut emissions.

Challenges faced:

The properties have been transformed as part of a regeneration programme. However, the limited flexibility of the housing type, i.e. with no off street parking, no garden and no garages, may restrict the market appeal of the properties.

Lessons learned:

Although often seen as a silver bullet to reduce carbon dioxide emissions, renewables are not always appropriate. For this project however, renewable technology has been chosen as the best carbon cutting solution for the individual application.

Potential for replication:

There is huge potential to replicate this type of project in terraced properties across the country.

Pendle Borough Council has stated that it hopes to further develop this approach into other terraced blocks and "continue to incorporate energy conservation technologies whilst maintaining the area's heritage."

Costs and funding:

The Housing Market Renewal work on Every Street has cost £860,000.

The project was funded by Elevate (the regeneration agency for Pennine Lancashire), the Housing Market Renewal programme, the Homes and Communities Agency and the Heritage Lottery Fund.

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Case study 2

Hanson

Pagefield Renewal Area: Upper St Stephen's Street, Wigan

This project involved re-skinning the external elevation of existing Victorian terraces to extend the life of the buildings and thereby retain the existing street pattern.

About the project:

The following work was undertaken on the properties:

Walls were re-skinned in brickwork with a new cavity created and filled with 50mm dritherm. Epoxy resin ties were embedded in the existing brickwork, to which new ties were linked as the external skin progressed.

The roof was re-slated with new battens on a breather membrane and 250mm fibreglass insulation was fitted to the ceiling of the room below.

Vertical sliding sash windows, double glazed with Pilkington 'K' glass, and composite foam-filled external doors were fitted.

Minimising disruption:

All of the work was carried out with the occupants in situ. A bay-front rather than a flat-front terrace means that the house is open for a day or two whilst the bay is rebuilt. Residents were offered the chance to de-camp but none took up the offer.

Project successes:

There was a high satisfaction rate amongst residents.

The project was completed in good time. The work was carried out in small packets (four houses at a time) which took twelve weeks in total.

Challenges faced:

Maintaining power to the houses throughout the works was occasionally problematic and there were unforeseen foundation problems in isolated incidents.

The contractors also faced occasional difficulty re-skinning walls where the header went through both skins.

Lessons learned:

It is practical and sensible to renovate this type of house. Renovation encourages residents to have confidence in the area and by involving other agencies, local police for example, issues such as crime prevention can be addressed. Reclaiming wasteland and forming new open spaces also improves quality of life for residents.

Potential for replication:

This is the fourth regeneration area in Wigan where this approach to upgrading the housing stock has been successful, and a fifth is planned. There is no reason why this approach should not be replicated in other areas.

Project partners:

Owner:	A mixture of owner-occupiers and tenants to private and social landlords
Architects and engineers:	Wigan Metropolitan Borough Council (MBC)
Contractors:	A number of local companies, all members of the Registered Contractors Scheme run by Wigan MBC

Objectives:

To show that it is possible to upgrade the existing housing stock to achieve the requirements of Part L of the Building Regulations and to prolong the life of the building.

To show that this can be achieved economically even when the market price of the upgraded building is low.

What was done:

Re-skinning of external walls, re-slating of roof, insulation measures and new external doors and windows.

What was achieved:

Existing properties upgraded to Part L insulation standards.

Properties during works

Gidlow Lane properties after works

St Stephen's Street properties after works

The question of scale is important. It seems that part of the success of this approach is upgrading houses in small packages and working away continuously. A blanket approach may gain from economy of scale but large numbers of homeowners would need to be moved causing major disruption.

Costs and funding:

Each unit cost £20,000, 90% of which was available as a grant from Wigan MBC with the remaining 10% contributed by the householder. Householders were able to obtain the 10% as a loan with five-year pay back.

The average cost of a house in the area is around £75,000 (prior to upgrade).

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Case study 3

Kingspan
Low Energy Victorian House

Complete renovation of a dilapidated 1850s semi-detached solid-walled property in a conservation area in Camden, North London.

About the project:

The following measures were installed in the property:

Insulation

Premium performance Kingspan Kooltherm insulation was used throughout.

		U value
Most walls	102.5mm Kingspan Kooltherm K18 insulated plasterboard on battens	0.19
Other walls	Insulated plasterboard of 37.5mm or thicker	0.43
Pitched roof	Two layers of 75mm Kingspan Kooltherm K7 pitched roof board and nilvent breathable membrane	0.15
Basement floor	50mm Kingspan Kooltherm K3 floor board on slab with screed above	0.23
Windows	Double-glazed, argon-filled	1.50

All insulation was taped and then skimmed where applicable. Penetrations of the envelope were either avoided completely through good works programming, or kept to a minimum and then sealed.

Post-refurbishment tests indicated a 78% improvement in airtightness from 30 m3/hr/m^2 to 6.5m3/hr/m^2.

Thermal bridging was minimised through the use of a continuous layer of insulation on the internal walls, by drawing insulation between the floors along the external perimeter, and using insulation upstands and flexible sealant or expanding foam at junctions between wall and floor to ensure a continuous layer.

Heating:

A Worcester Bosch Greenstar 12i condensing gas boiler was installed with programmer, roomstat and TRV's feeding 'Jaga' radiators.

Hot water:

A Worcester Green Skies 250 litre hot water cylinder with TDS10 controller was installed.

Two Worcester Green Skies solar hot water collectors with a total aperture of 4.5m^2 were installed on the pitched roof.

Electric power:

A SunnyBoy photovoltaic SB 3000 system with SunDog photovoltaic roof panels was installed.

Project partners:

Owner:	London Borough of Camden
Architects and engineers:	Landers and Associates
Energy consultants:	Kingspan Insulation, UCL (Bartlett School)
Contractors:	Lengard
Other advisors:	Urban Buzz, Sustainable Energy Academy, Green Homes Concierge Service

Objectives:

- To reduce carbon emissions by approximately 80%
- To improve air-tightness
- To make the most use of existing space
- To encourage and learn from on-site best practice
- To convert the building back to a single dwelling for social housing

What was done:

Internal wall, pitched roof and basement floor insulation, double glazing, replacement of boiler and hot water cylinder and installation of solar hot water and solar photovoltaics.

What was achieved:

Energy rating increased from F to B
65% reduction in CO_2 emissions
72% reduction in energy consumption from 84,000kWh to 23,400kWh per year

Roof insulation: K7 Pitched Roof Board

Wall insulation: K18 Insulated Plasterboard

Project successes:

The fabric of the building was improved significantly. If the house was a new build, it would have achieved a Code for Sustainable Homes Level 4 rating for Energy and CO_2.

A 55% to 70% reduction in actual gas consumption is predicted.

Challenges faced:

Balancing the needs of heritage conservation on the one hand with energy conservation on the other.

The ability of a non-English speaking householder to understand and manage the complicated heating and solar hot water controls.

Lessons learned:

Cooperation within the project team and programming of works to avoid one trade 'undoing' the work of another are vital from the start.

Controls for heating and solar PV need to be simple to understand and easy for plumbers and maintenance services to mend.

Potential for replication:

Internal wall insulation would be very easy to replicate across the housing stock, particularly where the property owner is already carrying out works such as re-wiring, re-roofing, re-rendering or even just fitting a new kitchen or bathroom or touching up internal finishes.

The application of insulation between floors at the wall junction may be more difficult to achieve unless the property owner is carrying out a full refurbishment.

Costs and funding:

The work (excluding works to remedy structural problems) cost approximately £75,000, of which:

Photovoltaics	£25,000
Solar Thermal	£8,000
Double glazing	£24,000
Insulation	£16,000
Leakage Reduction	£2,000

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Case study 4

Knauf Insulation

Low energy whole house refurbishment in Doncaster

A project to internally insulate an 1890s mid-terrace property to current energy standards.

About the project:

The attractive brick frontage made the property less suitable for external wall insulation but ideal for internal wall insulation. The project used the innovative Knauf Insulation EcoStud as a replacement for the more traditional timber stud framing as well as providing low energy lighting throughout and adding a new tightly fitting UPVC door to the top of the cellar.

Insulation

	U values	
Element	**Before**	**After**
Walls	2.0	0.35
Loft	0.43	0.13
Floor	0.71	0.21

External walls were insulated with 75mm EcoStud and EcoBatt and 12.5mm vapour check plasterboard.

27mm polyfoam linerboard was fitted around all window and door reveals and party wall junctions to remove the thermal bridges.

The existing 100mm of loft insulation was topped up with an additional 200mm.

The timber floor of the living room was insulated from below with 150mm of glass mineral wool, friction fitted between the floor joists. Insulation was also fitted between the floor joists and the external wall to ensure continuity of insulation between the two levels to remove the thermal bridges.

Glasswool EcoBatts were friction fitted between the EcoStuds to ensure intimate contact between the external wall and the plasterboard to prevent unwanted air movement and draughts through the system. All junctions with other elements were well sealed with Knauf Multi Purpose Sealant. Particular attention was paid to the joints between the EcoStud system and door and window frames and around electric sockets and plumbing service penetrations.

Previous methods of internal wall insulation, with a timber or metal frame to support the insulation and plasterboard, have always had to contend with the issue of thermal bridging (when the continuity of the insulation is broken causing the wall at that point to become much cooler than the insulated area). The EcoStud system consists of a thermally engineered insulated stud which avoids this problem.

Ensuring quality:

The builder was trained to install the EcoStud and ensure the EcoBatts were fitted correctly.

Project partners:

Extra components were provided by Knauf Drywall.

Work was completed by local builder who was trained and supervised by the Knauf Insulation team.

Objectives:

The project aimed to install systems that could be fitted by any competent builder to achieve an effective and efficient low energy refurbishment at a modest marginal cost over a normal refurbishment.

What was done:

Internal wall, loft and floor insulation and draught proofing.

What was achieved:

- The building's energy rating improved from 63(D) to 82(B)
- CO_2 emissions were reduced from 3.8 tonnes/yr to 1.8 tonnes/yr
- Fuel use was reduced by around 54% from 22,875 kWh/yr to 10,575 kWh/yr
- Annual fuel costs were reduced by 40% from £689 to £378

Kitchen during works

Completed kitchen

Minimising disruption:

During the project the building was unoccupied so disruption was not an issue. Other homeowners who have previously had the EcoStud system installed whilst they were still living in the property have stated that the refurbishment was quick and simple and resulted in minimal disruption.

Project successes:

The EcoStud proved quick and easy to install against the external wall using the recommended masonry fixings and universal wall plugs.

The EcoBatts friction fitted well between the centres of the EcoStuds to give complete coverage of insulation.

The finish of the EcoStud easily accepted plasterboard and drywall screws and the Polyfoam linerboard was easily fitted around the door and window reveals and at party wall junctions.

Challenges faced:

Considering the nature and extent of the refurbishment there were very few problems. The builder was unaccustomed to installing the EcoStud but was more than competent after on-site training.

Potential for replication:

The system is readily replicable in similar homes across the UK.

Costs and funding:

The cost of the EcoStud System installation and the insulation added to the suspended floor and loft area was £2,800, excluding one off training and instrumentation. This was the marginal cost over and above the work that was required to bring the property up to a decent standard. The reduction in energy bills results in the installation costs being recouped after approximately seven years based on current energy prices.

The project was funded as part of Knauf Insulation's ongoing Research and Development for in-situ testing of product installation and monitoring of in-situ product performance. The results of this monitoring show the levels of humidity at the wall interface to be as predicted in the Knauf Insulation architectural calculation suite.

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Case study 5

Lafarge

Greening The Box

Demonstrating extremely low carbon retrofit through a whole house approach including energy efficiency, passive solar design and household-scale renewable energy.

About the project:

	U-values	
Element	**Before**	**After**
Wall	1.84	0.28
Roof	4.3	0.13
Floor	0.97	0.17
Dwelling average	2.24	0.37

The following measures were installed:

Insulation:

The insulation of the building fabric was improved, and windows and doors were modified to increase solar gains and reduce heat losses. A super insulated in-situ concrete ground floor was introduced, while existing masonry walls had plasterboard, wallpaper and gypsum removed to increase those elements' active thermal mass.

The insulation detail continues to the inside of the perimeter of all openings and into the roof eaves, providing an almost continuously insulated building fabric.

An air pressure test was undertaken at completion with all trickle vents, flues etc. sealed with a result of $5.30 m^3/hr\ m^2/50pa$

Ventilation:

Designing out the requirement for mechanical air extraction in the wet rooms, contributes to a reduction in the overall energy demand of the building. Passive stack ventilators have been installed in the kitchen, utility room, and bathroom using 150 mm diameter vertical ducting terminating above the roof line. A passive cross ventilation regime is possible by virtue of the building layout which is effectively single room deep. This enables the residents to induce passive cross-ventilation from the south side to the north side by opening windows, doors or vents.

Heating:

A thermostatically controlled, low-grade electric underfloor back-up heating system is embedded in the concrete ground floor slab. In the absence of central heating, there are no pipe-work, radiators, switch-gear, boilers or flues. In case of increases in electricity prices or future shortages, a wood burner has been fitted in the living room.

Hot water:

A flat-plate solar water heating collector ($5.2m^2$) was placed on the south-facing roof, supplementing water heating and reducing electricity demand. It is estimated that annually 1,433kWh of water heating energy at a cost of £229.28 could be saved alongside a reduction in carbon dioxide emissions of 803kg.

Project partners:

Owner:	Wherry Housing Association
Architects:	SEArch (Sustainable Ecological Architecture Limited)
Engineers:	Scott Wilson
Contractors:	John Youngs
Project Managers:	Davis Langdon Everest
Building Control:	SAP: South Holland District Council
Solar PV Consultants:	South Facing
Underfloor Heating:	Underfloor Heating UK
Concrete:	Lafarge

Objectives:

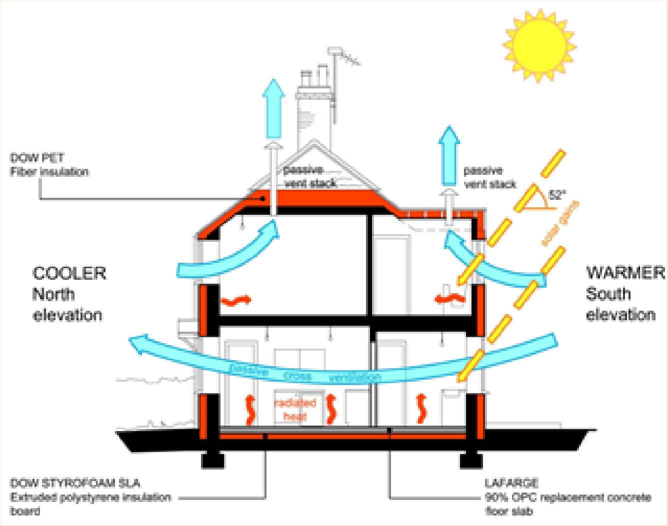
This project was designed to demonstrate that reducing carbon dioxide emissions to near zero in the UK's existing buildings can be achieved with passive solar design strategies combined with effective thermal mass.

What was done

Fabric insulation overhaul, designing out mechanical ventilation, and installing under-floor heating, solar water heating and solar photovoltaics.

What was achieved (predicted):

- SAP increased from 30 (F) to 86 (B)
- CO_2 emissions cut by 93% from 7.65 tCO_2 to 0.53 tCO_2 per year
- Energy consumption cut by 81% from 48,960 kWh to 9,272 kWh per year
- Fuel bills cut by 76% from £706 to £166



Natural ventilation

Rear elevation before and after works

Electric power:

A total area of 7.2m^2 of monochrystaline PV roof panels were fitted to the south roof slope, rated at 1.26kW peak. They are predicted to deliver 1,050kWh of electricity per year displacing 590kg of carbon dioxide emissions annually.

Minimising disruption:

The residents lived in a neighbouring property prior to and during the period when works were undertaken.

Project successes:

The majority of the refurbishment techniques used were familiar to the contractor and required no more additional time on the part of the design team in terms of instruction.

Challenges faced:

The maintenance team had little experience with some of the products used. There were challenges around post-construction attendance to the solar water heating and education of residents around a rainwater harvesting system that had also been installed.

Lessons learned:

The choice of low carbon and renewable technologies should take into account the need for service and maintenance which may be carried out by people who were not involved with the refurbishment work.

Potential for replication:

There is strong potential for modifying windows and doors with an emphasis on maximising solar gains.

Externally applied insulation is limited to non-listed buildings but is still widely applicable. Introduction of active thermal mass with the benefit of insulation is the key to maintaining stable internal ambient temperatures thereby reducing heating load requirements.

Most of these techniques can be implemented while residents remain in occupation but they are still nonetheless disruptive. The application of external insulation and the subsequent re-cladding changes a building's character and style, often improving the street scene and building aesthetics.

Costs and funding:

Grenning-The-Box formed part of a larger refurbishment of the property which was in a poor condition. The overall project cost was £104,000; the energy-related elements cost £48,000.

The Project was co-funded by Broadland District Council and Wherry Housing Association.

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Case study 6

Rockwool Limited

Edward Woods Estate, White City, London

A comprehensive low carbon refurbishment of a 1960s residential development. The scheme comprises of the refurbishment of three 24 storey towers.

About the project:

The £12.2 million refurbishment of the Edward Woods Estate near Shepherds Bush is intended to extend the life of the towers through comprehensive repair works as well as undertaking a thorough thermal and visual upgrade. In addition, the scheme establishes a flagship for building-integrated renewable technologies within the Borough. The project will see all of the tower blocks given a combination of rendered insulation and cladding panels that will smarten up the estate and improve insulation – lowering residents' heating bills.

Residents have been involved in the scheme from the start, with representatives from each block working with the design consultants, using their local knowledge to help steer the proposals for the benefit of all who live there.

The following work is to be undertaken:

The existing facing bricks on the gable ends will be stripped away because of deterioration and replaced with a light weight steel frame filled with 100mm Flexi between studs and 50mm Flexi behind in the original cavity. A cement particle board braces the frame to create an even substrate, on which a 90mm thick Rockshield insulation system will be externally applied to achieve a U-value of 0.18 W/m²K, nine times better than the existing make-up.

The principle south-facing gable of each tower block will receive a 318-panel photovoltaic rainscreen system, spanning from the 22nd floor to the 4th floor to provide around 82,000 kWh of solar generated electricity annually.

The east and west elevations, which include a 75 mm cavity in the window panels, will be blown with HP EnergySaver cavity wall insulation and then externally clad with Rockpanel.

On top of the 24 storey blocks, new build penthouse flats will be constructed incorporating lightweight steel frames with 300mm Flexi insulation, faced with Rockpanel wood finish cladding to achieve a U-value of around 0.15 W/m²K. DuoRock flat roof insulation will be included in the roof of these penthouses.

Finally, two 6kW Proven wind turbines are to be mounted on top of the stair towers on each block, providing in the region of 60,000 kWh annually across all three towers

Project partners:

Owner:	Hammersmith and Fulham Homes
Architects:	ECD Architects
Insulation:	Rockwool Limited and Rockwool Rockpanel
Main Contractors:	The Breyer Group

Objectives:

To deliver a strategy of energy efficiency and microgeneration, inspired by the London Plan mantra of "be lean, be clean, be green".

What was done:

Installation of a number of thermal insulation systems to ensure energy efficiency with a combination of photovoltaic and wind turbine energy generation facilities.

Images: Images: Hectic Electric.

Project objectives

The project has a number of key objectives:

- to extend the life of the buildings for another 40 years
- to improve SAP ratings and improve thermal comfort for residents
- to reduce fuel poverty concerns for many residents
- to improve the appearance of the towers in line with the wider regeneration of the area
- to establish an exemplar of building-integrated renewable technologies

Challenges faced

Constructing new flats on the top floor of a tower block presents a number of logistical challenges, as does removing facing bricks from 24 storeys! Even scaffolding to this height presents its own unique problems. The concept of dual turbines on top of an existing residential tower has never been done before and requires the support of a wide range of authorities including local Councillors, NATS, the MOD, the planning authority and the local environmental health teams. Proving that the turbines will not unduly impact on the local environment, particularly in terms of noise and vibration is still proving a particular challenge. Due to extensive and ongoing consultation resident support has been strong from the outset.

Potential for replication

In order for the UK to meet its future carbon reduction commitments, the measures undertaken within this project will have to become far more commonplace. The greater use of insulation over cladding (external wall insulation) and microgeneration technologies will play an important part in meeting these carbon objectives in the existing building stock.

Costs and funding.

The core of the project funding comes from H&F Homes' regeneration budget but this has been supplemented by the exemplar nature of the scheme through a substantial grant from the London Development Agency's Targeted Development Stream and CESP funding for the carbon reduction measures, obtained via British Gas. It was originally hoped to secure Low Carbon Buildings Programme Phase 2 funding for the renewable components but the timescales did not suit so now an alternative capital finance approach is being sought based on potential revenue from the new feed-in tariff scheme. In addition, it is hoped that revenue from the market sale of the 12 new penthouse flats will feed back into the project budget, with further income derived from the conversion of the ground storey into office space for the Borough's Community Liaison department.

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Case study 7

SIG Sustainable Solutions

The E.ON 2016 Low Carbon House

Challenge faced:

How to improve existing housing stock with practical retro-fit sustainable improvements is one of the biggest challenges the construction sector faces.

About the project

The E.ON 2016 Low Carbon House project will provide a research facility to assess current and near-market retrofit construction material technologies to upgrade existing houses.

The project baseline house is a 1930s style semi detached house of approximately 110m². It comprises two ground floor living rooms, a pantry, coal store and kitchen, with three bedrooms and bathroom upstairs.

The loft space is utilised as a research office with access provided through a full height 'service zone' to the party wall side of the house. The service zone simulates the performance of an adjacent property and contains monitoring equipment.

The three year research project will investigate how a typical home can be upgraded, using the latest high quality sustainable building products to reduce carbon emissions. It will show how existing housing may be brought into line with the carbon neutral status equivalent to code level 6 which the Government is seeking for all new homes by 2016.

The 1930s build

The house was designed as closely as possible to the standards of the day. A number of problems had to be overcome which included sourcing building products manufactured to a 1930's specifications.

Energy assessments

Prior to the upgrades the property had a SAP rating of 9 (Band G) and EPC of 19 (Band G)

Initial upgrades ranged from insulation, draft proofing and lighting and future improvements which are likely to include rain and grey water harvesting, as well as heating and domestic power generation. SIG Sustainable Solutions provided all the construction products required to significantly improve the energy efficiency of the 1930s House.

It is occupied as a normal domestic dwelling, with researchers subjecting the family to a 'big brother' style monitoring. More than 100 sensors built into the walls of the house record how much power and water is consumed together with its internal temperature and humidity. The latest tracking devices monitored the family's movement and using thermal imaging, researchers can ascertain how much energy the property is losing.

The following measures were installed:

The carbon and energy savings are sourced from "Explanatory Memorandum To The Electricity and Gas (Carbon Emissions Reduction) Order" published by Defra.

Project partners:

University of Nottingham, E.ON & SIG Sustainable Solutions

Owner:	University of Nottingham
Architects:	Marsh Grochowski
Construction Consultants	GASKELL
Contractors:	Miller Patterson Energy Management

Objectives:

The 2016 low carbon house project is about making thousands of existing homes better. Enabling existing housing stock to be brought into line with the carbon neutral status equivalent to code level 6 which the Government is seeking for all new homes by 2016.

What was done:

Construction of a 1930's style property, to the building specification outlined for the time. A three year research project will investigate how a typical home can be effectively upgraded.

What was achieved:

Successful build and occupation of an 1930's property to the build specification. Initial success in basic primary rudimentary upgrade

Insulation – Cavity			
Product	Knauf Supafil 40	**Cost**	£360 (£150 with grant)
Description	A loose, glass mineral wool insulation manufacturer quoted U-value is 0.5		
Reasons for Selection	The material was chosen as it commonly used for cavity wall insulation.		
Benefits	Net savings: Energy 3,012 kWh/yr and Carbon Dioxide 634.36kgCO_2/yr. Gross savings: Energy 3.544 kWh/yr and Carbon Dioxide 746.31 kgCO_2/yr		
Insulation – Roof			
Product	Isover Spacesaver	**Cost**	£325 (£180 with grant)
Description	A rolled glass mineral wool insulation product commonly available.		
Reasons for Selection	Many homes are likely to have roofs that would be insulated with this material.		
Benefits	Net savings: Energy 1,489 kWh/yr and Carbon Dioxide 313.36kgCO_2/yr Gross savings: Energy 1,752 kWh/yr and Carbon Dioxide 368.66kgCO_2/yr		
Glazing			
Product	Pilkington plain glass and Stipolyte	**Cost**	£325 (£180 with grant)
Description	All single glazing in the windows and external doors were replaced with 24mm argon filled double glazed units.		
Reasons for Selection	Timber frames provided the opportunity to upgrade the units to double glazing later.		
Benefits	Net savings: Energy 389 kWh/yr and Carbon Dioxide 82.12kgCO_2/yr Gross savings: Energy 458 kWh/yr and Carbon Dioxide 96.62kgCO_2/yr		
Draught Proofing			
Product	GTi P.A.L	**Cost**	£300
Description	An internally applied perimeter seal. Draft proofing was achieved without the involvement of building pressurisation.		
Reasons for Selection	Supplied by E. ON, it is a cost effective, easy to install product, comparable and equal to other products on the market.		
Benefits	Net savings: Energy 631 kWh/yr and Carbon Dioxide 132.81kgCO_2/yr Gross savings: Energy 743 kWh/yr and Carbon Dioxide 156.25kgCO_2/yr		
Chimney			
Product	Chimney balloon	**Cost**	£100 (4 units)
Description	An inflatable damper used to seal residential chimney flues.		
Reasons for Selection	A low cost item that reduces heat losses.		
Benefits	The heat losses from the chimney are significant and are a major part of the project's investigation. Under test.		
Lighting			
Product	Phillips / Genie E Saver	**Cost**	£25
Description	Low energy light bulb. The 18W bulb is equivalent to a power output of 100W. In total 15 bulbs were replaced.		
Reasons for Selection	The bulbs are a product offered by E.ON and considered appropriate.		
Benefits	By replacing every light fitting in the home with a low energy bulb the average family could save upto £45 a year.		

For more information, contact:

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For more information
A video of the project is viewable online at:
www.sigss.co.uk

Phased developments. Phase 2. September 2009 to January 2011

Upgrades of the property include:

- External wall insulation
- Whole house heat recovery
- Low flush WC
- Magic taps
- Water butt
- Cycle store
- Ground floor insulation

Phase 3 summer 2011

Further improvements and a third phase of occupancy. A number of factors will be influential in the choice of improvements for this third phase, based on the performance of the upgrades in phase 2 and new solutions available in the market at that time.

Case study 8

Travis Perkins and E.ON

Adopting a whole house approach to energy efficiency

A trial installation of a whole house approach including external wall insulation, boiler change, draught proofing and loft insulation, to the guidelines provided in the Community Energy Saving Programme.

About the project:

A suitable solid wall dwelling was identified and the following measures were installed:

Insulation:

External wall insulation was applied; a 50 mm Phenolic insulation board was used with an acrylic render finish. A U-value of 0.35 W/m^2K was achieved. The loft was insulated with a full 270 mm Rockwool quilt. Draught proofing was installed to wooden doors and the loft hatch.

Heating:

EON Property Services removed a G rated gas-fired central heating boiler, and an efficient SEDBUK A-rated combination boiler was installed in its place.

Ensuring quality:

All external wall insulation installers were trained by the manufacturer prior to the installation. The manufacturer also sent out a technical manager to check the works at all stages to ensure the system was being installed to the required standards (INCA accreditation received).

The gas appliance was fitted by an EON Property Services Gas Safe registered installer.

Technical monitoring equipment will shortly be installed to monitor fuel consumption.

Minimising disruption:

The works were fairly disruptive to the homeowner, with scaffolding erected around the property for twelve working days and limited access to outside areas during operational hours to ensure Health and Safety were not compromised.

To minimise disruption, all works were explained in advance during a series of visits from an EON Customer Liaison Officer and through provision of a customer handout pack.

Project successes:

In-depth pre-installation planning proved to be very worthwhile as all works were completed on time and budget, despite the majority of these works not being undertaken by EON Property Services before.

However, the team was satisfied with the U value that was attained and the subsequent fuel savings achieved for the occupant.

The homeowners are very positive about their increased warmth, ability to better control their heating system and fuel cost savings. They have also reported their personal pleasure at the aesthetic improvement to the exterior of their property and believe the value of their home to have increased due to the works undertaken.

Project partners:

Owner:	Mr & Mrs Young
Architects:	WBS Ltd
Energy consultants:	EON
Contractors:	EON Property Services
Other advisors:	Vaillant, Kingspan, INCA, Gas Safe

Objectives:

This project was designed to help EON Property Services to ready itself to carry out measures as set out under the government's Community Energy Saving Programme (CESP). CESP calls for a whole-house approach to energy efficiency retrofit with energy companies providing measures across as many properties as possible in defined areas. It is particularly focused on low-income households who are most likely to struggle with their fuel bills or to under-heat their homes.

What was done:

External wall insulation, loft insulation, draught proofing, replacement of boiler at one property.

What was achieved:

Anticipated reduction in fuel bills from £1300 to £700; greater comfort and warmth of occupants; wall U value of 0.35 W/m^2K.

Scaffolding erected during works

Rear elevation before and after works

Challenges faced:

The biggest area of concern prior to the installation was the weather, as external render cannot be applied unless the outside temperature is 5 degrees or higher. Time was lost during the installation due to frost; however, this time was recovered and the project completed to schedule.

Another challenge was identifying a property which was suitable for an integrated whole-house approach and which qualified for the full range of CESP measures, that is, one with both solid walls and a G-rated gas appliance. Under CESP guidelines, only G-rated appliances can be replaced.

Whilst the scaffold was erected, there was a loss of satellite television signal; this caused inconvenience to the occupants and highlights the needs to ensure that this potential disruption is pointed out at survey stage.

Lessons learned:

It is apparent that the whole house approach is an excellent way forward and one we all must embrace. The challenge, however, is ensuring that all works are planned in advance; this ranges from planning and highways approval to ensuring the occupants' expectations are managed and met. These works are fairly disruptive and the co-operation of householders is definitely needed during the installation.

The improvements in U values and the reduction in energy bills do tell us that these works are very worthwhile from a customer, business and environmental perspective.

Potential for replication:

All works could be easily replicated on a larger scale; however, stock condition must be known in advance. Finding properties in close proximity with G-rated gas appliances will be a challenge, particularly in the social housing sector where so much improvement work has been carried out.

Pre-planning is pivotal and to upscale these operations would require a proven project manager and suitable resources to ensure the project runs smoothly. Co-operation from all occupants, landlords and supply chain is critical to ensure the project delivery is not hampered in any way.

The main other challenge to all external wall insulation installers is completing works throughout the year in an unpredictable climate. Moderate dry weather is needed to complete these works and this becomes even more critical should the works be replicated on a large scale, whereby lost time is felt even more.

Costs and funding:

A learning & development budget of £30,000 was set for these works, fully funded by EON Property Services.

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Case study 9

Worcester/Wolseley

Energy Homes

As a demonstration project, Worcester Bosch Group set out to make a typical 1930s semi-detached home as energy efficient as possible.

Key supply partners Wolseley, were involved in helping to select and procure a variety of products within the scheme including windows, rainwater harvesting, phase change material, bathroom and showering products. As market leaders in sustainable construction products Wolseley have also developed a very low impact supply chain providing outstanding outcomes. The Wolseley Sustainable Building Center is a unique facility allowing construction stakeholders to see and experience a huge selection of sustainable construction products in a real working environment.

About the project:

The following measures were installed:

Heating:

For six months of the year, heating is supplied by a Greenstore ground source heat pump with outdoor and indoor temperature sensors and integrated controller. The downstairs areas are heated by wet system underfloor heating running at a flow temperature of 35°C; the upstairs is heated with low flow temperatures through convector radiators fitted with TRVs. For the remaining six months of the year, the house is heated with the Greenstar i system condensing gas boiler; upstairs and downstairs zones are separately controlled by radio frequency room controls.

For demonstration purposes, from April until October this year, the solar system will be working in conjunction with the gas-fired system boiler and the ground source heat pump will supply the heating purely from October until the following March.

Hot water:

When the house is being heated by the ground source heat pump, the hot water is provided by the heat pump's integral hot water cylinder. When the house is being heated by the condensing gas boiler, the hot water is provided by a twin coil unvented stainless steel cylinder. The cylinder is heated by the Greenskies solar panels assisted by the condensing gas boiler.

Insulation:

As well as renewable technologies, additional energy saving measures were also incorporated within the property, such as Thermafleece (lamb's wool) insulation in the loft and triple glazed timber windows sourced from managed forests.

Water conservation:

A rainwater harvesting system for toilet flushing and an A-rated Bosch dishwasher that conserves water and energy were installed.

Project partners:

Owner:	Worcester Bosch Group
Architects:	BBLB Architects
Key supply partners:	Wolseley

Objectives:

To demonstrate the running costs, efficiency gains and effectiveness of condensing boilers, solar water heating and other renewable technologies.

What was done:

Installation of a Greenstore 6kW combination ground source heat pump, Greenstar i system gas-fired boiler, Greenskies solar water heating system, Thermafleece loft insulation, triple glazed windows, underfloor heating and a rainwater harvesting system. Installation of A-rated kitchen domestic appliances.

What was achieved:

SAP increase from 34 (F) to 78 (C).

Underfloor heating

Greenskies solar panels

Installing the ground source heat pump

Project successes:

Before any work took place, the Energy Home had a fairly poor energy efficiency rating of 34 out of 100. It was clear from the outset that this property would not be able to achieve an 'A' energy rating. However, after the refurbishment the efficiency rating had improved to 78 out of 100.

The reduction in carbon emissions and fuel usage has been significant and, based on results so far, the property is expected to make energy savings of around 40% over a 12 month period. During the summer months, the solar panels are expected to generate 80 - 90% of the property's hot water requirements.

Challenges faced:

The project used a number of different technologies which are not usually combined, for instance, running both a boiler and a ground source heat pump. This caused initial difficulties in getting all the systems to work in association.

Lessons learned:

Open communication between all involved is essential. Throughout the project, some processes relied on earlier activity and work occasionally stopped as a result of misunderstandings.

Potential for replication:

The results are excellent proof of the benefits of domestic renewable technologies and could be replicated across the housing stock.

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A virtual tour of the property is available on the website.
Videos of Worcester ground source heat pump installations can be viewed on the Worcester You Tube channel at www.YouTube.com/Worcesterboschgroup.

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