Forum for the Future

Bristol Retrofit

Final Report

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Ove Arup & Partners Ltd
63 St Thomas Street, Bristol BS1 6JZ
Tel +44 (0)117 976 5432 Fax +44 (0)117 976 5433
www.arup.com

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1 Introduction

1.1 The Project Aims and Objectives

This project aims to identify the opportunities and barriers, in terms of finance and energy efficiency, for the refurbishment of private housing in large-scale contracts. The project will use the Bristol City Region[1] as a case study and will take a systems based approach to analyse the scale of savings available. Rather than a consumer-facing tool, the primary audience for this work would be investors, contractors and local authorities, which want to consider the economics of large contracts of refurbishment, similar to those carried out in social housing. Because of this, our assumptions and data input will be based on generic housing and cost estimate ranges. Our objective is to understand the approximate size of savings available if refurbishment of private homes could be carried out at scale to help inform the business case for larger contracts.

1.2 Existing Homes: The Challenge

1.2.1 Why Existing Homes?

There are an increasing number of government targets and initiatives targeted at producing new low carbon homes that enable sustainable lifestyles; the Code for Sustainable Homes was made mandatory in 2008 requiring all new homes to be zero carbon by 2016. However, by 2050, over 80% of the housing stock in the UK will be made up of the homes that we live in today[2], and turning these into low carbon, sustainable homes presents a greater challenge. The housing sector as a whole represents 28.6% of total emissions in the West of England[3] and achieving deep carbon cuts in this sector is imperative.

1.2.2 Why Private Homes?

By putting this in context, it is clear that we have to improve the energy efficiency of the existing housing stock. Whilst there have been some retrofitting programmes carried out amongst social landlords, action has been very slow moving in the private sector (both amongst homeowners and private landlords) and refurbishment has only taken place at an individual (single dwelling) level. Private housing accounts for 93% of housing in Bristol City[4] and hence represents a significant part of the carbon challenge. The average Bristol home has annual CO_2 emissions of 5.93 tonnes, which equates to annual running costs of £620.18[5]. This presents a significant cost for individuals, and over 6% of West of England residents live in fuel poverty[6].

The technical feasibility of retrofit is sound and many pilot projects and studies have been carried out throughout the UK[7]. Arup Bristol carried out a desk study of this work in the summer of 2008, which highlighted a wide variety of options are available for retrofit, with many of them incorporating relatively simple technology.

1.2.3 What Next?

When dealing with the existing housing stock, buildings range in age, materials, design and state, which complicates how improvements can be implemented. In addition, there are only broad estimates of how much this would cost and what impact any improvements would have on carbon reduction with no clearly established funding routes.

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[1] Throughout this report Bristol City Region refers to the West of England; the areas covered by the local authorities Bristol City Council, Bath and North East Somerset, North Somerset and South Gloucestershire.
[2] Brenda Boardman, University of Oxford Environmental Change Institute, *Home Truths: A Low Carbon Strategy to Reduce UK Housing Emissions By 80%*, November 2007
[3] Resource-accounting.co.uk
[4] Michael Dyson Associates Ltd for Bristol City Council, *Report following Bristol Private Sector House Condition Survey*, July 2008
[5] Michael Dyson, *ibid*
[6] Based on the government's official definition of fuel poverty and on data from www.fuelpovertyindicator.org.uk
[7] http://www.sustainable-energyacademy.org.uk/pages/locationsmap.html

In order to meet stringent carbon emissions reduction targets we need to start tackling private homes and doing so at scale. The UK Government's Low Carbon Transition Plan[8] says that emissions from all homes need to be at zero by 2050. We need to start that journey now.

1.3 Background

Engineers of the 21st Century is programme run by Forum For The Future, set up to bring engineering based organisations together to work on projects that address key challenges for sustainability. In August 2008, a partnership was set up with Arup's Bristol office to look at the challenge of refurbishing the existing stock of private homes.

Forum for the Future have embarked on a 10 year program to work in Bristol with the ambition to enable the area to become a Sustainable City Region; looking at all aspects of sustainable development, from food supply and transport to waste and energy. The housing work stream is now managed through the Re-Fit West programme and this project will be a key resource into the programme.

The project team consisted of Arup Bristol, ROK and Forum for the Future. Footprint Building has also supplied cost information.

1.4 The Approach

The main output from this project was to be a model to demonstrate the carbon and cost savings that could be achieved through retrofitting standard housing types that represent the housing stock in the West of England.

The method is described in more detail in sections 2-6, but broadly encompassed developing baseline house types; determining the refit options available and selecting the most appropriate; modelling the energy and carbon savings using NHER SAP software; and feeding in cost estimates provided by project partners.

2 Base Case Houses

2.1 Categorising the Housing Stock

Data provided by the Centre for Sustainable Energy (CSE) surveyed the housing stock in the West of England. This was broken down by Local authority area, age of property (presented in approx 30 year ranges), built form (detached, semi, terraced etc), number of bedrooms and access to gas. This data presented 237 housing types in the area of the Bristol City Region.

The age ranges presented in this data were as follows:

- pre 1920
- 1921 to 1945
- 1946 to 1980
- 1980 to present
- Mixed

There are differences in the built form of pre 1920 houses, and it was felt that it would be useful to break this category down further. Cavity walls were generally introduced around 1930, so in determining applicable retrofit measures, 1930 was found to be a more useful cut off point than either 1920 or 1945.

There were many examples of housing types where the retrofit measures applied would be similar enough that there was little benefit of describing the changes to both (for example, a 2 or 3 bed Victorian Terrace).

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[8] HM Government, *The UK Low Carbon Transition Plan: National strategy for climate and energy*, July 2009

The list of 12 housing types that we chose to cover, representing approximately 55% of the West of England housing stock is:

1. 3-bed semi, on gas, 1930 to 1980
2. 3-bed semi, 1900 – 1930
3. 3-bed Semi, Victorian
4. 3-bed Semi, Georgian
5. 2-bed flats, 1945 – 1980 (converted)
6. 2-bed flats 1945 – 1980 (purpose built)
7. 2-bed terrace, 1900 – 1930
8. 2-bed terrace, Victorian
9. 2-bed terrace, Georgian
10. 3-bed detached, 1945 – 1980
11. 4-bed detached, post 1945
12. 3-bed terrace, 1945-1980

2.2 Determining the base case

Evidence was reviewed to determine whether it would be possible to identify the current state of the housing stock in the West of England. There was some useful evidence, for example the *Report following the Bristol Private Sector House Condition Survey* (July 2008) identifies average SAP ratings in different areas of the city as well as providing evidence on the number of homes with specific measures installed (for example, of those with a cavity wall, 57% have no wall insulation). Whilst this is useful background information, it was felt that for completeness that we should define the base case houses as being completely unimproved[9], with no insulation or any other additional measures.

In order to identify average floor areas and other details, searches were made of local estate agents for houses fitting each of the 12 house types as identified in section 2.1 above.

To identify further details relating to the standard construction of an "average" house, reduced data SAP[10] was used to produce a base case SAP rating for each housing type.

The detail from the reduced SAP data was transferred to the full version of SAP to enable us to make more detailed analysis of the CO_2 and energy effects of adding retrofit measures.

Details of the base case houses used can be found in appendix 1.

3 Retrofit Measures

A list of potential housing retrofit measures was drawn up including measures to contribute to CO_2 reduction, climate change adaptation, wellbeing and other benefits:

3.1 CO_2 Reduction Measures

- Dedicated low energy lighting
- Loft Insulation (top-up)
- Draught Proofing
- Cavity Wall Insulation
- Internal/ External Solid Wall Insulation

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[9] This excludes obvious improvements, such as the addition of central heating to Victorian houses.
[10] https://www.nes-one.co.uk/

- Solar Thermal Hot Water
- New boiler and controls
- Floor Insulation
- Secondary double glazing
- New Windows (double/triple glazed)
- Install Smart Meter
- Floor Insulation
- Ceiling Insulation
- Secure Dry Bike Storage
- Air Source Heat Pump
- Ground Source Heat Pump
- Micro Wind Turbine
- Solar PV
- Energy efficient appliances

3.2 Climate Change Adaptation Measures

3.2.1 Water saving

- Low flow showers and taps
- Install water meter
- Install water efficient appliances
- Repair dripping tap
- Hippos in toilets
- Install water butt

3.2.2 Overheating Protection

- Window shutters
- Window film to reduce heat gain
- Insulation (see above)
- Awning

3.2.3 Flooding Protection

- Drainage bungs
- Air brick covers
- Move electrical sockets, meters and appliances above flood level
- Water-resistant paint

3.3 Wellbeing Measures

- Damp
- Sound insulation (see above)
- Overcrowding
- Security

3.4 Other Sustainability Measures

3.4.1 Waste

- Internal Storage
- External Storage

3.4.2 Garden

- Biodiversity
- Food production

In order to prioritise this long list and carry out a first trial, it was decided that we would concentrate on carbon reduction measures. We chose measures that could be assessed using SAP (standard assessment procedure). We excluded wind energy, as the effectiveness of this technology varies significantly depending on location. Therefore, our final list of retrofit measures was as follows:

- Dedicated low energy lighting
- Loft Insulation
- Draught Proofing
- Cavity Wall Insulation
- Internal/ External Solid Wall Insulation
- Solar Thermal Hot Water
- New boiler and controls
- Floor Insulation
- Secondary double glazing
- New Windows (double glazed)
- Floor Insulation
- Ceiling Insulation
- Solar PV

The detail of what is meant by each of these measures, and which measures are applicable to which housing type, can be found in appendix 2.

4 SAP Calculations

SAP is a logarithmic scale; adding different retrofit measures to a base case house has differing results depending on the combination of measures applied at any one time. It was therefore decided the most effective way of providing the results required to fulfil the aims and objectives of the project was to define 4 packages; each designed to combine measures that are efficient to complete together, and designed to become progressively more expensive.

Package 1

- Energy Saving Lighting
- Draught proofing
- Roof insulation
- Cavity wall insulation

Package 2

- New windows
- New boiler and controls

Package 3

- Internal wall insulation
- Floor Insulation

Package 4

- External wall insulation
- Floor Insulation
- Solar thermal
- Solar PV

Each package should be applied in order (i.e you cannot install package 2 until you have installed package 1), but packages 3 and 4 are mutually exclusive; a choice must be made between internal and external wall installation.

5 Costs

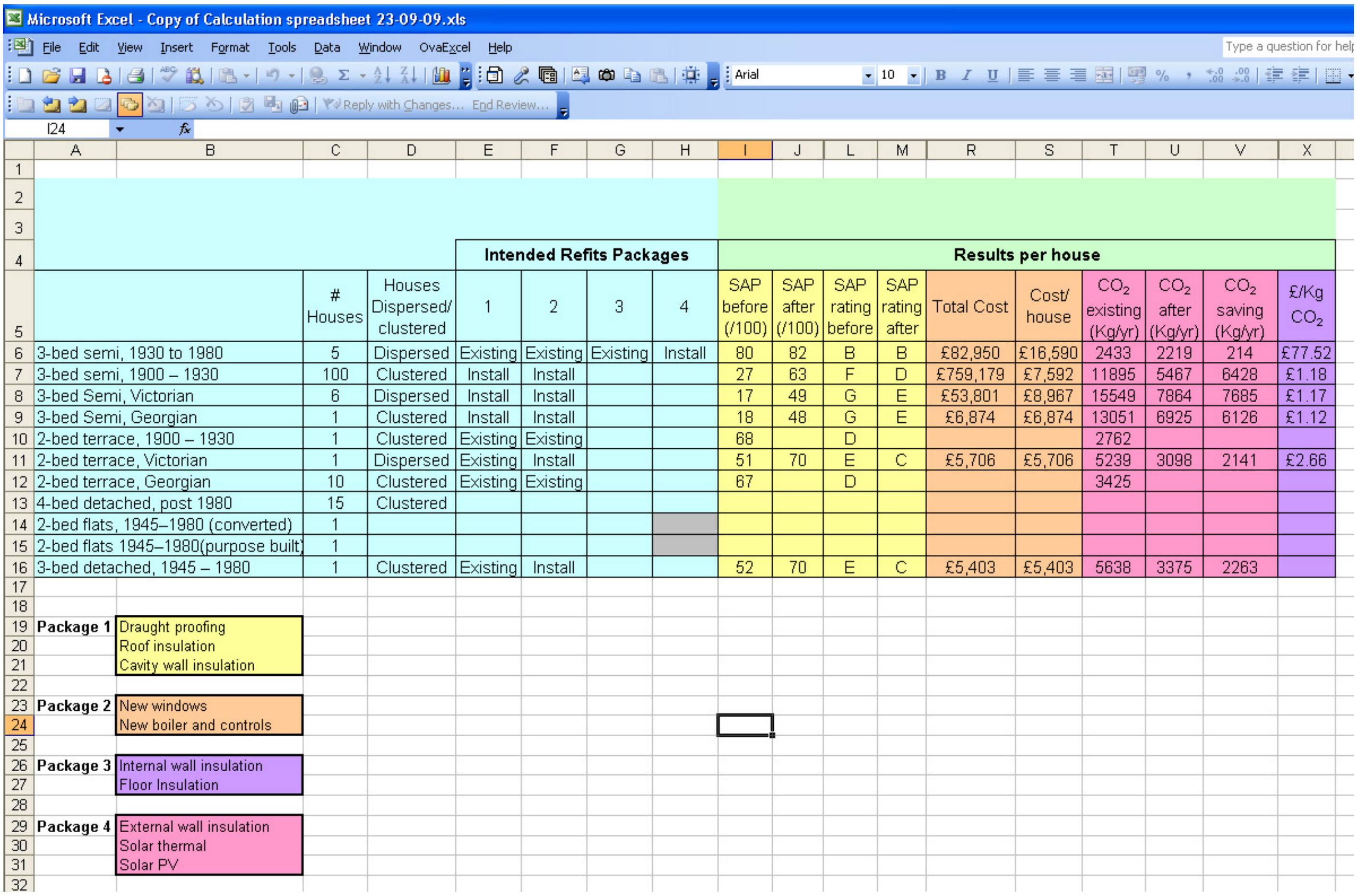
Cost information was gathered predominantly from ROK and a small local specialist retrofit firms (Footprint Building). This was benchmarked against prices available from Department for Energy and Climate Change (DECC), the Energy Savings Trust (EST) the Centre for Sustainable Energy (CSE) and World Wildlife Fund (WWF). The local builders' costs will be used to compare the costs of retrofitting individual homes (1-19), with the costs from ROK of retrofitting a large number of homes (20+) as one contract. Maintenance costs were excluded from our analysis.

6 Model Development

Figure 1 below shows a screenshot of the model to allow cost, energy and carbon savings to be compared. The model allows the user to enter the number of each house type to be upgraded, to specify any existing refit measures already in place and to specify the packages of measures to be installed. The inputs are all in blue.

The model produces figures on SAP rating and CO_2 reduction per house and both total and per house figures on cost, as well as a cost per kg of CO_2, which allows extra comparisons to be made.

Figure 1: Excel Model



			Intended Refits Packages				Results per house									
	# Houses	Houses Dispersed/ clustered	1	2	3	4	SAP before (/100)	SAP after (/100)	SAP rating before	SAP rating after	Total Cost	Cost/ house	CO_2 existing (Kg/yr)	CO_2 after (Kg/yr)	CO_2 saving (Kg/yr)	£/Kg CO_2
3-bed semi, 1930 to 1980	5	Dispersed	Existing	Existing	Existing	Install	80	82	B	B	£82,950	£16,590	2433	2219	214	£77.52
3-bed semi, 1900 – 1930	100	Clustered	Install	Install			27	63	F	D	£759,179	£7,592	11895	5467	6428	£1.18
3-bed Semi, Victorian	6	Dispersed	Install	Install			17	49	G	E	£53,801	£8,967	15549	7864	7685	£1.17
3-bed Semi, Georgian	1	Clustered	Install	Install			18	48	G	E	£6,874	£6,874	13051	6925	6126	£1.12
2-bed terrace, 1900 – 1930	1	Clustered	Existing	Existing			68		D				2762			
2-bed terrace, Victorian	1	Dispersed	Existing	Install			51	70	E	C	£5,706	£5,706	5239	3098	2141	£2.66
2-bed terrace, Georgian	10	Clustered	Existing	Existing			67		D				3425			
4-bed detached, post 1980	15	Clustered														
2-bed flats, 1945–1980 (converted)	1															
2-bed flats 1945–1980(purpose built)	1															
3-bed detached, 1945 – 1980	1	Clustered	Existing	Install			52	70	E	C	£5,403	£5,403	5638	3375	2263	

Package 1
Draught proofing
Roof insulation
Cavity wall insulation

Package 2
New windows
New boiler and controls

Package 3
Internal wall insulation
Floor Insulation

Package 4
External wall insulation
Solar thermal
Solar PV

6.1 Assumptions

In preparing the model, we made the following assumptions:

- The critical mass of homes at which a large contractor might be interested is not an exact science, but following discussions with ROK and Footprint, we have assumed that this could be around 20 homes. Further savings will occur when a large contractor is able to find further efficiencies (predominantly through more efficient working) and this is assumed to be for 50 houses.

- Upgrades to homes are only made by applying the packages identified in section 4 above.
- Clustered homes are within walking distance of each other; dispersed homes are anything further apart.
- We have made assumptions on costs based on information from a large contractor and small builder. The costs cover materials, plant, staff time, installation, finishing, but no decoration or maintenance.
- SAP ratings and CO_2 savings are based on data from NHER software.

7 Results and Discussion

7.1 Outputs from the model

Selected results from the model are displayed in tables 1-3 below. Table 1 displays results relating to package 1; it gives an idea of the CO_2 savings available for different house types. It is clear that larger, older houses have higher CO_2 use prior to any refit and therefore present the greatest potential for savings.

The two results for the 3-bed Georgian semi demonstrate the cost savings that can be made by retrofitting 50 clustered homes at once. This represents a 13.74% saving per home.

The greatest carbon saving made in these example homes is in the 3-bed detached house, 1945-1980. This home has cavity walls which can be insulated in this package and it has external walls on each side of the home, meaning a greater area to be insulated and thus a great potential for savings. Whilst the 2-bed flats are also assumed to have insulated cavity walls to start with, the savings are less here, as they are assumed to have less efficient electric heating and have a smaller wall space to insulate. They see a significant improvement, particularly in terms of SAP rating, when the new 'A' rated gas combi-condensing boiler is added in package 2.

The largest savings can be made in package 1 in homes where cavity wall insulation can be fitted. The equivalent wall insulation for solid wall homes is not fitted until package 3 or 4, as there are more costly and complicated measures.

		Intended Refit Packages				Results per house							
	# Houses (cluster)	1	2	3	4	SAP pre-refit (/100)	SAP post-refit (/100)	SAP rating pre	SAP rating post	Cost/ house	CO_2 saving (Kg/yr)	% CO_2 improvement	£/Kg CO_2 (year 1)
3-bed Semi, Georgian	1	Install				18	28	G	F	£1,425	2450	18.8%	£0.58
3-bed Semi, Georgian	50	Install				18	28	G	F	£1,229	2450	18.8%	£0.50
2-bed flats 1945–1980 (purpose built)	20	Install				23	34	F	F	£1,287	884	19.1%	£1.46
3-bed detached, 1945 – 1980	50	Install				27	52	F	E	£2,123	3796	40.2%	£0.56

Table 1: Selected results, package 1

The results in table 2 show examples of the savings that can be made in packages 2 and 3, which would be a much more extensive and significant refurbishment. The cost saving that can be achieved by retrofitting 50 rather than 20 3-bed detached, 1945-1980 homes is £300 per house, which equates to just less than a 5% saving. In percentage terms, this is a much smaller amount than is saved in increasing numbers from 1 to 20. The cost of retrofitting an individual 3-bed detached home 1945-1980 is £10,757.60, which is almost £4,500 more than the per house cost when 20 are installed. This illustrates that with a contract for 20 homes, a large contractor is able to command large orders and offer savings. Above this however, savings are minimal.

		Intended Refit Packages				**Results per house**							
	# Houses (cluster)	1	2	3	4	SAP (/100)	SAP (/100)	SAP rating pre	SAP rating post	Cost/ house	CO_2 saving (Kg/yr)	% CO_2 improvement	£/Kg CO_2 (year 1)
3-bed Semi, Georgian	1	Install	Install			18	48	G	E	£9,272	6126	46.9%	£1.51
2-bed flats 1945–1980 (purpose built)	1	Install	Install	Install		23	84	F	B	£7,851	3263	70.3%	£2.41
3-bed detached, 1945 – 1980	20	Install	Install	Install		27	75	F	C	£6,271	6590	69.9%	£0.95
3-bed detached, 1945 – 1980	50	Install	Install	Install		27	75	F	C	£5,971	6590	69.9%	£0.91

Table 2: Selected results, packages 2 and 3

Table 3 shows the selected results from implementing packages 3 and 4. The flats are unable to implement package 4, as it is assumed that they have cavity walls, (so external wall insulation is not applicable) and that they do not have access to roof space in order to install solar panels.

As can be seen from these results, it is not easy to achieve an A-rated home with an existing building, which requires a SAP rating of 93. This would require further improvements in u-values, or an increase in renewable technologies, either of which will add significant extra costs to the retrofit.

It should be noted that SAP ratings are “based on the energy costs associated with space heating, water heating, ventilation and lighting, less cost savings from energy generation technologies”. Carbon savings can be achieved without any saving in the cost of energy, by the installation of renewable energy technologies.

		Intended Refit Packages				**Results per house**							
	# Houses	1	2	3	4	SAP pre-refit (/100)	SAP post-refit (/100)	SAP rating pre	SAP rating post	Cost/ house	CO_2 saving (Kg/yr)	% CO_2 improvement	£/Kg CO_2 (year 1)
3-bed Semi, Georgian	50 (clust)	Install	Install		Install	18	81	G	B	£28,266	10578	81.1%	£2.67
3-bed Semi, Georgian	50 (disp)	Install	Install		Install	18	81	G	B	£31,940	10578	81.1%	£3.02
2-bed flats 1945–1980 (purpose built)	50 (clust)	Install	Install	Install		23	84	F	B	£5,446	3263	70.3%	£1.67
3-bed detached, 1945 – 1980	1	Install	Install		Install	27	79	F	C	£24,898	7048	74.7%	£3.53

Table 3: Selected results, packages 3 and 4

7.2 Benefits to the Homeowner

Our benchmarking exercise demonstrated that there are significant variations in costs of single measures to single dwellings and a large scale approach would remove this variability and give the consumer some consistency in what they could expect to be charged.

There are savings to be made through a whole house approach (rather than individual measures). ROK's cost analysis suggests that an average of over 4% can be saved by installing measures in packages. These savings are made predominantly due to the fact that one measure can be carried out by the same trade at the same time, cutting down on overhead costs, preparation time and plant (e.g. scaffolding could be used for more than one measure).

There are a growing number of individuals who will be attracted to the idea of retrofitting their home to help reduce their carbon footprint. The results contained within this report could help householders to make informed decisions about the carbon savings that they might achieve through implementing various measures.

The cost per kg of CO_2 saved in the first year was assessed. Using this metric, the best value for money is achieved by implementing package 1 on 50 or more clustered Victorian 3-bed semis, as can be seen from the excerpt from the model below. This kind of information could be valuable in producing marketing material and information for householders.

Intended Refit Packages						Results per house							
	No. of Houses (cluster)	1	2	3	4	SAP before (/100)	SAP after (/100)	Total Cost	Cost/ house	CO_2 before (Kg/yr)	CO_2 after (Kg/yr)	% CO_2 improv -ement	£/Kg CO_2 (year 1)
3-bed Semi, Victorian	50	Install				17	31	£73,068	£1,461	15549	11680	24.90 %	£0.38

Table 4: Best value for money

7.3 Benefits to Neighbourhoods

This research clearly shows the cost benefits that can be achieved by retrofitting multiple homes in the same neighbourhood. To achieve the best financial savings, retrofit at scale should be applied in clustered groups. Cost savings from carrying out measures at scale for a dispersed group of houses are more difficult to achieve due to the extra transport, management and logistics costs.

Although this research did not explore social or marketing benefits, it is likely that homeowners will have a higher level of confidence in the process if all of their neighbours are having the same work done at the same time. This may also provide an incentive for them to get the work done in the first place, as discussed in "I Will if you Will"[11].

7.4 Benefits to Builders and the Supply Chain

At present, there are a few refurb measures that are cheaper from a small specialist builder. For instance, solar PV and thermal solar are currently significantly cheaper through a small specialist contractor. Mainstream contractors currently have limited experience in renewable technology for single dwellings and the cost will initially reflect this risk for them. As the market changes, and

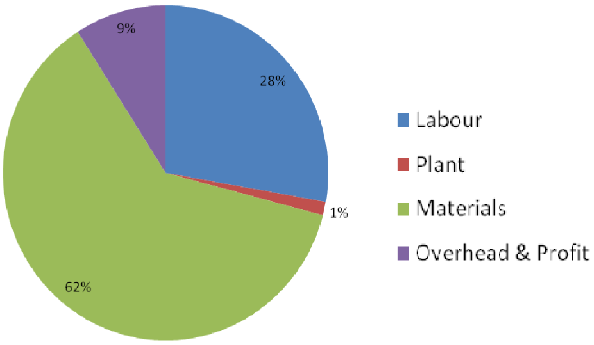


Fig. 2: Average breakdown of costs

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11 Sustainable consumption roundtable, *I will if you will: Towards sustainable consumption*, May 2006

installing these more “advanced” measures becomes more mainstream, it is likely that the cost of large contractors will come down to reflect this change.

For the majority of retrofit measures, the most significant costs are associated with the materials. As can be seen in fig. 2, on average[12], over 60% of the cost is associated with materials.

7.5 Benefits to Local Authorities

The performance of local authorities (LAs) and how they work in partnership is now measured against 198 National Indicators. These include:

- **NI 186** Per capita CO_2 emissions in the LA area
- **NI 187** Tackling fuel poverty – people receiving income based benefits living in homes with a low energy efficiency rating

Implementing a large scale retrofit in a local authority area will contribute to both of these indicators. It is possible that central government will begin to filter down the commitments made in the UK climate change bill to reduce greenhouse gas emissions by 80% by 2050 to local authorities to ensure that national targets are met. This research demonstrates that improving the current housing stock in a local authority will cost less when applied at scale, in clustered groups. There may also be additional benefits of improved social cohesion, and confidence.

The total cost of installing packages 1 and 2 on approximately 55% of all homes in the West of England (429,105 homes) is approximately £900,000,000, which is an average of £4,300 per house. This results in an average CO_2 saving of 62.9% per house in the first year, at an average cost of £0.84 per kg of CO_2 saved. These figures are estimated average costs or carbon savings and the base case homes do not represent the accurate current condition of all homes in the Bristol City Region, but the minimum possible standards. However, this approximate approach is useful to indicate potential contributions available for reducing the 28.6% of emissions that currently come from the housing sector. It is estimated that the West of England’s total carbon emissions could be reduced by 9% by implementing such a programme and that emissions from housing could be reduced by up to 30%.

Table 5 below uses a 3-bed Georgian semi-detached house as an example and explores the savings that can be made by retrofitting at scale; both at 20 houses[13], and at 50 houses[14]. The biggest savings come from the initial involvement of a large contractor (at 20 homes), which can offer savings of over 55%. A further discount of approximately 5% can be gained when retrofitting 50 homes or more that are within walking distance of each other. This reflects the fact that the initial savings are so significant and further savings become more difficult. The total saving can equate to over £12,000 per house for this scenario. This will clearly be of benefit to home owners and communities as well as, potentially, local authorities.

	No. of homes (cluster)	Package 1		Package 2		Package 3		Package 4	
		Cost/ House	% saving	Cost/ House	% saving	Cost/ House	% saving	Cost/ House	% saving
3-bed Semi, Georgian	1	£1,424.72		£9,271.72		£20,204.52		£39,740.92	
	20	£1,291.05	9.38	£4,394.54	52.60	£8,686.02	57.01	£29,763.58	25.11
	50	£1,228.97	4.81	£4,182.54	4.82	£8,271.14	4.78	£28,265.94	5.03

Table 5: Cost savings for 3-bed Georgian semi

Although not specifically covered in this research, it is possible that endorsement from the local authority might provide a further incentive for householders to get the work done. There

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[12] For all measures, excluding renewable measures, where a breakdown of costs was not available

[13] When it might become viable for a large contractor to become involved

[14] When additional cost reductions are introduced

is evidence to suggest that local authorities are better trusted than private companies; 44% us in the of UK trust business[15], compared to 60% trusting local government[16].

Although no conclusions can be drawn from this research, the number of jobs created or maintained through a large scale programme will also be significant. This is likely to be a particularly important benefit for local authorities, given the current economic climate and the number of construction projects that have been put on hold.

7.6 Benefits to Central Government

The UK Climate Change Bill requires that the UK reduces its greenhouse gas (GHG) emissions by 80% by 2050. The Low Carbon Transition Plan[17] sets out the emissions reduction required from each sector, and states that our homes will need to be near zero carbon by 2050. One of the aims of retrofitting existing housing has to be to help reach this target. The solutions proposed as part of this project only consider single house solutions; any locally distributed energy was outside of our scope, but may help in reaching a zero carbon housing target by 2050.

Table 6 sets out the percentage CO_2 reduction that can be obtained from applying the maximum packages of retrofit measures to each of the housing types. The average % reduction obtained is 78.59%.

Table 6: Carbon savings

	CO_2 Saved (kg/yr with Package 1-4)	% CO_2 saved
3-bed semi, 1930 to 1980	6697	75.11%
3-bed semi, 1900 – 1930	9642	81.06%
3-bed Semi, Victorian	12759	82.06%
3-bed Semi, Georgian	10578	81.05%
2-bed terrace, 1900 – 1930	5860	83.80%
2-bed terrace, Victorian	5957	81.83%
2-bed terrace, Georgian	6492	83.05%
4-bed detached, post 1980	4537	65.54%
2-bed flats, 1945 – 1980 (converted, top floor)	4866	84.11%
2-bed flats 1945 – 1980 (purpose built, middle floor)	3263	70.32%
3-bed detached, 1945 – 1980	7048	74.71%
3-bed terrace, 1945 - 1980	6350	80.43%
	Average:	**78.59%**

It is important to understand the elements that make up a home's CO_2 emissions. These are set out in figure 3. Emissions associated with appliances and cooking are not included in our model but there are clearly opportunities to reduce emissions associated with these areas by fitting homes with A+ rated appliances.

The government's Low Carbon Industrial Strategy[18] recognises retrofitting as an activity that will increase the number of jobs in a low carbon industry. It also recognises the need to provide skills for those in the construction industry to enable them to deliver the high standards that would be needed.

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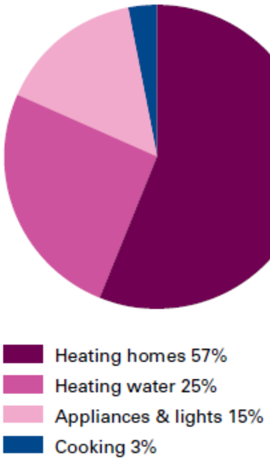
[15] Edelman Trust Barometer, 2009 mid year report, http://www.edelman.co.uk/mid-year-trust-2009/trust-barometer-findings/

[16] CLG, *2007-08 Citizenship Survey: Empowered Communities Topic Report, http://www.communities.gov.uk/publications/corporate/statistics/citizenshipsurvey200708empower*

[17] HM Government, *The UK Low Carbon Transition Plan: National strategy for climate and energy*, July 2009

[18] HM Government, *Low Carbon Industrial Strategy*, July 2009

The government's consultation on the Heat and Energy Saving Strategy[19] states that they would like all homes to have had a 'whole house' retrofit by 2030. This ambition requires more than 2 homes to be retrofitted every minute between 2010 and 2030[20]. It would appear indisputable that this has to take place at a large scale to achieve these targets and central government need to take a key role in enabling this.



Source: Department of Energy and Climate Change, Energy Trends (September 2008)

Figure 3: Carbon emissions in the home

8 Conclusions and Next Steps

In conclusion, the principal business benefits of retrofitting private homes at scale include:

- Consistency in price for individual homeowners;
- Significantly reduced costs (up to £11,000 per house) if a builder is given a contract of 20 houses or more in a cluster;
- Further cost reductions for over 50 homes, of up to an extra £1,500 per home;
- Providing a significant contribution to the UK's target to reduce carbon emissions by 80% by 2050.

The results of this research will feed into Forum for the Future's Refit West Project, which is aiming to retrofit 1000 private homes in the West of England by 2011.

The model produced for this project features the predominant housing types in the West of England, but could easily be adapted to other areas of the country. If large-scale retrofitting programmes were adopted across the UK, we would make significant progress towards the UK's carbon reduction targets, as well as providing benefits to householders through reduced bills, improved comfort and quality of life.

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[19] DECC and CLG, *Heat and Energy Saving Strategy*, February 2009

[20] Based on figures from the 2007 English House Condition Survey

Appendix A

Base Case Houses

A1 3-bed semi, on gas, 1930 to 1980

Description: A typical 3-bedroom semi-detached house from this period is likely to be spread over 2 floors and have uninsulated cavity walls[21]. This house will often be a family home, with the three bedrooms and bathroom on the first floor, and kitchen, living room and dining room on the ground floor. There may be a detached garage.

Figure 4: An example 3-bed semi, 1930 - 1980

Number of storeys: 2

Number of habitable rooms: 5

Age quoted on SAP: 1950-1966

Main roof: Pitched (rafters), access to loft, no insulation, u-value: 2.3
Main wall: Cavity wall, no insulation, U value 1.6
Main floor: solid ground floor, not sealed, U value 0.62
Number of habitable rooms: 5
Unheated rooms: No

Area

	Area (m²)	Height (m)
Main Floor 1	50	2.5
Main Floor 0	50	2.5

Total wall area: 105.48m²
Total glazed area: 18.46m², u-value: 4.8
Proportion double glazed: 0
Number of open fireplaces: 2
Mechanical ventilation: No
Electricity meter type: Unknown
Heater type: Boiler
Boiler type: Regular
Fan flue: Fan, not open flue

Fuel: Mains gas
Primary system: Pre 1998 - High or unknown thermal capacity
Controls: No time or thermostatic control of room temperature

---

[21] 57% of houses with cavity walls are not insulated, Bristol City Council Private Sector House Condition Survey 2008

Emitters: Radiators
Secondary fuel: None
Secondary system: None

Water Heating: From main system (Gas)
Water heating storage: Cylinder, assume no insulation
Has cylinder thermostat? N/A
Solar panels supply some water heating No

Photovoltaic array: No
Wind turbine: No
Low energy lights: None

SAP rating: 33

EPC Band: F

CO$_2$ (kg/yr): 9305

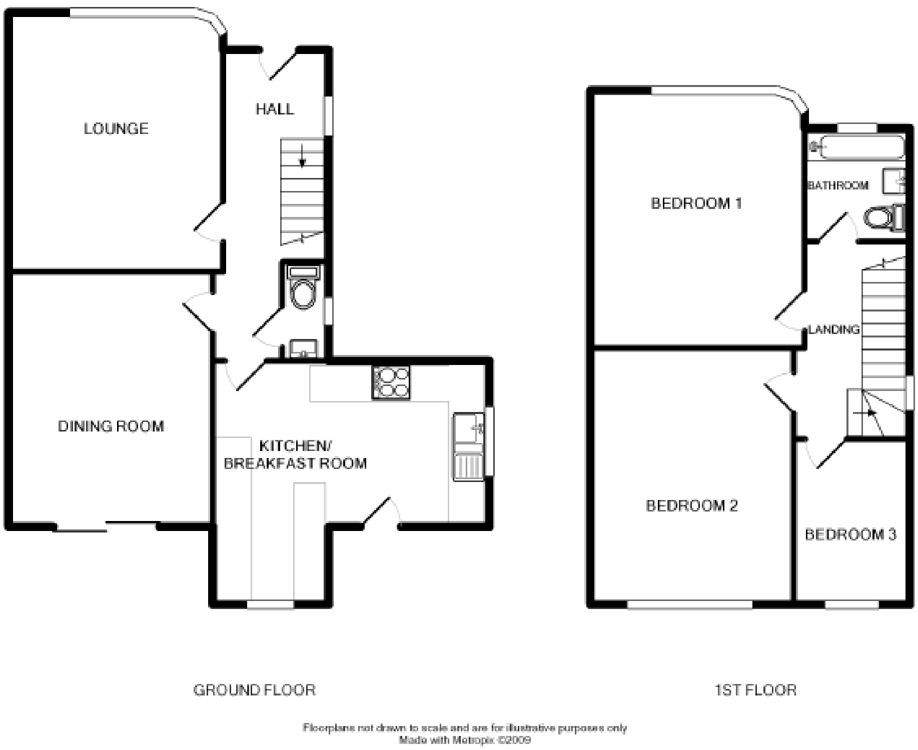


Figure 5: A typical floor plan

A2 3-bed semi, 1900 – 1930

Description: A typical 3-bedroom semi-detached house from this period is likely to be spread over 2 floors and have solid brick walls. This house will often be a family home, with the three bedrooms and bathroom on the first floor, and kitchen, living room and dining room on the ground floor. It may have a detached garage.

Number of storeys: 2

Number of habitable rooms: 5

Age quoted on SAP: 1900-1929

Main roof: Pitched (slates or tiles), no access to loft No insulation, u-value: 2.3
Main wall: Solid brick wall, Insulation as built, u-value: 2.4
Main floor: suspended timber with insulation between, not sealed, u-value: 0.59
Number of habitable rooms: 5
Unheated rooms: No

Figure 6: Example 3-bed semi, 1900 - 1930

Area

	Area (m²)	Height (m)
Main Floor 1	60	2.7
Main Floor 0	60	2.7

Total wall area: 124.18m^2
Total glazed area: 21.52 m^{2,} u-value: 4.8
Proportion double glazed: 0
Number of open fireplaces: 6
Mechanical ventilation: No

Electricity meter type: Unknown
Heater type: Boiler
Boiler type: Regular
Fan flue: Fan, not open flue
Fuel: Mains gas
Primary system: Pre 1998 - High or unknown thermal capacity
Controls: No time or thermostatic control of room temperature
Emitters: Radiators
Secondary fuel: None

Secondary system: None

Water Heating: From main system (Gas)
Water heating storage: Cylinder, assume no insulation
Has cylinder thermostat? N/A
Solar panels supply some water heating No
Photovoltaic array: No
Wind turbine: No
Low energy lights: None

SAP rating: 26

EPC Band: F

CO$_2$ (kg/yr): 12102

Figure 7: Typical floor plan

A3 3-bed Semi, Victorian

Description: A typical 3-bedroom semi-detached house from this period is likely to be spread over 2 floors and have solid stone walls. This house will often be a family home, with the three bedrooms and bathroom on the first floor, and kitchen, living room and dining room on the ground floor.

Figure 8: An example 3-bed Victorian Semi

Number of storeys: 2

Age quoted on SAP:

Main roof: Pitched (slates or tiles), no access to loft
No insulation
Main wall: Solid stone wall, insulation as built
Main floor:
Number of habitable rooms: 5
Unheated rooms: No

Area

	Area (m²)	Height (m)
Main Floor 1	62.6	2.75
Main Floor 0	64.6	2.5

Total wall area: 178.41m^2
Total glazed area: 22.39 m^2

Proportion double glazed: 0
Number of open fireplaces: 2

Mechanical ventilation: No

Electricity meter type: Unknown
Heater type: Boiler
Boiler type: Regular
Fan flue: Fan, not open flue
Fuel: Mains gas
Primary system: Pre 1998 - High or unknown thermal capacity
Controls: No time or thermostatic control of room temperature
Emitters: Radiators
Secondary fuel: None
Secondary system: None

Water Heating: From main system (Gas)

Water heating storage: Cylinder, assume no insulation
Has cylinder thermostat? N/A
Solar panels supply some water heating No
Photovoltaic array: No
Wind turbine: No
Low energy lights: None

SAP rating: 22

EPC Band: F

CO$_2$ (kg/yr): 14001

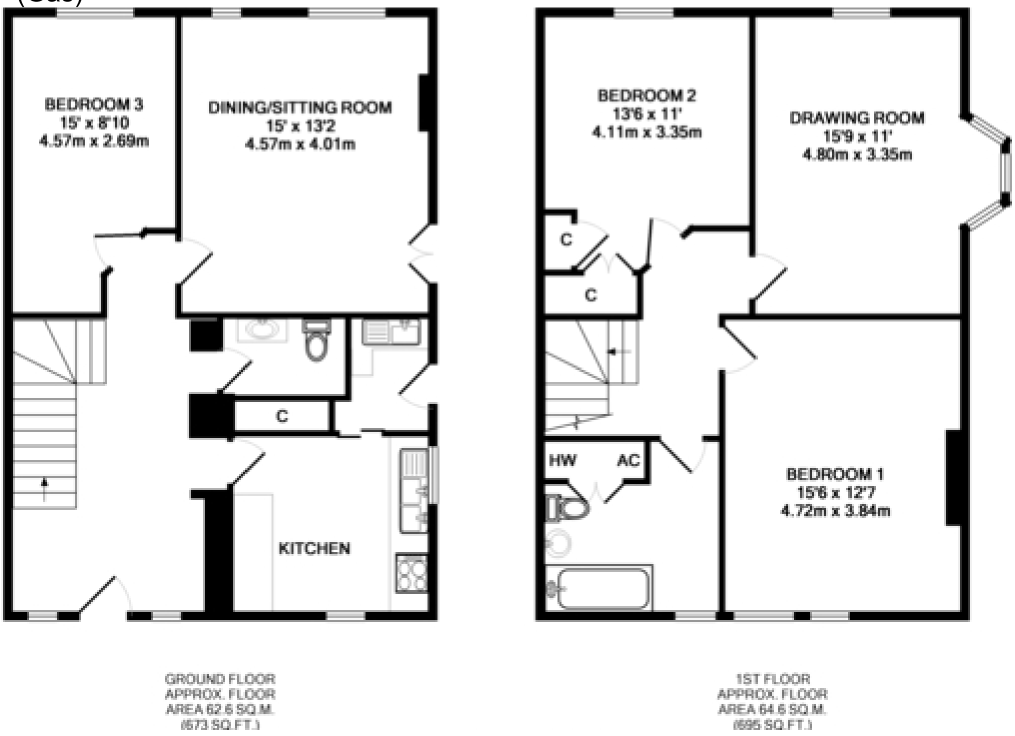


Figure 9: A typical floor plan

A4 3-bed Semi, Georgian

Description: A typical 3-bedroom semi-detached house from this period is likely to be spread over 2 floors and have solid brick walls. This house will often be a family home, with the three bedrooms and bathroom on the first floor, and kitchen, living room and dining room on the ground floor.

Number of storeys: 2

Age quoted on SAP:

Main roof: Pitched (slates or tiles), no access to loft No insulation, u-value: 2.3

Figure 10: An example 3-bed Georgian Semi

Main wall: solid stone wall, no insulation, u-value: 2.1
Main floor: suspended timber with insulation between, not sealed u-value: 0.94; 1st floor: timber upper floor, not sealed, u-value: 1.2
Number of habitable rooms: 5
Unheated rooms: No

Area

	Area (m²)	Height (m)
Main Floor 1	51	2.85
Main Floor 0	51	2.6

Total wall area: 171.88m^2
Total glazed area: 18.22 m^2
Proportion double glazed: 0
Number of open fireplaces: 2
Mechanical ventilation: No

Electricity meter type: Unknown
Heater type: Boiler
Boiler type: Regular
Fan flue: Fan, not open flue
Fuel: Mains gas
Primary system: Pre 1998 - High or unknown thermal capacity
Controls: No time or thermostatic control of room temperature
Emitters: Radiators
Secondary fuel: None

Secondary system: None

Water Heating: From main system (Gas)
Water heating storage: Cylinder, assume no insulation
Has cylinder thermostat? N/A
Solar panels supply some water heating No
Photovoltaic array: No
Wind turbine: No
Low energy lights: None

SAP rating: 16

EPC Band: G

CO$_2$ (kg/yr): 12817

Figure 11: A typical floor plan

Ground Floor

First Floor

A5 2-bed terrace, 1900 – 1930

Description: A typical 2-bedroom terraced house from this period is likely to be spread over 2 floors and have solid brick walls. This house

Number of storeys: 2

Age quoted on SAP:

Main roof: Pitched (slates or tiles), no access to loft No insulation, u-value: 2.3
Main wall: Cavity wall, Insulation As built, u-value: 2.1
Main floor: Suspended timber with insulation between, not sealed, u-value: 0.66
Number of habitable rooms: 4
Unheated rooms: No

Area

	Area (m²)	Height (m)
Main Floor 1	33	2.65
Main Floor 0	20	2.4

Total wall area: 66.62m²
Total glazed area: 13.34m², u-value: 4.8
Proportion double glazed: 0
Number of open fireplaces: 4
Mechanical ventilation: No

Electricity meter type: Unknown
Heater type: Boiler
Boiler type: Regular
Fan flue: Fan, not open flue
Fuel: Mains gas
Primary system: Pre 1998 - High or unknown thermal capacity
Controls: No time or thermostatic control of room temperature
Emitters: Radiators
Secondary fuel: None

Secondary system: None

Water Heating: From main system (Gas)
Water heating storage: Cylinder, assume no insulation
Has cylinder thermostat? N/A
Solar panels supply some water heating No
Photovoltaic array: No
Wind turbine: No
Low energy lights: None

SAP rating: 30

EPC Band: F

CO_2 (kg/yr): 6692

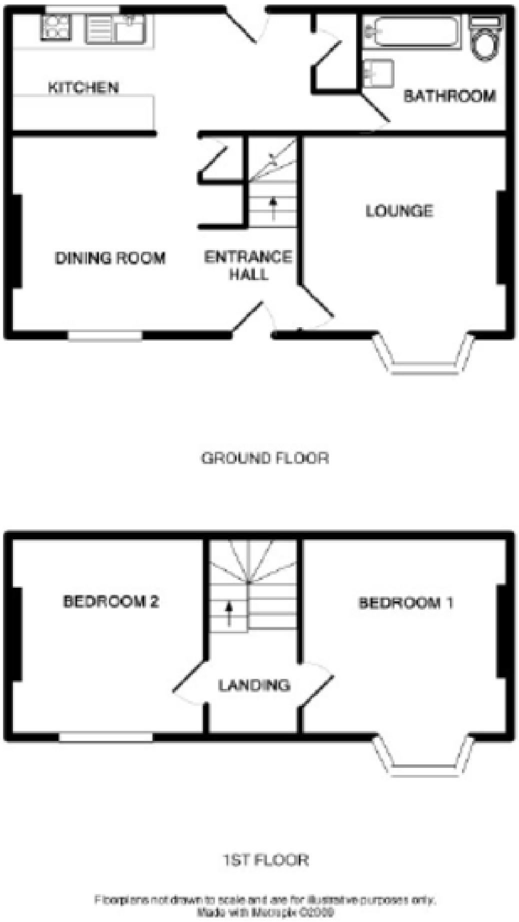


Figure 13: A typical floor plan

A6 2-bed terrace, Victorian

Description: A typical 2-bedroom terraced house from this period is likely to be spread over 2 floors and have solid brick walls.

Number of storeys: 2

Age quoted on SAP:

Main roof: Pitched (slates or tiles), no access to loft No insulation, u-value: 2.3
Main wall: Cavity wall, Insulation As built, u-value: 2.1
Main floor: Suspended timber with insulation between, not sealed, u-value: 0.55
Number of habitable rooms: 3
Unheated rooms: No

Figure 14: An example 2-bed Victorian terrace

Area

	Area (m^2)	Height (m)
Main Floor 1	20	2.65
Main Floor 0	33	2.4

Total wall area: 66.63m^2
Total glazed area: 13.34m^2, u-value: 4.8
Proportion double glazed: 0
Number of open fireplaces: 4
Mechanical ventilation: No

Electricity meter type: Unknown
Heater type: Boiler
Boiler type: Regular
Fan flue: Fan, not open flue
Fuel: Mains gas
Primary system: Pre 1998 - High or unknown thermal capacity
Controls: No time or thermostatic control of room temperature
Emitters: Radiators
Secondary fuel: None
Secondary system: None

Water Heating: From main system (Gas)
Water heating storage: Cylinder, assume no insulation
Has cylinder thermostat? N/A
Solar panels supply some water heating No
Photovoltaic array: No
Wind turbine: No
Low energy lights: None

SAP rating: 30

EPC Band: F

CO_2 (kg/yr): 6692

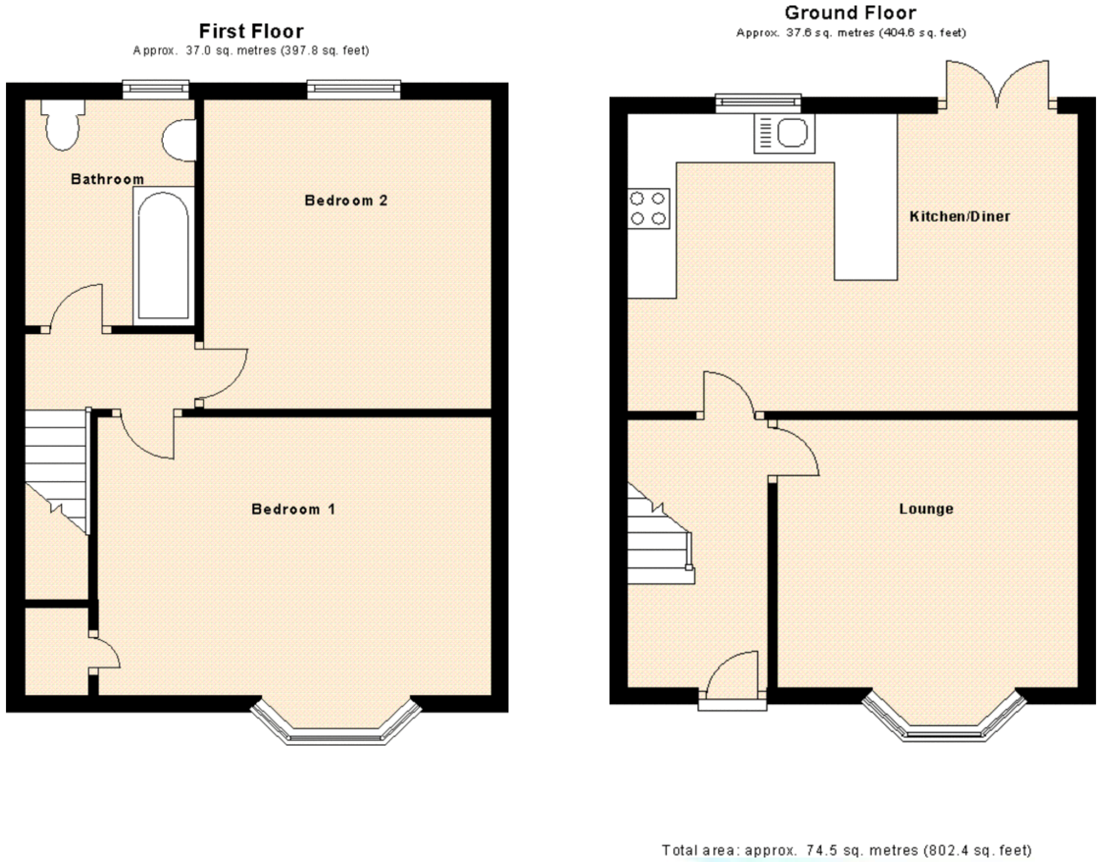


Figure 15: Typical floor plan

A7 2-bed terrace, Georgian

Description: A typical 2-bedroom terraced house from this period is likely to be spread over 2 floors and have solid brick walls.

Number of storeys: 2

Age quoted on SAP:

Main roof: Pitched (slates or tiles), no access to loft No insulation, u-value: 2.3
Main wall: Cavity wall, Insulation As built, u-value: 2.1
Main floor: Suspended timber with insulation between, not sealed, u-value: 0.6
Number of habitable rooms: 5
Unheated rooms: No

Figure 16: Example of 2-bed Georgian terrace

Area

	Area (m²)	Height (m)
Main Floor 1	36.6	2.85
Main Floor 0	36.6	2.6

Total wall area: 67.53m²
Total glazed area: 15.81m², u-value: 4.8
Proportion double glazed: 0
Number of open fireplaces: 4
Mechanical ventilation: No

Electricity meter type: Unknown
Heater type: Boiler
Boiler type: Regular
Fan flue: Fan, not open flue
Fuel: Mains gas
Primary system: Pre 1998 - High or unknown thermal capacity
Controls: No time or thermostatic control of room temperature
Emitters: Radiators
Secondary fuel: None

Secondary system: None

Water Heating: From main system (Gas)
Water heating storage: Cylinder, assume no insulation
Has cylinder thermostat? N/A
Solar panels supply some water heating No
Photovoltaic array: No
Wind turbine: No
Low energy lights: None

SAP rating: 34

EPC Band: F

CO_2 (kg/yr): 7407

Figure 17: Typical floor plan

A8 4-bed detached, post 1980

Description: A typical 4-bedroom detached house from this period is likely to be spread over 2 floors and have cavity walls, many of these will be insulated. This house will often be a family home, with the four bedrooms and bathroom on the first floor, and kitchen, living room, study and dining room on the ground floor.

Number of storeys: 2

Age quoted on SAP:

Figure 18: An example of a 4-bed detached house, post 1980

Main roof: Pitched (slates or tiles), no access to loft, some insulation, u-value: 2.3
Main wall: Cavity wall, Insulation As built, u-value: 0.45
Main floor: solid ground floor, not sealed, u-value: 0.51
Number of habitable rooms: 5
Unheated rooms: No

Area

	Area (m²)	Height (m)
Main Floor 1	49.86	2.75
Main Floor 0	49.86	2.5

Total wall area: 171.7m²
Total glazed area: 13.75m², u-pvc double glazed, u-value: 3.1
Proportion double glazed: 0
Number of open fireplaces: 0
Mechanical ventilation: No

Electricity meter type: Unknown
Heater type: Boiler
Boiler type: Regular
Fan flue: Fan, not open flue
Fuel: Mains gas
Primary system: 1998 or later, standard, permanent pilot
Controls: Programmer, no thermostat
Emitters: Radiators
Secondary fuel: None

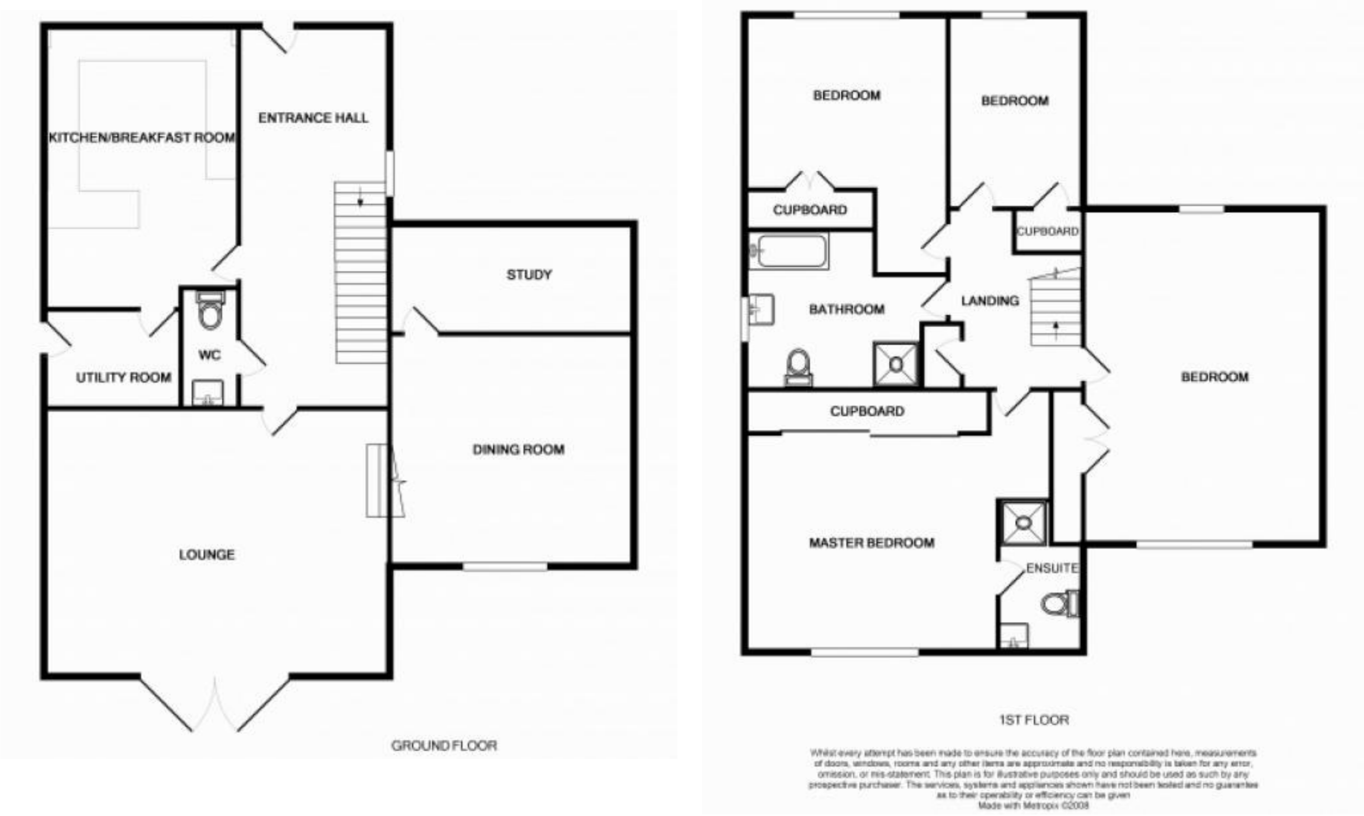
Secondary system: None

Water Heating: From main system (Gas)
Water heating storage: Cylinder, assume no insulation
Has cylinder thermostat? N/A
Solar panels supply some water heating No
Photovoltaic array: No
Wind turbine: No
Low energy lights: None

SAP rating: 46

EPC Band: E

CO_2 (kg/yr): 6938



Whilst every attempt has been made to ensure the accuracy of the floor plan contained here, measurements of doors, windows, rooms and any other items are approximate and no responsibility is taken for any error, omission, or mis-statement. This plan is for illustrative purposes only and should be used as such by any prospective purchaser. The services, systems and appliances shown have not been tested and no guarantee as to their operability or efficiency can be given
Made with Metropix ©2008

Figure 19: A typical floor plan

A9 2-bed flats, 1945 – 1980 (converted)

Description: A typical 2-bedroom converted flat from this period will be over one floor. It is likely to have cavity walls and be situated in a suburban area. It will have two bedrooms, a bathroom, and possibly just one further room.

Figure 20: An example 2-bed converted flat, 1945-1980

Number of storeys: 1

Age quoted on SAP:

Main roof: Pitched (slates or tiles), no access to loft No insulation, u-value: 2.3
Main wall: Cavity wall, Insulation as built, u-value: 1.6
Main floor: timber upper floor, not sealed, u-value: 0.7
Number of habitable rooms: 2
Unheated rooms: No

Area

	Area (m²)	Height (m)
Main Floor 1	33.8	2.2
Main Floor 0		

Total wall area: 44.95m²
Total glazed area: 9.71m², u-value:4.8
Proportion double glazed: 0

Number of open fireplaces: 0
Mechanical ventilation: No

Electricity meter type: Unknown

Heater type: Boiler
Boiler type: Regular
Fan flue: Fan, not open flue
Fuel: Electricity
Primary system: Room heaters
Controls: Appliance stats
Emitters: Radiators
Secondary fuel: None
Secondary system: None

Water Heating: Single immersion
Water heating storage: Cylinder, assume no insulation

Has cylinder thermostat? N/A
Solar panels supply some water heating No
Photovoltaic array: No
Wind turbine: No
Low energy lights: None

SAP rating: 2

EPC Band: G

CO$_2$ (kg/yr): 5187

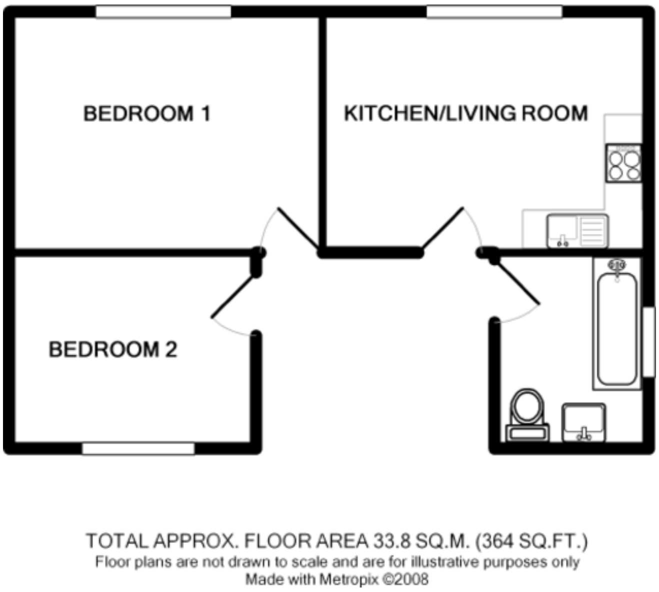


Figure 21: Typical floor plan

A10 2-bed flats 1945 – 1980 (purpose built)

Description: A typical 2-bedroom converted flat from this period will be over one floor. It is likely to have cavity walls and be situated in an urban area. It will have two bedrooms, a bathroom, and probably a kitchen and separate living room.

Figure 22: A typical purpose built 2-bed flat, 1945-1980

Number of storeys: 1

Age quoted on SAP:

Main roof: n/a
Main wall: Cavity wall, Insulation as built, main cavity u-value: 1.6, sheltered wall u-value: 0.98
Main floor: Timber upper floor, not sealed, u-value: 0.7
Number of habitable rooms: 3
Unheated rooms: No

Area

	Area (m²)	Height (m)
Main Floor 1	63	2.2
Main Floor 0		

Total wall area: 42.03m²
Total glazed area: 7.92m², u-value: 4.8
Proportion double glazed: 0
Number of open fireplaces: 0
Mechanical ventilation: No

Electricity meter type: Unknown
Fuel: Electricity
Primary system: Room heaters
Controls: appliance controls
Emitters: Radiators
Secondary fuel: None
Secondary system: None

Water Heating: Single immersion
Water heating storage: Cylinder, assume no insulation
Has cylinder thermostat?
Solar panels supply some water heating No
Photovoltaic array: No
Wind turbine: No
Low energy lights: None

SAP rating: 29

EPC Band: F

CO_2 (kg/yr): 4082

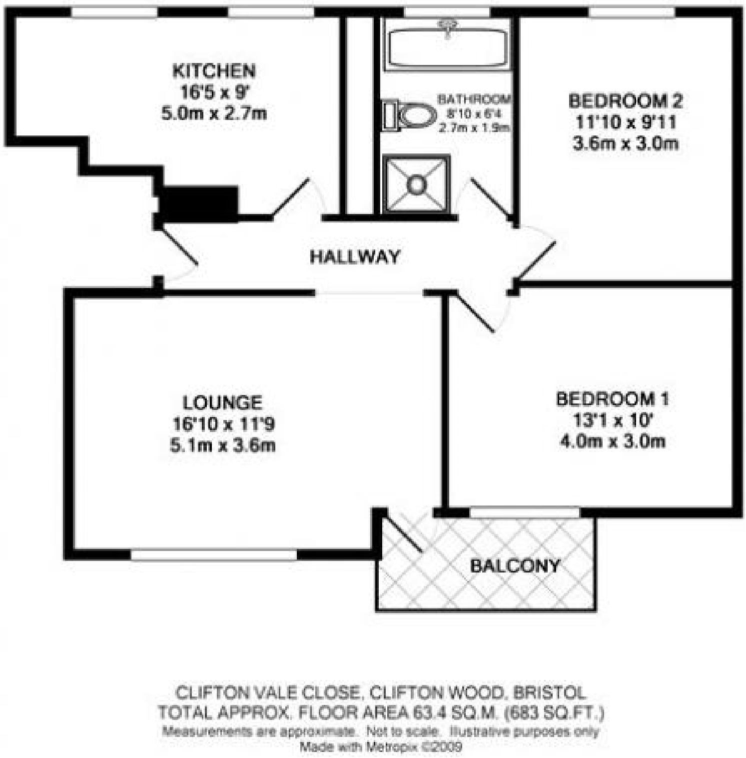


Figure 23: Typical floor plan

A11 3-bed detached, 1945 – 1980

Description: A typical 3-bedroom detached house from this period is likely to be spread over 2 floors and have cavity walls. This house will often be a family home, with the three bedrooms and bathroom on the first floor, and kitchen, living room and dining room on the ground floor.

Number of storeys: 2

Age quoted on SAP:

Figure 24: A typical 3-bed detached house, 1945-1980

Main roof: Pitched (slates or tiles), no access to loft No insulation, u-value: 2.3
Main wall: Cavity wall, Insulation As built, u-value: 1.6
Main floor: solid ground floor, not sealed, u-value: 0.83
Number of habitable rooms: 5
Unheated rooms: No

Area

	Area (m²)	Height (m)
Main Floor 1	43	2.95
Main Floor 0	43	2.7

Total wall area: 152.08m²
Total glazed area: 16.64m², u-value: 4.8
Proportion double glazed: 0
Number of open fireplaces: 0
Mechanical ventilation: No

Electricity meter type: Unknown
Heater type: Boiler
Boiler type: Regular
Fan flue: Fan, not open flue
Fuel: Mains gas
Primary system: Pre 1998 - High or unknown thermal capacity
Controls: No time or thermostatic control of room temperature
Emitters: Radiators
Secondary fuel: None

Secondary system: None

Water Heating: From main system (Gas)
Water heating storage: Cylinder, assume no insulation
Has cylinder thermostat? N/A
Solar panels supply some water heating No
Photovoltaic array: No
Wind turbine: No
Low energy lights: None

SAP rating: 29

EPC Band: F

CO_2 (kg/yr): 9056

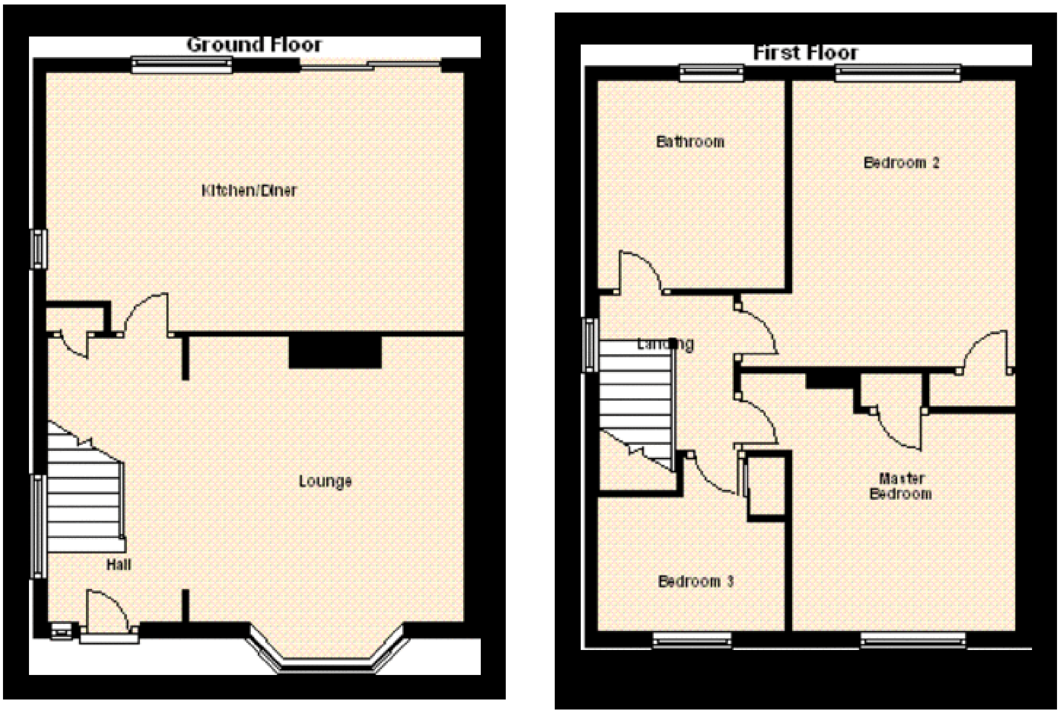


Figure 25: Typical floor plan

A12 3-bed terrace, 1945-1980

Figure 26: A typical 3-bed terrace, 1945-1980

Description: A typical 3-bedroom semi-detached house from this period is likely to be spread over 2 floors and have solid brick walls. This house will often be a family home, with the three bedrooms and bathroom on the first floor, and kitchen, living room and dining room on the ground floor.

Number of storeys: 2

Age quoted on SAP:

Main roof: Pitched (slates or tiles), no access to loft No insulation, u-value: 2.3
Main wall: Cavity wall, Insulation as built, u-value: 1.6
Main floor: solid ground floor, not sealed, u-value: 0.45
Number of habitable rooms: 5
Unheated rooms: No

Area

	Area (m^2)	Height (m)
Main Floor 1	48	2.65
Main Floor 0	48	2.4

Total wall area: 60.96m²,
Total glazed area: 17.94m², u-value: 4.8
Proportion double glazed: 0
Number of open fireplaces: 0
Mechanical ventilation: No

Electricity meter type: Unknown
Heater type: Boiler
Boiler type: Regular
Fan flue: Fan, not open flue
Fuel: Mains gas
Primary system: Pre 1998 - High or unknown thermal capacity
Controls: No time or thermostatic control of room temperature
Emitters: Radiators
Secondary fuel: None

Secondary system: None

Water Heating: From main system (Gas)
Water heating storage: Cylinder, assume no insulation
Has cylinder thermostat? N/A
Solar panels supply some water heating No
Photovoltaic array: No
Wind turbine: No
Low energy lights: None

SAP rating: 41

EPC Band: E

CO_2 (kg/yr): 7502

Figure 27: A typical floor plan

Appendix B

Retrofit Measures

B1 Package 1

B1.1 Draught Proofing

Description: Sealing of gaps around windows, doors, and floors whilst maintaining adequate ventilation. Also includes blocking up open chimneys

Quality Assurance: standard BS 7386; Draught Proofing Advisory Association Limited

Maintenance: None normally required.

Lifetime: 15 years.

Technical guidance: Many older windows will not be fitted with trickle vents. In such cases consideration should be given to the provision of background ventilation, either by the fitting of trickle vents or by the omission of 2m of draught-stripping per room. It is assumed that in wet rooms, such as kitchens and bathrooms, ventilation provision will be upgraded by the inclusion of extract fans.

Draught stripping of some internal doors can lead to significant improvements in comfort. Draughts from below suspended floors can be much worse than those from windows and doors, so sealing the floor is included in this measure. Hardboard fixed to wooden floors can be effective. The use of sealants around the junction between the floor boards and the skirting, and on top of the skirting where it meets the wall is included. The use of polythene sheet to draught proof floors is not recommended, particularly in wet areas.

Other areas that should be sealed against draughts include the loft hatch and any point where pipes or cables penetrate the heated envelope.

Draught stripping single glazed windows can lead to higher levels of condensation on the window-panes. Secondary glazing or new windows is therefore a preferable solution, and where packages 1 and 2 are applied together, this is the solution used.

Non-technical constraints: No specific issues.

Potential concerns with fuel poor: No specific issues.

Ancillary benefits: Absence of draughts can make occupants feel warmer and more comfortable even without improvements in the heating system. Floor insulation should also improve sound insulation between floors and protect against overheating in extreme heat.

Trigger points for work: Decorating work or other routine maintenance.

Next Step: new windows or secondary double glazing

Further Technical Guidance:

- BS 7386: 1997 Draughtstrips for the Draught Control of Existing Doors & Windows in Housing.
- BS7880: 1997 Code of Practice draught control of existing doors and windows in housing using draughtstrips
- Energy Saving Trust, CE137 / GPG 224 'Improving airtightness in dwellings'
- Energy Saving Trust, CE101/GPG 171 'Domestic energy efficiency primer'
- Energy Saving Trust, CE 83/GPG 155 'Energy-efficient refurbishment of existing housing'
- National Insulation Association (NIA) 01428 654011 www.insulationassociation.org.uk

B1.2 Cavity Wall Insulation

Description: Insulating material injected into the cavity of a cavity wall. The U-value achieved depends on the cavity width (average 65mm in the UK) and the insulating material. Carbon bead (EPS) is likely to provide the lowest U-value (with a k value of 0.032 W/m C - 0.034 W/m C), and so is taken as an example here.

Maintenance: None.

Quality Assurance: Cavity Insulation Guarantee Agency (CIGA) – 25 year guarantee (except Polyurethane systems)

Lifetime: Life of dwelling.

Technical guidance: Systems are available that can be used in any wall up to 12 metres in height, provided the installation is undertaken by approved installers to the appropriate BBA or British Standards Institute standard. In other circumstances installations may be allowed up to 25 meters in height provided certain conditions (such as absence of raked joints in brickwork) are met.

Problems with rain penetration are rare especially if walls are rendered. Polyurethane foams can be used in situations where the wall ties have begun to corrode to bond the two leaves of the cavity together. This negates the need for replacement of wall ties and potentially rebuilding, and so can be a cost effective solution. However, if the mortar bed joints have already split, replacing the wall ties may be required regardless.

Non-technical constraints: No specific issues.

Potential concerns with fuel poor: No specific issues.

Ancillary benefits: Work is undertaken from outside, so there is no disruption to tenants. Cavity wall insulation is also likely to improve sound insulation and protect residents from overheating.

Trigger points for work: When general refurbishment of the external wall is being undertaken, or when structural work is being considered. (N.B. Building Regulations Approval is required in England & Wales whenever any thermal element is renovated)

Process of Installation: [ROK]

Next Step: Loft insulation

Performance Limitations: Mineral fibre and Expanded Polystyrene bead CWI have BBA certificates for use in all areas: Urea Formaldehyde Foam has a BSI certificate with certain restrictions in severe weather zones, including coastal areas. The Cavity Insulation Guarantee Agency (CIGA) can supply guarantees that apply to all domestic retro-fit installations.

Further Technical Guidance Available:

- BUFCA (British Urethane Foam Contractors Association) 01428 654011 www.bufca.co.uk
- Cavity Insulation Guarantee Agency (CIGA) 01525 853 300 www.ciga.co.uk
- The Cavity Foam Bureau 0121 544 4949
- Energy Savings Trust, CE16/GPG 26 'Cavity insulation in existing housing'
- Energy Savings Trust, CE57 Refurbishing cavity-walled dwellings (2004 edition)
- Energy Savings Trust, GIL23 Cavity wall insulation: unlocking potential in existing dwellings (2002 edition)
- National Insulation Association Ltd (NIA) 01428 654011 www.insulationassociation.org.uk

B1.3 Loft Insulation

Description: Layer(s) of insulating material on floor of loft achieving a U-value of 0.16 W/m2K (Building Regulations). The average suggested thickness is 250mm. There are many insulating materials that could be used, as with wall insulation.

Maintenance: None

Lifetime: Lifetime of dwelling.

Technical guidance: Care should be taken to ensure that loft insulation does not block existing eaves ventilation. Eaves ventilation becomes more important when loft insulation is present (particularly if there is sarking felt below tiles/slates) because temperature inside loft will generally be lower leading to increased risk of condensation. In many older properties eaves ventilation is not provided deliberately and reliance is made on fortuitous ventilation. In these cases ventilation should be provided when the loft is insulated.

In some designs the rafters cut across the corner of the upper rooms to create an area of sloping ceiling. Insulation should not be packed between the rafters in this case unless provision is made to maintain eaves ventilation - rather, the sloping part of the ceiling can be insulated from within the room using an insulation board.

Air leakage around the loft hatch and light fittings should be addressed at the time the loft is insulated. In particular leakage from wet areas (e.g. bathrooms) into the loft should be minimised in order to mitigate against increased condensation in loft.

If the whole roof is being re-covered breathable sarking membranes could be used to achieve loft ventilation (assessments of suitability should be carried out in accordance with BS5250).

The insulation levels of water pipes and tanks within loft space should be checked because of an increased risk of freezing. If loft insulation completely covers joists a walkway may be needed to allow safe access to tanks etc.

Where possible electrical cables should run above the insulation layer; cables may need to be down-rated if they pass through or below the insulation layer. In cases of doubt a qualified electrician should be consulted.

Safe access to header tanks needs to be considered where joists are covered with insulation. The area below header tanks should not be insulated. Rather, the insulation layer should continue around and above tanks.

Non-technical constraints: Some lofts (for example with shallow pitch and trussed rafters) can be difficult to treat. Occupants' use of the loft as storage area can be significant barrier to treatment.

Potential concerns with fuel poor: No specific issues.

Ancillary benefits: Potential DIY measure.

Trigger points for work: Repairs to roof or any other work in the loft such as re-wiring (N.B. Building Regulations Approval is required in England & Wales whenever any thermal element is renovated)

Further Technical Guidance Available:

- Energy Saving Trust, GPG 171 'Domestic energy efficiency primer'
- Energy Saving Trust, CE104/GPG418 'Energy-efficient refurbishment of existing housing'
- Energy Saving Trust, CE184 - Practical refurbishment of solid-walled houses
- Energy Saving Trust, CE120 Energy efficient loft extensions (2005 edition)
- Energy Saving Trust, CE122 Energy efficient domestic extensions (2005 edition)
- National Insulation Association Ltd (NIA) 01428 654011 www.insulationassociation.org.uk
- NIA good practice guide for existing housing

B1.4 Dedicated Low-Energy Lighting

Description: Installation of light fittings that require low energy bulbs or change of light bulbs to low energy equivalents.

Maintenance: Bulbs require changing less often than standard tungsten bulbs, approximately once every 10 years.

Lifetime: For CFL bulbs - approx 4 years

For LED bulbs – approx 40 years

For fittings – life of dwelling

Technical guidance: Low energy CFLs (Compact Fluorescent Lamps) are appropriate for use in all standard fittings and now come in a very wide variety of shapes and sizes. Low energy halogen lights are also available on the market. LEDs are even more energy efficient than CFLs, and are becoming more widely available.

Non-technical constraints: There have been links made between CFLs and some diseases. These include auto-immune disease lupus, the genetic disorder Xeroderma Pigmentosum (XP), certain forms of eczema and dermatitis, photosensitivity, migraines, and porphyria.

Potential concerns with fuel poor: No specific issues.

Ancillary benefits: The light produced by CFLs is often described as softer than that of traditional bulbs, and many people prefer it.

Trigger points for work: For bulbs – when old bulbs die. For fittings – when any other electrical work is being done.

Performance Limitations: Most of the initial limitations have been overcome – e.g. they now produce a more consistent light, and are available with dimmer switches etc.

B2 Package 2

B2.1 New Boiler (condensing boiler)

Description: Condensing boilers are the only type that meet best practice requirements (90% efficient) and should always be considered as first choice in any application. They are available in both regular and combi modes, and will be room-sealed fan-flue models.

Maintenance: Basic plumbing maintenance

Lifetime: Tend to have a 2 to 3 year warranty

Technical guidance: Typically a new condensing gas boiler will have an efficiency of 90%, compared with 80% for a new non-condensing boiler and 55-65% for older types. It is assumed that a Worcester Bosch Greenstar 37cdi They are suitable for replacing most existing boilers (but not back boiler units (BBUs) in the same position). The boilers are as easy to install as non-condensing boilers, but need a connection from the condensate outlet to a drain.

Care is needed in siting the flue terminal due to the plume of water vapour usually present during boiler operation. The plume will be visible for much of the time the boiler is in operation. Can employ a range of extended flue and plume management options, with the visible plume less likely to be a nuisance at high levels.

Potential concerns with fuel poor: No specific issues.

Ancillary benefits: Grants may be available

Trigger points for work: When an old boiler breaks down

Next Step: Heating controls

B2.2 New Heating Controls

Description: Heating controls allow you to choose when and where the heating is on and how warm it is. They will save energy by ensuring that the boiler is only on when necessary.

Maintenance:

Lifetime:

Technical guidance: A full set of heating controls will include; a programmable thermostat (or separate time programmer and room thermostat), thermostatic radiator valves and a cylinder thermostat (if the house has a regular condensing boiler with a hot water cylinder).

A programmable room thermostat allows the user to choose the times they want their home to be heated and the temperature you want it to reach while it is on. In other words, it allows you to heat rooms or the whole house to different temperatures in your home at appropriate times of the day and week.

TRVs sense the air temperature around them and regulate the flow of hot water entering the radiators to keep a set temperature in a room. Again, they can help you save money and energy - by allowing temperatures in some rooms than in others, and to turn off the heating in rooms that aren't used.

In the majority of cases TRVs cannot turn off the boiler when the whole house has reached the right temperature. To do that, you will need a room thermostat as well. Radiators in the space containing the room thermostat should not normally have TRVs. But if they do, you should keep the TRVs on their highest possible settings, and set the room thermostat to the required temperature instead.

A cylinder thermostat keeps a constant check on the temperature of the water in a hot-water cylinder. It switches the heat supply from the boiler on and off as necessary to keep the water at a set temperature.

Programmable thermostats, room thermostats and TRVs all need a free flow of air to sense the temperature. They should not be covered by curtains or blocked by furniture. Nearby sources of heat such as lamps could also stop them from working properly.

Non-technical constraints:

Ancillary benefits: Increased thermal comfort

Trigger points for work: When boiler is being replaced

Next Step:

B2.3 Secondary Double Glazing

Description: An extra layer of glazing fitted on the inside of the original window.

Unit cost of installation: £1 – 2,000

Bulk cost of installation: [ROK]

Potential CO2 saving: 85-200 kgCO_2/year

Maintenance: None normally required

Lifetime: Commercial systems should last the life of the original frame to which it is fitted

Technical guidance: Need to consider ventilation issues when installing secondary glazing. Secondary glazing should be draught stripped, but the original frame should not (to prevent condensation between the two). Other issues raised under draught stripping are also relevant. Secondary glazing can restrict safe egress through a window in an emergency, so consideration should be given to the choice of an appropriate system or possibly leaving one window untreated. Need to ensure that rapid ventilation can still be achieved (i.e. that the secondary glazing does not prevent easy opening of windows).

Non-technical constraints: Secondary glazing may not be wanted in summer particularly if it restricts the opening of windows, so occupants may try and take it down. This can lead to a storage problem, and potential danger of breaking the panes leading to personal injury.

Ancillary benefits: New windows may be inappropriate in houses in conservation areas, or may be discounted in terms of cost. Secondary double glazing is not visible on the outside of the house, and is less disruptive to fit as original windows remain in place. Can be fitted as a DIY measure. Can also improve sound insulation and condensation problems.

Trigger points for work: small refurbishment jobs or decoration

Technical Guidance Available:

- Energy Saving Trust, *CE184 - Practical refurbishment of solid-walled houses*

B2.4 New Windows (Double glazing with low emissivity coating)

Description: Double glazing with low emissivity coating.

Maintenance: Occasionally the air-tight seal on the glazing units breaks down necessitating replacement of the sealed unit. This is more likely in situations when the sealed units are site-fixed into frames with no provision for draining the rebates (rather than factory applied into new frames).

Lifetime: 15 - 20 years for a sealed unit in an appropriate frame.

Technical guidance: Need to check bay windows to check if the window frames being replaced perform a structural function. With some older frames the lower edge of the glass may be lower than 800mm from the internal floor surface, in which case toughened units will be required. Care should be taken to ensure that the replacement glazing does not have a significantly lower U-value than any of the adjacent thermal elements, such as a solid brick external wall, as this could lead to surface condensation preferentially forming on the walls instead of the glazing itself. Attention also needs to be given to the safe egress of occupants in case of fire.

Non-technical constraints: In some areas (e.g. conservation areas), or in listed buildings, double glazing may require planning permission or the consent of English Heritage.

Ancillary benefits:
Double glazing has a number of non-energy benefits

- Units are usually more secure than older frames
- Inclusion of trickle vents can have a beneficial impact on indoor air quality
- Reduced condensation on inner surface of glass
- Sitting near windows is more comfortable
- Sound transmission from external noise is reduced (this is mainly the result of good draught-stripping which manufactured units have)

Technical Guidance Available:

- Approved Document N Glazing - materials and protection
- Approved Document B Fire Safety - Part B1 Means of warning and escape
- British Plastics Federation windows group 020 7457 5000, www.bpfwindowsgroup.com
- British Woodworking Federation 0870 458 6939 0 http://www.bwf.org.uk/
- Energy Saving Trust, CE66 Windows for new and existing housing
- Energy Saving Trust, CE184 - Practical refurbishment of solid-walled houses
- Energy Saving Trust, GPG 295 Refurbishment site guidance for solid-walled houses - windows and doors
- Steel Window Association 020 7637 3571 http://www.steel-window-association.co.uk/

B3 Package 3

B3.1 Internal Wall Insulation

Description: There are two primary options for internal wall insulation; directly applied internal insulation and internal insulation with studwork. Directly applied insulation is generally in the form of a plasterboard sheet and an insulation board, which may or may not be laminated together. Studwork creates a small cavity between the internal wall surface and the insulation board, and should be used if there have been previous issues with damp.

Lifetime:

Technical guidance: Solid walls loose more heat than cavity walls, so the effect of insulation is greater. It is important that the condition of the existing wall is assessed prior to specifying internal insulation. It may be difficult to avoid excessive thermal bridging, walls may be unsuitable because of rain penetration or the disruption of fixtures may be excessive.

Directly applied internal insulation
There are various methods for fixing internal insulation over good quality existing plaster, including using adhesive; or screwing, bonding or nailing it to the wall with plaster dabs; or to timber battens affixed to the wall; to existing timber-framed walling or screwed to smooth dry walls.

Indirectly applied internal insulation
Rigid or semi-rigid insulation may be carefully cut and friction-fitted between battens, fixed to the wall and then covered with a vapour control layer, or with flanged paper-faced quilt insulation incorporating a vapour-control layer stapled to battens and taping joints, then finished with plasterboard. A timber frame may be installed, which is braced between the floor and ceiling and kept clear of the external wall. Insulation is then stapled to the frame with a vapour control layer and plasterboard finish. Aluminium-faced polyethylene air bubble sheet (or multi foil) may be attached to vertical battens that are fixed to the external wall. Counter-battens (arranged perpendicular to the first set of battens) should then be fixed over the insulation to receive the plasterboard finish. It is suggested that a horizontal batten is fixed below the ceiling in order to prevent any downward flow of cold air from the loft space into the space behind the plasterboard or internal insulation.

Of the insulation types that score highly (A+ or A) in the BRE Green Guide, Expanded polystyrene (EPS) will reportedly give the lowest U-value[22], so it is assumed that this is insulation will be used. However, there may be a case for a thinner insulation, such as phenolic, which achieves a U-value of 0.25 W/mK at just 80mm.

Non-technical constraints: Installation will result in a loss of floor area, so smaller rooms for householders; it is a relatively disruptive installation process for residents; if interior appearance (e.g. ornate plasterwork or wood panelling) needs to protected (e.g. as a listed building) then it will not be suitable; cost – external insulation is generally more expensive than internal.

Ancillary benefits: increased thermal comfort, sound insulation.

Trigger points for work: Any major refurbishment, including installing new wiring, plumbing or central heating system or re-plastering walls.

Further Technical Guidance Available:

- Energy Saving Trust, Internal wall insulation in existing housing: a guide for specifiers and contractors, 2008

B3.2 Floor Insulation

Description: Insulating layer above or below floor.

Maintenance: None normally required

Lifetime: Lifetime of dwelling

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[22] Energy Saving Trust, *Internal wall insulation in existing housing: a guide for specifiers and contractors*, 2008

Technical suitability: For suspended floors ensure any water pipes below the floor are well insulated. Care should be taken around edges to ensure a continuous insulation layer and avoid cold spots. The edges of suspended floors should be sealed with a flexible sealant to reduce air infiltration. Ensure that there is adequate sub-floor ventilation and that airbricks are not blocked or restricted.

Where internal solid floors are in good condition an insulation / chipboard composite floor can be installed, creating floating floor. This will increase the finish floor level, so doors will need to be shortened. The increase in thickness can be minimised by using a thin layer of foam (down to 5mm latex foam), although the thermal performance will be lower. In either case skirting needs to be removed and re-fitted above the new layer. This will allow the new composite covering to be laid up to the external wall (allowing for expansion of the timber layer) thus minimising any remaining cold bridge.

If any increase in floor level would be unacceptable waterproof insulation can be installed vertically below ground level against the external wall or horizontally (for example beneath a footpath) to reduce cold bridging.

Non-technical constraints: No specific issues.

Ancillary benefits: Insulating suspended floors will also improve airtightness, thus making the room more comfortable to sit in.

Trigger points for work: Replacement of solid floor or of floor boards in a suspended floor. (N.B. Building Regulations Approval is required in England & Wales whenever any thermal element is renovated, and a U-value of 0.25W/m^{2}K would normally be required. However a lesser standard may be acceptable if it is not technically or functionally possible to achieve this U-value).

Further Technical Guidance Available

- Energy Saving Trust, *CE101/GPG 171 'Domestic Energy Efficiency Primer'*
- Energy Saving Trust, *CE83/GPG 155 'Energy-efficient refurbishment of existing housing'*
- Energy Saving Trust, *CE184 - 'Practical refurbishment of solid-walled houses'*

B4 Package 4

B4.1 External Wall Insulation

Description: External insulation is the alternative option for solid walls. This involves applying a layer of insulation to the outside of the house. It will comprise the following components:
Insulant – providing the thermal insulation.
Fixings or framework – securely fixing the system to the substrate.
Finish – a protective layer providing weather protection and a finish (often including accessories that offer further protection and connection to elements of the building such as windows and doors).

Quality Assurance: The Insulated Render and Cladding Association (INCA). INCA provides a Latent Defects Insurance Scheme covering design, materials and workmanship for the refurbishment and new build of all building types. Only participating INCA installers can offer the Scheme on BBA or BRE Certified INCA systems.

Maintenance: External insulation is vulnerable to damage, particularly at ground floor level, therefore:

- Either avoid or strengthen external insulation where damage may occur.
- Provide additional reinforcement for wet render systems in vulnerable areas, such as on ground floor level, around entrances or near vehicular access.
- For dry systems, select toughened panels and stronger fixings for vulnerable areas.

- Tackle graffiti through the use of textures and colours, or a finish which can be safely over-painted.
- Most wet render systems can be used in severe weather conditions. However, evidence of test results or a proven track record in these situations should be sought. Ease of maintenance will depend on the external finish or cladding used. Dry systems with smoother surfaces tend to need less maintenance than wet systems.
- The frequency of maintenance also depends on the location, and the appearance required. North walls and those with reduced wind turbulence – those adjacent to other buildings, for example – may suffer from algal growth and the effects of pollution. External flues and fans will also cause a localised build-up of dirt.
- Maintenance work on wet render systems can vary from very occasional to regular overcoating with an acrylic or silicone paint finish.
- Often the only deterioration is in the finish itself. It can develop a dirty or stained appearance; if this becomes aesthetically unacceptable, it will require maintenance.
- Some manufacturers recommend periodic pressure washing at 5-10 year intervals.

Lifetime: Lifetime will depend on quality of workmanship and proper preparation.

Technical guidance:
Insulants: These can be broken down into the following categories:
Mineral fibre – quilt or rigid slab.
Closed cell foam – rigid panels, e.g. polyisocyanurate, urethane or phenolic.
Expanded pentane blown polystyrene – rigid panel.
Extruded polystyrene – rigid panel, used below the damp proof course.
Others – plant-based (e.g. cork, cellulose, woodfibre, reed matting, hemp) or cellular glass.
Fixings:
Mechanical – metal or timber batten/rail system or framework and mechanical anchors or dowels.
Chemical – various adhesives.
Mechanical and chemical – a combination, e.g. chemical anchors.
Finishes: There are two generic finishes:
Wet render – these may be cementitious renders, polymer and fibre-reinforced cementitious renders, polymeric coatings or insulating renders.
Dry cladding – rigid boards, panels and tiling in a variety of materials.

Of the insulation types that score highly (A+ or A) in the BRE Green Guide, Expanded polystyrene (EPS) will reportedly give the lowest U-value[23], so it is assumed that this is insulation will be used. However, there may be a case for a thinner insulation, such as phenolic, which achieves a U-value of 0.25 W/mK at just 80mm.

Non-technical constraints: It will affect the external appearance of the house and therefore may require planning permission and may not be appropriate in conservation areas etc

Ancillary benefits: increased thermal comfort; can bring major aesthetic improvements; can improve property value, by extending the life of the building, and modernising its appearance; lower maintenance costs; can strengthen the existing structure; avoids internal building works; can help to eliminate problems of damp, condensation and mould growth (when accompanied by controlled ventilation); can mitigate the cost of replacing old render (with insulating render systems there is no need to chip off the old render, which would normally be necessary when replacing with render alone); can eliminate the need for extensive re-pointing, thus saving money.

Trigger points for work: when updating appearance of external walls (re-rendering or re-pointing); when addressing damp issues

Further Technical Guidance Available:

- Building Regulations, Part L1B
- Energy Saving trust, *External insulation for dwellings*, 2006
- Energy Saving Trust, *CE184 - 'Practical refurbishment of solid-walled houses'*

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[23] Energy Saving Trust, *Internal wall insulation in existing housing: a guide for specifiers and contractors*, 2008

B4.2 Photovoltaic Panels (Solar PV)

Description: Solar panels that convert the sun's energy in to electricity

Maintenance: PV installations have no moving parts and require minimal maintenance. However they need to be kept clean for optimum performance and regular cleaning to remove dust accumulation may be needed. However, systems can be designed and located so that they can 'self-clean' when it is raining.

Lifetime: The durability of PV cells varies according to the type of cell used, but for silicon-based cells, it will be between 15-30years.

Technical guidance: A 1kWp (kilowatt peak) system is enough to run appliances and processes that are in constant use for a typical UK dwelling. The South West has the highest levels of solar radiation in the UK, 1300kWh/m².
A suitable site is required for the solar panels, which means that the technology may not be suitable for all dwelling types. Ideally the panels should be facing due South and inclined at 30° (which is the average incline of a roof in the UK).
When designing roof mounted systems checks should be made to ensure that the roof structure is able to support the additional weight of the panels, and that the fixings are able to withstand wind uplift on the panels.

Non-technical constraints: There may be planning issues in some areas. Some housing providers have reported vandalism (damage resulting objects being thrown at the panels), so consideration should be given to appropriate protection if panels are in a vulnerable location.

Ancillary benefits: There is some anecdotal evidence that installing renewable energy measures helps to increase householders' awareness of energy use.

Trigger points for work: repairs to roof

Further Technical Guidance Available:

B4.3 Solar Thermal Panels (hot water)

Description: Solar panels, usually mounted on the roof, deliver warm water heated by solar energy. Two basic types of solar collector are used, 'flat plate' and 'evacuated tube'. Assumptions below are based on an evacuated tube system, which is more expensive, but more efficient. The panel comprises a number of separate tubes each being separately sealed and containing a small amount of a fluid. Heat is extracted by evaporating the fluid in the tube which then condenses at the top, releasing the heat to the fluid circulating in the closed loop.

There are also two methods of heat transfer, 'direct' where the water that will be used for bathing etc. is heated directly by being passed through the solar collector and 'indirect' whereby the water passing through the solar collector is in a closed loop and transfers heat to the hot water cylinder via a heat exchange coil.

Maintenance: Solar collectors may need periodic cleaning, and electromechanical components (e.g. circulation pump) will need to be replaced periodically.

Lifetime: 20years

Technical guidance: A suitable site is required for the solar panel (i.e. South facing with minimal shading), which means that the technology may not be suitable for all dwelling types. The hot water cylinder requires two coils, one for heating via the domestic boiler, the other for heating via the solar collector.

Non-technical constraints: may be planning issues in some areas. Some housing providers have reported vandalism (damage resulting objects being thrown at the panels), so consideration should be given to appropriate protection if panels are in a vulnerable location. Evacuated tube systems are more easily modified to increase the capacity of the system.

Ancillary benefits: There is some anecdotal evidence that installing renewable energy measures helps to increase householders' awareness of energy use.

Trigger points for work: roof repairs or major works to hot water system

Further Technical Guidance Available:

- CADDET Renewable Energy - 01235 436806: www.caddet-re.org
- Energy Saving Trust, GIR 88 'Solar hot water systems in new housing - a monitoring report'
- Solar Trade Association - 01908 442290: www.solartradeassociation.org