Programme Area: Buildings

Project: Building Supply Chain for Mass Refurbishment of Houses

Title: Single dweling implementation plan

Abstract:

Please note this report was produced in 2011/2012 and its contents may be out of date. This deliverable is number 4b of 7 in Work Package 3. The report describes the retrofit solutions which have been designed to target the house types most likely to be occupied by consumer segments with whom a successful retrofit engagement is most likely. As such 9 house types have been identified for each of which 2 levels of retrofit package (basic and enhanced) have been created. The impacts of these retrofit packages have been quantified through the use of the Thermal Efficiency model developed within Work Package 1 of the project. This report highlights that occupant behaviour has a significant impact on the viability of retrofit and that advances in materials and techniques are needed if a meaningful impact on energy consumption is to be achieved through retrofit.

Context:

This project looked at designing a supply chain solution to improve the energy efficiency of the vast majority of the 26 million UK homes which will still be in use by 2050.It looked to identify ways in which the refurbishment and retrofitting of existing residential properties can be accelerated by industrialising the processes of design, supply and implementation, while stimulating demand from householders by exploiting additional opportunities that come with extensive building refurbishment.The project developed a top-to-bottom process, using a method of analysing the most cost-effective package of measures suitable for a particular property, through to how these will be installed with the minimum disruption to the householder. This includes identifying the skills required of the people on the ground as well as the optimum material distribution networks to supply them with exactly what is required and when.

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The **ENERGY ZONE CONSORTIUM**:

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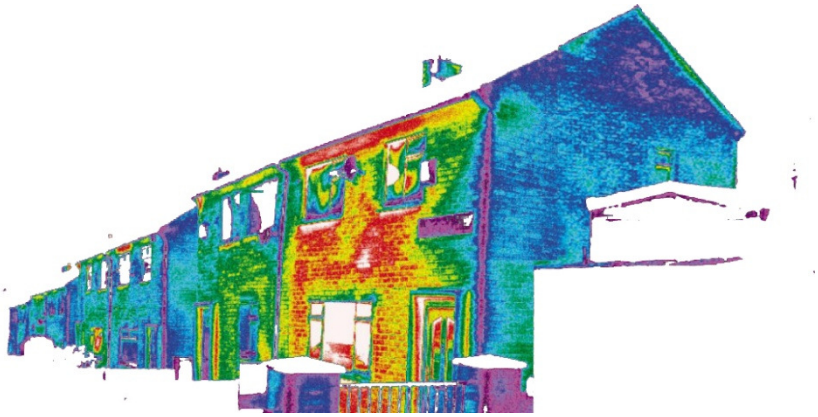
wates



Optimising Thermal Efficiency of Existing Housing

Single Dwelling Implementation Plan

Final Report v3.0

Submitted by PRP on behalf of the
ENERGY ZONE CONSORTIUM

27 January2011

Optimising Thermal Efficiency of Existing Housing

Single Dwelling Implementation Plan

PRP Contact and Work Package 3 Leader	**Andrew Mellor** PRP Architects 10 Lindsey Street Smithfield London EC1A 9HP P) 0207 653 3504 M) 07720 451 466 E) andrew.mellor@prpenvironmental.co.uk
Author	**Marylis Ramos & Kirsten Burrows**, PRP Architects
FAO	**Matthew Barton** Energy Technologies Institute LLP Holywell Building Holywell Way Loughborough LE1 3UZ E) matthew.barton@eti.co.uk
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Contents

1 Executive Summary

The Single Dwelling Implementation Plan report outlines the development of individualised improvement scenarios that are tailored to the customer segments and house types identified previously by the consortium. The report draws on the demographic information from WP5 in order to better understand customer motivations and barriers toward retrofit. This information has also been useful in determining customer awareness of wider green issues and their interest in home improvement.

Using customer segments as a guide, the BRE stock data was analysed to determine the properties in which these groups tend to reside. Customer segments and property types have been extensively detailed to provide robust improvement packages. These packages were developed during the Single Dwelling Refurbishment Plan workshop which involved project partners from PRP, Wates, Total Flow and BRE. All aspects of thermal efficiency, including lighting and appliance use, were considered for each house type. The result was a set of two refurbishment packages for each property, divided into 'Basic' and 'Enhanced' packages based on what are considered basic improvements or those which are best practices. Each plan is designed to address the drivers and barriers for each customer profile while effectively retrofitting their property according to age, typologies and unique considerations. Each measure has been tested with the BRE/UCL model in order to assess the effectiveness of the interventions. The result is a group of solutions that covers a representative percentage of the UK population and housing stock, presenting solutions that are thermally robust as well as represent added value to potential retrofit customers.

The results of our analysis of the whole house packages show that:

- Post-1980 properties are not cost effective to retrofit at our basic level, but all Pre-1980 properties reasonably demonstrate cost effectiveness in terms of retrofit. While Post-1980 homes do show benefits at enhanced level for carbon emissions reduction and fuel savings, but it is not very cost effective because of the high cost to achieve minimal improvements
- Occupant behaviour is a factor that should not be ignored, particularly when predicting energy savings - we have demonstrated that for the same house type and same set of solutions different types of occupants greatly influence fuel savings and CO_2 emissions reductions. For example, despite reductions in lighting, appliance and hot water use, given the same house type, Greener Graduates use up more energy overall - spending around £100 more per annum than the Young Starters, living in the same type of property but heating to a 1°C higher set temperature.
- Some Pre-1919 properties experience a reduction in carbon emissions by up to 50% for the basic packages, and up to 58% for the enhanced packages. Achieving Passivhaus performance standards can result in reductions of up to 75%.
- If we want to hit more ambitious "low carbon" targets, relying on current construction methods and available materials is not enough. We can only hit these targets if we aspire to

meet Passivhaus-type standards, and promote the development of solutions that will enable us to hit the high performance U-values that are required.

- Loft conversions are not generally viable in terms of cost effectiveness and thermal benefits. We need to explore other ways of adding value by creating habitable/storage space.

We also looked at gaps in the current technology available to us for retrofit - there are many products that are not readily available that could greatly contribute to the success of a mass retrofit, in particular products that are able to deliver high levels of insulation without requiring material depth, as well as off-site manufactured multi-functional solutions that combine functions, e.g. finishing and insulation, security and insulation, etc. We would need to further develop some of these "dream materials" if we want to hit more ambitious targets, such as an affordable mass-scale "Passivhaus retrofit standard" exercise.

2 Introduction

- The Single Dwelling Implementation Plan report draws on the work completed in WP3.3 and 3.4a, as well as work completed by project partners on customer segments and supply chain issues
- The report presents 24 whole house package variations specifically tailored to customer segments and the properties in which they are most likely to live
- Packages include not only specific technical solutions but also value propositions and necessary enabling works
- Solutions have been tested with the single dwelling model developed by BRE/UCL to assess the effectiveness of each of the proposed packages

This Single Dwelling Implementation Plan report outlines 24 whole house package variations for the most promising customer segments and associated house types. Chosen house types were determined according to the typology in which the highest percentage of the customer segment live, and the house types which emit the most CO_2 emissions per segment. Customer profiles have dictated aspirations, values, motivations and energy consumption behaviour, which were then used to develop design solutions and delivery programmes.

The pivotal exercise of WP3.4 was the Single Dwelling Implementation Plan workshop which drew on the practical expertise of consortium partners to develop design solution for each house types. This included not only architectural and construction considerations but the customer segment most likely to reside in each house type and their attitudes toward thermal refurbishment.

The design workshop also helped to identify gaps in materials and process which may lead to a demand for particular product innovations that will facilitate the retrofit process. 'Dream' products that would help improve the retrofit process in terms of cost, efficiency and overall attractiveness to the general public were also taken into account. These products have been analysed by project partners at BASF and have been also been utilised by WP4.

All aspects have been supported by the single dwelling model developed by BRE/UCL. It has been especially insightful to see the difference in carbon savings between the various whole house packages as they have been tailored to the occupants - how different types of occupants can result in varying degrees of CO_2 reduction given the same house type and thermal efficiency improvement package.

2.1 Report Objectives

- Develop tailored whole house solution based on dominant customer segments and house types
- Packages cover house types that have been determined to be likely candidates for improvement or those which represent a large portion of the UK stock
- Ensure proposed solutions have been tested and analysed to ensure they are cost and carbon efficient
- Synthesis of other WP findings relevant to single dwelling refurbishment

3 Methodology and Process

- Developed house type and customer segment pairings based on BRE stock data and findings from WP5
- Single Dwelling Refurbishment Plans were created during day-long workshop with project partners
- BRE Model used to test measures proposed in both the basic and enhanced Single Dwelling Refurbishment Plans

The house types and customer segments to be used in developing improvement scenarios in this report build on the work completed in previous stages, specifically WP3.4 and WP5. House types were selected based on frequency of occurrence, contribution to the CO_2 emissions of the UK's existing housing stock and geographical spread. These were narrowed largely according to the chosen customer segments as determined by the consortium to be the most likely groups to accept and undertake a retrofit process. Other groups were included regardless of their inclination toward retrofit as a result of their significant population size. Using stock data provided by the BRE, we can determine what house types these demographic groups will likely live in and their contribution to overall stock CO_2 emissions. We will then develop strategies for the entire retrofit process which will be tested with the single dwelling model and stock model, developed by the BRE.

3.1 Selection of House Type and Customer Type combinations

The original intention was to narrow customer segments to fewer than the ten originally investigated in WP5. Consortium partners undertook a collective exercise to rank each customer group out of three according to the size of the segment, their overall awareness of green issues and their openness toward a retrofit project (with 1 being a small population or negative feelings toward retrofit, while 3 represents a large population or a group that likely has positive feelings toward retrofit). This was based on BRE population data and findings

from WP5 (see Appendix A). However, all ten were included in the Whole House Solutions, as even those who are unlikely to undertake a retrofit project, the customer segment may represent a significant population that will need to be addressed in a mass retrofit programme.

Following this exercise, the BRE stock data was used to determine in which house type each customer segment is likely to live. For most of the customer types, the top two house types for each were chosen. For some segments, only one house type was analysed as a result of either small population size or because the customer type is unlikely to undertake a retrofit.

3.2 GENERATION OF WHOLE HOUSE PACKAGES

The generation of whole house packages involved the findings of WP3.3 Whole House Solutions and drew in the findings of WP5 to consider customer motivations and barriers for a retrofit project. A workshop was organised to develop these packages and was held over one day with architects from PRP, construction specialists from Wates and project partners from Total Flow and BRE. In teams, each group was given a house type and customer segment package (see Appendix B).

For their given house type, each team was given the typical dimensions of the property as well as baseline conditions. Based on these assumptions, the teams were required to identify unique features of the property that would require special attention during a retrofit. Following this exercise, each group developed a basic thermal package of work (Retrofix) and an enhanced package (Retromax) for their given house type. For the basic package, groups were required to formulate a basic whole house package for this type of property. For the enhanced package, teams were to formulate a "good practice" whole house package for this type of property. Enhanced packages tended to involve more investment and more disruption, although teams were required to consider cost effectiveness for both. For each measure, groups were told to include a description of the enabling works required.

Following this stage, teams moved on to the customer segments associated with their house types. Each team was provided with demographic information, customer profiles and aspirations for home improvements/retrofit. With these guidelines, groups determined which solution their segment would likely undertake- a basic, enhanced or bespoke package- and consider the added value measures that can be undertaken at the same time in order to incentivise the customer to undertake a retrofit project.

3.3 MODELLING THE WHOLE HOUSE PACKAGES

After generating the whole house packages, we then tested both basic and enhanced packages. Starting with a baseline run, we tailored the base data for average wall, floor, window, door and roof areas and their current state U-values, boiler performance and airtightness using a set of occupant behaviour profiles - changing the values for occupancy, set temperature, and behavioural consumption for lighting, appliances and hot water depending on our profile of each occupant type. A detailed profile of the occupants can be found in Appendix C.

With the baseline established, we then proceeded to run iterations of the basic and enhanced packages which are described in the next chapter. The resulting data gives us a heat loss profile before and after each package is implemented, CO_2 Emissions, Primary Energy Consumption broken down into Electricity and Gas, Fuel Cost and Construction Cost.

4 Whole House Packages: Basic

- Packages were developed during the Single Dwelling Refurbishment workshop
- Packages were divided into 'Basic' and 'Enhanced' options in order to give alternatives based on cost and disruption
- Basic packages are designed to be sufficient to improve the thermal efficiency to a level which will make a significant step towards the 2050 Climate Change commitments (20-50% savings) without excessive cost
- Enhanced packages are based on the highest level of performance we can envisage with products and processes widely available in the next 5 years irrespective of current cost
- Costs included in each performance table are based on current costs and not target future prices

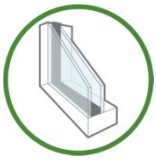
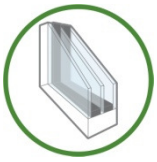
The following whole house packages were developed during the Single Dwelling Refurbishment workshop, where the participants were divided into groups and asked to develop solutions for a specific house type with specific customer groups residing within them. What was interesting was that the main driver for variation between the work packages was the age of construction - older properties may be subject to conservation issues but have the greater potential for thermal improvement, while newer properties may be easier to retrofit in terms of the architectural language that they use, however these are built closer to building regulation standards and therefore show less "bang for buck" in terms of the cost of retrofit versus the increase in energy. In a way, for the newer properties, you have to push available technology a little bit further in order to make retrofit a worthwhile proposition.

The first section of the Whole House Packages starts with the basic packages, which were considered at the workshop to be interventions that would improve a property's thermal efficiency by 20-50%. Customer aspirations reflect on these only in that lower income groups may not even be able to afford the basic retrofit package, hence the development of "Basic Lite" packages that feature options for customer segments earning significantly less than £30,000 per annum. Enhanced Packages are covered in the subsequent section.

The following table shows the complete set of measures used in generating our whole house packages. Light green circles signify that the measure belongs to the "Basic Packages" set and dark green circles signify that the measure belongs to the "Enhanced Packages" set. Orange circles denote unique features that have a high probability of occurrence for that particular housetype, which could potentially increase the complexity and cost of the retrofit, or require special attention to thermal bridging features. Blue circles denote "Added Value"

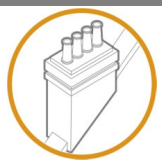
features which are not necessarily thermal efficiency related but have been added to the Enhanced packages in order to respond to the requirements of the customer segment.

SOLUTIONS, FEATURES and ADDED VALUE OPTIONS

WALLS	ROOF	FLOOR	DOORS/ WINDOWS	AIRTIGHTNESS	VENTILATION	HEATING/ CONTROLS
 EWI **0.20 W/m²K**	 Loft insulation **0.15 W/m²K**	 GFloor edge insulation	 Secondary glazing **2.0 W/m²K**	 Airtightness **8 m³/m².hr**	 Single room heat recovery	 A-rated boiler
 IWI front only, EWI **0.20 W/m²K**	 Insulated loft hatch	 UFloor edge insulation	 Draughtstripping	 Airtightness **7 m³/m².hr**	 MVHR	 HW tank jacket
 IWI **0.25 W/m²K**		 Floor insulation **0.15 W/m²K**	 Double glazing **1.3 W/m²K**	 Airtightness **6 m³/m².hr**		 TRVs,zoned controls
 CWI **0.15 W/m²K**		 Solid floor insulation **0.30 W/m²K**	 Triple glazing **0.80 W/m²K**	 Airtightness **5 m³/m².hr**		 Modulating boiler
 Removable reveals			 Insulated secure door **1.5 W/m²K**	 Airtightness **3 m³/m².hr**		 Heat pump

UNIQUE FEATURES

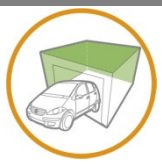
 Extension - EWI

 Chimney-fill and insulate

 Decorative features

 Bay window - upgrade

 Recessed door - insulate

 Garage wall/s & soffit

 Party walls/floors

ADDED VALUE

 Security features

 Loft conversion

 Storage deck

 New kitchen

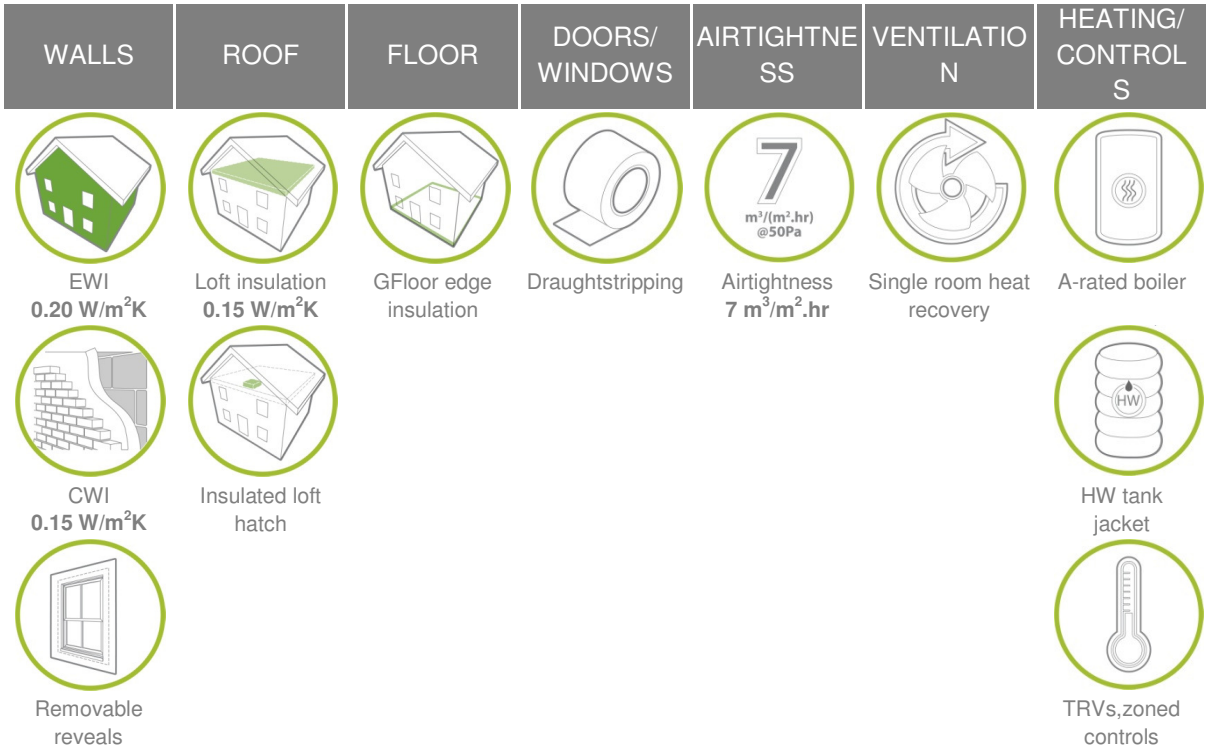
 New bathroom

 Underfloor heating

 Solar thermal HW


A-rated appliances
Energy monitors
Rainwater collection
Greywater recycling
LED lighting
Sunpipes/fiber optics
PV

4.1 BASIC PACKAGE



For the **Basic Packages**, they were built around the following strategy:

- **Wall Insulation** - typically EWI +CWI with a target U-value of 0.15 W/m^{2}K for existing cavity walls (0.2 W/m^{2}K if CWI is not feasible). For solid walls, the approach is tailored to the house type. We do not recommend insulating the reveals at this point as the package does not include window replacement or door replacement and therefore any future window or door replacement could compromise the integrity of the EWI. However, render should be installed to the reveals and heads in order to maintain the aesthetics of the property. Sacrificial strips could be installed to be easily removed without having to be cut out of the installed insulation when future installation occurs. If a cavity wall is encountered, it may be unfilled or filled badly if the CWI installation has not been done in the recent past. If it is feasible to remove the existing fill, remove and replace with better quality CWI. If unfilled, install CWI along with EWI to reduce the depth of insulation required on the exterior of the building. Since window replacement is not a fundamental part of the basic package, removable insulation around the window and entrance reveals will allow for future upgrades without compromising the quality of the EWI installation.
- **Loft Insulation** - typically top up to a U-value of 0.15 W/m^{2}K
- **External Floor Edge Insulation**
- **Airtightness** of 7 m^3/(m^2.hr) @ 50Pa for Post-1945 properties, 8 m^3/(m^2.hr) @ 50Pa for Pre-1945 Properties
- **Draughtstripping** of existing doors and windows
- **Boiler replacement to 90% efficiency A-rated boiler, 80mm jacket for HW tank**
- **Heat recovery extract fans for bathrooms and kitchens**

- **TRVs and zoned controls**

We started with these basic solutions and then customised the solutions based on the unique features of each house - architectural features, wall construction, party walls, configuration. For the basic solutions, we didn't customise the solutions for the occupants - but during the modelling we did tweak the occupancy settings in order to account for behavioural adjustments.

4.1 19MID-YS, 19MID-GG, 19MID-EE &19CNV-GG

Pre-1919 Mid-terrace

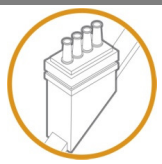
inhabited by Young Starters, Greener Graduates or Early Entrepreneurs

19MID-YS, 19MID-GG, 19MID-EE & 19CNV-GG BASIC						
WALLS	ROOF	FLOOR	DOORS/ WINDOWS	AIRTIGHTNESS	VENTILATION	HEATING/ CONTROLS
IWI front only, EWI **0.20 W/m²K**	Loft insulation **0.15 W/m²K**	GFloor edge insulation	Secondary glazing **2.0 W/m²K**	Airtightness **8 m³/m².hr**	Single room heat recovery	A-rated boiler
Removable reveals	Insulated loft hatch	UFloor edge insulation	Draughtstripping			HW tank jacket

TRVs,zoned controls

UNIQUE FEATURES

Extension - EWI



Chimney-fill and insulate

Decorative features

Bay window - upgrade

Recessed door - insulate

Party walls/floors

For the **Basic Package**, we developed the following set of solutions:

- **Wall Insulation 0.20 W/m^{2}K. IWI + EWI.** Mid-terraces are one of the most common house types in the UK and in many areas form an integral part of the urban streetscape. Pre-1919 mid terraces (which are sometimes converted flats as well) can be richly decorated on the front facade, plus the common occurrence of a constrained site means there probably will not be space for EWI, and therefore we opted to go for IWI on the front with EWI everywhere else, and because of the solid wall construction we recognise that a U-value of 0.15 W/m2K would be too demanding, so the target would be 0.20 W/m2K for the walls.
- **Bay window detailing and Extension detailing.** 45% of this stock type will have bay windows and 75% will have extensions, therefore bay window and extension thermal bridging and insulation detailing may be required.
- **Upper Floor Insulation (front façade only).** Because we opted for IWI in order to preserve the front façade, we risk thermal bridging at the upper floor, therefore some floor boards need to be lifted in order for spray foam insulation to be blown into the upper floor perimeter:
- **Secondary Glazing 2.0 W/m^{2}K.** Since window thermal standards can be really sub-standard in these properties if they haven't already had double glazing installed, we recommend secondary glazing that can be removed in the future in the event of full window replacement:
- **Chimney Insulation.** A property of this age is likely to have a chimney stack, so we would cap the top of the chimney and fill it with insulation.

The rest of the package consists of the standard solutions:

- **Loft Insulation** - typically top up to a U-value of 0.15 W/m^{2}K
- **External Ground Floor Edge Insulation**
- **Airtightness** of 8 m^3/(m^2.hr) @ 50Pa for Pre-1945 Properties
- **Draughtstripping** of existing doors and windows
- **Boiler replacement to 90% efficiency A-rated boiler, 80mm jacket for HW tank**
- **Heat recovery extract fans for bathrooms and kitchens**
- **TRVs and zoned controls**

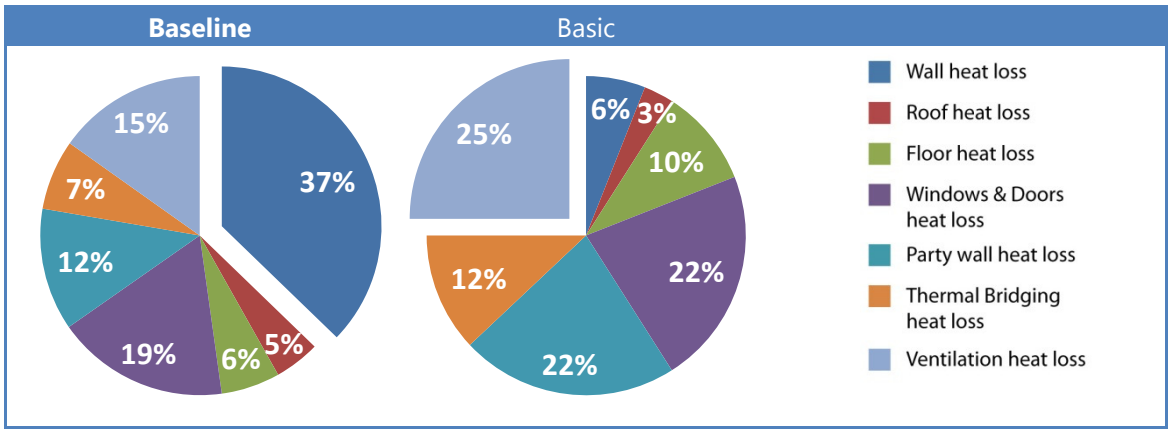
Party walls would require internal works so in the interests of minimising disruption and keeping costs down we have opted to leave party wall insulation for the enhanced packages.

MODELLING RESULTS

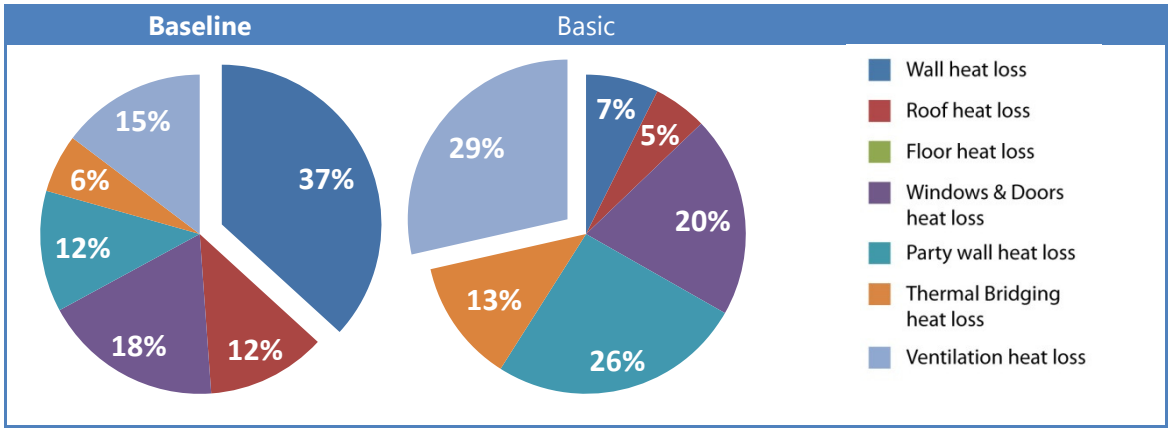
19MID-YS	Baseline	Basic Package	% Improvement
Cost	£0	£18,826	
Carbon Emissions	75 $kgCO_2/m^2/yr$	46 $kgCO_2/m^2/yr$	39%
Heating Energy Consumption	286 $kWh/m^2/yr$	139 $kWh/m^2/yr$	51%
Fuel Costs	£1,271/yr	£822/yr	35%
Cost per $kgCO_2$ saved	£0	£7.23/$kgCO_2$/yr	
Main Heat Loss Route	Wall Heat Loss (37%)	Ventilation (25%)	

19MID-GG	Baseline	Basic Package	% Improvement
Cost	£0	£20,540	
Carbon Emissions	81 $kgCO_2/m^2/yr$	52 $kgCO_2/m^2/yr$	36%
Heating Energy Consumption	332 $kWh/m^2/yr$	150 $kWh/m^2/yr$	55%
Fuel Costs	£1,333.00/yr	£930.00/yr	30%
Cost per $kgCO_2$ saved	£0	£7.95/$kgCO_2$/yr	
Main Heat Loss Route	Wall Heat Loss (37%)	Ventilation (25%)	

19MID-EE	Baseline	Basic Package	% Improvement
Cost	£0	£20,790	
Carbon Emissions	83 $kgCO_2/m^2/yr$	53 $kgCO_2/m^2/yr$	36%
Heating Energy Consumption	291 $kWh/m^2/yr$	137 $kWh/m^2/yr$	53%
Fuel Costs	£1,428.00/yr	£962.00/yr	33%
Cost per $kgCO_2$ saved	£0	£7.68/$kgCO_2$/yr	
Main Heat Loss Route	Wall Heat Loss (37%)	Ventilation (25%)	



19CNV-GG	Baseline	Basic	% Improvement
Cost	£0	£18,301	
Carbon Emissions	84 $kgCO_2/m^2/yr$	41 $kgCO_2/m^2/yr$	51%
Heating Energy Consumption	362 $kWh/m^2/yr$	145 $kWh/m^2/yr$	60%
Fuel Costs	£1,139.00/yr	£591.00/yr	48%
Cost per $kgCO_2$ saved	£0	£5.75/$kgCO_2$/yr	
Main Heat Loss Route	Wall heat loss (37%)	Ventilation (29%)	



4.2 19DET-SR

Pre-1919 Detached House
inhabited by Successful Ruralites

19DET-SR BASIC						
WALLS	ROOF	FLOOR	DOORS/ WINDOWS	AIRTIGHTNESS	VENTILATION	HEATING/ CONTROLS
IWI **0.15-0.20 W/m²K**	Loft insulation **0.15 W/m²K**	GFloor edge insulation	Secondary glazing **2.0 W/m²K**	Airtightness **8 m³/m².hr**	Single room heat recovery	A-rated boiler
Removable reveals	Insulated loft hatch	UFloor edge insulation	Draughtstripping			HW tank jacket
						TRVs,zoned controls

UNIQUE FEATURES				
Extension - EWI	Chimney-fill and insulate	Decorative features	Bay window - upgrade	Recessed door - insulate

For the **Basic Package**, we developed the following set of solutions:

- **Wall Insulation 0.20 W/m^{2}K, IWI throughout.** We were working under the assumption that Pre-1919 detached houses, particularly the ones inhabited by Successful Ruralites would likely have significant architectural value and may even be located within a conservation area. Therefore we proposed a 100% IWI solution. Due to the extent of the IWI, we would also likely have issues with the removal and reinstatement of internal decoration, as well as need to install upper floor perimeter insulation, similar to the one for the 19MID solution.
- **Bay window detailing and extension detailing.** 38% of this stock type will have bay windows and 75% will have extensions, therefore bay window and extension thermal bridging and insulation detailing may be required.
- **Recessed door** - This property type typically features a recessed doorway that loses heat through the soffits and the recess walls. Where possible, use thin high performance insulation to mitigate the cold bridges.
- **Secondary Glazing 2.0 W/m^{2}K.** Similarly to 19MID, if the property hasn't already had double glazing installed, we recommend secondary glazing that can be removed in the future in the event of full window replacement.
- **Chimney Insulation.** A property of this age is likely to have a chimney stack, so we would cap the top of the chimney and fill it with insulation.

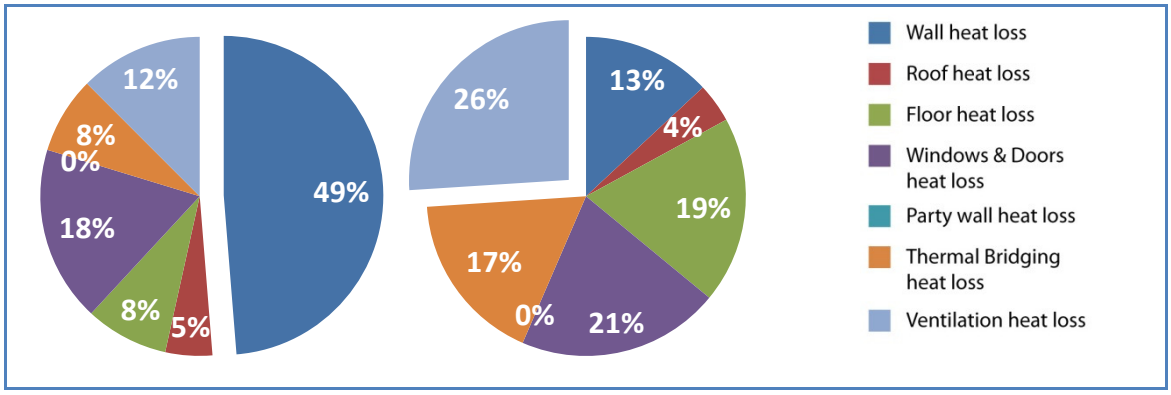
The rest of the package consists of the standard solutions:

- **Loft Insulation** - typically top up to a U-value of 0.15 W/m^{2}K
- **External Ground Floor Edge Insulation**
- **Airtightness** of 8 m^3/(m^2.hr) @ 50Pa for Pre-1945 Properties
- **Draughtstripping** of existing doors and windows
- **Boiler replacement to 90% efficiency A-rated boiler, 80mm jacket for HW tank**
- **Heat recovery extract fans for bathrooms and kitchens**
- **TRVs and zoned controls**

MODELLING RESULTS

19DET-SR	Baseline	Basic	% Improvement
Cost	£0	£41,637	
Carbon Emissions	82 kgCO_2/m^2/yr	38 kgCO_2/m^2/yr	54%
Heating Energy Consumption	336 kWh/m^2/yr	115 kWh/m^2/yr	66%
Fuel Cost	£2,528.00/yr	£1,269.00/ yr	50%
Cost per kgCO_2 saved	£0	£5.70/kgCO_2/yr	
Main Heat Loss Route	Wall Heat Loss (49%)	Ventilation (26%)	

Baseline	Basic



4.3 30SEM-MG, 30SEM-TR*, 30SEM-OE* & 30SEM-UC

1919-1944 Semi-detached

inhabited by Middle Grounders, Transitional Retirees, Older Established and Urban Constrained

*(*indicates that these groups are prime candidates based on acceptance of retrofit)*

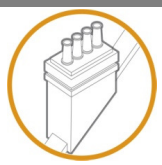
30SEM-MG, 30SEM-TR*, 30SEM-OE* & 30SEM-UC BASIC						
WALLS	ROOF	FLOOR	DOORS/ WINDOWS	AIRTIGHTNESS	VENTILATION	HEATING/ CONTROLS
EWI **0.20 W/m²K**	Loft insulation **0.15 W/m²K**	GFloor edge insulation	Draughtstripping	AT **8 m³/m².hr**	Single room heat recovery	A-rated boiler
CWI	Insulated loft hatch					HW tank jacket

Removable reveals

TRVs,zoned controls

UNIQUE FEATURES

Extension - EWI



Chimney-fill and insulate

Decorative features

Bay window - upgrade

Recessed door - insulate

Party wall

For the **Basic Package**, we developed the following set of solutions:

- **Wall Insulation 0.15 W/m^{2}K, EWI.** Decorative detailing is less of an issue with these properties and it is more feasible to apply EWI to these properties. Wall construction may vary largely - for this age of property there is a mix of solid and cavity wall construction. If a cavity wall is encountered, it will likely be unfilled or filled badly if the CWI installation has not been done in the recent past. If it is feasible to remove the existing fill, remove and replace with better quality CWI. If unfilled, install CWI along with EWI to reduce the depth required on the exterior of the building. Since window replacement is not a fundamental part of the basic package, removable insulation around the window and entrance reveals will allow for future upgrades without compromising the quality of the EWI installation.
- **Bay window detailing and extension detailing.** 66% of this stock type will have bay windows and 45% will have extensions, therefore bay window and extension thermal bridging and insulation detailing may be required.
- **Recessed door** - This property type typically features a recessed doorway that loses heat through the soffits and the recess walls. Where possible, use thin high performance insulation to mitigate the cold bridges.
- **Chimney Insulation.** A property of this age is likely to have a chimney stack, so we would cap the top of the chimney and fill it with insulation.

Basic packages would not involve internal insulation of the party wall - this will be included in the Enhanced packages.

The rest of the package consists of the standard solutions:

- **Loft Insulation** - typically top up to a U-value of 0.15 W/m^{2}K
- **External Ground Floor Edge Insulation**
- **Airtightness** of 8 m^3/(m^2.hr) @ 50Pa for Pre-1945 Properties
- **Draughtstripping** of existing doors and windows
- **Boiler replacement to 90% efficiency A-rated boiler, 80mm jacket for HW tank**
- **Heat recovery extract fans for bathrooms and kitchens**
- **TRVs and zoned controls**

MODELLING RESULTS

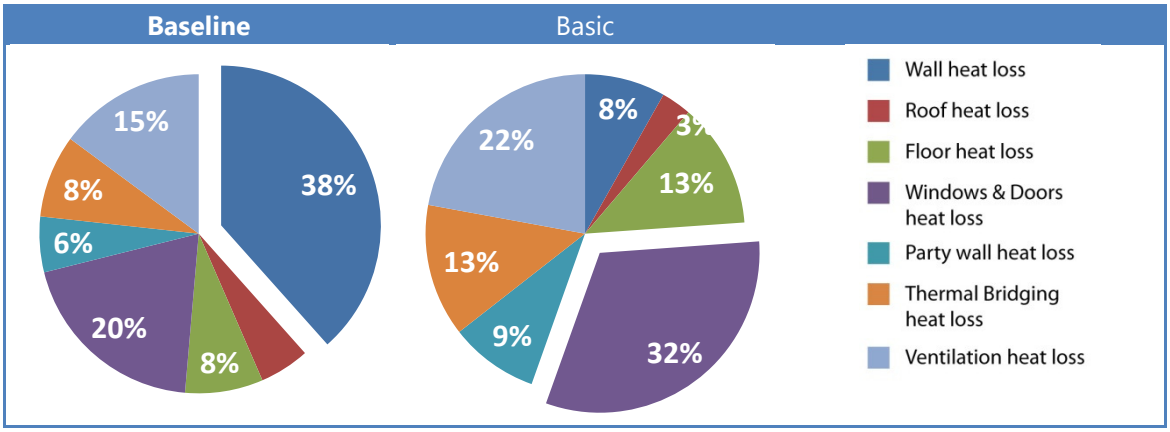
30SEM-MG	Baseline	Basic	% Improvement
Cost	£0	£15,777.00	
Carbon Emissions	81 kgCO_2/m^2/yr	53 kgCO_2/m^2/yr	35%
Heating Energy Consumption	299 kWh/m^2/yr	154 kWh/m^2/yr	48%
Fuel Cost	£1,414.00/year	£962.00/yr	32%
Cost per kgCO_2 saved	£0	£6.01/kgCO_2/yr	
Main Heat Loss Route	Wall Heat Loss (38%)	Windows/Doors (32%)	

30SEM-TR*	Baseline	Basic	% Improvement
Cost	£0	£15,777.00	
Carbon Emissions	78 kgCO_2/m^2/yr	48 kgCO_2/m^2/yr	38%
Heating Energy Consumption	298 kWh/m^2/yr	149kWh/m^2/yr	50%

Fuel Cost	£1, 332.00/year	£868.00/ yr	35%
Cost per kgCO_2 saved	£0	£5.86/kgCO_2/yr	
Main Heat Loss Route	Wall Heat Loss (38%)	Windows/Doors (32%)	

30SEM-UC	Baseline	Basic	% Improvement
Cost	£0	£16,027.00	
Carbon Emissions	88 $kgCO_2/m^2/yr$	59 $kgCO_2/m^2/yr$	33%
Heating Energy Consumption	295 $kWh/m^2/yr$	146$kWh/m^2/yr$	51%
Fuel Cost	£1, 570.00/year	£1,108.00/ yr	29%
Cost per $kgCO_2$ saved	£0	£5.98/$kgCO_2$/yr	
Main Heat Loss Route	Wall heat loss (38%)	Windows/Doors (32%)	

30SEM-OE* (Prime Candidate)	Baseline	Basic	% Improvement
Cost	£0	£15,777.00	
Carbon Emissions	78 $kgCO_2/m^2/yr$	48 $kgCO_2/m^2/yr$	38%
Heating Energy Consumption	298 $kWh/m^2/yr$	149 $kWh/m^2/yr$	50%
Fuel Cost	£1, 332.00/year	£868.00/ yr	35%
Cost per $kgCO_2$ saved	£0	£5.86/$kgCO_2$/yr	
Main Heat Loss Route	Wall heat loss (38%)	Windows/Doors (32%)	



4.4 50SEM-TR*, 50SEM-OE*, 50SEM-UD, 50SEM-UC, 50SEM-SP*

1945-1964 Semi-detached

inhabited by Transitional Retirees, Older Established, Unconvinced Dependents, Urban Constrained and Stretched Pensioners

*(*indicates that these groups are prime candidates based on acceptance of retrofit)*

50SEM-TR*, 50SEM-OE*, 50SEM-UD, 50SEM-UC *50SEM-SP* BASIC

WALLS	ROOF	FLOOR	DOORS/ WINDOWS	AIRTIGHTNESS	VENTILATION	HEATING/ CONTROLS
EWI **0.20 W/m²K**	Loft insulation **0.15 W/m²K**	GFloor edge insulation	Draughtstripping	Airtightness **7 m³/m².hr**	Single room heat recovery	A-rated boiler
CWI **0.15 W/m²K**	Insulated loft hatch					HW tank jacket
Removable reveals						TRVs,zoned controls

UNIQUE FEATURES

Chimney-fill and insulate | Recessed door - insulate | Party wall

The **Basic Package** consists of the typical basic set of solutions:

- **Wall Insulation**
- **Loft Insulation**
- **External Floor Edge Insulation**
- **Airtightness** of 7 $m^3/(m^2.hr)$ @ 50Pa
- **Draughtstripping** of existing doors and windows
- **Boiler replacement to 90% efficiency A-rated boiler, 80mm jacket for HW tank**
- **Heat recovery extract fans for bathrooms and kitchens**
- **TRVs and zoned controls**

In addition, this house type contains the following features which may require attention:

- **Chimney Insulation.** A property of this age is likely to have a chimney stack, so we would cap the top of the chimney and fill it with insulation.
- **Recessed door** - This property type typically features a recessed doorway that loses heat through the soffits and the recess walls. Where possible, use thin high performance insulation to mitigate the cold bridges.

Basic packages would not involve internal insulation of the party wall - this will be included in the Enhanced packages.

MODELLING RESULTS

50SEM-UD	Baseline	Basic	% Improvement
Cost	£0	£15,580.00	
Carbon Emissions	74 $kgCO_2/m^2/yr$	58 $kgCO_2/m^2/yr$	22%
Heating Energy Consumption	219 $kWh/m^2/yr$	138 $kWh/m^2/yr$	37%
Fuel Cost	£1, 293.00/yr	£1,053.00/ yr	19%
Cost per $kgCO_2$ saved	£0	£11.20/$kgCO_2$/yr	
Main Heat Loss Route	Windows/Doors (24%)	Windows/Doors (29%)	

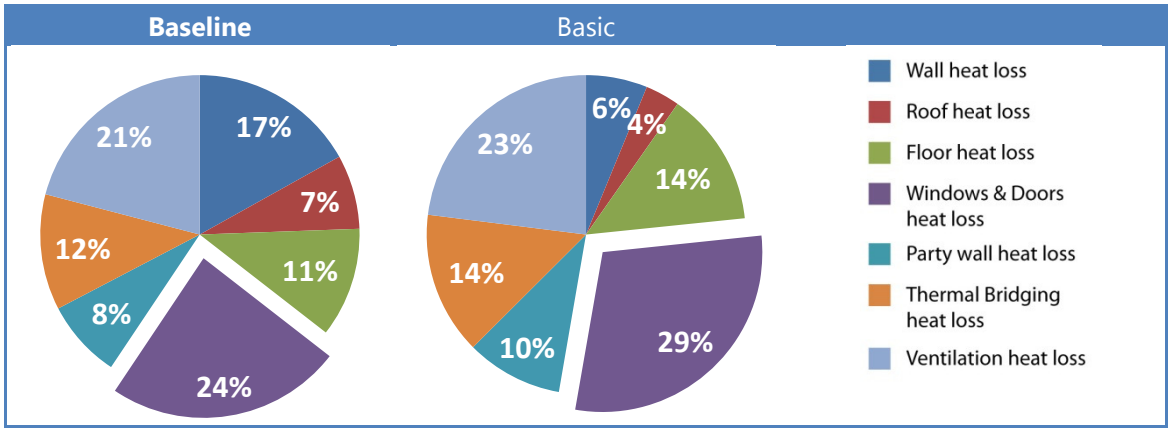
50SEM-UC	Baseline	Basic	% Improvement
Cost	£0	£15,580.00	
Carbon Emissions	78 $kgCO_2/m^2/yr$	58 $kgCO_2/m^2/yr$	26%
Heating Energy Consumption	238 $kWh/m^2/yr$	138 $kWh/m^2/yr$	42%
Fuel Cost	£1, 350.00/yr	£1,053.00/ yr	22%
Cost per $kgCO_2$ saved	£0	£9.04/$kgCO_2$/yr	
Main Heat Loss Route	Windows/Doors (24%)	Windows/Doors (29%)	

50SEM-SP*	Baseline	Basic	% Improvement
Cost	£0	£15,330.00	
Carbon Emissions	61 $kgCO_2/m^2/yr$	43 $kgCO_2/m^2/yr$	30%
Heating Energy Consumption	247 $kWh/m^2/yr$	158 $kWh/m^2/yr$	36%
Fuel Cost	£976.00/yr	£711.00/ yr	27%

Cost per $kgCO_2$ saved	£0	£9.98/$kgCO_2$/yr
Main Heat Loss Route	Windows/Doors (24%)	Windows/Doors (29%)

50SEM-TR*	Baseline	Basic	% Improvement
Cost	£0	£15,330.00	
Carbon Emissions	62 $kgCO_2/m^2/yr$	47 $kgCO_2/m^2/yr$	24%
Heating Energy Consumption	218 $kWh/m^2/yr$	142 $kWh/m^2/yr$	35%
Fuel Cost	£1,045.00/yr	£820.00/ yr	22%
Cost per $kgCO_2$ saved	£0	£11.73/$kgCO_2$/yr	
Main Heat Loss Route	Windows/Doors (24%)	Windows/Doors (29%)	

50SEM-OE*	Baseline	Basic	% Improvement
Cost	£0	£15,330.00	
Carbon Emissions	62 $kgCO_2/m^2/yr$	47 $kgCO_2/m^2/yr$	24%
Heating Energy Consumption	218 $kWh/m^2/yr$	142 $kWh/m^2/yr$	35%
Fuel Cost	£1, 045.00/yr	£820.00/ yr	22%
Cost per $kgCO_2$ saved	£0	£11.73/$kgCO_2$/yr	
Main Heat Loss Route	Windows/Doors (24%)	Windows/Doors (29%)	



4.5 70DET-OE*

1965-1980 Detached house

inhabited by Older Established

*(*indicates that these groups are prime candidates based on acceptance of retrofit)*

70DET-OE* BASIC						
WALLS	ROOF	FLOOR	DOORS/ WINDOWS	AIRTIGHTNESS	VENTILATION	HEATING/ CONTROLS
EWI **0.20 W/m²K**	Loft insulation **0.15 W/m²K**	GFloor edge insulation	Draughtstripping	Airtightness **8 m³/(m².hr)**	Single room heat recovery	A-rated boiler
CWI **0.15 W/m²K**	Insulated loft hatch					HW tank jacket
Removable reveals						TRVs,zoned controls
UNIQUE FEATURES						
Extension - EWI	Garage wall/s & soffit					

The **Basic Package** consists of the typical basic set of solutions:

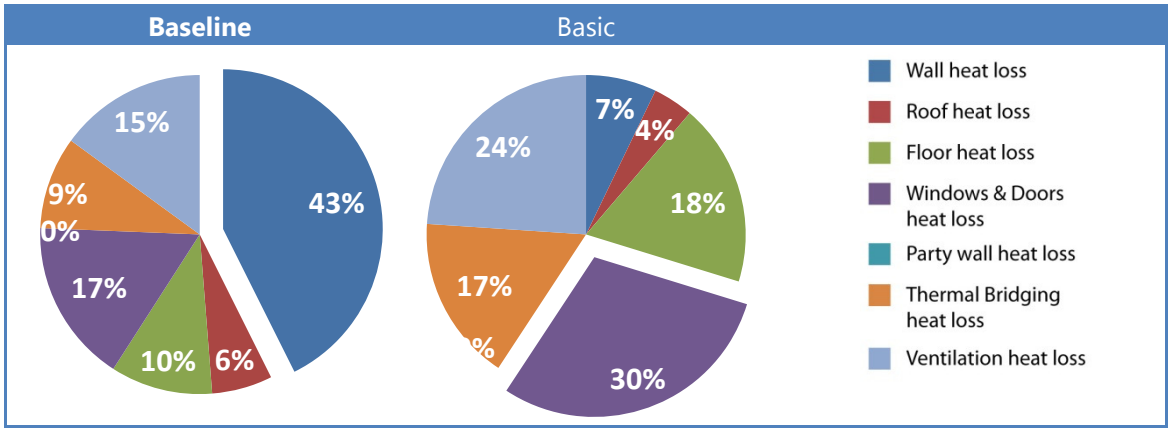
- **Wall Insulation**
- **Loft Insulation**
- **External Floor Edge Insulation**
- **Airtightness** of 8 $m^3/(m^2.hr)$ @ 50Pa
- **Draughtstripping** of existing doors and windows
- **Boiler replacement to 90% efficiency A-rated boiler, 80mm jacket for HW tank**
- **Heat recovery extract fans for bathrooms and kitchens**
- **TRVs and zoned controls**

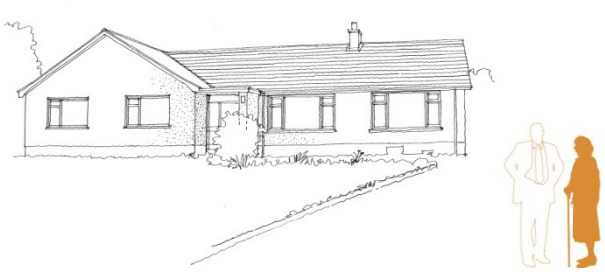
In addition, this house type contains the following features which may require attention:

- **Extension detailing.** 61% of this stock type will have extensions, therefore thermal bridging and insulation detailing may be required.
- **Garage.** Since this is a detached property, it is likely to have its own garage attached to the main house, which will need to be insulated at the soffit if the ceiling of the garage has a heated space above it, and at the walls where it is attached to the main house.

MODELLING RESULTS

70DET-OE*	Baseline	Basic	% Improvement
Cost	£0	£22,059.00	
Carbon Emissions	73 $kgCO_2/m^2/yr$	40 $kgCO_2/m^2/yr$	45%
Heating Energy Consumption	294 $kWh/m^2/yr$	127 $kWh/m^2/yr$	57%
Fuel Cost	£1, 827.00/yr	£1,064.00/ yr	42%
Cost per $kgCO_2$ saved	£0	£4.98/$kgCO_2$/yr	
Main Heat Loss Route	Wall Heat Loss (43%)	Windows/Doors (30%)	



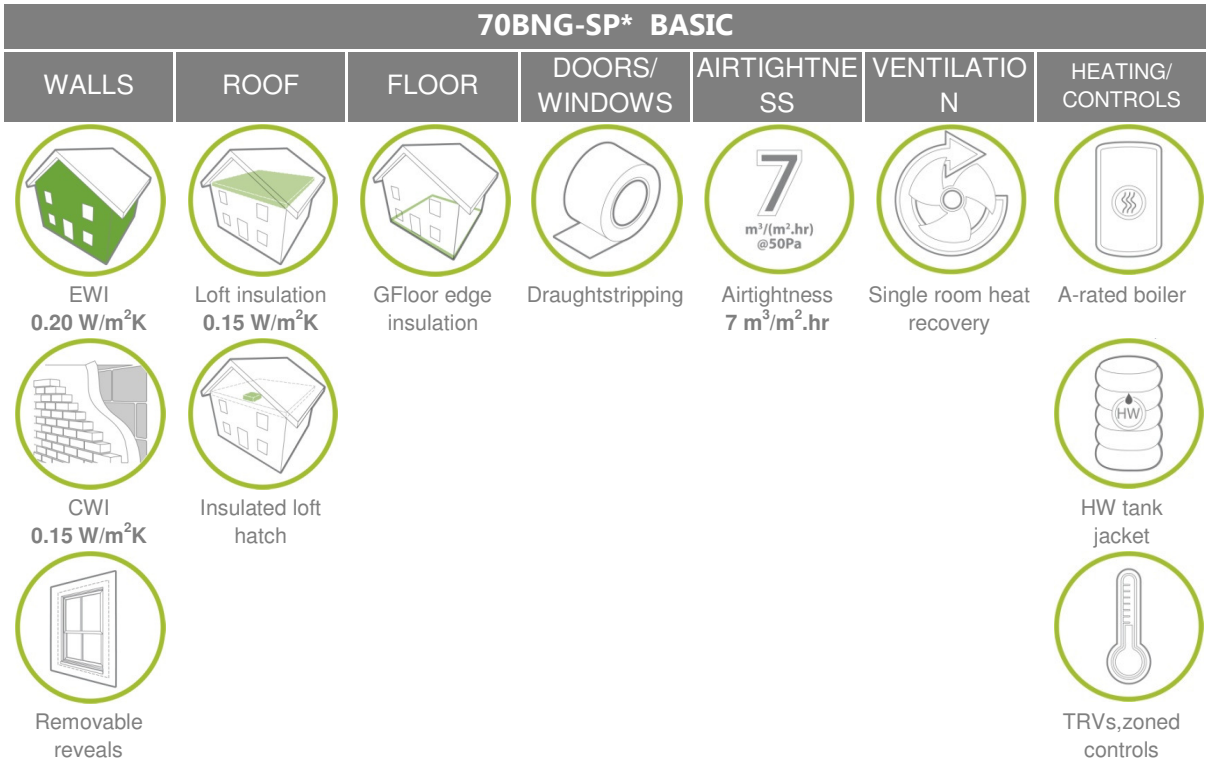


4.6 70BNG-SP*

1960-1980 Bungalow

inhabited by Stretched Pensioners (funding necessary for SP)

*(*indicates that these groups are prime candidates based on acceptance of retrofit)*

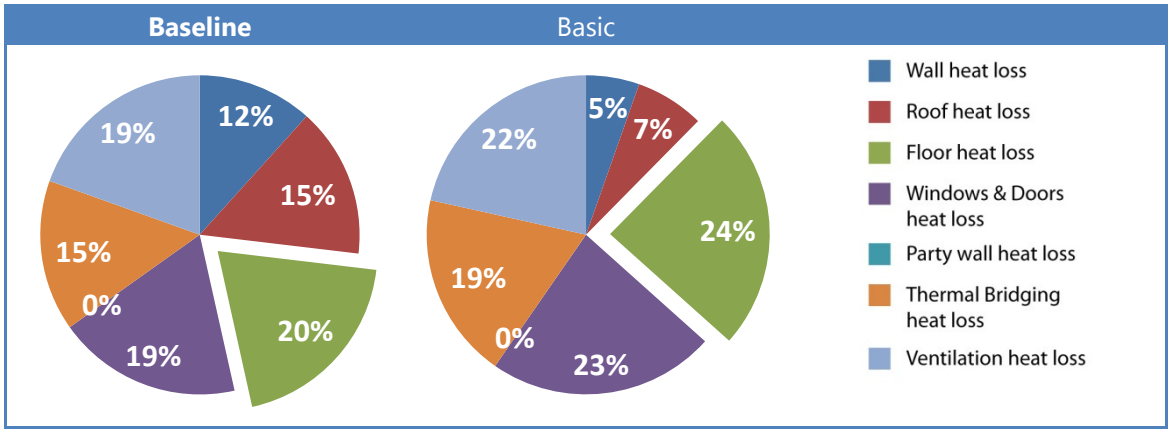


The **Basic Package** consists of the typical basic set of solutions:

- **Wall Insulation**
- **Loft Insulation**
- **External Floor Edge Insulation**
- **Airtightness** of 8 $m^3/(m^2.hr)$ @ 50Pa
- **Draughtstripping** of existing doors and windows
- **Boiler replacement to 90% efficiency A-rated boiler, 80mm jacket for HW tank**
- **Heat recovery extract fans for bathrooms and kitchens**
- **TRVs and zoned controls**

MODELLING RESULTS

70BNG-SP*	Baseline	Basic	% Improvement
Cost	£0	£13,772.00	
Carbon Emissions	72 $kgCO_2/m^2/yr$	50 $kgCO_2/m^2/yr$	31%
Heating Energy Consumption	301 $kWh/m^2/yr$	188 $kWh/m^2/yr$	38%
Fuel Cost	£997.00/yr	£710..00/ yr	29%
Cost per $kgCO_2$ saved	£0	£8.25/$kgCO_2$/yr	
Main Heat Loss Route	Floor Heat Loss (20%)	Floor Heat Loss (24%)	



4.7 70LRF-YS

1965-1980 Purpose Built Low Rise Flat
inhabited by Young Starters

70LRF-YS BASIC						
WALLS	ROOF	FLOOR	DOORS/ WINDOWS	AIRTIGHTNESS	VENTILATION	HEATING/ CONTROLS
EWI **0.20 W/m²K**	Loft insulation **0.15 W/m²K**	GFloor edge insulation	Draughtstripping	Airtightness **7 m³/m².hr**	Single room heat recovery	A-rated boiler
CWI **0.15 W/m²K**	Insulated loft hatch					HW tank jacket
Removable reveals						TRVs,zoned controls
UNIQUE FEATURES						
Party walls/ floors						

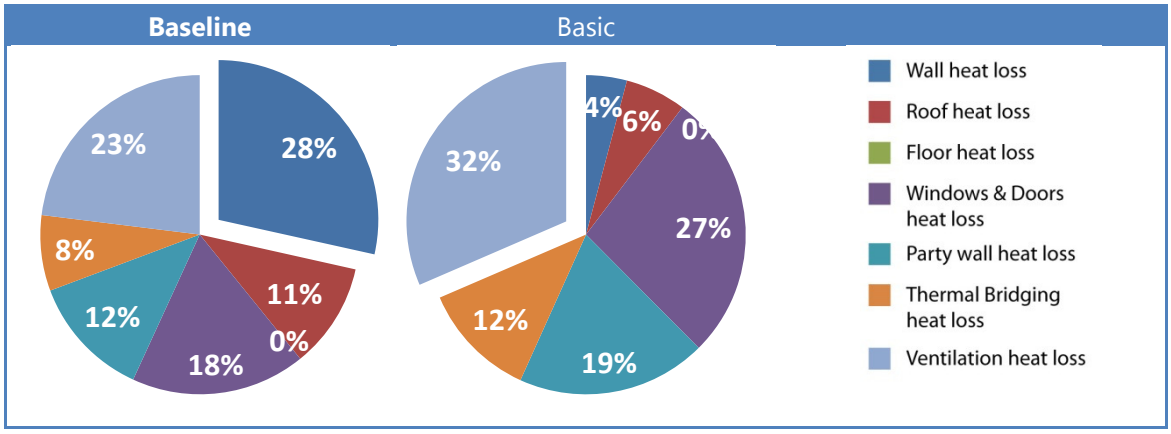
The **Basic Package** consists of the typical basic set of solutions:

- **Wall Insulation**
- **Loft Insulation**
- **External Floor Edge Insulation**
- **Airtightness** of 8 $m^3/(m^2.hr)$ @ 50Pa
- **Draughtstripping** of existing doors and windows
- **Boiler replacement to 90% efficiency A-rated boiler, 80mm jacket for HW tank**
- **Heat recovery extract fans for bathrooms and kitchens**
- **TRVs and zoned controls**

Basic packages would not involve internal insulation of the party wall - this will be included in the Enhanced packages.

MODELLING RESULTS

70LRF-YS	Baseline	Basic	% Improvement
Cost	£0	£8,427.00	
Carbon Emissions	72 $kgCO_2/m^2/yr$	52 $kgCO_2/m^2/yr$	28%
Heating Energy Consumption	224 $kWh/m^2/yr$	122 $kWh/m^2/yr$	46%
Fuel Cost	£805.00/yr	£610.00/ yr	24%
Cost per $kgCO_2$ saved	£0	£7.44/$kgCO_2$/yr	
Main Heat Loss Route	Wall Heat Loss (28%)	Ventilation (32%)	



4.8 90DET-SR, 90DET-MG & 90DET-EE*

Post-1980 Detached house

inhabited by Successful Ruralites, Middle Grounders, Early Entrepreneurs

*(*indicates that these groups are prime candidates based on acceptance of retrofit)*

90DET-SR, 90DET-MG & 90DET-EE* BASIC						
WALLS	ROOF	FLOOR	DOORS/ WINDOWS	AIRTIGHTNESS	VENTILATION	HEATING/ CONTROLS
EWI **0.20 W/m²K**	Loft insulation **0.15 W/m²K**	GFloor edge insulation	Draughtstripping	Airtightness **7 m³/m².hr**	Single room heat recovery	TRVs,zoned controls
CWI **0.15 W/m²K**	Insulated loft hatch					
Removable reveals						
UNIQUE FEATURES						
Extension - EWI	Garage wall/s & soffit					

The **Basic Package** consists of the typical basic set of solutions, minus a new boiler since the average boiler efficiency for this age of property is around 85% on average. If boiler efficiency is less than 85%, however, we would recommend that a replacement is included in the package.

- **Wall Insulation**
- **Loft Insulation**
- **External Floor Edge Insulation**
- **Airtightness** of 8 $m^3/(m^2.hr)$ @ 50Pa
- **Draughtstripping** of existing doors and windows
- **Heat recovery extract fans for bathrooms and kitchens**
- **TRVs and zoned controls**

In addition, this house type contains the following features which may require attention:

- **Extension detailing.** 61% of this stock type will have extensions, therefore thermal bridging and insulation detailing may be required.
- **Garage.** Since this is a detached property, it is likely to have its own garage attached to the main house, which will need to be insulated at the soffit if the ceiling of the garage has a heated space above it, and at the walls where it is attached to the main house.

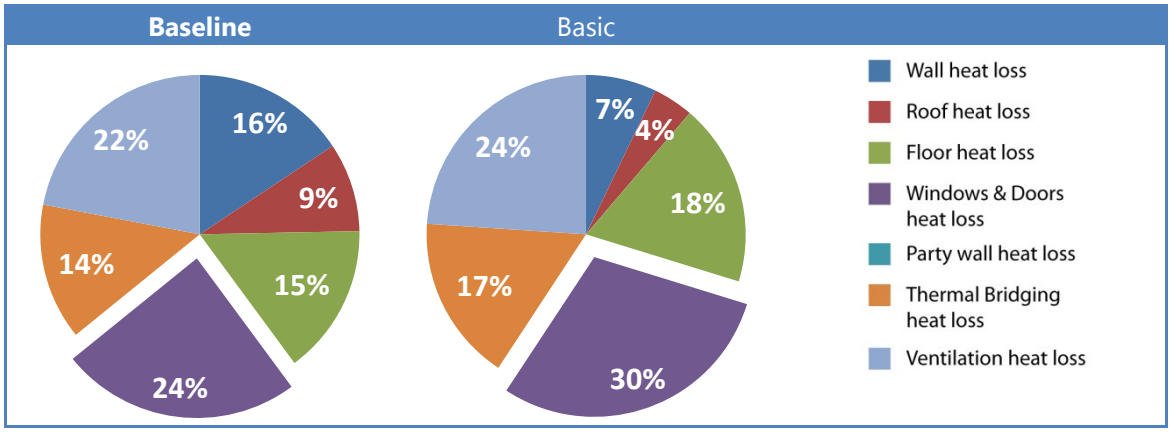
MODELLING RESULTS

90DET-SR	Baseline	Basic	% Improvement
Cost	£0	£22,059.00	
Carbon Emissions	49 $kgCO_2/m^2/yr$	43 $kgCO_2/m^2/yr$	12%
Heating Energy Consumption	172 $kWh/m^2/yr$	142 $kWh/m^2/yr$	17%
Fuel Cost	£1,269.00/yr	£1,131.00/yr	11%
Cost per $kgCO_2$ saved	£0	£27.50/$kgCO_2$/yr	
Main Heat Loss Route	Windows/Doors (24%)	Windows/Doors (30%)	

90DET-MG	Baseline	Basic	% Improvement
Cost	£0	£22,059.00	
Carbon Emissions	52 $kgCO_2/m^2/yr$	46 $kgCO_2/m^2/yr$	12%
Heating Energy Consumption	170 $kWh/m^2/yr$	140 $kWh/m^2/yr$	18%
Fuel Cost	£1,359.00/yr	£1,222.00/yr	10%
Cost per $kgCO_2$ saved	£0	£27.71/$kgCO_2$/yr	
Main Heat Loss Route	Windows/Doors (24%)	Windows/Doors (30%)	

90DET-EE*	Baseline	Basic	% Improvement
Cost	£0	£22,309.00	
Carbon Emissions	54 $kgCO_2/m^2/yr$	48 $kgCO_2/m^2/yr$	11%
Heating Energy Consumption	170 $kWh/m^2/yr$	140 $kWh/m^2/yr$	18%
Fuel Cost	£1,438.00/yr	£1,299.00/ yr	10%

Cost per kgCO_2 saved	£0	£27.58/kgCO_2/yr
Main Heat Loss Route	Windows/Doors (24%)	Windows/Doors (30%)


Baseline
Basic
16%
9%
15%
24%
14%
22%
7%
4%
18%
30%
17%
24%
Wall heat loss
Roof heat loss
Floor heat loss
Windows & Doors heat loss
Party wall heat loss
Thermal Bridging heat loss
Ventilation heat loss

5 Whole House Packages: Enhanced

- 'Enhanced' packages were developed during the Single Dwelling Refurbishment workshop based on best practices
- These packages also consider 'Added Value' incentives which are personalised based on the likely residents of the house type
- 'Enhanced' packages are likely to involve a greater level of disruption and investment than the 'Basic' packages

"Enhanced" packages include what were considered as "Good Practice" measures coupled with "Added Value" options that would be tailored to the customers living within them. Hence there are 8 main variations on the Basic Package theme, while there are 20 variations on the Enhanced Package theme.

4.1 Typical Enhanced Package

Enhanced packages take the basic package as a starting point and then further improve thermal efficiency using floor insulation, replacement doors and windows, better airtightness and more innovative heating systems.

1.5 W/m^{2}K

Therefore, the Enhanced Package includes the following features from the **Basic Package**:

- **Wall Insulation**
- **Loft Insulation**
- **External Floor Edge Insulation**
- **Airtightness** (for enhanced it's between 3-6 $m^3/(m^2.hr)$ @ 50Pa)
- **Draughtstripping** of existing doors and windows
- **Boiler replacement to 90% efficiency A-rated boiler, 80mm jacket for HW tank**
- **Heat recovery extract fans for bathrooms and kitchens**
- **TRVs and zoned controls**

These additional components are then included to the basic package:

- **Floor Insulation** - for suspended floors, we would propose lifting and insulating between the joists to achieve a target U-value of 0.15 W/m^2K. For solid floors we really need to have a thin insulation solution to place on top of the solid floor without any need for a major change in height that will affect the bottom of stairs and doorways. For the properties that may have solid floors, the target U-value is 0.3 W/m^2K due to the challenge of sourcing an appropriate material.
- **Replacement windows** - Replace existing windows with thermally broken triple-glazed windows with a U-value of 0.80 W/m^2K. Because the doors and windows are being replaced, there is no need for the removable strip around the reveals. Also, because a window replacement is being undertaken in conjunction with EWI, maximise the opportunity to create a better window detail by moving the window outwards so that it coincides with the EWI depth, to minimise thermal bridges. Cills may need to be extended.
- **Replacement doors** - Replace existing external doors with insulated security doors, and create a draught lobby where feasible and aesthetically acceptable.
- **Airtightness** of 5 $m^3/(m^2.hr)$ @50Pa for Post-1945 properties, 5 $m^3/(m^2.hr)$ @ 50Pa for Pre-1945 properties. 3 $m^3/(m^2.hr)$ @50Pa only when in conjunction with MVHR for ventilation.
- **Modulating boiler** - a product that will be on the market in 5 years, is a futureproofing solution to ensure that boilers have a flexible range of capacities to enable them to adjust to reduced hot water and heating requirements that may result from future improvements to the thermal efficiency of the property and changes in occupancy. Forward compatibility with solar thermal systems is also recommended so that the transition to solar hot water can be made more easily in the future.

We started with this set of solutions and then customised them based on the unique features of each house - architectural features, wall construction, party walls, configuration. For the enhanced packages we also drew inspiration from the occupants in terms of the added value offerings and lifestyle triggers that would incentivise them to undertake whole house retrofit.

5.1A 19MID-YS & 19MID-GG ENHANCED

Pre-1919 Mid-terrace
inhabited by Young Starters or Greener Graduates

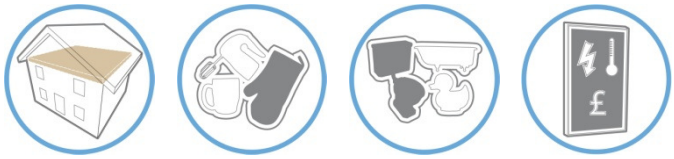
19MID-YS & 19MID-GG ENHANCED

WALLS	ROOF	FLOOR	DOORS/ WINDOWS	AIRTIGHTNESS	VENTILATION	HEATING/ CONTROLS
IWI front only, EWI **0.20 W/m²K**	Loft insulation **0.15 W/m²K**	Floor insulation **0.15 W/m²K**	Secondary glazing **2.0 W/m²K**	Airtightness **6 m³/m².hr**	Single room heat recovery	HW tank jacket
	Insulated loft hatch		Draughtstripping			TRVs,zoned controls
			Insulated secure door **1.5 W/m²K**			Modulating boiler
						Consider Heat pump

UNIQUE FEATURES

Extension - EWI | Chimney-fill and insulate | Decorative features | Bay window - upgrade | Recessed door - insulate | Party wall

ADDED VALUE



For the Pre-1919 mid-terrace, we took the basic package for this house type (see section 4.1) and modified it as follows:

- **Floor Insulation** - for suspended floors, we would propose lifting and insulating between the joists to achieve a target U-value of 0.15 W/m^2K. External floor edgeinsulation would no longer be needed as the floor joist insulation should be adequate.
- **Replacement doors** - Replace existing external doors with insulated security doors, and create a draught lobby where feasible and aesthetically acceptable.
- **Airtightness** of 6 m^3/(m^2.hr) @50Pa
- **Modulating boiler** - a product that will be on the market in 5 years, is a futureproofing solution to ensure that boilers have a flexible range of capacities to enable them to adjust to reduced hot water and heating requirements that may result from future improvements to the thermal efficiency of the property and changes in occupancy. Forward compatibility with solar thermal systems is also recommended so that the transition to solar hot water can be made more easily in the future.
- **Heat pumps** should be considered if the property is off-grid and there is enough space on site. This measure would require a reasonably well-informed occupant, hence this option has been made available to Successful Ruralites, Young Starters, Greener Graduates, Early Enterprisers and Middle Grounders.
- **Party walls** would now be insulated with thin high-performance insulation.

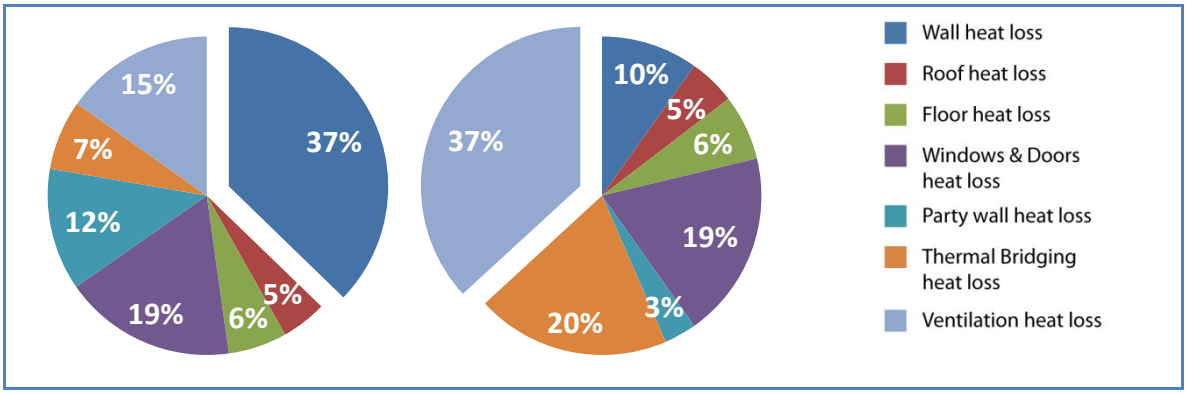
In terms of added value items, Young Starters and Greener Graduates would likely be responsive to the following triggers and incentives:

- **Additional storage space** which can be created by creating a storage deck over the installed loft insulation - this will also protect the installation
- **New kitchen and bathroom**
- **Energy monitors** (Greener Graduates only)

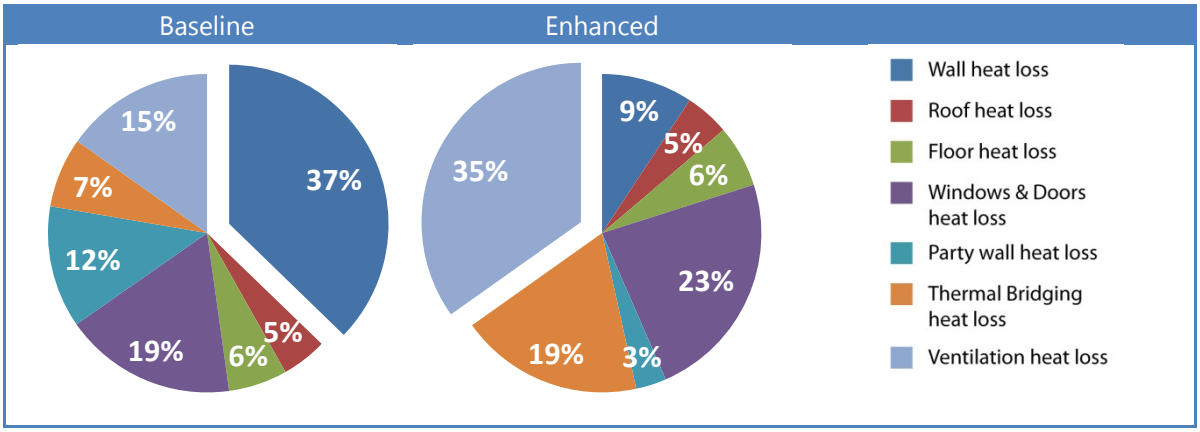
MODELLING RESULTS

19MID-YS ENHANCED	Baseline	Enhanced Package	% Improvement
Cost		£28,488.00	
Cost + Added Value		£36, 488.00	
Carbon Emissions	75 $kgCO_2/m^2/yr$	42 $kgCO_2/m^2/yr$	44%
Heating Energy Consumption	286 kWh/m^2/yr	119 kWh/m^2/yr	58%
Fuel Costs	£1,271/yr	£764/yr	40%
Cost per $kgCO_2$ saved		£9.68/$kgCO_2$/yr	
Main Heat Loss Route	Wall Heat Loss (37%)	Ventilation (37%)	

Baseline	Enhanced



19MID-GG ENHANCED	Baseline	Enhanced Package	% Improvement
Cost		£28,488.00	
Cost + Added Value		£36, 488.00	
Carbon Emissions	81 $kgCO_2/m^2/yr$	41 $kgCO_2/m^2/yr$	49%
Heating Energy Consumption	332 $kWh/m^2/yr$	131 $kWh/m^2/yr$	61%
Fuel Costs	£1,333.00/yr	£724.00/yr	46%
Cost per $kgCO_2$ saved		£8.05/$kgCO_2$/yr	
Main Heat Loss Route	Wall Heat Loss (37%)	Ventilation (35%)	



5.1B 19MID-EE* ENHANCED

Pre-1919 Mid-terrace
inhabited by Early Enterprisers

19MID-EE* ENHANCED

WALLS	ROOF	FLOOR	DOORS/ WINDOWS	AIRTIGHTNESS	VENTILATION	HEATING/ CONTROLS
IWI front only, EWI **0.20 W/m²K**		Floor insulation **0.15 W/m²K**	Secondary glazing **2.0 W/m²K**	Airtightness **6 m³/m².hr**	Single room heat recovery	HW tank jacket
			Draughtstripping			TRVs,zoned controls
			Insulated secure door **1.5 W/m²K**			Modulating boiler
						Consider Heat pump

UNIQUE FEATURES

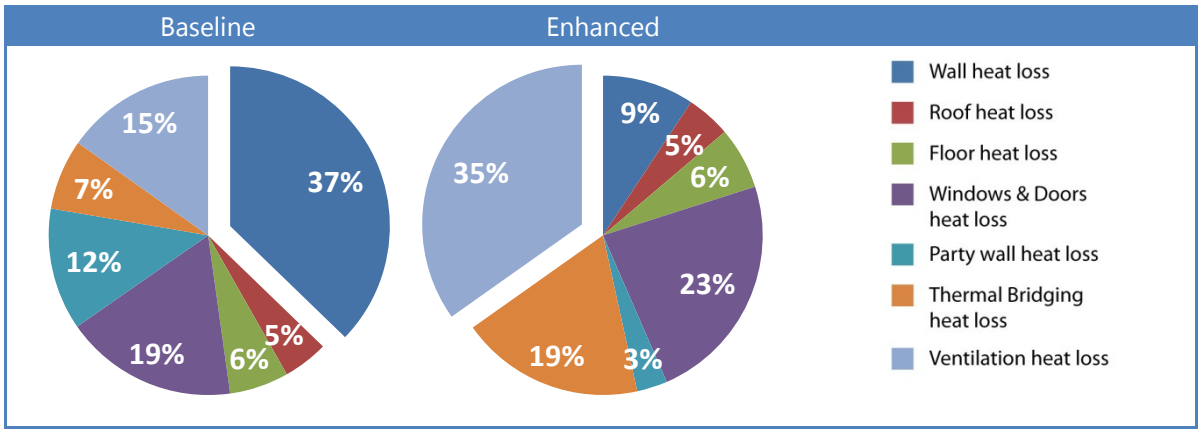
Extension - EWI | Chimney-fill and insulate | Decorative features | Bay window - upgrade | Recessed door - insulate | Party wall

ADDED VALUE

This package is similar to the enhanced package for 5.1A, with the exception of the Loft Conversion, which was identified as potential trigger factor for Early Enterprisers and their growing families. Other added value items include a new kitchen and bathroom.

MODELLING RESULTS

19MID-EE ENHANCED	Baseline	Enhanced Package	% Improvement
Cost		£28,454.00	
Cost + Added Value		£70,854.00	
Carbon Emissions	83 $kgCO_2/m^2/yr$	48 $kgCO_2/m^2/yr$	42%
Heating Energy Consumption	291 $kWh/m^2/yr$	115 $kWh/m^2/yr$	60%
Fuel Costs	£1,428.00/yr	£896.00/yr	37%
Cost per $kgCO_2$ saved		£9.21/$kgCO_2$/yr	
Main Heat Loss Route	Wall Heat Loss (37%)	Ventilation (35%)	



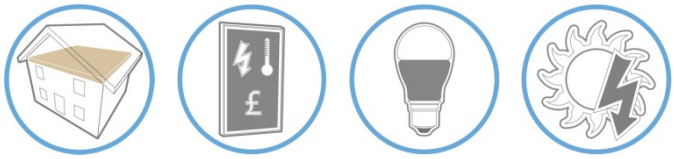
5.2 19DET-SR ENHANCED

Pre-1919 Detached house
inhabited by Successful Ruralites

19DET-SR ENHANCED						
WALLS	ROOF	FLOOR	DOORS/ WINDOWS	AIRTIGHTNESS	VENTILATION	HEATING/ CONTROLS
IWI **0.25 W/m²K**	Loft insulation **0.15 W/m²K**	Floor insulation **0.15 W/m²K**	Secondary glazing **2.0 W/m²K**	Airtightness **6 m³/(m².hr)**	Single room heat recovery	HW tank jacket
	Insulated loft hatch	Solid floor insulation **0.30 W/m²K**	Draughtstripping			TRVs,zoned controls
			Insulated secure door **1.5 W/m²K**			Modulating boiler
						Consider Heat pump

UNIQUE FEATURES				
Extension - EWI	Chimney-fill and insulate	Decorative features	Bay window - upgrade	Recessed door - insulate

ADDED VALUE



For the Pre-1919 Detached house, we took the basic package for this house type (see section 4.2) and modified it as follows:

- **Floor Insulation** - for suspended floors
- **Replacement doors**
- **Airtightness**
- **Modulating boiler**
- **Heat Pump** - would be particularly suitable due to the likely rural location of these properties and larger site area.

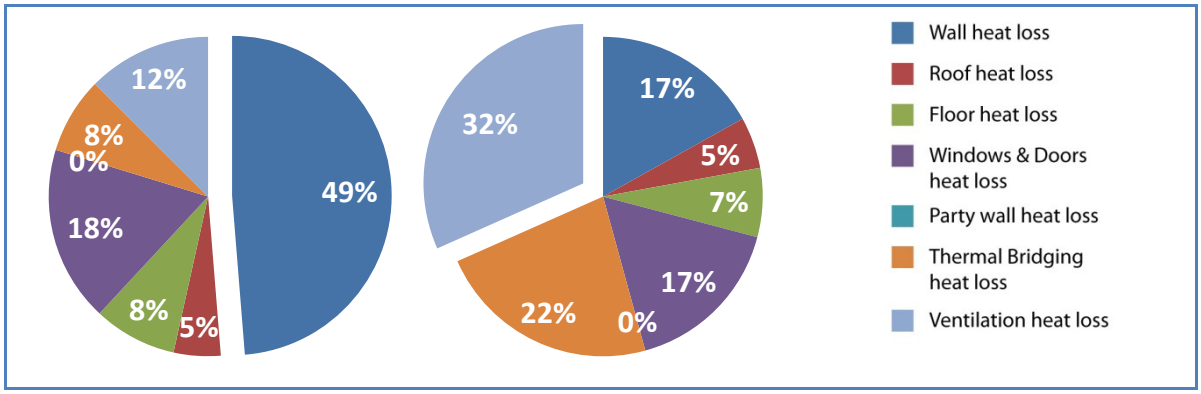
In terms of added value items, Successful Ruralites would likely be responsive to the following triggers and incentives:

- **Additional storage space** (loft storage deck)
- **Energy monitors**
- **LED lighting**
- **Photovoltaics** - particularly suitable due to the likely rural location of these properties and higher probability of solar availability

MODELLING RESULTS

19DET-SR ENHANCED	Baseline	Enhanced Package	% Improvement
Cost		£65,406.00	
Cost + Added Value		£76,156.00	
Carbon Emissions	82 $kgCO_2/m^2/yr$	32 $kgCO_2/m^2/yr$	61%
Heating Energy Consumption	336 $kWh/m^2/yr$	93 $kWh/m^2/yr$	72%
Fuel Costs	£2,528.00/yr	£1,067.00/yr	58%
Cost per $kgCO_2$ saved		£7.82/$kgCO_2$/yr	
Main Heat Loss Route	Wall Heat Loss (49%)	Ventilation (32%)	

Baseline	Enhanced


12%
8%
0%
18%
8%
5%
49%
32%
17%
5%
7%
17%
0%
22%
Wall heat loss
Roof heat loss
Floor heat loss
Windows & Doors heat loss
Party wall heat loss
Thermal Bridging heat loss
Ventilation heat loss

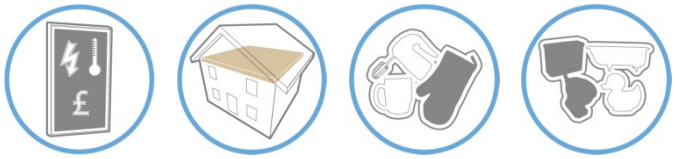
5.3 19CNV-GG ENHANCED

Pre-1919 Converted Flat
inhabited by Greener Graduates

19CNV-GG ENHANCED						
WALLS	ROOF	FLOOR	DOORS/ WINDOWS	AIRTIGHTNESS	VENTILATION	HEATING/ CONTROLS
IWI front only, EWI **0.20 W/m²K**	Loft insulation **0.15 W/m²K**	Floor insulation **0.15 W/m²K**	Double glazing **1.3 W/m²K**	Airtightness **6 m³/m².hr**	Single room heat recovery	HW tank jacket
	Insulated loft hatch		Draughtstripping			TRVs,zoned controls
			Insulated secure door **1.5 W/m²K**			Modulating boiler
						Consider Heat pump

UNIQUE FEATURES					
Extension - EWI	Chimney-fill and insulate	Decorative features	Bay window - upgrade	Recessed door - insulate	Party walls and floors

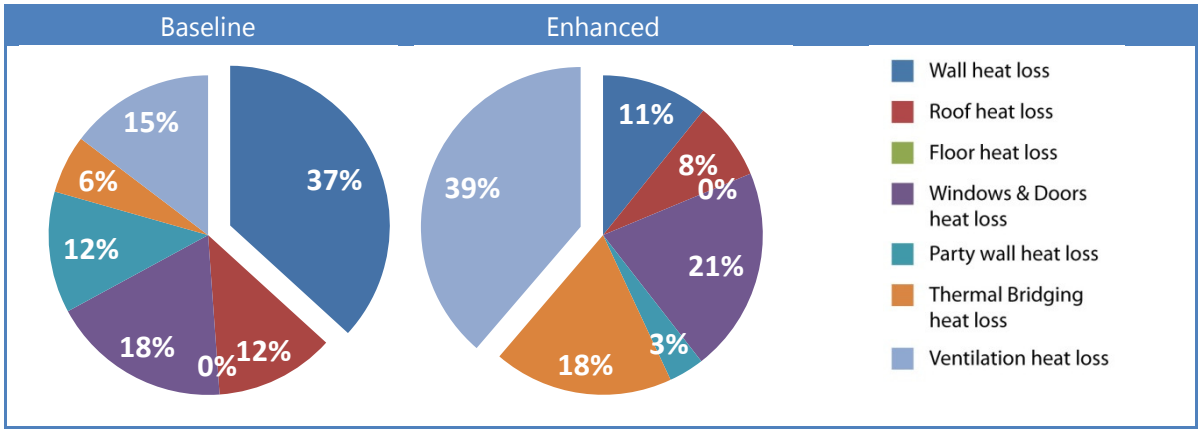
ADDED VALUE


Energy monitors
Storage deck
New kitchen
New bathroom

This package is similar to the enhanced package for 5.1A, except in this case we have the added feature of a communal unheated hallway that is shared between all flats - for the enhanced package this will be insulated using thin-high-performance insulation to individualise the heating requirements of each flat. Party floor insulation should also be undertaken where possible.

MODELLING RESULTS

19CNV-GG ENHANCED	Baseline	Enhanced Package	% Improvement
Cost		£20,775.00	
Cost + Added Value		£20,775.00	
Carbon Emissions	84 $kgCO_2/m^2/yr$	39 $kgCO_2/m^2/yr$	54%
Heating Energy Consumption	362 $kWh/m^2/yr$	134 $kWh/m^2/yr$	63%
Fuel Costs	£1,139.00/yr	£564.00/yr	50%
Cost per $kgCO_2$ saved		£6.22/$kgCO_2$/yr	
Main Heat Loss Route	Wall Heat Loss (37%)	Ventilation (39%)	



5.4A 30SEM-MG ENHANCED

1919-1944 Semi-Detached house
inhabited by Middle Grounders

30SEM-MG ENHANCED

WALLS	ROOF	FLOOR	DOORS/ WINDOWS	AIRTIGHTNESS	VENTILATION	HEATING/ CONTROLS
EWI **0.20 W/m²K**		Floor insulation **0.15 W/m²K**	Triple glazing **0.80 W/m²K**	Airtightness **5 m³/m².hr**	Single room heat recovery	HW tank jacket
CWI **0.15 W/m²K**		Solid floor insulation **0.30 W/m²K**	Draughtstripping			TRVs,zoned controls
			Insulated secure door **1.5 W/m²K**			Modulating boiler
						Consider Heat pump

UNIQUE FEATURES

Extension - EWI | Chimney-fill and insulate | Decorative features | Bay window - upgrade | Recessed door - insulate | Party wall

ADDED VALUE

This package is built on the standard inclusions of the Enhanced package plus the following improvements:

- **Party walls** would be insulated using thin high-performance insulation.
- **No loft insulation, instead undertake a loft conversion**
- **Consider heat pumps**

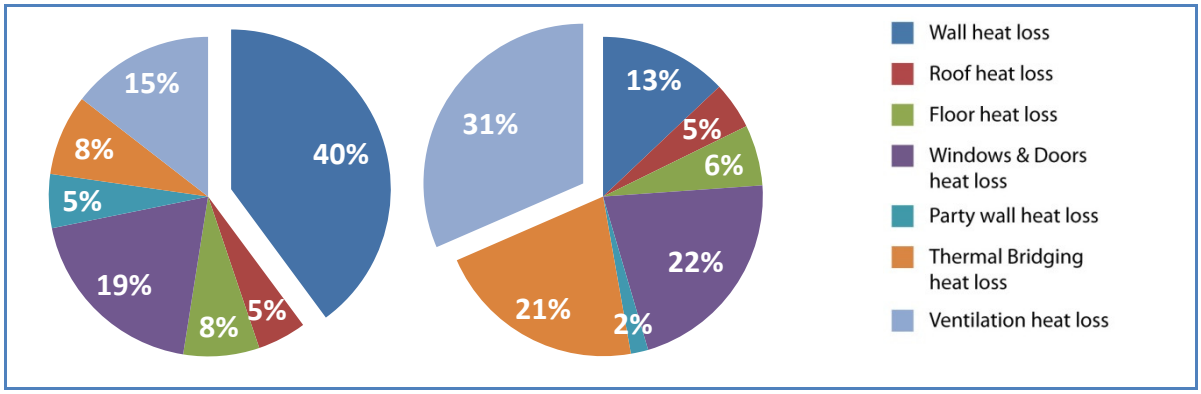
In terms of added value items, Middle Grounders would likely be responsive to the following triggers and incentives:

- **Loft conversion**
- **Underfloor heating**
- **Community-based solutions** such as district/communal heating. Middle Grounders are also more likely to be in touch with their community and therefore would be receptive to neighbourhood or street-by-street retrofits.

MODELLING RESULTS

30SEM-MG ENHANCED	Baseline	Enhanced Package	% Improvement
Cost		£43,532.00	
Cost + Added Value		£73,532.00	
Carbon Emissions	81 $kgCO_2/m^2/yr$	43 $kgCO_2/m^2/yr$	47%
Heating Energy Consumption	299 $kWh/m^2/yr$	107 $kWh/m^2/yr$	64%
Fuel Costs	£1,414.00/yr	£598..00/yr	58%
Cost per $kgCO_2$ saved		£12.54/$kgCO_2$/yr	
Main Heat Loss Route	Wall Heat Loss (40%)	Ventilation (31%)	

Baseline	Enhanced


15%
40%
8%
5%
19%
8%
5%
31%
13%
5%
6%
22%
21%
2%
Wall heat loss
Roof heat loss
Floor heat loss
Windows & Doors heat loss
Party wall heat loss
Thermal Bridging heat loss
Ventilation heat loss

5.4B 30SEM-TR* ENHANCED

1919-1944 Semi-Detached house
inhabited by Transitional Retirees

30SEM-TR* ENHANCED

WALLS	ROOF	FLOOR	DOORS/ WINDOWS	AIRTIGHTNESS	VENTILATION	HEATING/ CONTROLS
EWI **0.20 W/m²K**	Loft insulation **0.15 W/m²K**	Floor insulation **0.15 W/m²K**	Triple glazing **0.80 W/m²K**	Airtightness **5 m³/m².hr**	Single room heat recovery	HW tank jacket
CWI **0.15 W/m²K**	Insulated loft hatch	Solid floor insulation **0.30 W/m²K**	Draughtstripping			TRVs,zoned controls
			Insulated secure door **1.5 W/m²K**			Modulating boiler

UNIQUE FEATURES

Extension - EWI | Chimney-fill and insulate | Decorative features | Bay window - upgrade | Recessed door - insulate | Party wall

ADDED VALUE

Storage deck | Solar thermal HW | Rainwater collection | Greywater recycling | LED lighting | Sunpipes/fiber optics

This package is built on the standard inclusions of the Enhanced package plus the following improvements:

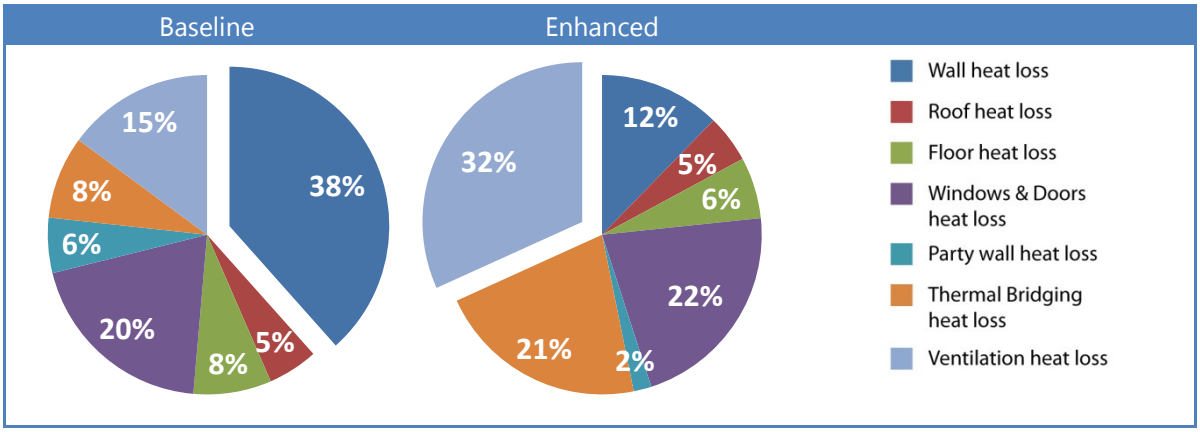
- **Party walls** would be insulated using thin high-performance insulation.

In terms of added value items, Transitional Retirees would likely be responsive to the following triggers and incentives:

- **Additional storage space**
- **Solar thermal hot water**
- **Rainwater collection and Greywater recycling**
- **LED lighting**
- **Sunpipes/fibre optic lighting**

MODELLING RESULTS

30SEM-TR ENHANCED	Baseline	Enhanced Package	% Improvement
Cost		£43,867.00	
Cost + Added Value		£47,117.00	
Carbon Emissions	78 $kgCO_2/m^2/yr$	38 $kgCO_2/m^2/yr$	51%
Heating Energy Consumption	298 $kWh/m^2/yr$	100 $kWh/m^2/yr$	66%
Fuel Costs	£1,332.00/yr	£716.00/yr	46%
Cost per $kgCO_2$ saved		£12.26/$kgCO_2$/yr	
Main Heat Loss Route	Wall Heat Loss (38%)	Ventilation (32%)	



5.4C 30SEM-UC ENHANCED

1919-1944 Semi-Detached house
inhabited by Urban Constrained

30SEM-UC ENHANCED

WALLS	ROOF	FLOOR	DOORS/ WINDOWS	AIRTIGHTNESS	VENTILATION	HEATING/ CONTROLS
EWI **0.20 W/m²K**		Floor insulation **0.15 W/m²K**	Triple glazing **0.80 W/m²K**	Airtightness **5 m³/m².hr**	Single room heat recovery	HW tank jacket
CWI **0.15 W/m²K**		Solid floor insulation **0.30 W/m²K**	Draughtstripping			TRVs,zoned controls
			Insulated secure door **1.5 W/m²K**			Modulating boiler

UNIQUE FEATURES

Extension - EWI | Chimney-fill and insulate | Decorative features | Bay window - upgrade | Recessed door - insulate | Party wall

ADDED VALUE

Loft conversion | New bathroom | Solar thermal HW | A-rated appliances | Energy monitors

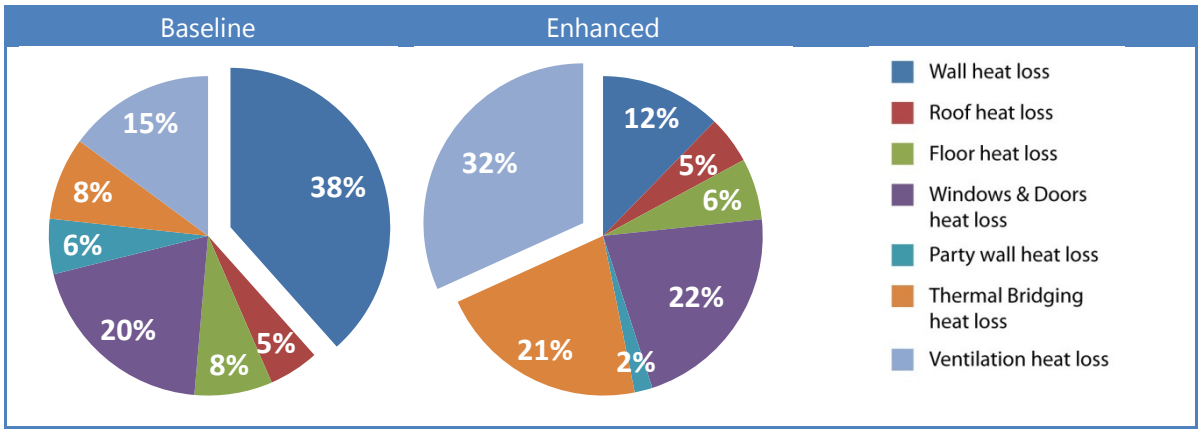
This package has the same standard features of the Enhanced Package for 5.4A.

In terms of added value items, Urban Constrained residents would likely be responsive to the following triggers and incentives:

- **Loft conversion**
- **New bathroom**
- **Solar thermal**
- **Energy efficient appliances**
- **Energy monitors** - good for engaging with children in order to contribute to increased awareness of energy efficient behaviour

MODELLING RESULTS

30SEM-UC ENHANCED	Baseline	Enhanced Package	% Improvement
Cost		£43,782.00	
Cost + Added Value		£71,182.00	
Carbon Emissions	88 $kgCO_2/m^2/yr$	50 $kgCO_2/m^2/yr$	
Heating Energy Consumption	295 $kWh/m^2/yr$	103 $kWh/m^2/yr$	
Fuel Costs	£1,570.00/yr	£974.00/yr	
Cost per $kgCO_2$ saved		£12.66/$kgCO_2$/yr	
Main Heat Loss Route	Wall Heat Loss (38%)	Ventilation (32%)	



5.4D 30SEM-OE* ENHANCED

1919-1944 Semi-Detached house
inhabited by Older Established

30SEM-OE ENHANCED

WALLS	ROOF	FLOOR	DOORS/ WINDOWS	AIRTIGHTNESS	VENTILATION	HEATING/ CONTROLS
EWI **0.20 W/m²K**	Loft insulation **0.15 W/m²K**	Floor insulation **0.15 W/m²K**	Triple glazing **0.80 W/m²K**	Airtightness **3 m³/m².hr**	MVHR	HW tank jacket
CWI **0.15 W/m²K**	Insulated loft hatch	Solid floor insulation **0.30 W/m²K**	Draughtstripping			TRVs,zoned controls
			Insulated secure door **1.5 W/m²K**			Modulating boiler

UNIQUE FEATURES

Extension - EWI | Chimney-fill and insulate | Decorative features | Bay window - upgrade | Recessed door - insulate | Party wall

ADDED VALUE

Storage deck | New kitchen | New bathroom | Energy monitors | LED lighting | Sunpipes/fiber optics | Solar thermal HW

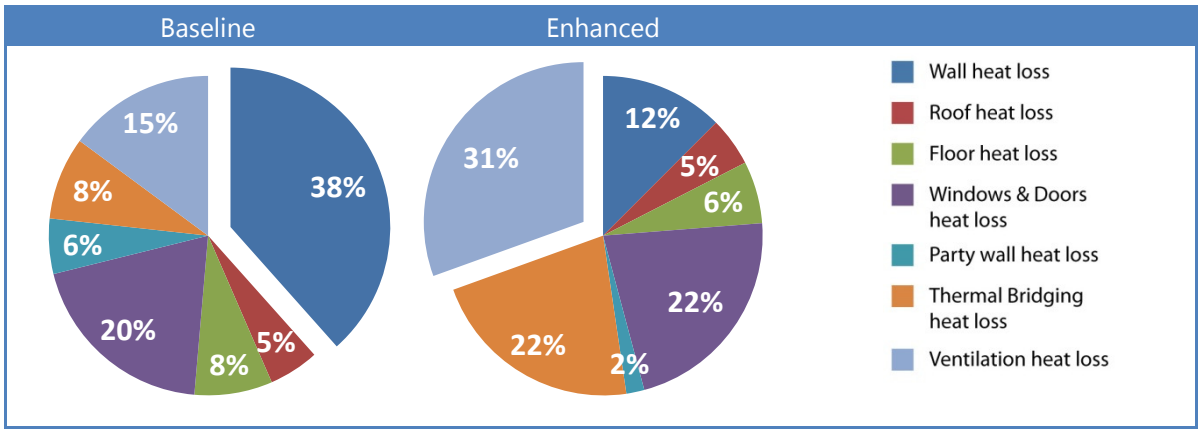
This package has the same standard features of the Enhanced Package for 5.4B, with the exception of MVHR, which would require a corresponding Airtightness of 3.0 m^3/m^2.hr @50Pa.

In terms of added value items, Older Established residents would likely be responsive to the following triggers and incentives:

- **Additional storage space**
- **New kitchen and bathroom**
- **Energy monitors**
- **LED lighting**
- **Sunpipes/fibre optic lighting**
- **Solar thermal**

MODELLING RESULTS

30SEM-OE ENHANCED	Baseline	Enhanced Package	% Improvement
Cost		£43,867.00	
Cost + Added Value		£55,617.00	
Carbon Emissions	78 $kgCO_2/m^2/yr$	37 $kgCO_2/m^2/yr$	53%
Heating Energy Consumption	298 $kWh/m^2/yr$	99 $kWh/m^2/yr$	67%
Fuel Costs	£1,332.00/yr	£696.00/yr	48%
Cost per $kgCO_2$ saved		£11.97/$kgCO_2$/yr	
Main Heat Loss Route	Wall Heat Loss (38%)	Ventilation (31%)	



5.5A 50SEM-UD ENHANCED

1945-1964 Semi-Detached house inhabited by Unconvinced Dependents

50SEM-UD ENHANCED

WALLS

- EWI **0.20 W/m²K**
- CWI **0.15 W/m²K**

ROOF

- Loft insulation **0.15 W/m²K**
- Insulated loft hatch

FLOOR

- Floor insulation **0.15 W/m²K**
- Solid floor insulation **0.30 W/m²K**

DOORS/ WINDOWS

- Triple glazing **0.80 W/m²K**
- Draughtstripping
- Insulated secure door **1.5 W/m²K**

AIRTIGHTNESS

- Airtightness **5 m³/m².hr**

VENTILATION

- Single room heat recovery

HEATING/ CONTROLS

- HW tank jacket
- TRVs,zoned controls
- Modulating boiler

UNIQUE FEATURES

- Chimney-fill and insulate
- Recessed door - insulate
- Party wall

ADDED VALUE

- Storage deck
- Underfloor heating
- Community initiatives

This package is built on the standard inclusions of the Enhanced package plus the following improvements:

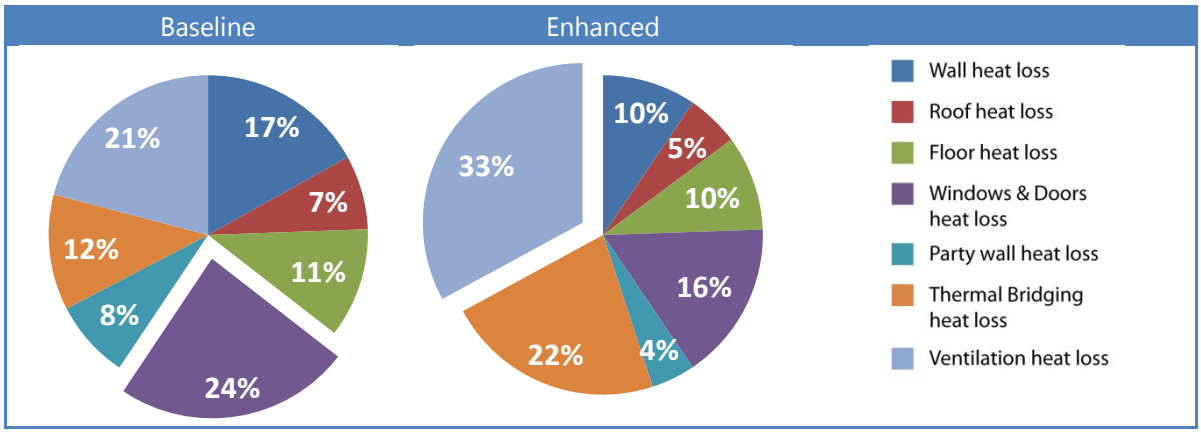
- **Party walls** would be insulated using thin high-performance insulation.

In terms of added value items, Unconvinced Dependents would likely be responsive to the following triggers and incentives:

- **Additional storage space**
- **Underfloor heating**
- **Renewable heat incentives**
- **Community solutions**

MODELLING RESULTS

50SEM-UD ENHANCED	Baseline	Enhanced Package	% Improvement
Cost		£39,515.00	
Cost + Added Value		£44,665.00	
Carbon Emissions	74 $kgCO_2/m^2/yr$	54 $kgCO_2/m^2/yr$	27%
Heating Energy Consumption	219 $kWh/m^2/yr$	114 $kWh/m^2/yr$	48%
Fuel Costs	£1,293.00/yr	£991.00/yr	23%
Cost per $kgCO_2$ saved	£0	£22.32/$kgCO_2$/yr	
Main Heat Loss Route	Windows/Doors (24%)	Ventilation (33%)	



5.5B 50SEM-UC ENHANCED

1945-1964 Semi-Detached house
inhabited by Urban Constrained

50SEM-UC ENHANCED

WALLS	ROOF	FLOOR	DOORS/ WINDOWS	AIRTIGHTNESS	VENTILATION	HEATING/ CONTROLS
EWI **0.15-0.20 W/m²K**		Floor insulation **0.15 W/m²K**	Triple glazing **0.80 W/m²K**	Airtightness **5 m³/m².hr**	Single room heat recovery	HW tank jacket
CWI **0.15 W/m²K**		Solid floor insulation **0.30 W/m²K**	Draughtstripping			TRVs,zoned controls
			Insulated secure door **1.5 W/m²K**			Modulating boiler

UNIQUE FEATURES

Chimney-fill and insulate

Recessed door - insulate

Party wall

ADDED VALUE

Loft conversion

New bathroom

Solar thermal HW

A-rated appliances

Energy monitors

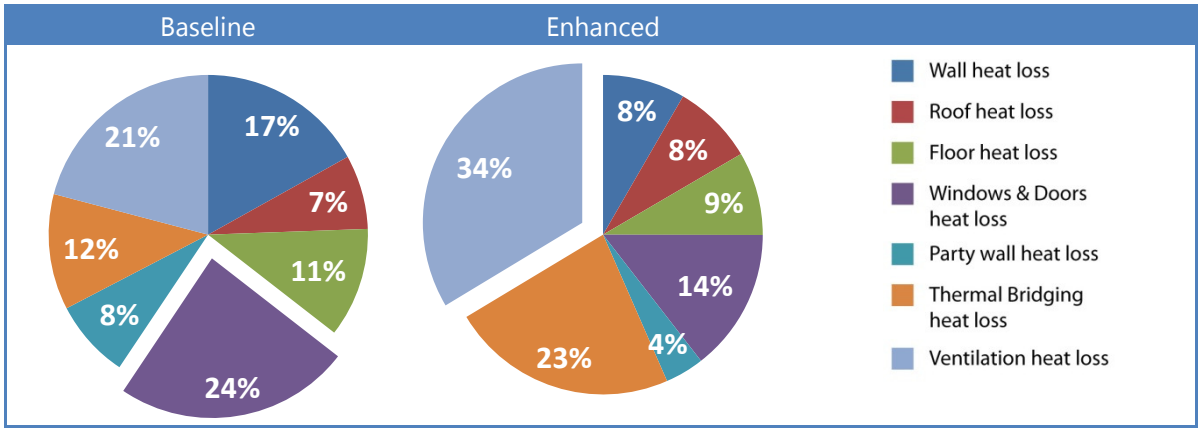
This package is built on the standard inclusions of the Enhanced package except it includes a **Loft conversion** and therefore will not include top-ups for loft insulation. Also, **Party walls** would be insulated using thin high-performance insulation.

In terms of added value items, Urban Constrained occupants would likely be responsive to the following triggers and incentives:

- **Loft Conversion**
- **New bathroom**
- **Solar thermal**
- **Energy efficient appliances**
- **Energy monitors**

MODELLING RESULTS

50SEM-UC ENHANCED	Baseline	Enhanced Package	% Improvement
Cost		£39,173.00	
Cost + Added Value		£66,573.00	
Carbon Emissions	78 $kgCO_2/m^2/yr$	54 $kgCO_2/m^2/yr$	31%
Heating Energy Consumption	238 $kWh/m^2/yr$	124 $kWh/m^2/yr$	48%
Fuel Costs	£1,350.00/yr	£987.00/yr	27%
Cost per $kgCO_2$ saved		£18.93/$kgCO_2$/yr	
Main Heat Loss Route	Windows/Doors (24%)	Ventilation (34%)	



5.5C 50SEM-SP* ENHANCED

1945-1964 Semi-Detached house
inhabited by Stretched Pensioners

50SEM-SP* ENHANCED

WALLS	ROOF	FLOOR	DOORS/ WINDOWS	AIRTIGHTNESS	VENTILATION	HEATING/ CONTROLS
EWI **0.20 W/m²K**	Loft insulation **0.15 W/m²K**	Floor insulation **0.15 W/m²K**	Triple glazing **0.80 W/m²K**	Airtightness **5 m³/m².hr**	Single room heat recovery	HW tank jacket
CWI **0.15 W/m²K**	Insulated loft hatch	Solid floor insulation **0.30 W/m²K**	Draughtstripping			TRVs,zoned controls
			Insulated secure door **1.5 W/m²K**			Modulating boiler

UNIQUE FEATURES

Chimney-fill and insulate

Recessed door - insulate

Party wall

ADDED VALUE

Security features

Storage deck

New bathroom

A-rated appliances

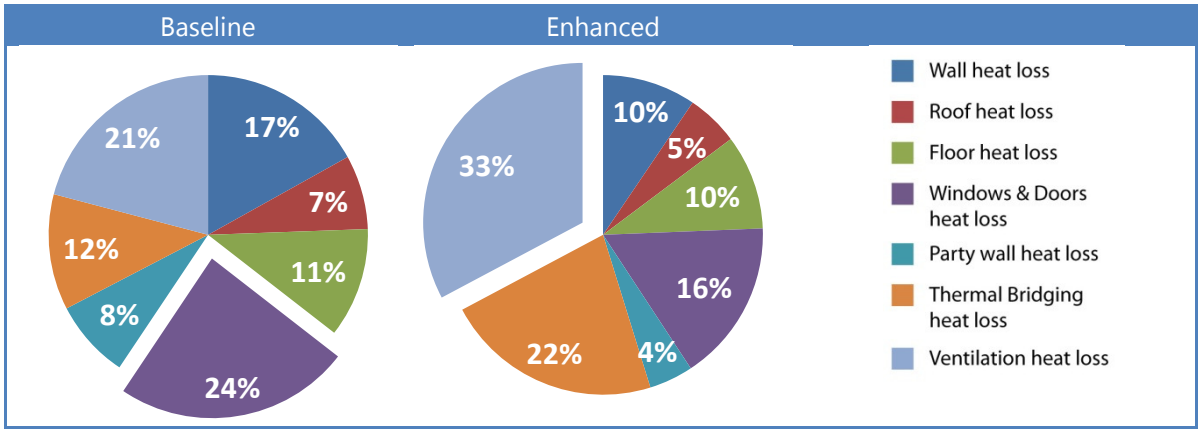
This package has the same standard features of the Enhanced Package for 5.5A.

In terms of added value items, Stretched Pensioners would likely be responsive to the following triggers and incentives:

- **Security features**, i.e. burglar alarms and security systems
- **Additional storage space**
- **New bathroom**
- **Energy efficient appliances**

MODELLING RESULTS

50SEM-SP* ENHANCED	Baseline	Enhanced Package	% Improvement
Cost		£39,265.00	
Cost + Added Value		£42,265.00	
Carbon Emissions	61 $kgCO_2/m^2/yr$	37 $kgCO_2/m^2/yr$	39%
Heating Energy Consumption	247 $kWh/m^2/yr$	128 $kWh/m^2/yr$	48%
Fuel Costs	£976.00/yr	£626.00/yr	36%
Cost per $kgCO_2$ saved		£19.30/$kgCO_2$/yr	
Main Heat Loss Route	Windows/Doors (24%)	Ventilation (33%)	



5.5D 50SEM-TR* ENHANCED

1945-1964 Semi-Detached house
inhabited by Transitional Retirees

50SEM-TR* ENHANCED

WALLS	ROOF	FLOOR	DOORS/ WINDOWS	AIRTIGHTNESS	VENTILATION	HEATING/ CONTROLS
EWI **0.20 W/m²K**	Loft insulation **0.15 W/m²K**	Floor insulation **0.15 W/m²K**	Triple glazing **0.80 W/m²K**	Airtightness **5 m³/m².hr**	Single room heat recovery	HW tank jacket
CWI **0.15 W/m²K**	Insulated loft hatch	Solid floor insulation **0.30 W/m²K**	Draughtstripping			TRVs,zoned controls
			Insulated secure door **1.5 W/m²K**			Modulating boiler

UNIQUE FEATURES

Chimney-fill and insulate

Recessed door - insulate

Party wall

ADDED VALUE

Storage deck

Solar thermal HW

Rainwater collection

Greywater recycling

LED lighting

Sunpipes/fiber optics

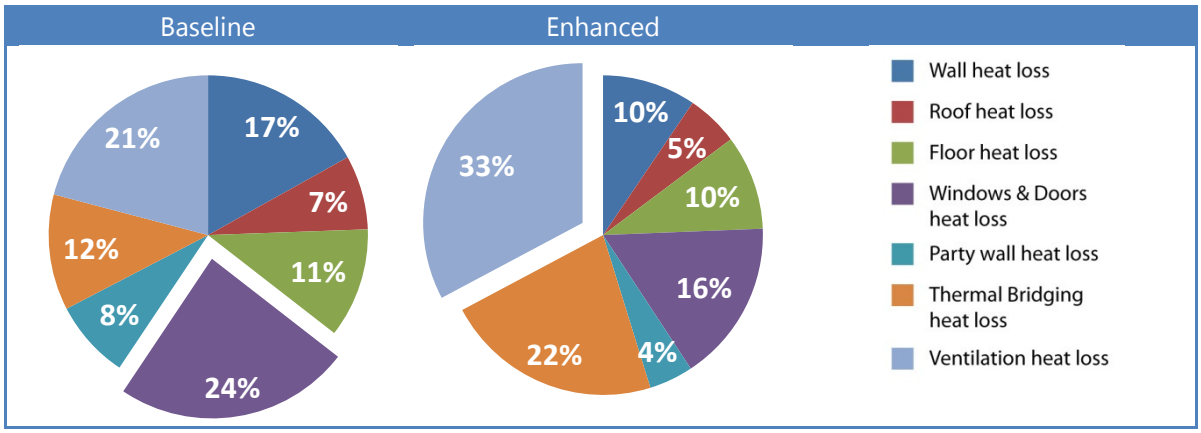
This package has the same standard features of the Enhanced Package for 5.5A.

In terms of added value items, Transitional Retirees would likely be responsive to the following triggers and incentives:

- **Additional storage space**
- **Solar Thermal**
- **Rainwater collection**
- **Greywater recycling**
- **LED lighting**
- **Sunpipes/fiber optics**

MODELLING RESULTS

50SEM-TR ENHANCED	Baseline	Enhanced Package	% Improvement
Cost		£39,265.00	
Cost + Added Value		£42,515.00	
Carbon Emissions	62 $kgCO_2/m^2/yr$	40 $kgCO_2/m^2/yr$	35%
Heating Energy Consumption	218 $kWh/m^2/yr$	105 $kWh/m^2/yr$	52%
Fuel Costs	£1,045.00/yr	£715.00/yr	32%
Cost per $kgCO_2$ saved		£20.34/$kgCO_2$/yr	
Main Heat Loss Route	Windows/Doors (24%)	Ventilation (33%)	



5.5E 50SEM-OE* ENHANCED

1945-1964 Semi-Detached house
inhabited by Older Established

50SEM-OE* ENHANCED

WALLS	ROOF	FLOOR	DOORS/ WINDOWS	AIRTIGHTNESS	VENTILATION	HEATING/ CONTROLS
EWI **0.20 W/m²K**	Loft insulation **0.15 W/m²K**	Floor insulation **0.15 W/m²K**	Triple glazing **0.80 W/m²K**	Airtightness **3 m³/m².hr**	MVHR	HW tank jacket
CWI **0.15 W/m²K**	Insulated loft hatch	Solid floor insulation **0.30 W/m²K**	Draughtstripping			TRVs,zoned controls
			Insulated secure door **1.5 W/m²K**			Modulating boiler

UNIQUE FEATURES

Chimney-fill and insulate | Recessed door - insulate | Party wall

ADDED VALUE

Storage deck | New kitchen | New bathroom | Solar thermal HW | Sunpipes/fiber optics | LED lighting | Energy monitors

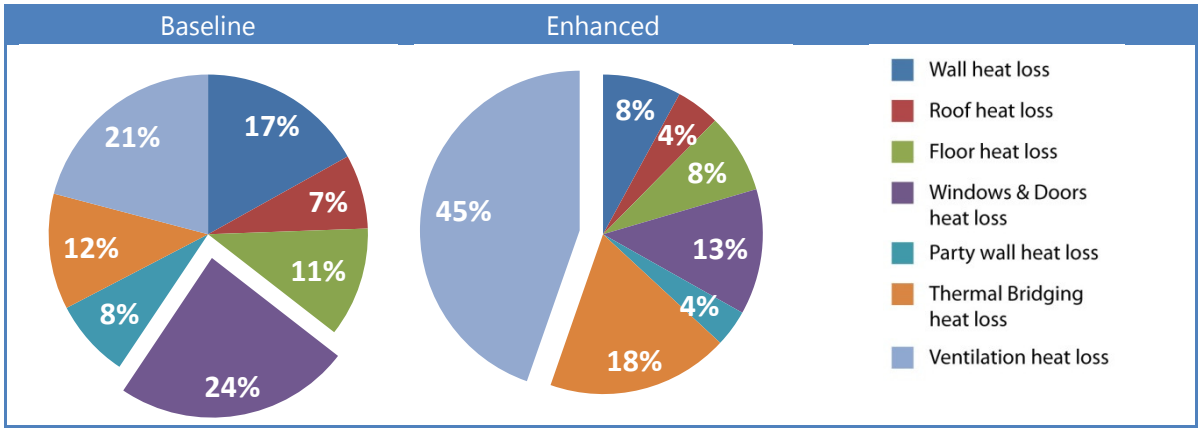
This package has the same standard features of the Enhanced Package for 5.5A, except instead of Single Room Heat Recovery we have **MVHR**, which would require a corresponding Airtightness of 3.0 m^3/m^2.hr @50Pa.

In terms of added value items, Older Established residents would likely be responsive to the following triggers and incentives:

- **Additional storage space**
- **New bathroom**
- **New kitchen**
- **Solar thermal**
- **Sunpipes/fiber optics**
- **LED lighting**
- **Energy monitors**

MODELLING RESULTS

50SEM-TR* ENHANCED	Baseline	Enhanced Package	% Improvement
Cost		£39,265.00	
Cost + Added Value		£51,015.00	
Carbon Emissions	62 $kgCO_2/m^2/yr$	47 $kgCO_2/m^2/yr$	24%
Heating Energy Consumption	218 $kWh/m^2/yr$	130 $kWh/m^2/yr$	40%
Fuel Costs	£1,045.00/yr	£654.00/yr	37%
Cost per $kgCO_2$ saved		£30.75/$kgCO_2$/yr	
Main Heat Loss Route	Windows/Doors (24%)	Ventilation (45%)	



5.6 70DET-OE* ENHANCED

1965-1980 Detached house
inhabited by Older Established

70DET-OE* ENHANCED						
WALLS	ROOF	FLOOR	DOORS/ WINDOWS	AIRTIGHTNESS	VENTILATION	HEATING/ CONTROLS
EWI **0.20 W/m²K**	Loft insulation **0.15 W/m²K**	Solid floor insulation **0.30 W/m²K**	Triple glazing **0.80 W/m²K**	Airtightness **3 m³/m².hr**	MVHR	HW tank jacket
CWI **0.15 W/m²K**	Insulated loft hatch		Draughtstripping			TRVs,zoned controls
			Insulated secure door **1.5 W/m²K**			Modulating boiler

UNIQUE FEATURES
Garage wall/s & soffit

ADDED VALUE						
Storage deck	New kitchen	New bathroom	Solar thermal HW	Sunpipes/fiber optics	LED lighting	Energy monitors

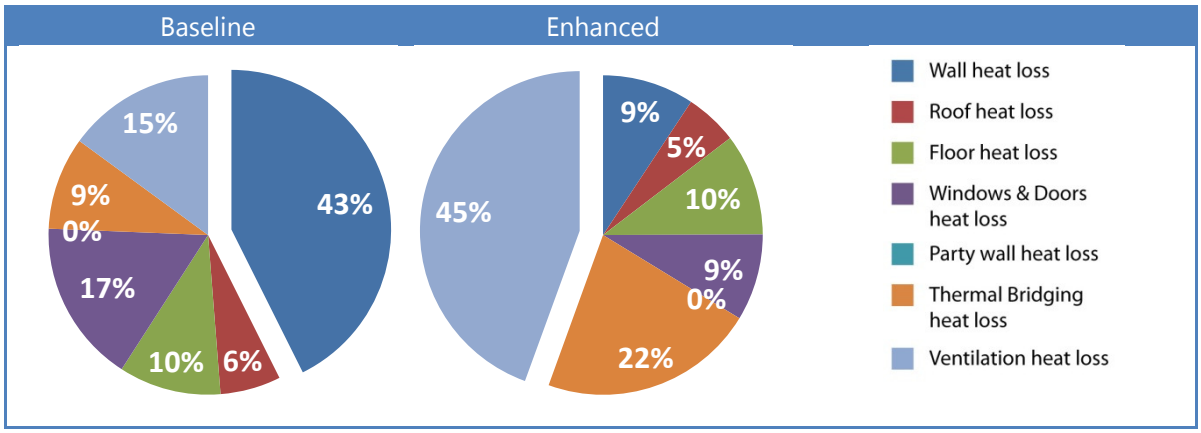
This package is built on the standard inclusions of the Enhanced package except it includes **MVHR,** which would require a corresponding Airtightness of 3.0 m^3/m^2.hr @50Pa. It's also more likely to be a solid floor.

In terms of added value items, Older Established occupants would likely be responsive to the following triggers and incentives:

- **Additional storage space**
- **New bathroom**
- **New kitchen**
- **Solar thermal**
- **Sunpipes/fiber optics**
- **LED lighting**
- **Energy monitors**

MODELLING RESULTS

70DET-OE* ENHANCED	Baseline	Enhanced Package	% Improvement
Cost		£68,356.00	
Cost + Added Value		£80,106.00	
Carbon Emissions	73 $kgCO_2/m^2/yr$	38 $kgCO_2/m^2/yr$	48%
Heating Energy Consumption	294 $kWh/m^2/yr$	99 $kWh/m^2/yr$	66%
Fuel Costs	£1,827.00/yr	£825.00/yr	55%
Cost per $kgCO_2$ saved		£14.62/$kgCO_2$/yr	
Main Heat Loss Route	Wall Heat Loss (43%)	Ventilation (45%)	



5.7 70BNG-SP* ENHANCED

1965-1980 Bungalow

inhabited by Stretched Pensioners

70BNG-SP ENHANCED

WALLS	ROOF	FLOOR	DOORS/ WINDOWS	AIRTIGHTNESS	VENTILATION	HEATING/ CONTROLS
EWI **0.20 W/m²K**	Loft insulation **0.15 W/m²K**	Solid floor insulation **0.30 W/m²K**	Triple glazing **0.80 W/m²K**	Airtightness **5 m³/(m².hr)**	Single room heat recovery	HW tank jacket
CWI **0.15 W/m²K**	Insulated loft hatch		Draughtstripping			TRVs,zoned controls
			Insulated secure door **1.5 W/m²K**			Modulating boiler

UNIQUE FEATURES

ADDED VALUE

Security features

Storage deck

New bathroom

A-rated appliances

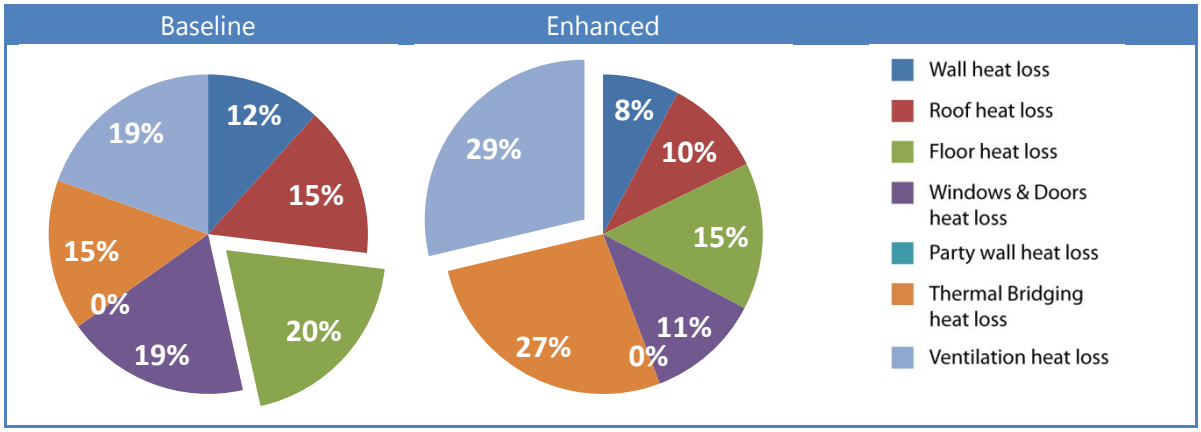
This package is built on the standard inclusions of the Enhanced package. Bungalows have a larger floor and roof to volume ratio, so thermally improving the roof and the floors are more critical than improving the walls. Unfortunately these properties are more likely to be solid floor rather than suspended so currently, options for upgrading the thermal performance of the floor are limited.

In terms of added value items, Stretched Pensioners occupants would likely be responsive to the following triggers and incentives:

- **Burglar alarm and security system**
- **Additional storage space**
- **New bathroom**
- **Energy efficient appliances**

MODELLING RESULTS

70BNG-SP* ENHANCED	Baseline	Enhanced Package	% Improvement
Cost		£34,050.00	
Cost + Added Value		£37,050.00	
Carbon Emissions	72 $kgCO_2/m^2/yr$	43 $kgCO_2/m^2/yr$	40%
Heating Energy Consumption	301 $kWh/m^2/yr$	128 $kWh/m^2/yr$	57%
Fuel Costs	£997.00/yr	£128.00/yr	87%
Cost per $kgCO_2$ saved		£15.32/$kgCO_2$/yr	
Main Heat Loss Route	Floor Heat Loss (20%)	Ventilation (29%)	



5.8 70LRF-YS ENHANCED

1965-1980 Purpose Built Low-rise Flat

inhabited by Young Starters

70LRF-YS ENHANCED

WALLS	ROOF	FLOOR	DOORS/ WINDOWS	AIRTIGHTNESS	VENTILATION	HEATING/ CONTROLS
EWI **0.20 W/m²K**	Loft insulation **0.15 W/m²K**	Solid floor insulation **0.30 W/m²K**	Triple glazing **0.80 W/m²K**	Airtightness **5 m³/m².hr**	Single room heat recovery	HW tank jacket
CWI **0.15 W/m²K**	Insulated loft hatch		Draughtstripping			TRVs,zoned controls
			Insulated secure door **1.5 W/m²K**			Modulating boiler

UNIQUE FEATURES

Party walls & floors

ADDED VALUE

Storage deck | New kitchen | New bathroom

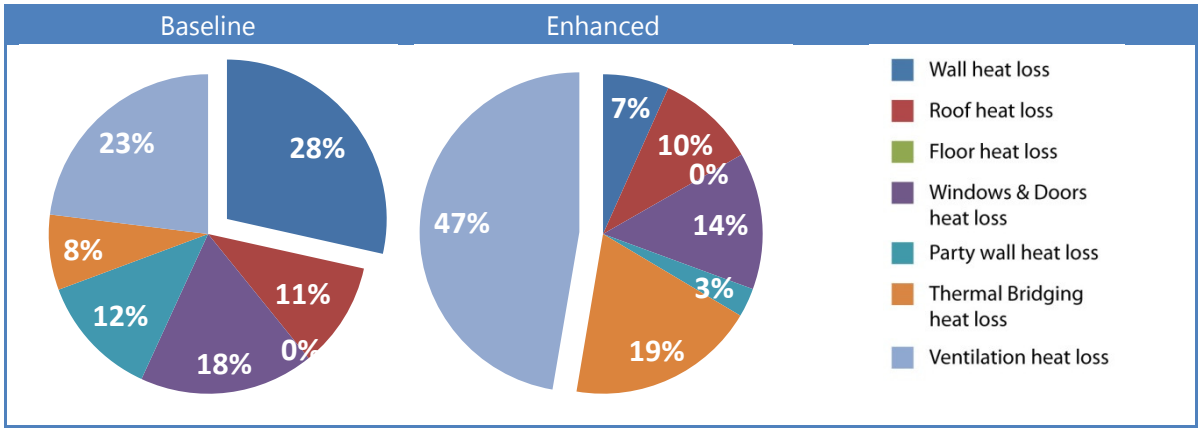
This package is built on the standard inclusions of the Enhanced package. Because it is a group of flats, party floors and walls will need to be insulated, including common areas and hallways.

In terms of added value items, Young Starters would likely be responsive to the following triggers and incentives:

- **Additional storage space**
- **New kitchen**
- **New bathroom**

MODELLING RESULTS

70LRF-YS ENHANCED	Baseline	Enhanced Package	% Improvement
Cost		£18,305.00	
Cost + Added Value		£26,305.00	
Carbon Emissions	72 $kgCO_2/m^2/yr$	48 $kgCO_2/m^2/yr$	33%
Heating Energy Consumption	224 $kWh/m^2/yr$	100 $kWh/m^2/yr$	55%
Fuel Costs	£805.00/yr	£576.00/yr	28%
Cost per $kgCO_2$ saved		£13.61/$kgCO_2$/yr	
Main Heat Loss Route	Walls (28%)	Ventilation (47%)	



5.9A 90DET-SR & 90DET-MG ENHANCED

Post-1980 Detached House
inhabited by Successful Ruralites and Middle Grounders

90DET-SR & 90DET-MG ENHANCED

WALLS	ROOF	FLOOR	DOORS/ WINDOWS	AIRTIGHTNESS	VENTILATION	HEATING/ CONTROLS
EWI **0.20 W/m²K**	Loft insulation **0.15 W/m²K**	Solid floor insulation **0.30 W/m²K**	Draughtstripping	Airtightness **5 m³/m².hr**	Single room heat recovery	HW tank jacket
CWI **0.15 W/m²K**	Insulated loft hatch		Triple glazing **0.80 W/m²K**			TRVs,zoned controls
			Insulated secure door **1.5 W/m²K**			Modulating boiler
						Heat pump

UNIQUE FEATURES

Extension - EWI

Garage wall/s & soffit

ADDED VALUE

Storage deck

Underfloor heating

LED lighting*

PV*

Community initiatives**

* SR only
** MG only

This package is built on the standard inclusions of the Enhanced package. Based on the occupant profiles, it may also be possible to consider Heat pumps, particularly if there is enough site area and the location is off-grid.

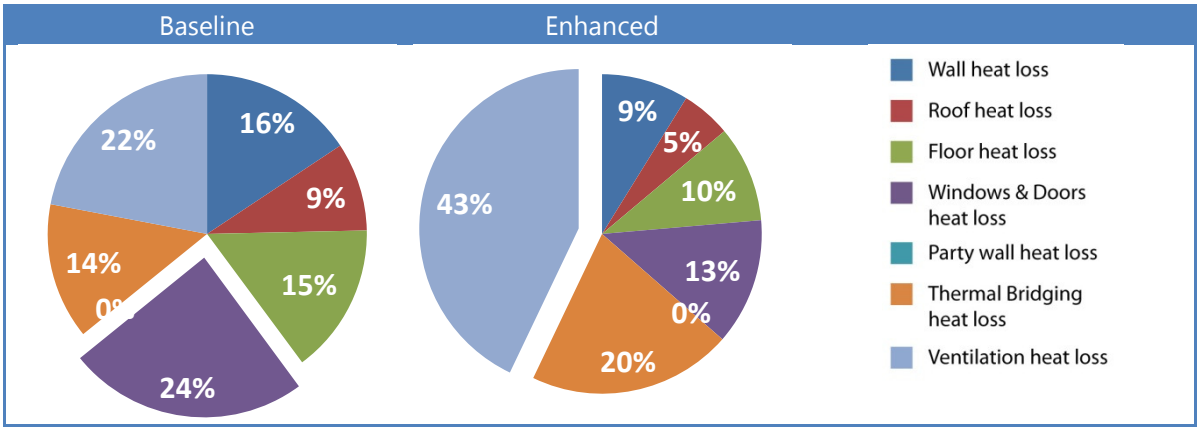
In terms of added value items, Successful Ruralites and Middle Grounders would likely be responsive to the following triggers and incentives:

- **Additional storage space**
- **Underfloor Heating**

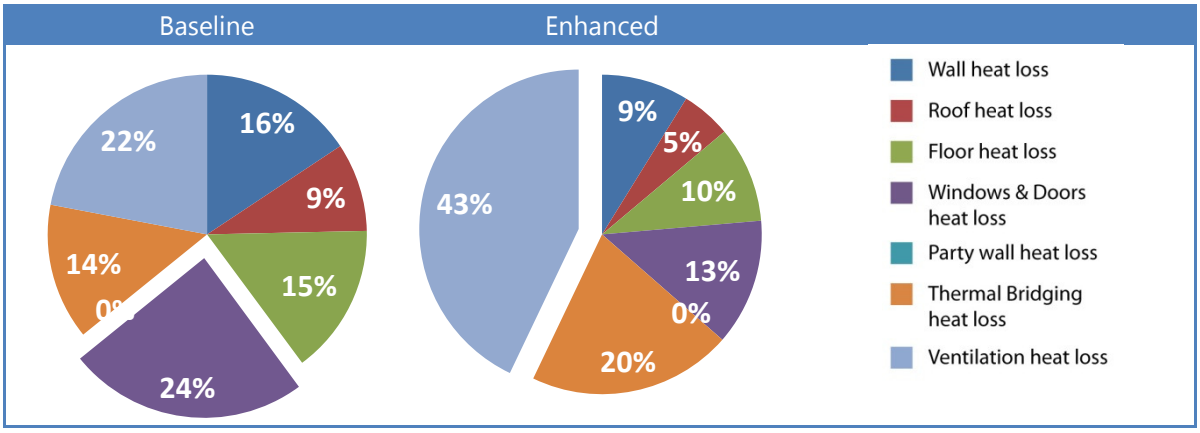
In addition, Successful Ruralites would respond well to the inclusion of LED lighting and PV, while Middle Grounders are receptive to Community-based solutions.

MODELLING RESULTS

90DET-SR ENHANCED	Baseline	Enhanced Package	% Improvement
Cost		£58,706.00	
Cost + Added Value		£69,456.00	
Carbon Emissions	49 $kgCO_2/m^2/yr$	34 $kgCO_2/m^2/yr$	31%
Heating Energy Consumption	172 $kWh/m^2/yr$	83 $kWh/m^2/yr$	52%
Fuel Costs	£1,269.00/yr	£961.00/yr	24%
Cost per $kgCO_2$ saved		£30.12/$kgCO_2$/yr	
Main Heat Loss Route	Windows/Doors (24%)	Ventilation (43%)	



90DET-MG NHANCED	Baseline	Enhanced Package	% Improvement
Cost		£58,706.00	
Cost + Added Value		£58,706.00	
Carbon Emissions	52 $kgCO_2/m^2/yr$	42 $kgCO_2/m^2/yr$	19%
Heating Energy Consumption	170 $kWh/m^2/yr$	94 $kWh/m^2/yr$	45%
Fuel Costs	£1,359.00/yr	£1,173.00/yr	14%
Cost per $kgCO_2$ saved		£43.58/$kgCO_2$/yr	
Main Heat Loss Route	Windows/Doors (24%)	Ventilation (43%)	



5.9B 90DET-EE ENHANCED

Post-1980 Detached House
inhabited by Early Entrepreneurs

SOLUTIONS, FEATURES and ADDED VALUE OPTIONS

WALLS	ROOF	FLOOR	DOORS/ WINDOWS	AIRTIGHTNESS	VENTILATION	HEATING/ CONTROLS
EWI **0.20 W/m²K**		Solid floor insulation **0.30 W/m²K**	Draughtstripping	Airtightness **5 m³/m².hr**	Single room heat recovery	HW tank jacket
CWI **0.15 W/m²K**			Triple glazing **0.80 W/m²K**			TRVs,zoned controls
			Insulated secure door **1.5 W/m²K**			Modulating boiler
						Heat pump

UNIQUE FEATURES

Extension - EWI

Garage wall/s & soffit

ADDED VALUE

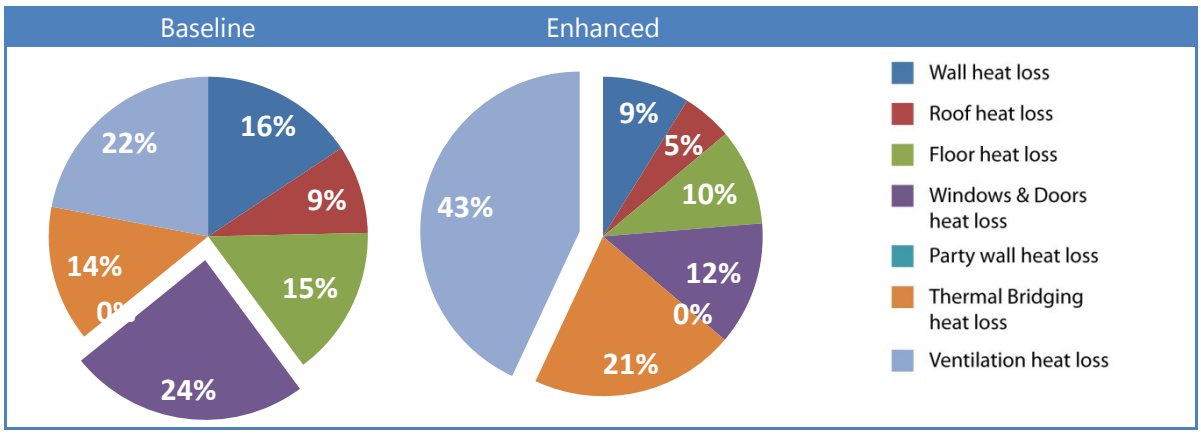
This package is built on the standard inclusions of the Enhanced package, and is similar except for the Loft Conversion. Based on the occupant profile, it may also be possible to consider Heat pumps, particularly if there is enough site area and the location is off-grid.

In terms of added value items, Early Entrepreneurs would likely be responsive to the following triggers and incentives:

- **Loft Conversion**
- **New kitchen and bathroom**

MODELLING RESULTS

90DET-EE ENHANCED	Baseline	Enhanced Package	% Improvement
Cost		£58,956.00	
Cost + Added Value		£101,356.00	
Carbon Emissions	54 $kgCO_2/m^2/yr$	45 $kgCO_2/m^2/yr$	17%
Heating Energy Consumption	170 $kWh/m^2/yr$	93 $kWh/m^2/yr$	45%
Fuel Costs	£1,438.00/yr	£1,269.00/yr	12%
Cost per $kgCO_2$ saved		£45.74/$kgCO_2$/yr	
Main Heat Loss Route	Windows/Doors (24%)	Ventilation (43%)	



6 Analysis

- Post-1980 properties are not cost effective to retrofit at our basic level, all Pre-1980 properties reasonably demonstrate cost effectiveness in terms of retrofit. While Post-1980 homes show benefits at enhanced level for carbon emissions reduction and fuel savings, but it is not very cost effective because of the high cost of minimal carbon reductions
- Occupant behaviour is a factor that should not be ignored, particularly when predicting energy savings - we have demonstrated that for the same house type and same set of solutions different types of occupants greatly influence fuel savings and CO_2 emissions reductions. For example, despite reductions in lighting, appliance and hot water use, given the same house type, Greener Graduates use up more energy overall - spending around £100 more per annum than the Young Starters, living in the same type of property but heating to a 1°C higher set temperature.
- Some Pre-1919 properties experience a reduction in carbon emissions by up to 50% for the basic packages, and up to 58% for the enhanced packages. Achieving Passivhaus standards can result in reductions of up to 75%.
- If we want to hit more ambitious "low carbon" targets, relying on current construction methods and materials is not enough. We can only hit these targets if we aspire to meet Passivhaus-type standards, and promote the development of solutions that will enable us to hit the high performance U-values that are required.
- Loft conversions are generally not viable in terms of cost effectiveness and thermal benefits. We need to explore other ways of adding value by creating habitable/storage space.

The next stage of the work is the mass implementation plan for retrofit, therefore it is crucial at this stage to evaluate these single dwelling packages in terms of mass-scale implementation. In this chapter we will look at the following metrics:

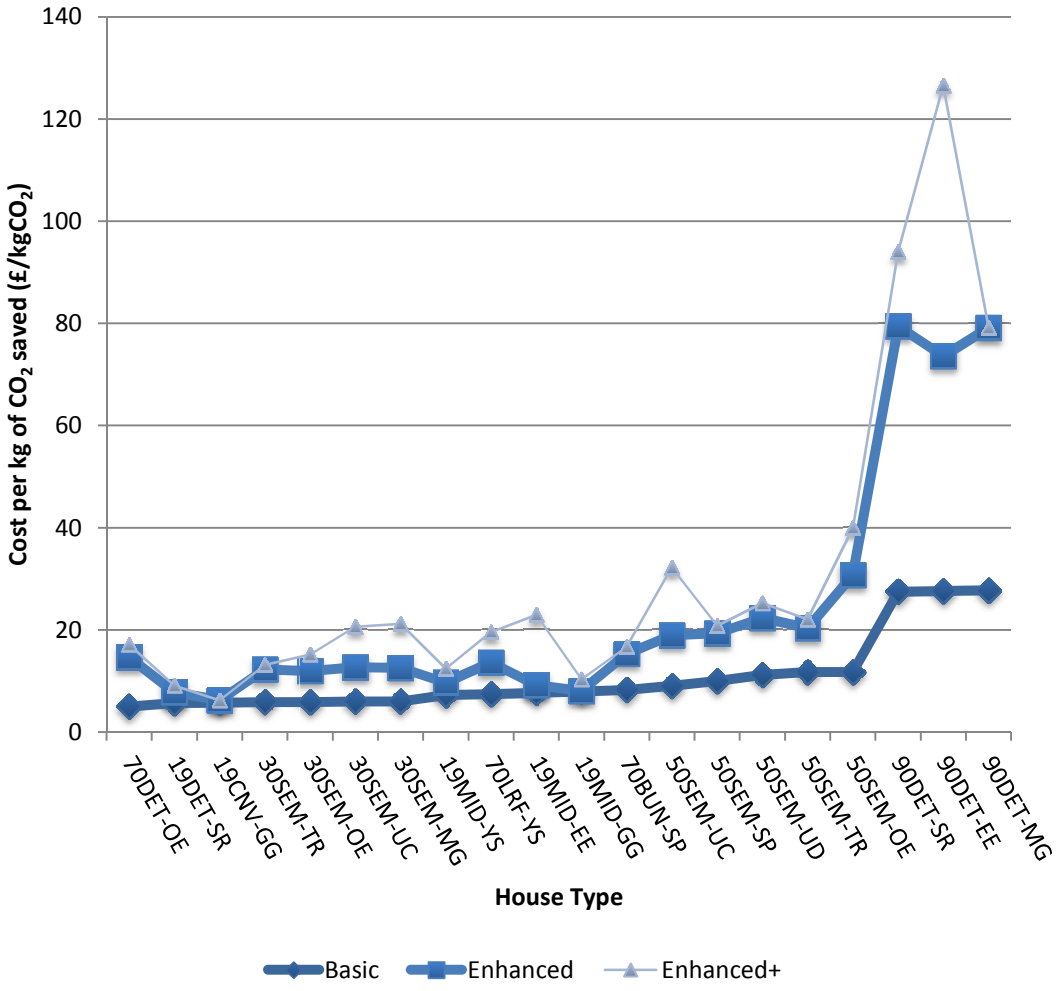
- Cost efficiency - Is the cost of the retrofit worth the carbon emissions reduction benefit?
- Degree of improvement - Will the retrofit make a significant difference to the carbon footprint of the property? To the fuel bills of the occupant?
- Customer acceptance - Which properties are the most straightforward to retrofit in terms of disruption to the resident-in-occupation? How does the cost of the retrofit compare to the income of the customer group?

- Benchmarking - are we hitting common reduction targets, and are the plans ambitious enough?

A detailed analysis of the supply chain issues and the construction programme for each of these work packages has been carried out in WP4.3, therefore we will not dwell too much on this aspect of the single dwelling plans and concentrate on it only in terms of the impact on the occupants.

6.1 COST EFFICIENCY

Is the cost of the retrofit worth the carbon emissions reduction benefit? This can be expressed in terms of £ per $kgCO_2$ saved. The following graph shows the relative £/$kgCO_2$ figures for the basic and enhanced packages. For clarity we have made the distinction between standard enhanced thermal measures (Enhanced packages) and added-value enhanced thermal packages (Enhanced+ packages) which would also include things like loft conversions and new kitchens and bathrooms that may skew the results.



For the basic packages, the most cost efficient property to retrofit is the 1965-1980 Detached property occupied by Older Established at £4.98 per kgCO_2 saved. Most of the properties fall below £12 per kgCO_2 with the exception of the Post-1980 detached house, which will cost significantly more to retrofit on the basis of carbon reduction effectiveness. This is due to the fact that these houses would already have been insulated to a reasonable (but not low carbon) standard under current building regulations and getting them up to the next level would require more effort and cost to see a noticeable improvement. It stands to reason, therefore that any property older than 1980 is worth retrofitting and that for the mass scale refurbishment we can focus less on the Post-1980 properties.

There seems to be no hard and fast rule that determines whether the configuration (i.e. detached, semi-detached, mid-terrace) means that it is easier or harder to fit basic measures. Pre-1919 mid-terrace properties are scattered across the spectrum between £5.75 and £7.94 per kgCO_2 saved - and the difference is mainly in occupant behaviour. Ironically, Greener Graduates push their carbon emissions up a bit by having their temperature set to 21°C

instead of 20°C which is the norm for the other groups (as derived from the focus group and survey data in WP5), and despite reductions in lighting, appliance and hot water use, given the same house type, Greener graduates use up more energy overall - spending around £100 more per annum than the Young Starters, living in the same type of property. 1919-1945 Semi-detached properties all fall within the range of £5.86 to £6.01 while 1945-1964 Semi-detached properties all fall within the range of £9.04 to £11.72, presumably because of the better baseline fabric, hence the application of the same basic measures would have less effect.

For the enhanced packages, the properties more likely to experience the most benefit from the basic packages plus floor insulation, better airtightness and new doors and windows are the Pre-1919 properties (from £6.22 to £12.39), as the improvement of the glazing would pose a significant improvement over what currently exists. The only exception to this would be the enhanced package for the Pre-1919 mid-terrace occupied by Early Entrepreneurs - the higher occupancy rate (4 persons) compared to the other occupant types means that they would experience less CO_2 savings as a result of increased space heating and hot water use.

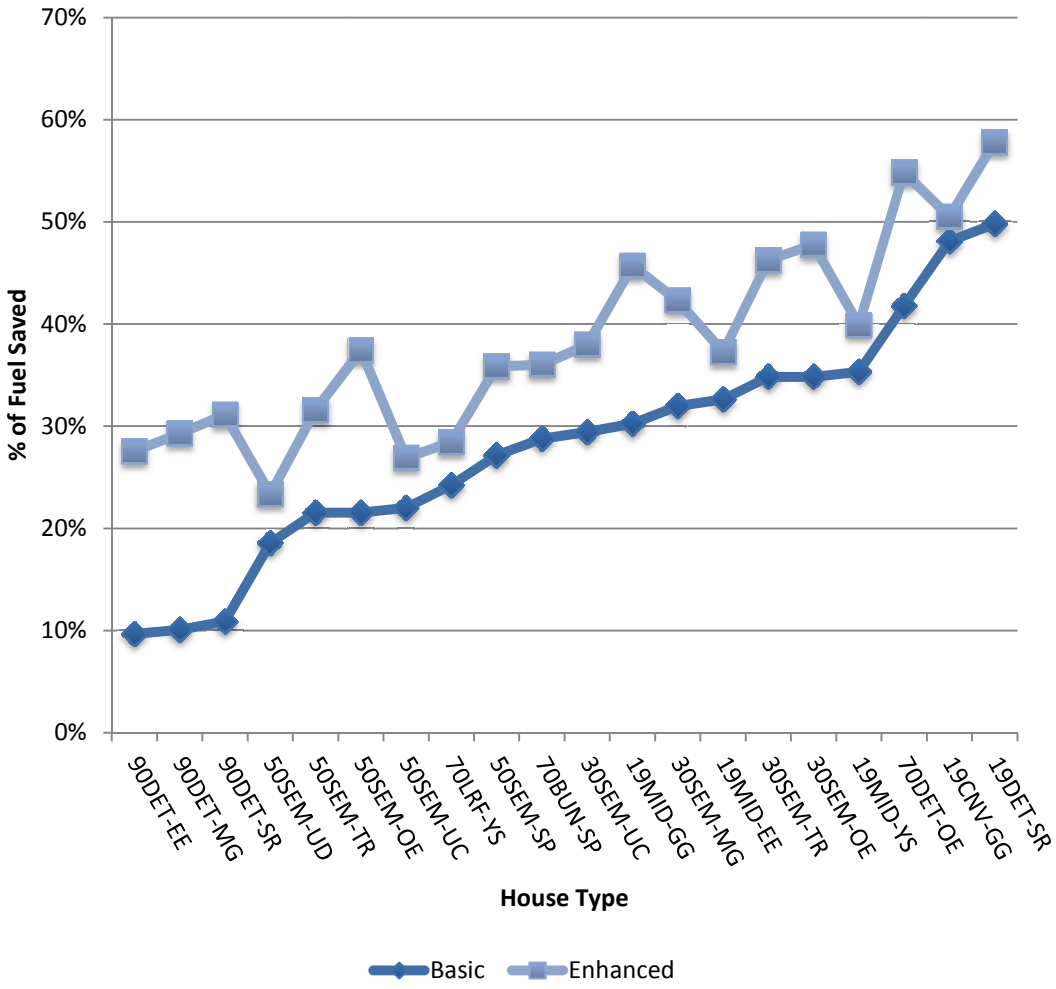
Similarly to the basic packages, Post-1980s properties experience the least cost-efficiency among all the house types because of their newer fabric and construction. Post-1980s owners may find it very cost-efficient in terms of carbon and fuel savings to undertake a low-carbon retrofit, which is a shame considering their typical occupants - Middle Grounders, Successful Ruralites and Early Entrepreneurs - are reasonably affluent and have the capacity to pay and generally aspire for green lifestyles.

Enhanced+ packages that cause a significant cost-efficiency drop are the packages which include loft conversions, which were offered as an added value factor for growing families who need more space, but it is a significant cost and construction programme inflator. There is an industry gap here that may present valuable business opportunity and significantly improve the efficiency of a refurbishment project. If we can develop a mass-manufacturable loft conversion solution that will make it a cost-effective value, it may be possible to target loft conversion applications for marketing thermal efficiency retrofit for the rest of the house.

New kitchens and bathrooms, depending of course on the standard of kitchen and bathroom on offer, appear to be a comfortable added value proposition in terms of cost efficiency and do not significantly add to the total cost of construction.

6.2 DEGREE OF IMPROVEMENT

The following graph illustrates the tangible degree of improvement likely to be experienced by the occupants, measured in percentage of fuel savings. The prices detailed below are based on current domestic fuel costs and has assumed mains gas heating only. The impact and viability of solutions on the use of other fuel types, such as electric, oil and LPG will presumably come out in the Stock Model in WP3.5.

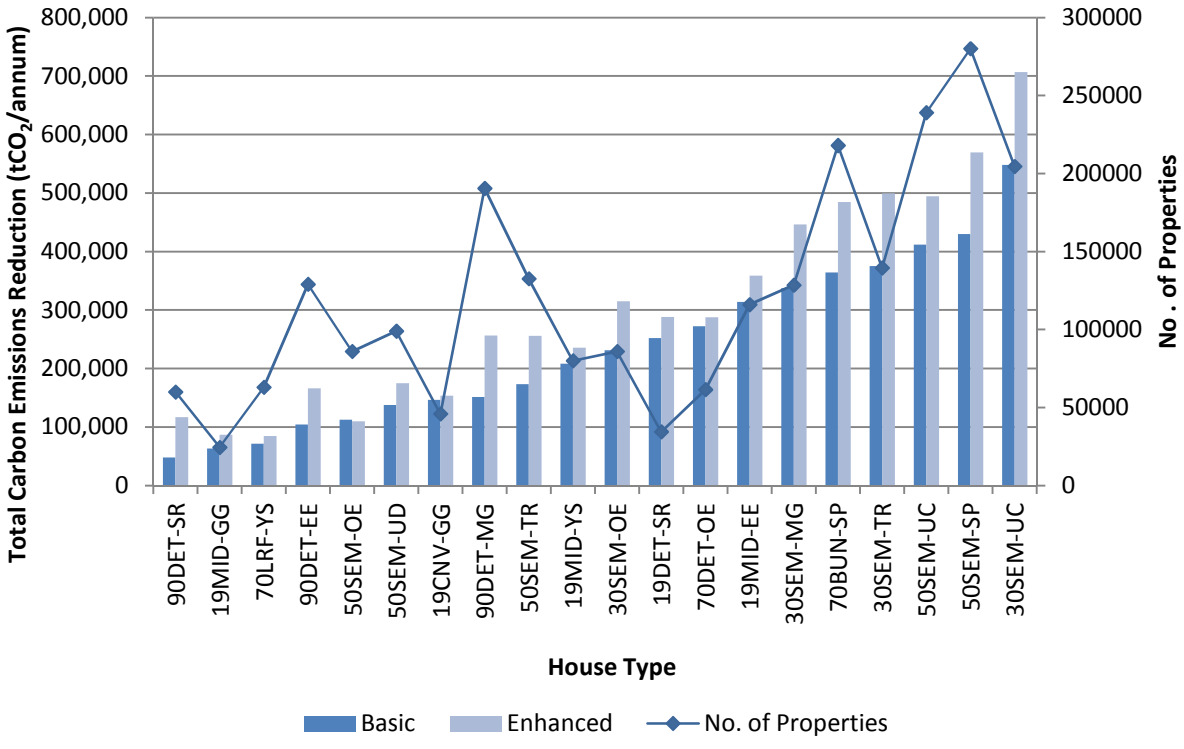


Occupants of the Post-1980 properties are likely to experience only a 10% reduction in their fuel bills, while occupants of the Pre-1919 detached (inhabited by Surburban Ruralites) can experience up to a 50% cut in their fuel bills after implementation of the basic packages. In terms of actual figures, this 50% cut equates to a savings of £1,259 per year. This same house type-householder combination also experiences the most fuel savings for the enhanced packages, with a fuel saving of up to 58%, or £1,461 per year.

Interestingly, while the basic packages of the Post-1980 properties do not yield substantial savings, the enhanced packages greatly improve the picture, going up to 31% fuel savings for the Post-1980 properties inhabited by Successful Ruralites. It is worth noting that between the three different residents for the Post-1980 properties, the differences are purely down to occupancy - a couple for Successful Ruralites, a family of 3 for the Middle Grounders and a family of four for the Early Entrepreneurs, which leads to a fuel savings range from 28% - 31%. This shows that for these newer properties, new windows and doors, floor insulation and improved airtightness will result in tangible fuel savings even though they are not necessarily cost-effective since these are the more expensive measures to implement.

Here we again the see the negating impact of Loft Conversions for the enhanced packages - any fuel saved by the improved thermal performance in the roof area is balanced by the addition of habitable heated areas, which add value for the occupants in terms of space but are not the most efficient at carbon savings or reduced fuel bills.

Another measure for the degree of improvement is on a national scale - what are the carbon emissions reductions from applying the basic and enhanced packages to all the houses with that particular house type and customer combination? In the next phase of work we will be working with the stock model to apply scenarios at an individual house level, but for now we are using averages across the stock to represent the geometry and fabric performance of a particular house type. The following bar graph presents the total CO_2 savings resulting from application of the basic and enhanced packages.



The graph shows that in terms of the basic packages, there is relatively little yield in terms of CO_2 emissions reductions from the Post-1980 properties - there is a relatively substantial amount of them in terms of population but this is not balanced by the scale of the improvement. In terms of Pre-1919 mid terraces occupied by Greener Graduates, the overall carbon footprint reduction is small due to the small amount of properties. In contrast, the Pre-1919 Detached properties also number less than 50,000 however the resulting carbon reductions from retrofitting them is more significant. We have to bear in mind, however, that these properties are often rural and therefore probably more difficult to retrofit using a supply chain efficient street-by-street or neighbourhood-based rollout.

On the opposite end of the scale, 1919-1945 Semi-detached properties are quite balanced in terms of population and results - there are a lot of them and they have proportional carbon reduction potential. 1945-1964 Semi-detached properties are also on the higher end of the scale but work has to be undertaken to retrofit a lot of them in order to make a difference.

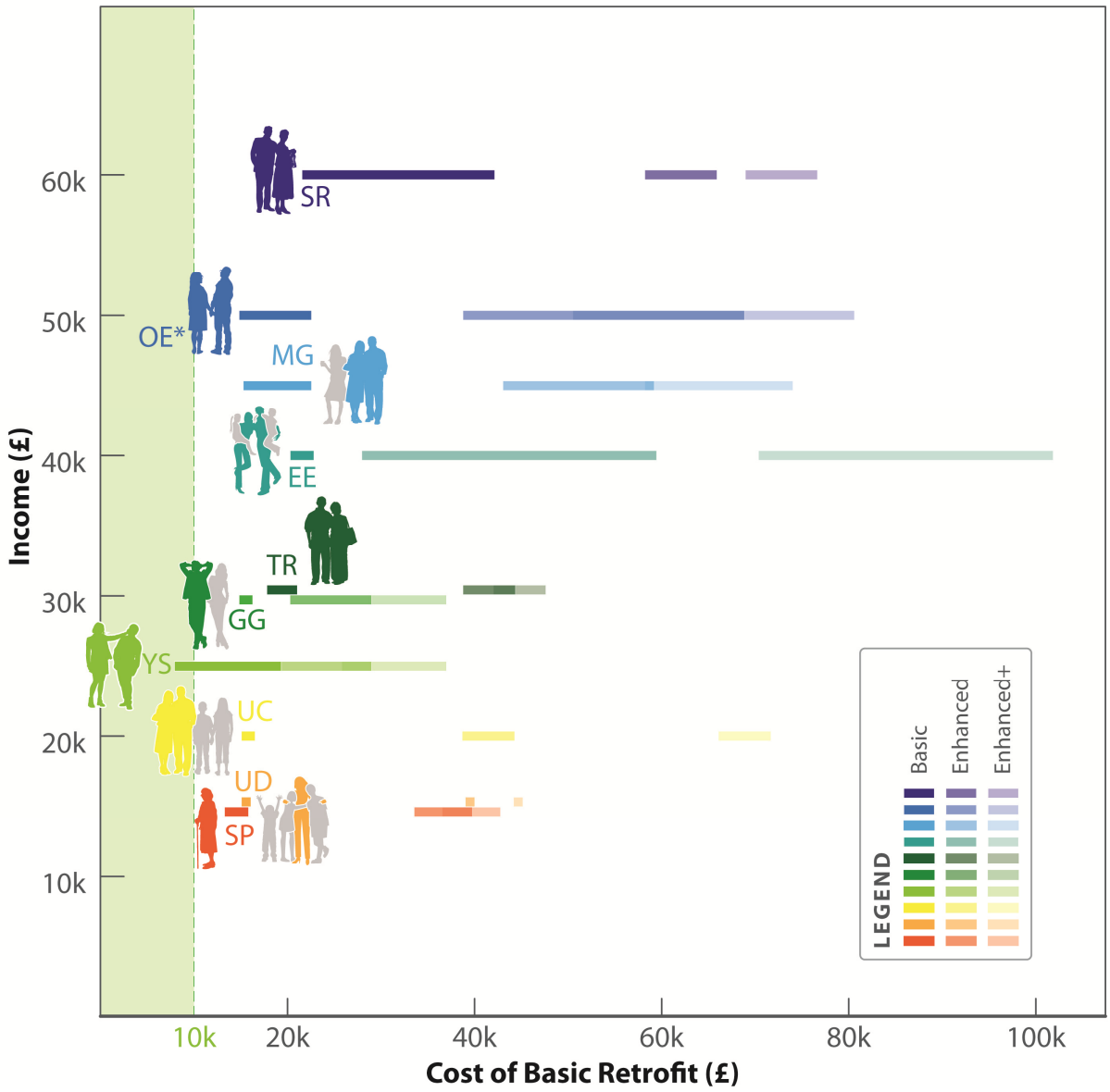
6.3 CUSTOMER ACCEPTANCE

In terms of customer acceptance, we looked at two metrics: the degree of potential disruption of the retrofit and the cost of the retrofit versus the income of the occupant.

For disruption Wates developed theoretical construction programmes for each house type based on the following scenarios:

- **Basic package, vacant property** - in this case the number of contractors is not so critical and the focus should be on the compression of the programme.
- **Basic package, resident in occupation** - this adds a substantial degree of complexity to retrofits which require internal works. For basic packages is limited to properties that require IWI works. As such, for most of the basic packages, the maximum number of workers and the duration of works is the same for both vacant and occupied scenarios.
- **Enhanced package, vacant properties** - the number of contractors is not so critical and the focus should be on the compression of the programme.
- **Enhanced package, resident in occupation** - for the enhanced packages, most require internal works and as a result, the programme can potentially be greatly extended if the resident is not decanted. In addition, there is a limit to the number of people on site in order to avoid the residents feeling unsafe and outnumbered.

Another metric that gives us some indication of the uptake for retrofit is affordability. The following matrix shows the relationship between the construction cost of the basic retrofit packages and occupant income:



If we set £10,000 as a threshold value we find that nearly all of our basic and enhanced packages for the low income groups to not fall within this zone. The only customer segment that fits comfortably within this threshold is the Young Starters Basic package. Some of the basic packages for the higher income groups come close to this threshold, but presumably even with a slightly higher cost they may decide it is worth it if they can be convinced that the retrofit is of value. For Successful Ruralites, by nature of the type of properties they inhabit (Detached Houses), retrofit is generally an expensive (yet good value in terms of energy reduction) proposition. In any case it is clear that costs must come down or financial

enablers must be made available to make whole house retrofit available to our target customer groups.

It is worth noting however that these costs are based on current state pricing and the most efficient methodology currently in operation. These are also calculated using the ETI TE model and as such are based on a measure-by measure approach rather than a systems approach.

Packages that include a loft conversion make it a very expensive retrofit, even with relative affluence, as is the case for the Middle Grounders and Early Entrepreneurs, and even more so with the Urban Constrained. Still, the aspect of increasing space is of substantial added value for these groups, so it would be worth exploring other options, such as extensions (if space allows) or innovative storage solutions.

6.4 BENCHMARKING

Are we being ambitious enough? The retrofit standards we have chosen for the packages are certainly ambitious in terms of current UK Building Regulations 2010 but is it enough? We have concentrated on solutions that are buildable today, using current and rapidly emerging technology. But while the modelling results show a high degree of reduction in carbon emissions, is that really as far as we can hope to go? How much benefit would be get from a national-scale Passivhaus retrofit, for example? The Passivhaus standard is recognised in Europe as a progressive and advanced benchmark for building energy performance. The key feature of a Passivhaus is that they space heating requirement is reduced by means of passive measures to the point at which there is no longer any need for a conventional space heating system, whilst providing a high level of thermal comfort. Passivhaus retrofit standard, or Ener PHit, is an adapted version of Passivhaus for retrofit projects - it has less stringent requirements for air leakage and U-values, and this is in recognition of the fact that it is not always possible to achieve Passivhaus standard for existing buildings, even with generous funding.

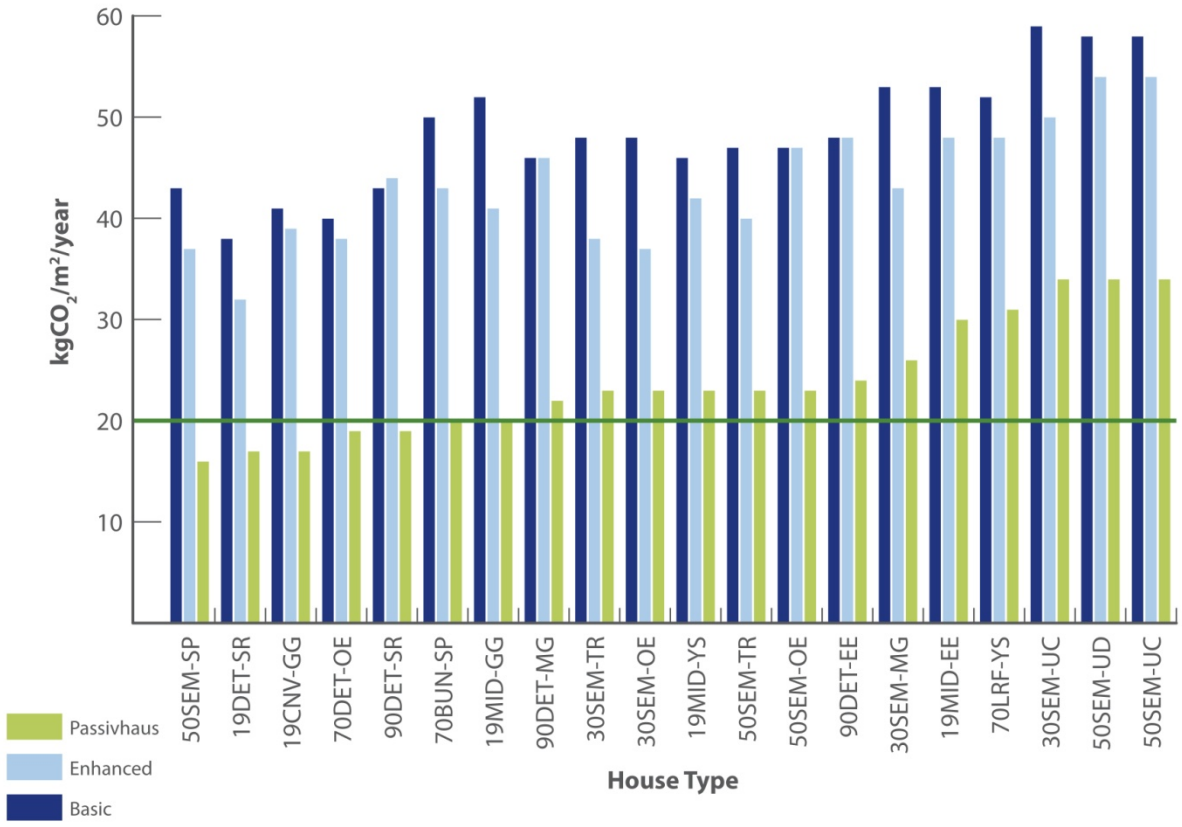
The Retrofit for the Future project aimed to meet or exceed a benchmark emissions target of 17 $kgCO_2/m^2$/year. How many of our packages meet this target? We compare our modelling results with an additional set of iterations, this time with a typical 'Passivhaus' retrofit package[1], which includes:

- Walls and roof U-value of 0.1 W/m^2K

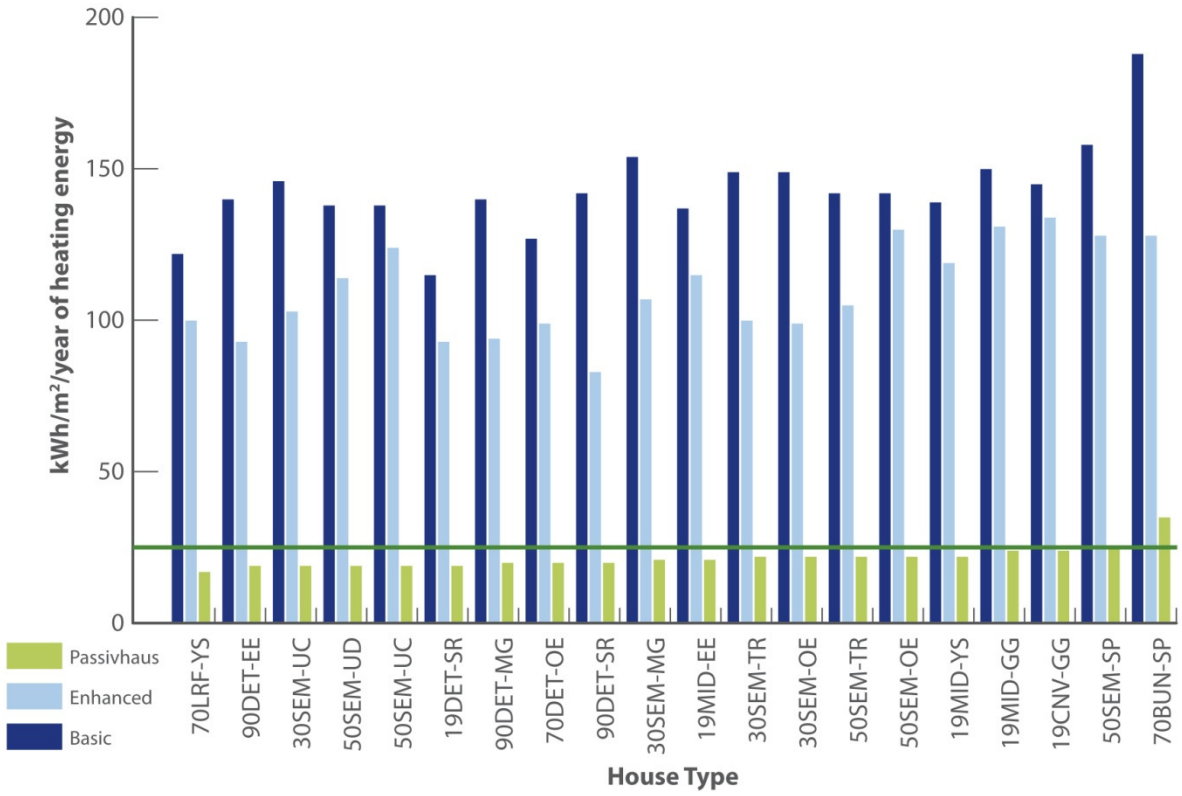
[1] Passive House Institute. *EnerPHit: Criteria for Residential-Use Refurbished Buildings*. 2011.

- Floors U-value of 0.18 W/m^{2}K
- Door U-value of 1.0 W/m^{2}K
- Window triple-glazed with a U-value of 0.6 W/m^{2}K
- High-efficiency heating system with an efficiency of at least 90%
- Solar thermal hot water
- MVHR with an airtightness of 1.0 m^3/(m^2.hr) @ 50Pa
- Thermal bridge detailing

The following graph shows that our basic and enhanced packages do not meet the RftF target, and that not all of the Passivhaus packages do either. This may be due to the difference in calculation methodology - the ETI TE model includes energy for cooking, appliances and lighting.



Let's try comparing using another metric - the Passivhaus metric of 25kWh/m^2/year for heating energy:



Therefore, our basic and enhanced packages, which are based on what is currently deliverable, fall quite short of Passivhaus retrofit standards. If we want to aspire for ultra low carbon there are many gaps in the industry that need to be addressed, in particular materials that will enable us to achieve a U-value of 0.1 W/m^{2}K for walls and roofs without occupying too much space, a solution for getting floor U-values down to 0.18 W/m^{2}K, glazed doors with a U-value of 1.0 W/m^{2}K, more affordable triple glazing, thermal bridging solutions that are easy and straightforward to install, and a resolution to all the concerns over the use of MVHR in relation to health and indoor air quality. Heat pumps are an option but they are not likely to be suitable for mass-scale refurbishment but should definitely be considered.

7 Innovation

- List of innovative 'dream' products grew out of the Single Dwelling Refurbishment Plan
- Practical experience of partners was used to think of products that would allow retrofit projects to be more efficient, cheaper and more appealing to the UK public
- Following completion of the product list, partners from BASF were consulted to consider which products are already available, in development or are unlikely to be realised

The final exercise of the Single Dwelling Refurbishment Plan workshop took place after two rounds of whole house package development - by this time all the teams were familiar with the issues of existing housing and had gone through the exercise of developing solutions for their assigned house types and clients. This exercise was to do with "dream solutions" - what products should be invented in order to make the retrofit process easier/faster/more efficient/cheaper? The listed innovation possibilities that are not yet within the construction mainstream but could be developed further in order to prime the retrofit process.

Once we identified the gap and some potential products, we asked BASF to make a commentary on the viability of these solutions, and where relevant, to identify emerging products that already exist that may fill the gap.

Below is a list of the products that would be especially helpful in improving the implementation of both Single Dwelling Refurbishment and the rollout of a mass retrofit programme. A more detailed list, including commentary from BASF can be found in Appendix E.

Roofs

- Invisible PV/solar thermal
- Roof coverings with integral insulation

Walls

- Super Thin insulation
- Range of high-quality wall finishes with integral insulation
- Fixings to eliminate need for drilling
- Prefab pre-cut and sized insulation
- Old cavity wall insulation eating device/material that is eco-friendly

Doors

- Thermally broken timber door sets
- Letterbox and cat flap airtightness solution

Windows

- Aerogel-filled windows
- Carbon capture glazing (CO_2 for filling window cavities)

Floors

- Perimeter biscuit cutter (all-in-one DPC slice and replace)
- Thin solid floor insulation
- Flooring with integral insulation
- Floor insulation 10mm max so lambda value is 0.007
- Narrow trench tool for floor edge insulation installation

Controls

- Explore possibilities for externally-managed BMS

Heating

- Modular boiler (multi-stage so that it does not need to run at peak all the time to be efficient)
- Combi boiler warm feed

Survey

- Non-traditional house type recognition software coupled with hand-held devices
- Thermal imaging app for smart phones
- In situ U-value checker tool
- Whole stock energy database
- Auto survey kit usable by unqualified people

Ventilation

- Passive heat exchanger
- MVHR integrated into cooker hood or chimney
- MVHR dynamic control- remote controls
- Self-sealing ventilation products (e.g. exhaust fans), duct and flue interfaces

Condensation

- Passive dehumidification
- Insulated bath/toilet

8 Summary

The Single Dwelling Implementation Plan report outlines the development of individualised improvement scenarios that are tailored to the customer segments and house types identified previously by the consortium. The report draws on the demographic information from WP5 in order to better understand customer motivations and barriers toward retrofit. This information has also been useful in determining customer awareness of wider green issues and their interest in home improvement.

Using customer segments as a guide, the BRE stock data was analysed to determine the properties in which these groups tend to reside. Customer segments and property types have been extensively detailed to provide robust improvement packages. These packages were developed during the Single Dwelling Refurbishment Plan workshop which involved project partners from PRP, Wates, Total Flow and BRE. All aspects of thermal efficiency were considered for each house type. The result was a set of two refurbishment packages for each property, divided into 'Basic' and 'Enhanced' packages based on thermal efficiency improvements of 20-50%, or those which are best practices. Each plan is designed to address the drivers and barriers for each customer profile while effectively retrofitting their property according to age, typologies and unique considerations. Each measure has been tested with the BRE/UCL model in order to assess the effectiveness of the interventions.

The result is a group of solutions that covers a representative percentage of the UK population and housing stock, presenting solutions that are thermally robust as well as represent added value to potential retrofit customers.

The results of our analysis of the whole house packages show that:

- Post-1980 properties are not cost effective to retrofit at our basic level, but that all Pre-1980 properties reasonably demonstrate cost effectiveness in terms of retrofit. They do show benefits at enhanced level for carbon emissions reduction and fuel savings, but it is not very cost effective.
- Occupant behaviour is a factor that should not be ignored, particularly when predicting energy savings - we have demonstrated that for the same house type and same set of solutions different types of occupants greatly influence fuel savings and CO_2 emissions reductions. For example, despite reductions in lighting, appliance and hot water use, given the same house type, Greener Graduates use up more energy overall - spending around £100 more per annum than the Young Starters, living in the same type of property but heating to a 1°C higher set temperature.
- Some Pre-1919 properties experience a reduction in carbon emissions by up to 50% for the basic packages, and up to 58% for the enhanced packages. Going up to Passivhaus standard can result in reductions of up to 75%

- If we want to hit more ambitious "low carbon" targets, relying on current construction methods and available materials is not enough. We can only hit these targets if we aspire to meet Passivhaus-type standards, and promote the development of solutions that will enable us to hit the high performance U-values that are required.
- Loft conversions generally do not add up in terms of cost effectiveness and thermal benefits. We need to explore other ways of adding value by creating habitable/storage space

We also looked at gaps in the current technology available to us for retrofit - there are many products that are not readily available that could greatly contribute to the success of a mass retrofit, in particular products that are able to deliver high levels of insulation without requiring material depth, as well as off-site manufactured multi-functional solutions that combine functions, e.g. finishing and insulation, security and insulation, etc. We would need to further develop some of these "dream materials" if we want to hit more ambitious targets, such as an affordable mass-scale "Passivhaus retrofit standard" exercise.

9 Next Steps

- The next stage will take the findings of the Single Refurbishment Implementation Plans report and investigate their applicability across the UK
- The Mass Retrofit Implementation Plan will consider technical solutions as well as supply chain issues, customer engagement strategies and necessary public policy to create end-to-end strategies

The next stage in WP3 will be the development of the Mass Retrofit Implementation Plan. Building upon the packages developed in this report, we intend to investigate the implications of rolling out these individualised plans at a national level. Issues to consider include the speed of implementation, customer acceptance strategy, supply chain design and proposing public policies to facilitate the process.

Similar methods of collaboration with consortium partners that were highly successful in WP3.4b will be used during WP3.5. The development of robust end-to-end engagement strategies will require drawing on the expertise and findings from different work packages. The need for innovation has been outlined in this report and will be furthered in WP3.5 by identifying opportunities for streamlining processes, minimising waste and utilising new and emerging technologies. We will continue to draw on the findings of WP3.4b, as well as stock model data, in order to determine which house types will make the most impact in terms of the cost and carbon targets.

During the next stage we intend to dig deeper into the solutions and explore ways in which we can "mass customise" and tailor these standard solutions to the myriad of properties that exist, and in varying stages of improvement. We also intend to work with our WP2 collaborators on running scenarios for retrofit in order to have a quantitative analysis of the impacts of the retrofit on the UK's carbon targets.

Appendix A

Tenure / Attitudes	Owner Occ					Social Renters					Private Renters					Product	Sum
Group Segment	Pop	Open	Aware	x	+	Pop	Open	Aware	x	+	Pop	Open	Aware	x	+	Score	Score
Unconvinced Dependents	1	2	2	4	5	3	2	1	6	6	1	2	1	2	4	48	15
Urban Constrained	2	2	2	8	6	2	2	2	8	6	1	2	2	4	5	256	17
Young Starters	2	1	2	4	5	2	1	2	4	5	2	1	2	4	5	64	15
Stretched Pensioners	2	3	3	18	8	2	3	3	18	8	1	3	3	9	7	2916	23
Greener Graduates	1	1	3	3	5	1	1	3	3	5	3	1	3	9	7	81	17
Early Enterprisers	3	3	3	27	9				-	-	2	3	3	18	8	0	17
Middle Grounders	3	2	1	6	6	1	2	1	2	4	1	2	1	2	4	24	14
Successful Ruralites	3	3	2	18	8				-	-	1	3	2	6	6	0	14
Transitional Retirees	3	3	2	18	8	2	3	2	12	7	1	3	2	6	6	1296	21
Older Established	3	3	3	27	9	1	3	3	9	7	1	3	3	9	7	2187	23

Appendix B: Example Workshop Worksheets

Improvement Scenario No. **001**

10 mins **THE PROPERTY**

Property Age	Pre-1919
Property Type	Mid-terrace
No. of properties of this type in the UK	1,860,000 properties

Typical Dimensions:	m^2
Wall Area	68
Ground Floor Area	46
Roof Area	44
Window Area	20
Door Area	4.2
No. of storeys	2

	Description	U-value W/m^2K
Wall type	Solid	2.0
Roof insulation	50mm loft insulation	0.5
Floor type	Suspended	0.6
Window type	Double glazing	3.3
Door type	Standard	3.8
	$m^3/m^2/hr$	
Airtightness	10	

Heating system	On/off combi boiler, 72% efficiency
Fuel	Mains Gas
Hot water system	Boiler
Tank insulation thickness	27mm

10 mins **FEATURES and DETAILS**

What features and details are likely to require special attention for this type of property?

20 mins **BASIC THERMAL PACKAGE**

Formulate a basic "bare minimum" whole house package for this type of property. For each measure, include a description of the enabling works required.

Roof	
Walls	
Windows	
Doors	
Floors	
Airtightness	
Heating	
Ventilation	

15 mins **GOOD PRACTICE PACKAGE**

Formulate a basic "good practice" whole house package for this type of property. For each measure, include a description of the enabling works required.

Roof	
Walls	
Windows	
Doors	
Floors	
Airtightness	
Heating	
Ventilation	

10 mins **CLIENT 001**

Name of Client	Dave and Amanda
Type of Client	Young Starters
Age Group	Under 35
Income	Less than 30k
Occupancy	Couple
Tenure	Private rental

PROFILE

Dave and Amanda are a childless young married couple that have lived in their home for 2 years. They are busy juggling work and home life, and are thinking of having children in the next few years. They have one car but would like to buy a new one. They would like to become more connected with new technology.

They are familiar with green terms and issues of climate change but have low levels of understanding. They would like to become more aware but will not take action based on environmental concerns alone. They do not take part in 'green' activities such as recycling or turning lights off when not in use. Their behaviour is dominated by their lifestyle and a dependence on cars- they are potentially responsive to activities which would not impact their normal routine.

Aspirations for home improvement/ retrofit

- ✓ **increase house value**
- ☐ **better thermal comfort**
- ☐ **lower fuel bills**
- ✓ **more space**
- ☐ **lower upkeep/maintenance costs**
- ☐ **green lifestyle**
- ☐ **accommodate growing family**
- ☐ **income generation**
- ✓ **latest technology**
- ☐ **other:**

SOLUTION

5 mins Bare Minimum or Good Practice, or somewhere in between?

- ☐ **Bare Minimum**
- ☐ **Good Practice**
- ☐ **other (please explain)**

15 mins **ADDED VALUE**

Added Value Improvements - based on their aspirations, what added value incentives can be efficiently done at the same time, in terms of cost, time and disruption?

10 mins

CLIENT 002

Name of Client	Murray
Type of Client	Greener Graduates
Age Group	25 45
Income	More than 30k
Occupancy	Single professional
Tenure	Private Rental

PROFILE

Murray is a young well educated single who is early in his career. He lives in a nice flat in an urban centre and has a busy social life. He is environmentally aware with the right attitude although behaviour is lagging in some respects. He chooses some environmentally friendly actions, such as buying organic meat or eco-friendly goods. The compulsion to do something would be the main driver for him to make changes to his flat.

Aspirations for home improvement/ retrofit

- ☐ **increase house value**
- ✓ **betterthermal comfort**
- ✓ **lower fuel bills**
- ☐ **more space**
- ☐ **lower upkeep/maintenance costs**
- ✓ **green lifestyle**
- ☐ **accommodate growing family**
- ☐ **income generation**
- ✓ **latest technology**
- ☐ **other:**

SOLUTION

5 mins

Bare Minimum or Good Practice, or somewhere in between?

- ☐ **Bare Minimum**
- ☐ **Good Practice**
- ☐ **other (please explain)**

15 mins

ADDED VALUE

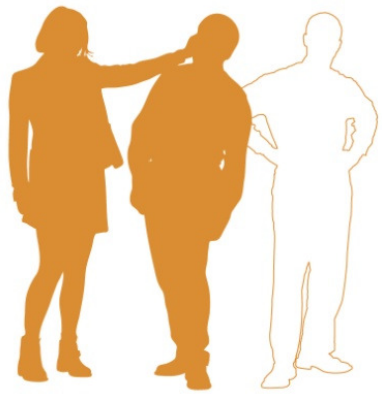
Added Value Improvements - based on their aspirations, what added value incentives can be efficiently done at the same time, in terms of cost, time and disruption?

Appendix C: Customer Types

- Understanding of customer types key in developing targeted refurbishment plans
- Demographic information has been sourced from WP5 and customer profiles have been developed based on this background data
- Key motivators and added value incentives are the result of the Single Dwelling Refurbishment Plan workshop to develop individualised refurbishment plans tailored to each customer type

Customer profiles have been narrowed down from the demographic segments used throughout the project. We have identified 10 customer profiles that are most likely to undertake a retrofit project or represent a significant population group, and these profiles will dictate individual refurbishment plans. These were chosen based on the size of the customer segment, as well as their openness and awareness regarding retrofit.

Following the development of detailed profiles, key motivators for each customer type were detailed to guide the selection of measures to be installed. This in turn led to 'Added Value' incentives, which are considered measures unrelated to thermal efficiency but which may help to incentivise customers to undertake a retrofit project. For example, Young Starters may be motivated to install new windows because of the need for increased security, rather than improved thermal efficiency alone. The chosen ten profiles include:



Dave and Amanda, 25

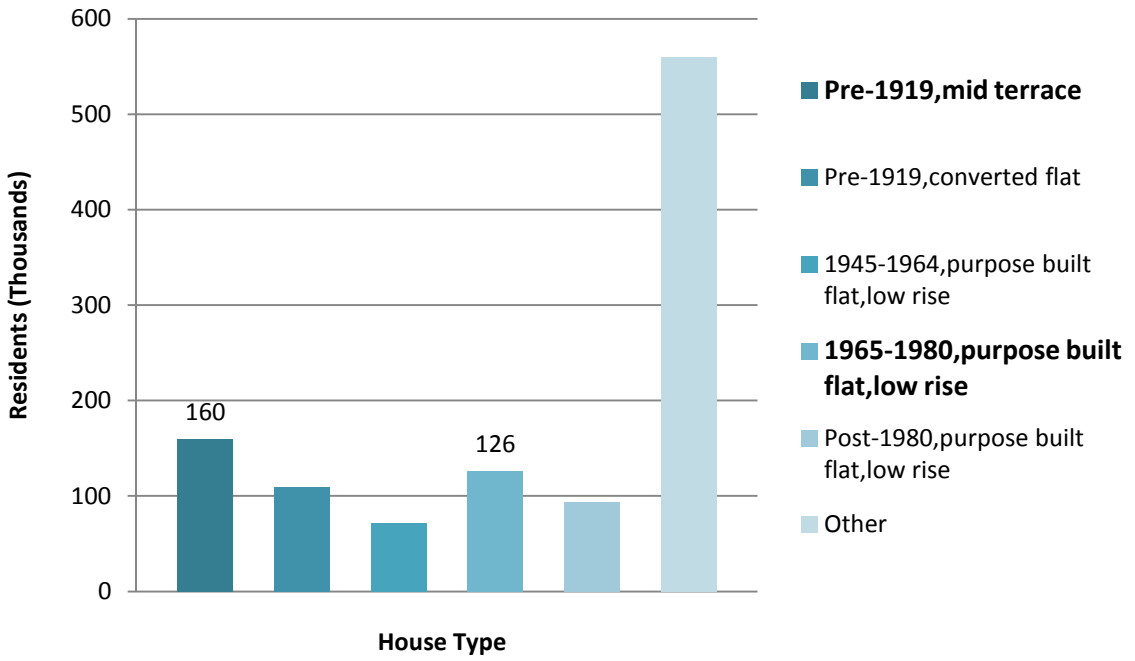
YOUNG STARTERS

Age <35 years old

Income <30k per annum

Tenure Private rent

House Type Profile



Dave and Amanda are a childless young married couple that have lived in their home for 2 years. They are busy juggling work and home life, and are thinking of having children in the next few years. They have one car but would like to buy a new one. They would like to become more connected with new technology.

They are familiar with green terms and issues of climate change but have low levels of understanding. They would like to become more aware but will not take action based on environmental concerns alone. They do not take part in 'green' activities such as recycling or turning lights off when not in use. Their behaviour is dominated by their lifestyle and a dependence on cars- they are potentially responsive to activities which would not impact their normal routine.

Dave and Amanda typically live in either a pre-1919 mid-terrace property or a 1965-1980 low-rise purpose-built flat. They are both at work from 9am until 5pm and evenings are spent either socialising with friends or having quiet dinner at home and relaxing in front of the television. Lighting and appliance usage are average, and they use less hot water because they don't have any children. Their temperature would be set at 21°C.

Key Motivators (Landlord)

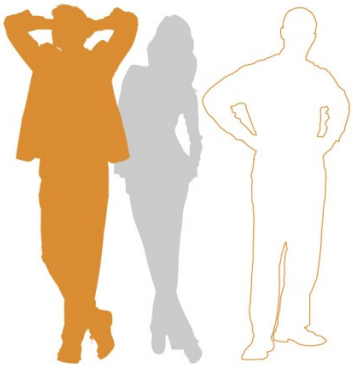
- Increase house value
- Increase rent
- Tenant longevity

Key Motivators (Tenant)

- More space
- Latest technology

Added Value

- Door and window security
- Flexible controls, easy to use
- Low maintenance materials
- New bathroom
- Storage space
- Minimal disruption
- No rent increase



Murray, 30

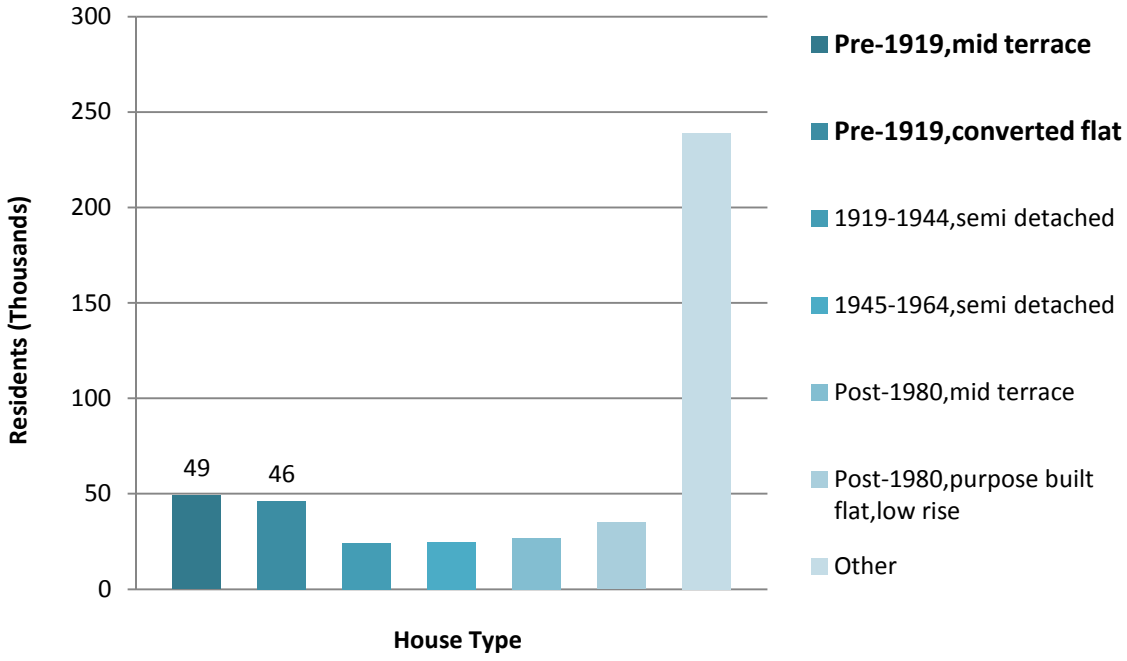
GREENER GRADUATES

Age 20-45 years old

Income >30k per annum

Tenure Private rent

House Type Profile



Murray is a young well educated single who is early in his career. He lives in a nice flat in an urban centre and has a busy social life. He is environmentally aware with the right attitude although behaviour is lagging in some respects. He chooses some environmentally friendly actions, such as buying organic meat or eco-friendly goods. The compulsion to do something would be the main driver for him to make changes to his flat.

Murray and his girlfriend typically live in a pre-1919 mid-terrace house, but he says that if he were single he would probably move to a smaller pre-1919 converted flat. He works from 9am to 5pm and evenings are spent either out on the town socializing with friends or networking, with the occasional quiet night at home. Being eco-conscious, lighting and appliance energy consumption are less than the average, and since he has no kids, hot water usage is also less than the average. The temperature of his home would typically be kept at 21°C.

Murray's landlord likes him. He pays his rent on time and takes care of the flat reasonably well. He might be motivated to refurbish the flat if that would attract more tenants like Murray, or ensure that Murray stays in the property for a while.

Key Motivators (Landlord)

- Increase house value
- Increase rent
- Tenant longevity
- Tenant type

Key Motivators (Tenant)

- Better thermal comfort
- Lower fuel bills
- Green lifestyle
- Latest technology

Added Value

- Door and window security
- Flexible controls, easy to use
- Smart meters
- Low maintenance materials
- New bathroom and kitchen
- Energy efficient appliances
- Latest technology and gadgets
- No rent increase

Justin and Stephanie, 30

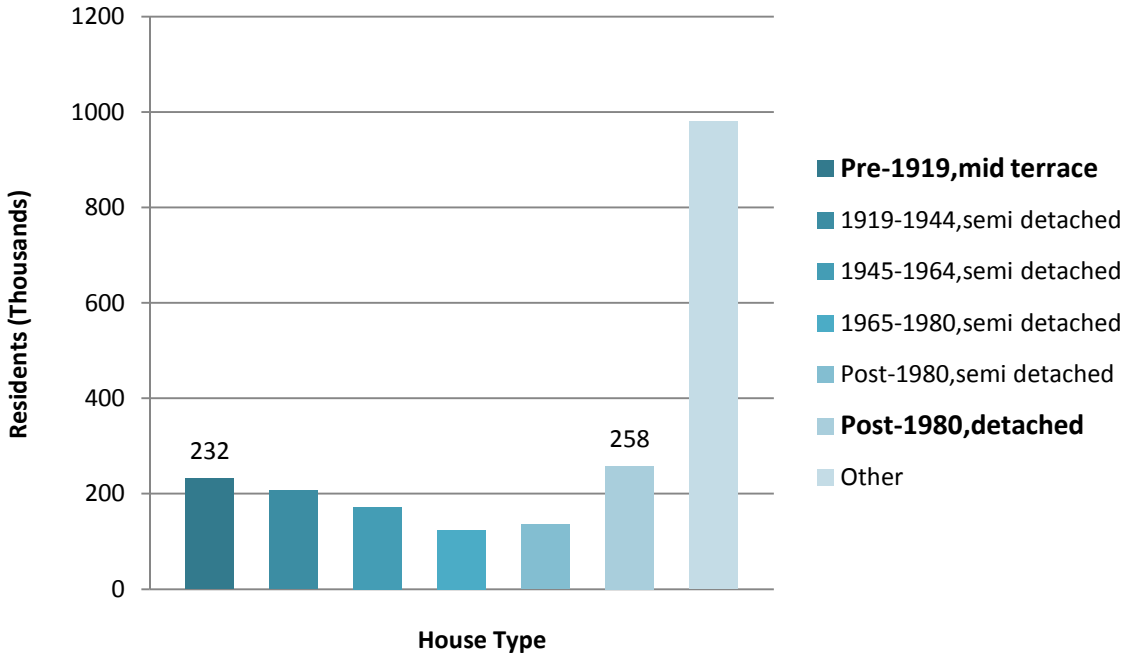
EARLY ENTREPRENEURS

Age 35-50 years old

Income >30k per annum

Tenure Owner Occupier

House Type Profile



Justin and Stephanie are an early middle-aged professional couple who have owned their home for over 5 years. They are both degree educated with intermediate management occupations and continue to be ambitious in their careers, though they are both keenly involved in their children's education. They have two children aged 8 and 11. Though they are comfortable and presently value their home, they would eventually like to have a bigger, better home in a good neighbourhood. They tend to shop at Waitrose and M&S and place value on having a good car.

While they are familiar with green terms and the issues of climate change, they do not take action out of concern for the environment. They are likely to be resistant to change even if they could be convinced it would help environmental issues.

Justin and Stephanie typically live in a pre-1919 mid-terrace property, though they would ideally move further into the suburbs to a post-1980 detached home. They are both at work from 9am until 5pm though they are home most evenings with their children. A couple of nights a week they are out of the house at their children's various after-school activities. Lighting and appliance usage are above average, as is their hot water use. The temperature of their home would typically be kept at 21°C.

Key Motivators

- Increase house value
- More space
- Accommodate growing family

Added Value:

- Door and window security
- More wall space
- Child-friendly energy monitors/displays
- Smart meters
- Increase house re-sale value
- New bathroom and kitchen
- Room in roof or garage conversion or extension (more habitable space)
- More storage space
- Energy provider information

Vikki and Raj, 50

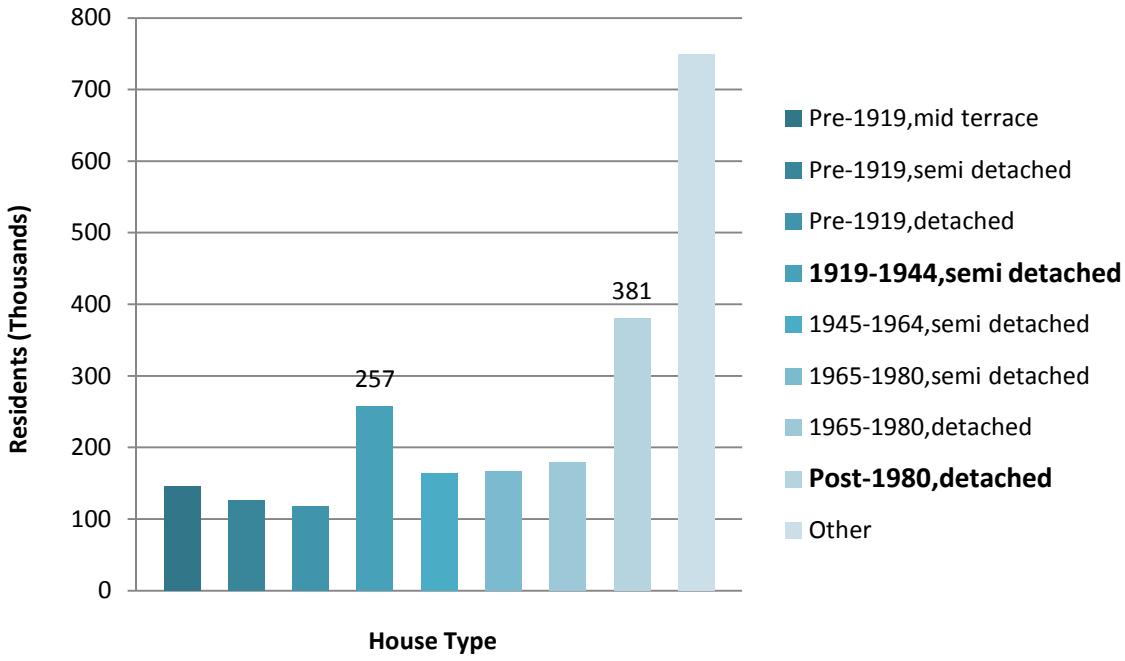
MIDDLE GROUNDERS

Age 40-60 years old

Income 45k per annum

Tenure Owner Occupier

House Type Profile



Vikki and Raj are a middle income married couple living in a moderate successful detached home. They have lived there for over 10 years and their eldest son recently moved home after finishing university. They are both well educated with good jobs but would like to be more comfortable financially. They tend to like to shop at Waitrose, but also shop at Tesco.

They are not particularly informed regarding global green issues but have a general concern for the environment. They are involved in small-scale proactive behaviour including recycling, being energy conscious in the home and buying fair-trade/organic/locally produced goods. They like to think they do the right thing environmentally though they would more likely to do more if the price was right. They would like to be seen as understanding environmental issues and doing the responsible thing.

Vikki and Raj typically live in either a post-1980 detached home, or a 1919-1944 semi-detached property. They are both at work full time from 9am until 5pm, as is their son. While Vicki and Raj spend most evenings at home, their son is typically out after work socialising with friends. Lighting and appliance usage are average, as is their hot water use. The temperature of their home would typically be kept at 20°C.

Key Motivators

- Increase house value
- Lower fuel bills
- Green lifestyle
- Income generation
- Latest technology

Added Value

- No plans to move
- Community-based retrofit/micro-generation
- Whole house plan- staggered capital cost
- Room in roof/annex room
- Energy advice/provider switch
- Under floor heating- remove radiators for extra space

Jane and Peter, 50

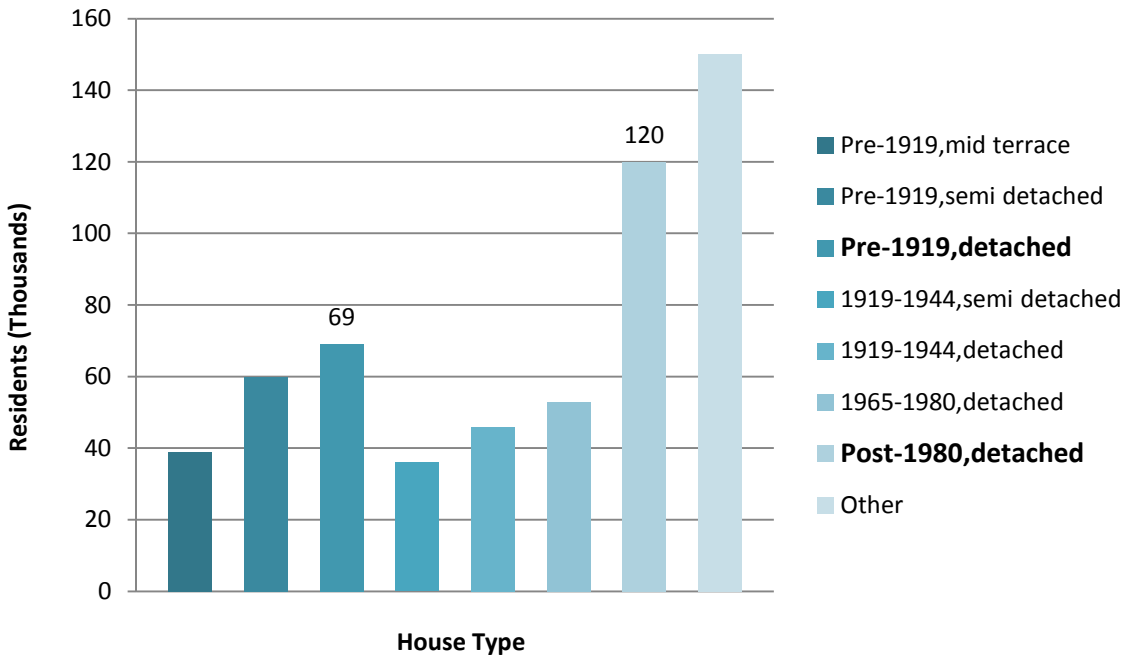
SUCCESSFUL RURALITES

Age 40-60 years old

Income 60k+ per annum

Tenure Owner Occupier

House Type Profile



Jane and Peter have lived in their home for nearly 10 years and commute to the nearby urban centre for work. They tend to shop at Waitrose and M&S, and take up to five holidays per year. They have a high standard of living with a good social life and like to stay up to date with technology. They are engaged in their community.

They are not particularly informed regarding global green issues but have a general concern for the environment. They are involved in small-scale proactive behaviour including recycling, being energy conscious in the home and buying fair-trade/organic/locally produced goods. They like to think they do the right thing environmentally though they would more likely to do more if the price was right.

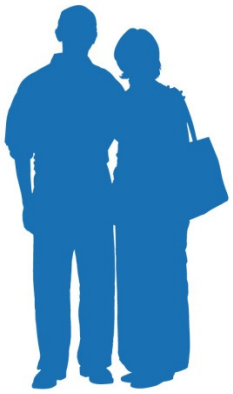
Jane and Peter typically live in either a post-1980 detached home, or a pre-1919 detached property. While Peter still works full time from 9am-5pm, Jane now works part time and is only at work 3 days a week. She spends the other two days working with local community groups. They spend most evenings in the local village either visiting friends or out for dinner. Lighting and hot water use is average, while their appliance use is above average. The temperature of their home would typically be kept at 20°C.

Key Motivators

- Latest technology
- Green lifestyle
- Increase house value

Added Value

- Prefer visual enhancements ('bling')- fashion based decisions exploited for CO_2 savings
- No plans to move- will be there in the long term
- Enhanced energy monitors
- PV or solar thermal
- Under floor heating
- LED lighting



Geoff and Sally, 60

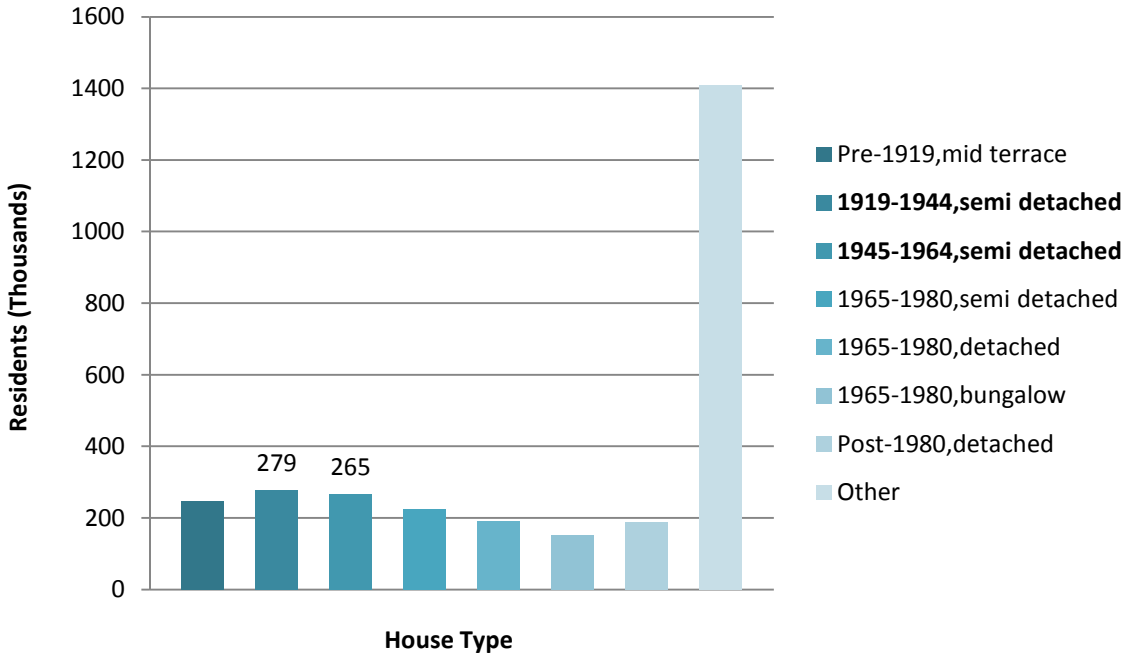
TRANSITIONAL RETIREES

Age 55-70 years old

Income 30k per annum

Tenure Owner Occupier

House Type Profile



Geoff and Sally are a married couple that are now empty nesters. Geoff recently retired while Sally is planning on retiring within the next 5 years. They have decent savings and are the type to save or invest for the future. Both will have private pensions from employers and are unlikely to claim benefits. They are a financially secure couple who are fairly sociable and are motivated to do more for green issues than others. They are reasonably well educated on new technology, but would like to embrace it more. They would like to enjoy their new retirement by travelling more, improving their home and reducing bills and buy a greener car.

They are more 'green aware', as they are educated with some knowledge but are often misinformed. They often lean toward buying energy efficient electric products and cars. Sometimes their actions are not taken out of concern for the environment but for other reasons as well.

Geoff and Sally typically live in either a 1919-1944 or 1945-1964 semi-detached house. While Geoff is a busy retiree, he spends a large amount of the week at home. Sally still works full time from 9am to 5pm. They spend most evenings at home cooking dinner together and watching a bit of television. Their lighting and hot water use is average, while their appliance use is below average. The temperature of their home would typically be kept at 20°C.

Key Motivators

- green lifestyle
- increase house value

- better thermal comfort
- lower fuel bills

Added Value

- Scale back work in loft to insulation only
- No to solar thermal as not enough water use
- Increased zone control

Helen, 60
Unconvinced Dependents

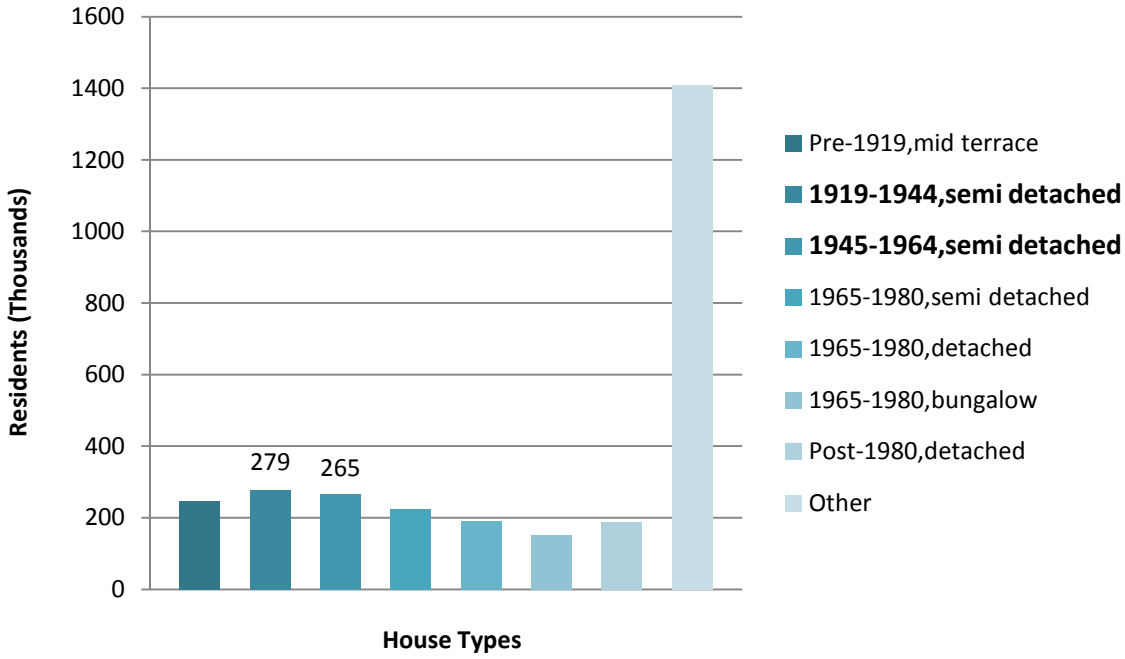
UNCONVINCED DEPENDENTS

Age 25-45 years old

Income 15k per annum

Tenure Social Renter

House Type Profile



Helen is a single female with three dependent children. Her home is on the fringes of an urban centre and she has no savings or assets and is currently struggling with her current income. She works part time at the post office and is a benefits claimant, receiving lone parents, disablement and housing/CT benefit. She is predominately focused on raising her children. She does not own a car and uses public transport and would like to socialise more and have a greater connection with the wider community.

She is apathetic toward green and political issues and has an overall wasteful lifestyle, both in terms of energy and goods. She is unconvinced of arguments for environmental actions,

and is not interested in doing more. There is also some price-sensitivity to green goods which are perceived to be more expensive. Overall, current personal issues are more important than wider social and environmental issues.

Helen has lived in both a 1919-1944 and a 1945-1964 semi-detached houses. Helen works part time at a local post office 3 days a week while she is at home the other two. She spends every evening at home with her children cooking a quick dinner and watching television. Her lighting and appliance use is average, while her hot water usage is above average. The temperature of her home would typically be kept at 20°C.

Key Motivators

- Better thermal comfort
- Lower fuel bills

Added Value

- Under floor heating to maximise space
- District heating scheme and RHI
- Install P.V.

Jack and Lizzie, 45

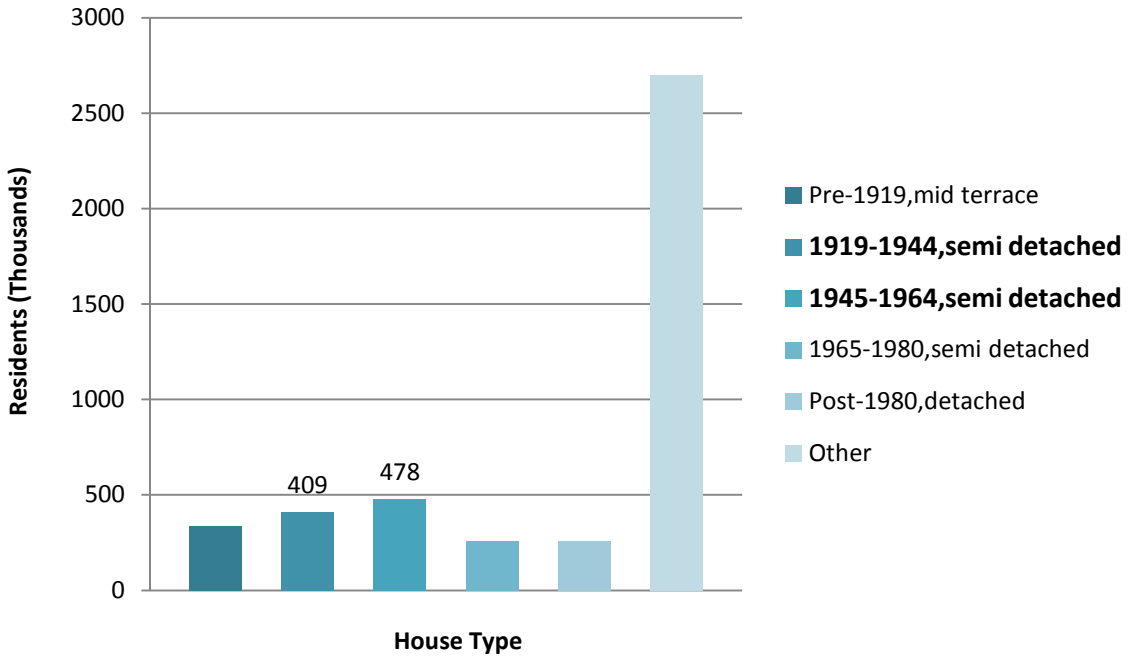
URBAN CONSTRAINED

Age 40-60 years old

Income 20k per annum

Tenure Social Renter/Owner Occupier

House Type Profile



Jack and Lizzie are a family living a low value house in a traditional industrial area. They have lived in the house for more than 11 years. They both have relatively low incomes and low education levels with no savings. Overall, they are finding it hard to cope with raising their

two children, working and paying bills. They are benefits claimants and tend to shop at Netto, Farmfoods or Iceland. They are largely uninterested in improving the house but would like to be more comfortable and warm and maybe move to a better area.

They both have a low awareness and knowledge of green/carbon-related issues but would potentially 'buy green' if the price was right. They currently take little action for the environment, and don't even recycle, but would like to be more socially responsible. However, if this cost them anything, they are unlikely to be interested.

Jack and Lizzie typically live in a 1919-1944 or 1945-1964 semi-detached house. While Jack works full-time from 9am-5pm, Lizzie works part-time 3 days a week. They spend most evenings at home with their children. Their lighting and appliance use is average, while their hot water use is above average. The temperature of their home would typically be kept at 20°C.

Key Motivators

- Better thermal comfort
- Lower fuel bills

Added Value

- Constant running low energy fans in wet rooms
- Room in roof
- Upgrade boiler and solar thermal
- EWI- only in conjunction with room in roof works

Alice, 75

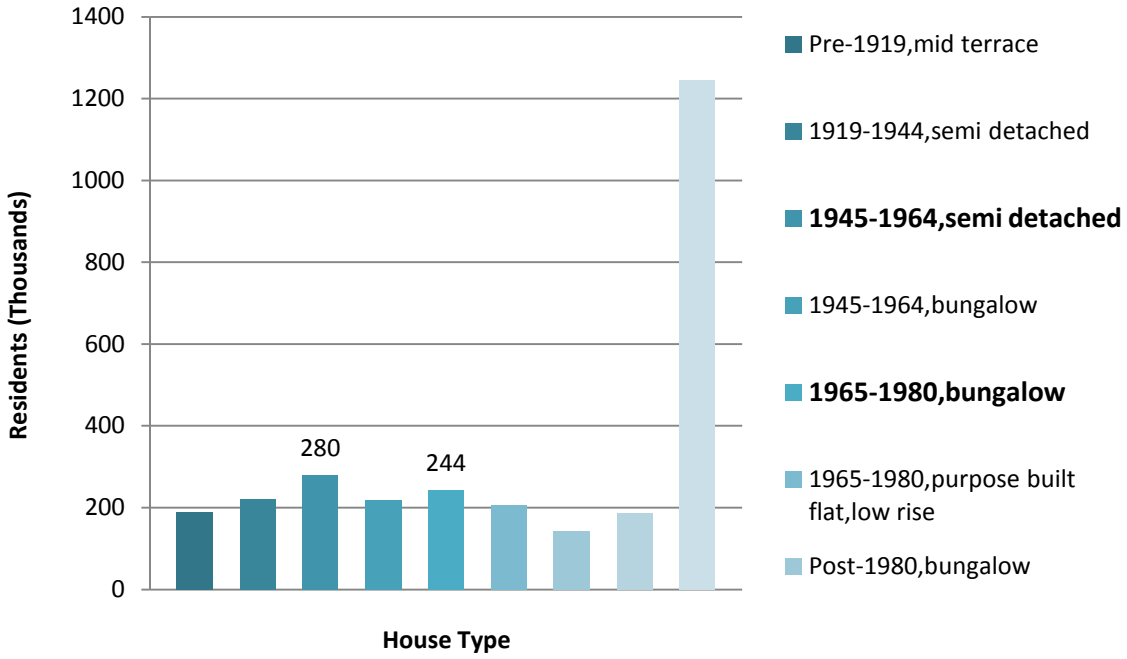
STRETCHED PENSIONERS

Age 65+ years old

Income 15k per annum

Tenure Social Renter/Owner Occupier

House Type Profile



Alice is a widow who has lived in her home for over 20 years. She has few assets with a very low income. She is a benefit claimant, including pension and Council tax benefits. She is worried about crime in her neighbourhood but has no money to move or improve her home. She would also like to be more comfortable and warm in her home. She has few friends but would like to be more sociable and independent.

She lacks awareness of knowledge around green issues and is sceptical regarding a lot of issues, including the use of fossil fuels impacting climate change. She makes little use of private transport, opting for public transport the majority of the time. She doesn't think that she is personally responsible for tackling climate change.

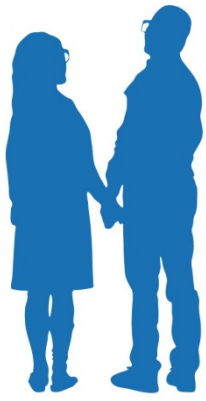
Alice typically lives in a 1945-1964 semi-detached house or 1965-1980 bungalow. She spends most of the day and evening at home, apart from a few hours each week buying groceries. Her hot water and lighting use is average, while her appliance use is below average. The temperature of her home would typically be kept at 19°C.

Key Motivators

- lower upkeep/maintenance costs
- better thermal comfort
- lower fuel bills

Added Value

- Draught lobby installed
- Low energy appliances
- Combine toilet and bathroom
- Burglar alarm and security lights



John and Tracey, 70

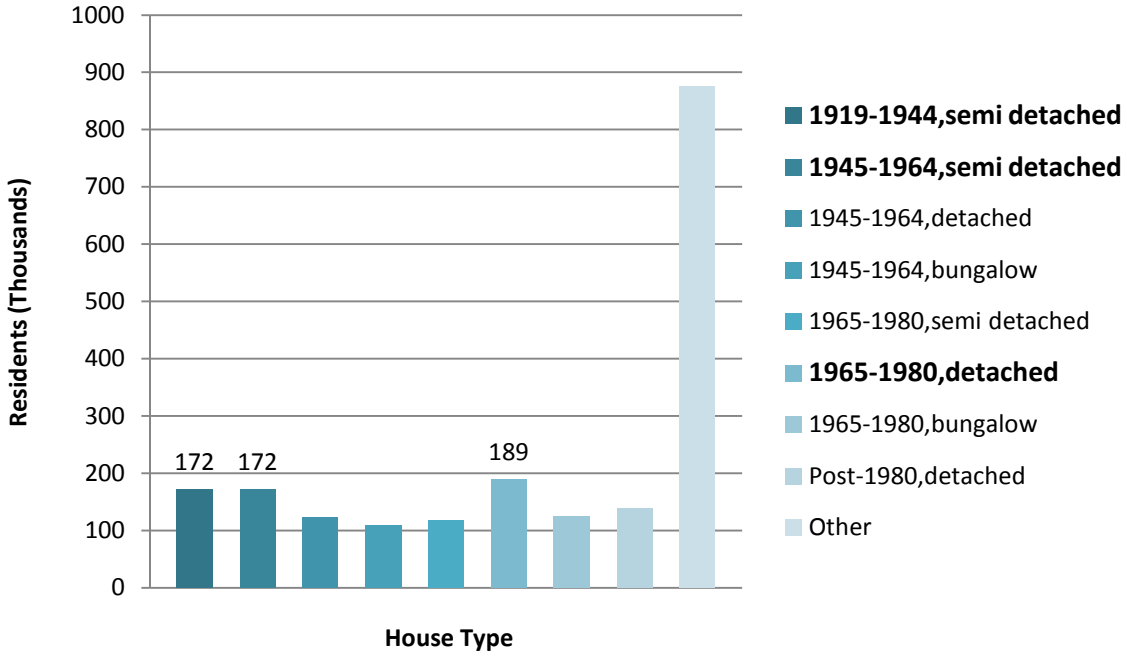
Older Established

Age 65+ years old

Income 20k (plus nest egg)

Tenure Owner Occupier

House Type Profile



John and Tracey are better-off pensioners that have lived in their home for over 15 years. They are both receiving state pensions but are financially secure. They are scared of being ripped off and new technology remains a challenge. They socialise occasionally and tend to shop at Waitrose and M&S.

They are fairly well informed regarding green issues both at small and large scales, though they believe it to be largely exaggerated by the media. Overall, they display good behaviours in terms of energy consumption and purchasing goods and foods (which may be the result of more traditional attitudes and values). Energy efficiency played a part in decisions around the purchase of cars. Financial incentives would likely work in motivating further action and they would respond to more information about how and why they should change their behaviour.

John and Tracey typically live in a 1919-1944 or 1945-1964 semi-detached house or 1965-1980 detached property. They spend most of their days at home though once or twice a week they visit friends nearby in the evenings. Their hot water use is average, while their appliance and lighting use is below average. The temperature of their home would typically be kept at 22°C.

Key Motivators

- Increase house value
- Better thermal comfort
- Lower fuel bills
- Lower upkeep/maintenance costs
- Green lifestyle
- Latest technology

Added Value

- Draught lobby installed
- Triple glazing
- Solar thermal
- Solid floor insulation
- Airtightness and MVHR
- Move windows to outside EWI
- Energy displays
- New kitchen and bathroom
- Sunpipes
- Lighting design service

Appendix D: House Types

- House types were chosen according to customer segments and the houses in which they are most likely to live
- Each house type includes typical dimensions, baseline information, existing heat loss routes and unique features that will likely need to be addressed during a retrofit project
- This information was provided to each group involved in the Single Dwelling Refurbishment Plan workshop in order to develop tailored single dwelling implementation packages

Pre-1919 Detached

Pre-1919 detached homes account for only 2.6% of the total UK stock and will likely have a range of non-standard features to address. Their age and construction means there are likely to be ornate façade detailing including bay windows (1), eaves overhangs (2), soffits, barge boards (3), tall and thin windows (4), as well as recessed porches (5) to consider. There may also be necessary considerations for internal decorative features, in addition to any stained glass windows, cellars, chimneys (6) and extensions of various ages. The roof will pose unique constraints, as a result of dropped eaves and sloping ceilings, steep roof pitch (7), small eaves, solid brick or stone cills (8) and existing rooms in roofs.

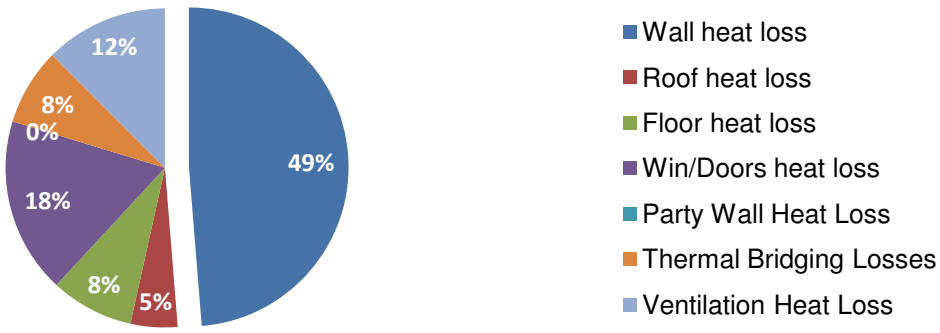
Typical Dimensions: m^2

Wall Area	193
Ground Floor Area	100
Roof Area	99
Window Area	33
Door Area	5.1
No. of storeys	2

	Description	**U-value W/m^2K**
Wall type	solid uninsulated	1.0
Roof Insulation	50mm loft insulation	0.4
Floor type	suspended	0.7
Window type	single glazing	2.9
Door type	standard	3.7

Airtightness	10 $m^3/(m^2.hr)$
Heating system	On/off regular boiler, 72% efficiency
Fuel	Mains Gas
Hot water system	Boiler
Tank insulation thickness	26mm

Existing Heat Loss Routes:



Likely residents of this House Type: Successful Ruralites

PRE-1919 MID-TERRACE

Pre-1919 mid terraces will have similar features to detached homes of the same age, although the number of mid terraces is higher, accounting for 8.5% of the total UK stock. Likely features include bay windows (45% chance of occurrence) (1), extensions (75% change of occurrence), cellars and recessed porches (2). The roof will again require special consideration dropped eaves (3) and sloping ceilings, as well as chimneys (4). Unlike detached properties, mid-terrace properties have party walls that will require considerations (5). Ornate façade detailing and solid brick or stone cills (6) will also need to be addressed.

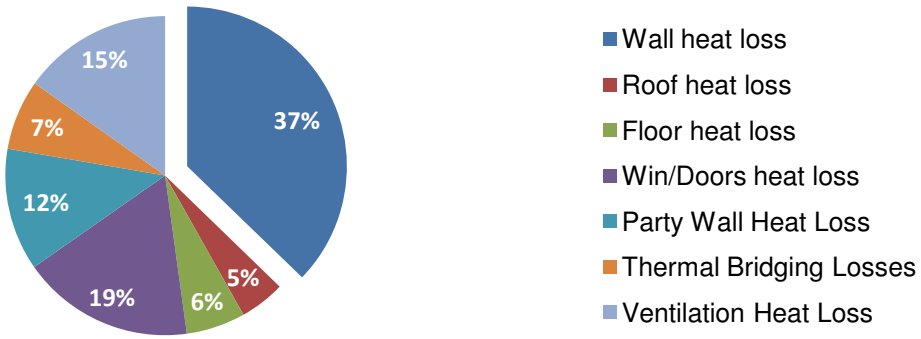
Typical Dimensions:	**m2**
Wall Area	68
Ground Floor Area	46
Roof Area	44

Window Area	20
Door Area	4.2
No. of storeys	2

	Description	**U-value W/m^2K**
Wall type	Solid	2.0
Roof Insulation	50mm loft insulation	0.5
Floor type	Suspended	0.6
Window type	Double glazing	3.3
Door type	Standard	3.8

Airtightness	10 $m^3/(m^2.hr)$
Heating system	On/off combi boiler, 72% efficiency
Fuel	Mains Gas
Hot water system	Boiler
Tank insulation thickness	27mm

Existing Heat Loss Routes:



Likely residents of this House Type: Young Starters, Greener Graduates, Early Entrepreneurs

PRE-1919 CONVERTED FLAT

As the third house type of the pre-1919 construction, the converted flat has similar features to those previously detailed. This includes bay windows (1) (45% chance of occurrence), extensions (75% change of occurrence), cellars and recessed porches. The roof will again require special consideration with dropped eaves and sloping ceilings, as well as chimneys (2). Ornate façade detailing and solid brick or stone cills (3) will also need to be addressed.

At 3% of the UK's total stock, pre-1919 converted flats will likely be found in a wide range of designs and state of repairs. A feature unique to this house type is the communal unheated hallway.

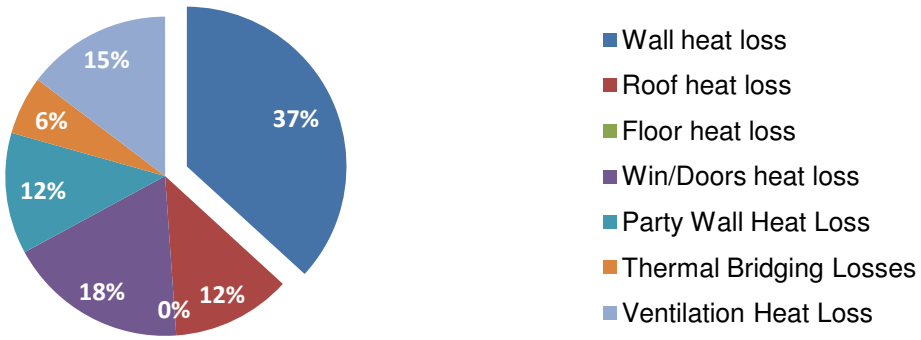
Typical Dimensions: **m^2**

Wall Area	63
Ground Floor Area	62
Roof Area	63
Window Area	14
Door Area	3
No. of storeys	2

	Description	**U-value W/m^2K**
Wall type	solid uninsulated	2.7
Roof Insulation	50mm loft insulation	0.5
Floor type	suspended	0.7
Window type	single glazing	3.0
Door type	standard	3.8

Airtightness	10 $m^3/(m^2.hr)$
Heating system	On/off regular boiler, 71% efficiency
Fuel	Mains Gas
Hot water system	Boiler
Tank insulation thickness	26mm

Existing Heat Loss Routes:



Likely residents of this House Type: Greener Graduates

1919-1944 SEMI-DETACHED

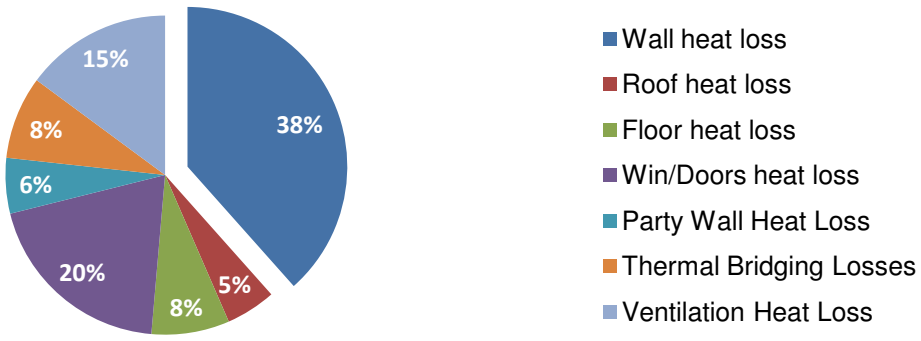
Contributing to 8% of the total stock in the UK, 1919-1944 semi-detached homes can have either solid or cavity walls (1). Like other semi-detached properties, party walls will have to be addressed during a retrofit (2). Other common features include bay windows (66% chance of occurrence) (3), extensions (45% change of occurrence), chimneys (4), recessed porches (5) and solid brick or stone cills (6). In addition to dropped eaves (7), houses of this age and construction may have gable end walls (8) to consider.

Typical Dimensions:	m^2
Wall Area	99
Ground Floor Area	50
Roof Area	52
Window Area	24
Door Area	4.7
No. of storeys	2

	Description	U-value W/m^2K
Wall type	Solid/cavity uninsulated	1.4
Roof Insulation	100 mm loft insulation	0.3
Floor type	suspended	0.5
Window type	double glazing	2.9
Door type	standard	3.8

Airtightness	10 $m^3/(m^2.hr)$
Heating system	On/off regular boiler, 75% efficiency
Fuel	Mains Gas
Hot water system	Boiler
Tank insulation thickness	30mm

Existing Heat Loss Routes:



Likely residents of this House Type: Middle Grounders, Transitional Retirees, Urban Constrained, Older Established

1945-1964 SEMI-DETACHED

Contributing to 8% of the total UK stock, the 1945-1964 semi-detached is likely to have a cavity wall construction (1), although the presence of CWI is unknown. Like other semi-detached properties, party walls (2) will have to be addressed during a retrofit. Chimneys (3), recessed porches (4), dropped eaves (5) and gable end walls (6) are all features that may be present in this house type.

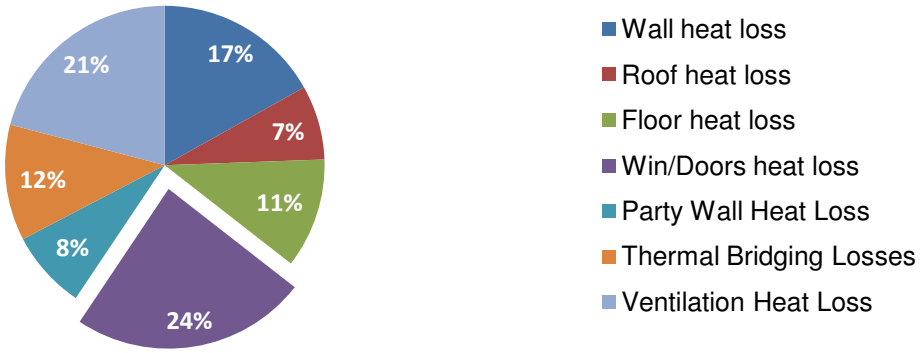
Typical Dimensions:	**m^2**
Wall Area	95

Ground Floor Area	48
Roof Area	53
Window Area	20
Door Area	4.5
No. of storeys	2

	Description	**U-value W/m^2K**
Wall type	cavity insulated/uninsulated	1.1
Roof Insulation	50mm loft insulation	0.4
Floor type	suspended	0.7
Window type	double glazing	3.0
Door type	standard	3.7

Airtightness	10 $m^3/(m^2.hr)$
Heating system	On/off regular boiler, 76% efficiency
Fuel	Mains Gas
Hot water system	Boiler
Tank insulation thickness	27mm

Existing Heat Loss Routes:



Likely residents of this House Type: Unconvinced Dependents, Urban Constrained, Stretched Pensioners, Transitional Retirees, Older Established

1965-1980 DETACHED

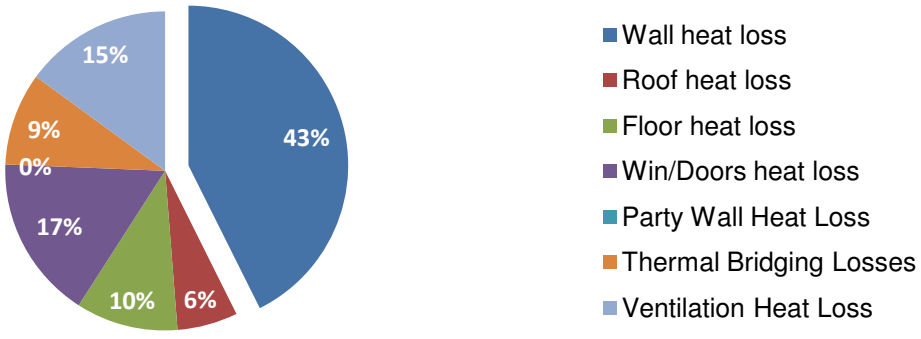
This detached home, with 4% of the total housing stock, is likely to have both a garage and garden (1). The presence of CWI is unknown although the property is liable to have a large eaves overhang (2) and a shallow roof pitch (3). The home may also have a back boiler and some sort of extension (4) (61% chance of occurrence).

Typical Dimensions:	m^2
Wall Area	153
Ground Floor Area	85
Roof Area	88
Window Area	29
Door Area	5.4
No. of storeys	2

	Description	U-value W/m^2K
Wall type	cavity insulated/uninsulated	1.0
Roof Insulation	100mm loft insulation	0.4
Floor type	solid	0.7
Window type	double glazing	2.9
Door type	standard	3.7

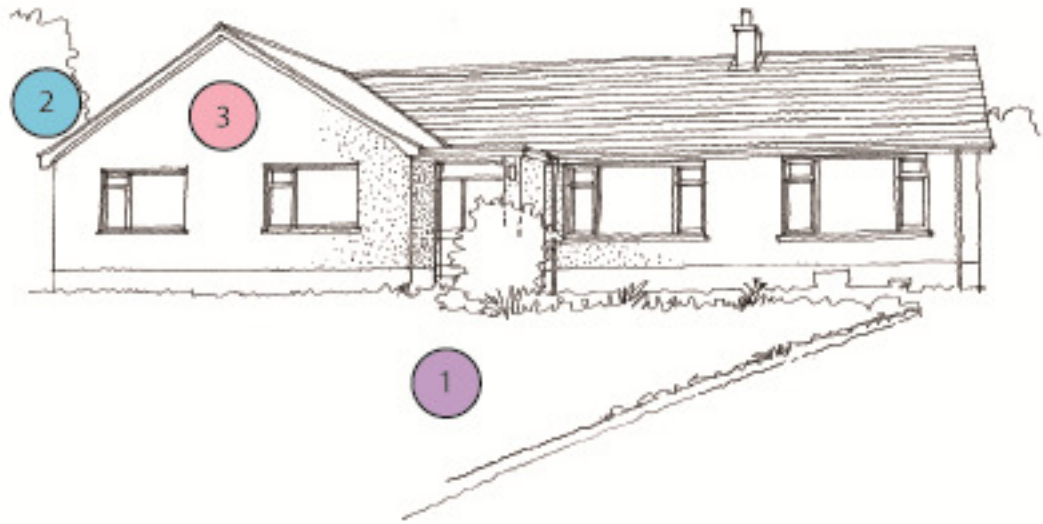
Airtightness	10 $m^3/(m^2.hr)$
Heating system	On/off regular boiler, 72% efficiency
Fuel	Mains Gas
Hot water system	Boiler
Tank insulation thickness	26mm

Existing Heat Loss Routes:



Likely residents of this House Type: Older Established

1965-1980 BUNGALOW



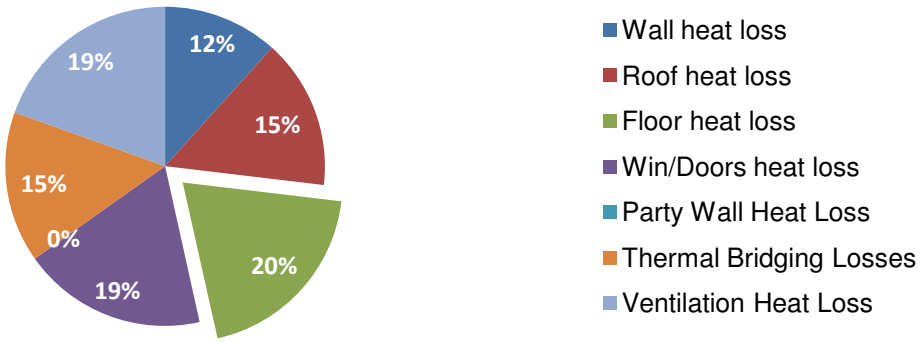
Similarly to the previous detached house type, the 1965-1980 bungalow is likely to have a garden(1) as well as a large eaves overhang (2). With 3% of the total stock, bungalow properties will have a wide variety of styles though they will be largely uncomplicated designs (3).

Typical Dimensions:	m^2
Wall Area	79
Ground Floor Area	76
Roof Area	103
Window Area	14
Door Area	4.3
No. of storeys	1

	Description	U-value W/m^2K
Wall type	cavity insulated	0.9
Roof Insulation	100mm loft insulation	0.4
Floor type	solid	0.7
Window type	double glazing	3.0
Door type	standard	3.7

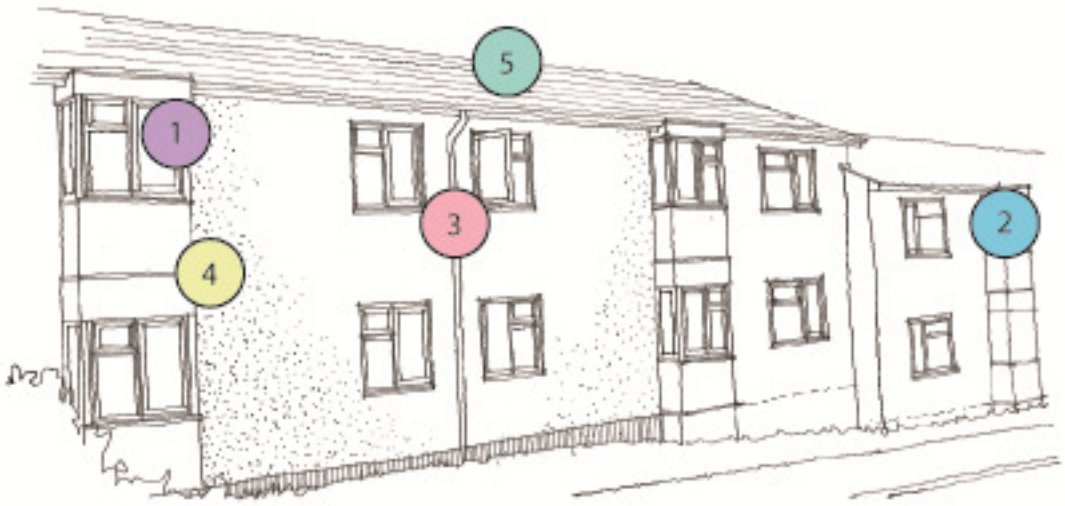
Airtightness	10 $m^3/(m^2.hr)$
Heating system	On/off regular boiler, 72% efficiency
Fuel	Mains Gas
Hot water system	Boiler
Tank insulation thickness	27mm

Existing Heat Loss Routes:



Likely residents of this House Type: Stretched Pensioners

1965-1980 Purpose Built Low Rise Flat



Purpose built low rise flat of this age and construction are likely to have uncomplicated façade features with box windows (1). With 4% of the total stock, there are a wide range of configurations and sizes. Features unique to these properties include external stairwells and multiple entrances (2). Other common characteristics consist of party walls (3) and floors (4), as well as shallow roof pitches (5).

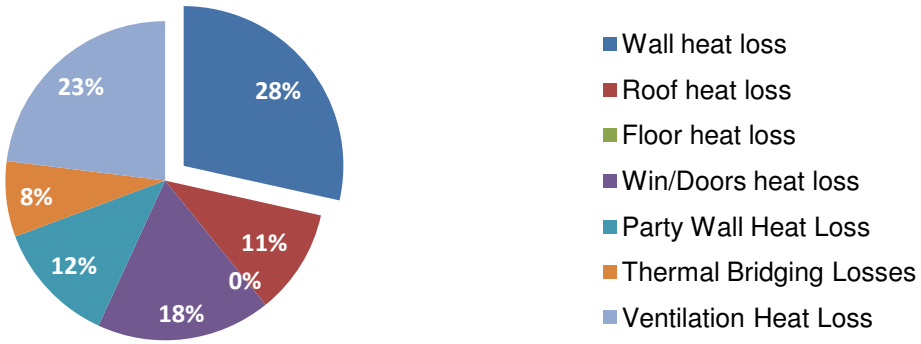
Typical Dimensions:	**m^2**
Wall Area	34
Ground Floor Area	54 (ground), 0 (mid and top)
Roof Area	51 (top), 0 (mid and ground)
Window Area	9
Door Area	3.7
No. of storeys	1

	Description	U-value W/m^2K
Wall type	cavity uninsulated	1.4
Roof Insulation	100mm loft insulation	0.2
Floor type	solid	0.7
Window type	double glazing	3.1
Door type	standard	3.7

Airtightness	10 $m^3/(m^2.hr)$
Heating system	On/off regular boiler, 74%

	efficiency
Fuel	Mains Gas
Hot water system	Boiler
Tank insulation thickness	27mm

Existing Heat Loss Routes:



Likely residents of this House Type: Young Starters

POST-1980 DETACHED

At 7% of the total UK stock, post-1908 detached homes tend to be successful properties built to a reasonable standard, typically under Building Regulations. While most will have central heating and double glazed windows (1) with trickle vents, it is unknown how many homes will have cavity wall insulation. While these homes will have a higher than average number of bathrooms, they are unlikely to have mechanical ventilation systems. There is a 52% chance that a home will have an extension (2).

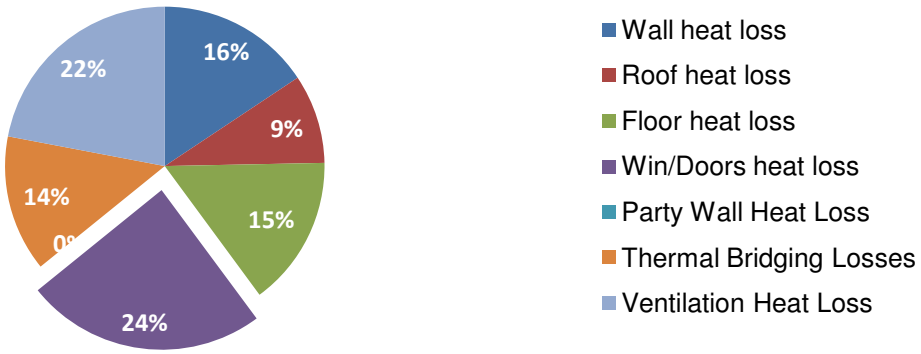
Typical Dimensions:	**m^2**
Wall Area	168
Ground Floor Area	85
Roof Area	93
Window Area	28
Door Area	5.8
No. of storeys	2

	Description	**U-value W/m^2K**

Wall type	cavity insulated/ uninsulated	0.5
Roof Insulation	100mm loft insulation	0.3
Floor type	solid	0.5
Window type	double glazing	2.9
Door type	standard	3.7

Airtightness	10 $m^3/(m^2.hr)$
Heating system	On/off regular boiler, 85% efficiency
Fuel	Mains Gas
Hot water system	Boiler
Tank insulation thickness	27mm

Existing Heat Loss Routes:

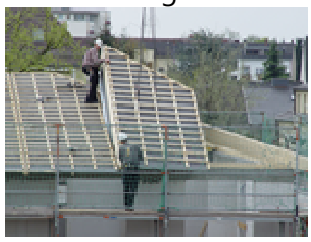
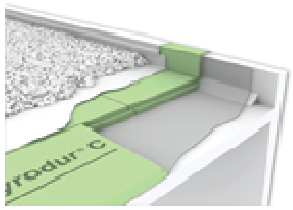


Likely residents of this House Type: Stretched Pensioners, Middle Grounders, Early Entrepreneurs

Appendix E: Innovation

GAP	Opportunity	Industry Commentary
CULTURE/ATTITUDES		
Regulation and planning constraints currently limit retrofit possibilities	Overall aesthetic shift	Regulation also enables retrofit, for example: New Energy Performance Building Directive to set targets for energy efficiency improvements. Government has set carbon budgets to meet. Energy Performance Certificates need to become a requirement for all properties. Introduction of Smart Meters to all homes by 2019. New Energy Companies Obligation towards carbon & energy savings. New committee being established for integration of product innovation into SAP/ SBEM Government's Green Construction Board Consequential Improvements, energy efficient upgrades with

		extensions.
Unused chimneys are a remnant of a former era and can compromise thermal efficiency	Develop MVHR system that is designed to fit into existing chimney stacks May be useful for wood burning stoves particularly in rural areas Can they be removed completely? Shift of attitudes towards retaining chimneys.	
Dynamic thermal modelling tools are not currently widely used for demonstrating carbon savings through retrofit	TAS/IES for retrofit Materials libraries for thermal modelling software that focus on materials for retrofit and ease of creating scenarios for baseline fabric performance ETI TE tool could be developed further	Modeling tools being created within Work Package 1,2, need to be able to integrate new products brought to market. Recent introduction of government BIM strategy, Importance of Sustainable building frameworks – TC350 Impact of materials BREEAM Refurbishment for housing
Lack of consolidated information about different technologies and products and their carbon and cost savings	Importance of Sustainable building frameworks – TC350 Impact of materials	Many tools exist to calculate a products environmental performance through LCA assessments. For example; EPDs, green guide etc.

GAP	Opportunity	Industry Commentary
ROOFS		
PV/PVT is expensive, not very efficient and considered by many to be unsightly Make it cheaper **Make them more efficient** **Make them more aesthetically pleasing OR make them invisible**	Invisible PV/solar thermal More efficient PV and PVT Micro solar trackers	Solutions with organic based PV (OPV) which are thin, light, flexible and effective are expected in about 10 years. Common development BASF with TATA for metal sheeting used as an energy-harvester alternative. See also SPECIFIC-Project together with SBEC-Sustainable Envelope Building Center
Roof is made up of many separate components that need to be assembled on site, making the process time-consuming and disruptive. **Insulation is often installed incorrectly**	Roof coverings with integral insulation Optimise off-site manufacture, develop roofing materials that have more than one function • Flat to pitch roof conversions offer an opportunity to change the appearance of properties with new energy efficiency measures. • Existing flat roof solutions could be turned into Green Roof Areas. These would improve Biodiversity and reduce the effect from flash flooding in high risk areas. • Pitch Roof Tile replacement could be replaced with a room in the Roof Pod.	Use existing solutions with prefabricated sandwich panels (e.g. Isobouw) and modify them for special building types. If possible use 2 layers of insulation staggerd in reverse order to avoid thermal bridges.  solutions with Neopor®  Inverted Roof systems exist and could be incorporated into screening solutions for open terraces, walkways etc. Many Loft insulation solutions exist and can be easily installed.

		
We need to think about Urban Heat Island too, don't we?	Urban Heat Island mitigating materials	Plasticeram (See Note 2)
GAP	**Opportunity**	**Industry Commentary**
WALLS		
Damp and condensation is not very easy to detect Need innovative solutions for detecting problems in the building fabric.	Passive moisture sensing walls Passive temperature sensing walls (like litmus paper or using RFID technology)	
Narrow eaves depth in existing properties is a recurring problem - not enough space to install EWI and thick EWI will obscure any architectural character. Thin insulation is very expensive at the moment and subject to supply shortages. Need external wall insulation that fits and is affordable	Cheap super thin insulation Effective insulating paint	Aerogel (see Note 1) High efficient insulation material that can be applied as ordinary insulation is currently being developed. Expected to be available as board, laminated, may be as filling and in renderings. Could be available in 1-2 years.
Wall is made up of several layers and need to be assembled on site, making the process time consuming and disruptive. Years later, it is also hard to assess the quality and performance of the wall. Need a more integrated, off-site manufactured solution	Range of high-quality wall finishes with integral insulation. Standard guaranteed products will ensure that what you see is what you get.	Wall finishes with integrated insulation (see Note 3)
Drilling on site is a noisy activity, has health and safety risks associated with it and is prone to imperfections of workmanship. Need a more elegant solution for fastening building components together	Fixings to eliminate need for drilling. Will also facilitate future demountability	
Materials are often cut and assembled on-site, which wastes unused materials, is	Paint by numbers style - prefab pre-cut and sized insulation	The New Build sector has embraced offsite solutions in the last decade.

time consuming, and prone to error. Need a prefabricated solution that promotes ease of installation		A variety of solutions could be modified and used within refurbishment solutions. The AIMC4 Project is an excellent example of this. Use fillings or spray foam if possible or create standardized systems so that the industry can provide precut shapes. A variety of new composite materials exist and cutting technologies are available from the printing industry. There is an opportunity to discuss this with the printing industry. The BASF house at Nottingham University also used separate roof panels and composite insulation boards on the roof. This process has now been updated by TATA and now a new composite offsite metal roof composite panel system has been created. This is known as the Urban Roof system.
Insulation comes in all shapes and sizes, it's hard to tell without measurement and technical specs how it will perform, or what you are getting just by looking at the product. Need a visual identification system for insulation products	Standardise colour-coded insulation across all manufacturers for easy recognition, based on performance	Product performance is certified by independent third party accreditation processes. Ensuring the products delivered to site and installed meet the design specified is down to "Best Practice" on Site and Installation guidelines. Often these insulation materials may change, or

		not be installed as specified. Furthermore, the calculation of U-values is done manually by a variety of professionals, this could leave room for error and incorrect specification data of products being included in the calculator. Prefabricated sizes and product types already exist within the market place. For future mass scale retrofit of specific insulation requirements there is an opportunity to discuss these with the insulation sector. Need to update SAP 2013/16 with a robust U-value calculator.
PCMs are a great product but only provide thermal mass, can we have insulating ones as well? Need to develop a product that has both thermal mass and insulative properties	PCMs that cover the a thermal range that will enable them to not only function as thermal mass but also insulation	
Existing cavity wall insulation, particularly in older properties, is severely degraded and very difficult to remove. Need to develop a cavity wall remover so that we can put in better and proper stuff	Old cavity wall insulation eating device/material/substance that is eco-friendly	A variety of insulation materials are available for Cavity wall applications. Different funding streams and thermal performance criteria has meant only a certain percentage of housing has been insulated. There are still a large proportion to do. Invent or investigate if an old cavity wall insulation eating device/material/substance exists.

	Specify higher insulation grades of materials for use in cavity walls. Please refer to the the NBBA (National Blown bead association for further details). The National Insulation Insulation (NIA) can also provide further details.

GAP	Opportunity	Industry Commentary
DOORS		
Thermal detailing around doors is often an issue in terms of retrofitted solutions, and insulated doors are very expensive. Entire door assembly needs to be thermally broken, affordable, integrally insulated and secure	Thermally broken timber door sets Cost-effective 1.2 U-value doors (currently incredibly expensive) - target of £500 for door set	See Masterdor http://www.masterdor.co.uk/ 
Letterboxes and cat flaps are a cause of draughts and heat loss, but people require them	Letterbox and cat flap airtightness solution	External mounted letter box
GAP	**Opportunity**	**Industry Commentary**
WINDOWS		See Note 7
Secondary glazing feels like a clunky solution to the improvement of windows with heritage value, but these windows are a main source of heat loss	Openable, invisible secondary glazing with U-value of 1.0 insulating curtains - Spacetherm curtains	Spacetherm curtains offer some solutions for this area.
Window U-value is substantially of a lower standard compared to wall U-value - can we make windows better and still let in daylight?	Aerogel-filled windows	Aerogel-filled windows Is a research topic. Solution could be available in a few years. Insulated profiles of plastic windows to avoid thermal bridges , eg., this example from Aluplast.
Thermal bridges through sash boxes are often a tricky retrofit solution. Need a pre-manufactured, easily installable solution that fits the architectural language	insulated sash boxes	New boxes could be manufactured e.g with Styrodur (XPS) or with plaster laminated EPS. Install new windows with hinged windows instead of sliding windows. Profiles of modern plastic windows can be insulated and avoid thermal bridges (e.g.

		aluplast)
Can we use buildings for carbon capture?	carbon capture glazing (CO_2 for filling window cavities)	
Wouldn't it be great if windows had the same U-value as walls?	virtual windows (eliminate need for windows)	
It is often risky to retrofit around windows structural risk from degraded lintels, sometimes removing the window risks lintel collapse	structural windows (eliminate lintels)	
If you apply thick EWI, chances are you are reducing the amount of daylight entering the rooms, how do we get the light back?	vertical fibre optic lighting affordable LED lighting and sunpipes	
GAP	**Opportunity**	**Industry Commentary**
FLOORS		
Dealing with floor voids is risky and difficult - are there any products that can make things easier and enable us to install floor insulation with better performance?	displacement piling but with insulation foundation insulator PIG (small robot that can go under the floor and clean/up debris, detect draft sources and blow insulation in	See Note 5
Need an easier, more streamlined way of installing ground floor edge insulation	perimeter biscuit cutter (all-in-one DPC slice and replace) Narrow trench tool for floor edge insulation installation	Perimeter insulation is "common" practice in some European countries such as German. It is not mainstream in the UK. It offers many savings for energy efficiency in a building. Existing solutions with Styrodur® C
Need effective and very thin solution for insulating above solid floors without having to change floor levels for doors	thin solid floor insulation Spacetherm carpet Floor insulation 10mm max so lambda value is	

and stairs	0.007 Flooring with integral insulation

GAP	Opportunity	Industry Commentary
CONTROLS		
People often don't know how to use their heating controls propertly - we need more foolproof systems!	Learning controls that learn occupant settings and reduce heating energy wastage Externally/centrally managed BMS Window-controlled heating system (turns off when windows are opened, fail-safe for occupants' energy inefficient behaviour Remote controlled MVHR dynamic controls Intelligent BMS based on IAQ monitor (monitors CO_2 and humidity to adust ventilation rates in order to preserve IAQ)	
Need a better solution for move switches and power outlets when installing IWI so that we don't need to wait for an electrician	Light switch/power outlet transfer kit with no need for rewiring Wireless switches	
GAP	**Opportunity**	**Industry Commentary**
HEATING		
Is there an easy solution for converting existing homes for district heating?	District heating retrofit	In many European Countries, heating systems are shared between neighbours, neighborhoods. In the UK this is not common practice and this type of thinking brings a cultural change. Opportunities exist to review other combined heating systems and district heating systems operated in other countries.

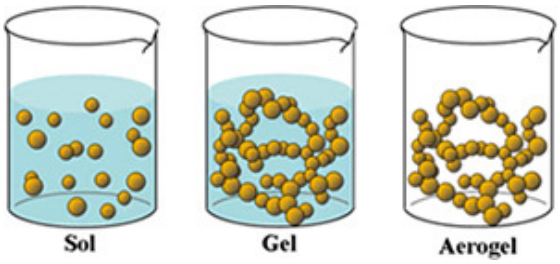
Condensing boilers are not very efficient when running at less than peak capacity - as houses become more and more thermally efficient, boilers quickly go out of date, how do we futureproof so that we don't have to keep replacing boilers?	Modulating boiler (multi-stage so that it can cope with a wide range of operating capacities without having to run at peak all the time) Combi boiler warm feed	
How do we ensure that future boiler replacements are straightforward and efficient?	Boiler backing plate (so that future boiler replacement can be just a clip-in solution	
Can we stop losing heat through cold toilet cisterns and how can we keep bathwater hot for longer?	Insulated bath and toilet	A variety of solutions already exist - see Bathroom association website
GAP	**Opportunity**	**Industry Commentary**
SURVEY & DESIGNING OUT RISK A variety of tools, skills and equipment are required to make an assessment of a building. To ensure the correct measures are subsequently designed and installed within the building the following key factors have to be taken into consideration, such as; **Airtightness, Thermal Imaging, Indoor Air Quality, Ventilation Rate, Co-Heating Tests, Lighting Provisions** Changes in Building regulations and technologies and demand for low energy solutions could provide new triggers to innovate for use in these areas. More importantly, ensuring a building performs as specified will also be an important factor. Monitoring techniques and the ability to predetermined product performance will be an integral part of these developments. Some ideas which have been generated for consideration include:		
Can we have digital photographic solution that uses image recognition based on house features in order to identify house type and link to a database containing information on building fabric, energy consumption, details, etc?	Non-traditional house type image recognition software coupled with hand-held devices/compact cameras Whole stock energy database	
Can we have more mobile tools that are not prohibitively expensive?	Thermal imaging app for smartphones	

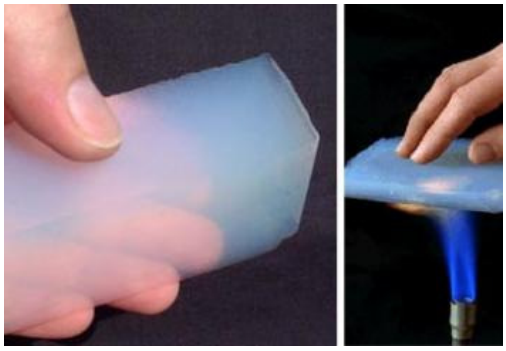
Maybe even tools that homeowners can use themselves?	Cheap co-heating and AT diagnostic/testing tools, e.g. AT test that can be done through a letterbox Portable, in-situ U-value checker tool Auto survey kit usable by unqualified people	
Can we have more mobile tools that are not prohibitively expensive? **Maybe even tools Damp and condensation is not very easy to detect**	Thermal imaging app for smartphones Need innovative solutions for detecting problems in the building fabric Building regulations need to align with new technology / product advances from integrated design.	Passive temperature sensing walls (like litmus paper or using RFID technology)
GAP	**Opportunity**	**Industry Commentary**
VENTILATION		
Low-tech products for avoiding condensation without having to resort to full-blown mechanical ventilation	Stirrer for air to avoid condensation Passive heat exchanger	Passive heat exchanger could be managed partly with Micronal PCM. See www.micronal.de.
MVHR systems are usually cost prohibitive and disruptive to install due to the extent of new ductwork required	MVHR solution that can be integrated into cooker hood, or chimney	
Need rapidly installable and high-quality airtightness solutions	Self-sealing ventilation products (e.g. exhaust fans) Self-sealing duct and flue penetration interfaces	
Need even cheaper local heat recovery units so that we can use them all the time	Local heat recovery units (target £50 with easier installation	
GAP	**Opportunity**	**Industry Commentary**
CONDENSATION		
Can we use condensation solutions for boats and labs	Sacrificial anodes for houses (like the ones for boats for	

in buildings?	avoiding rust), or maybe a condensing toilet cistern Passive dehumidification - dessicants?	

GAP	Opportunity	Industry Commentary
HOT WATER		
Legionella issues	Clear legionella guidance Legionella zapper Hot water at 45°C	
Need a cost-effective, proven wastewater heat recovery solution	Wastewater heat recovery	

NOTE 1	Aerogel





Description

An aerogel is derived from a wet gel in a process that replaces the entrained liquid phase with air. The gel is dried by a so called 'supercritical' extraction, which lowers the surface tension between the liquid and the solid pore surfaces so that depressurization of the system leaves the pore structure filled with gas. Aerogel materials are mostly derived from silicate materials

Special characteristics

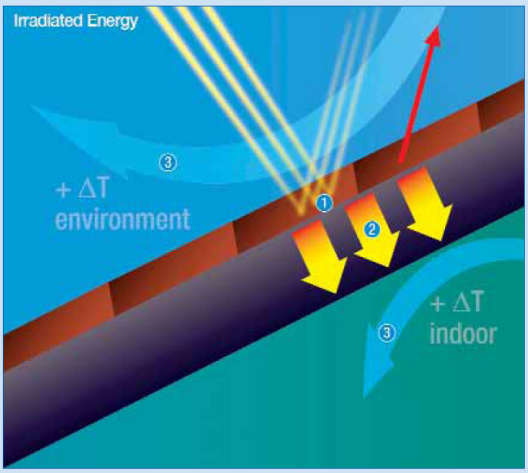
- Extreme low thermal conductivity 0.011-0.018 W/(mK)
- Hydrophobic. Resistant against moisture. Does not rot.
- exceptional reflectors of audible sound
- Light and translucent
- Not flammable

Possible applications

- Facade insulation
- Different fillings
- Between window glasses
- Roof insulation
- Floor insulation
- sound insulation

Sources: Cabot and Aspen Aerogels

NOTE 2 — Plasticeram



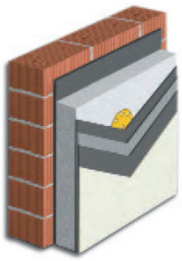
1. Heat generation by radiation absorption
2. Heat transport by thermal conduction
3. Transfer to air and convection

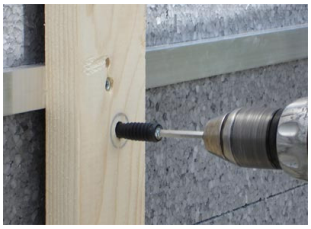
Traditional roofing materials absorb solar energy, generating heat that is transported by thermal conduction into the roof and by convection to the surrounding air. The roof area of the BASF house project at the University of Nottingham is one of the first UK applications of a coated roof using heat management pigments on a single dwelling domestic property.
This system uses an enhanced version of BASF's Coil Coating, PLASTICERAM®. The new coating features superb UV durability and corrosion protection as well as achieving the maximum solar reflectance through the best combination of pigments used.

This type of technology can be incorporated into a variety of coatings and can be used to reduce the heat island effect.

Roof Gardens and Brown Roofs can also reduce the impact of heat island effects whilst at the same time providing energy efficiency measures in buildings.

NOTE 3 — Wall+Insulation Solutions





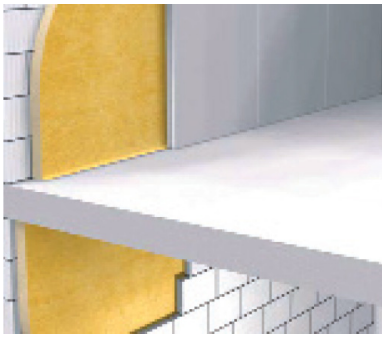
Range of high-quality wall finishes with integral insulation already exist. Standard guaranteed products will ensure that what you see is what you get. New PAS2030 installation guidelines and code of practice for Green Deal, ECO will help to control wall systems installed meet stipulated requirements.

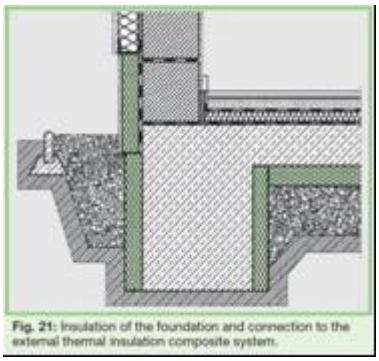
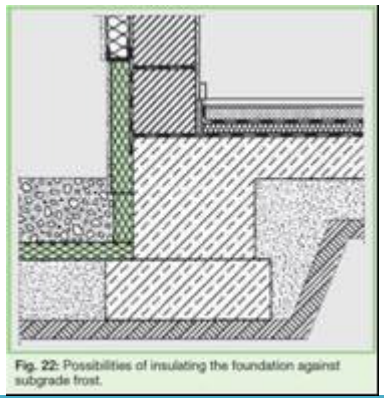
Solid Wall Example: Insulation boards made of Neopor® and the Heck® external render system

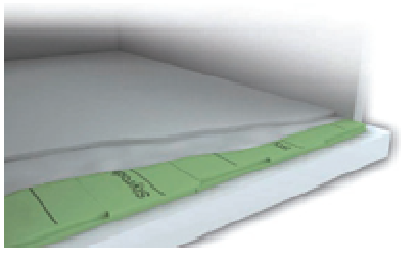
A ventilated wall system exists – System Swisspur Vento

Composite Wall systems exist which could be

modified further for this type of application

NOTE 4	IWI
The National Refurbishment Centre (NRC) has established a database of projects which lists a variety of projects and the types of materials used.	**A variety of solutions exist, made from a variety of insulation materials. Some examples have been taken from the BRE, Victorian Terrace project:** Magnesium oxide boards were adhered to an 80mm Polyisocyanurate (PIR) insulation board consisting of a foam core with two low emissivity facers. This achieved a U-value of 0.22W/m2K. Polyurethane rigid foam is a fast and efficient method of internal insulation. Polyurethane is extremely durable and insulates at the same high level over the life of the building, enabling excellent long term energy savings. For every ton of carbon generated during its production, polyurethane insulation saves 233 tons in its lifetime.
	**WALLTITE®** WALLTITE® spray foam insulation from BASF Polyurethanes UK, was spray applied to the south wall of the presentation room in the Victorian Terrace. The wall was very unstable so a number of structural repairs had to take place before all the existing plaster was removed. WALLTITE® was then sprayed directly onto the rough, bare brick substrate to a thickness of 100mm without the need for primer or levelling coat. The strength of WALLTITE® helped to consolidate this very unsound surface. WALLTITE® is a closed cell foam. Its structure helps to control the movement of vapour and moisture throughout the building, reducing the risk of mould and condensation. At a thickness of 100mm, WALLTITE® achieved a u-value of 0.25W/m2k.
	

NOTE 5	FLOORS
Uninsulated floors can produce as much as 15% of heat loss from a building. What solutions are available?  Fig. 21: Insulation of the foundation and connection to the external thermal insulation composite system.	A variety of solutions already exist, but insulation is not always specified due to level of current building regulation requirements. Existing solutions with Styrodur® C Thin solid floor insulation possible solutions with PUR boards (e.g. Kingspan), or VIP, available but very expensive. BASF is working on solutions with PUR. Customer Va-Q-tec Spacetherm carpet Floor insulation 10mm max so lambda value is 0.007  Fig. 22: Possibilities of insulating the foundation against subgrade frost.

NOTE 6	Dampproofing and Flood Protection
Products exist today and can be used in conjunction with insulation materials and underfloor heating solutions 	The BRE Victorian Terrace Project demonstrated how the building could be made watertight using using BASF's Thoroseal® Super, which was also lapped up the walls to form a damp proof course. Styrodur® C, a BASF insulation board, fully bonded and joined together using PCI Pecitape WS - waterproofing self adhesive tape which was chosen to ensure that the floor exceeded the thermal requirements of this project. In order for the total floor to be finished in one weekend ready for follow on trades, the substrate was finished with BASF's PCI Novoment® Z3, a fast track screeding solution with rapid cure capabilities. The result is an overall floor U-value considerably less

	than the target of 0.22 W/m^{2}K stipulated in the proposed improvements to the new Part L of the Building Regulations

NOTE 7	Overheating - Lightweight structures
Highly insulated buildings in the future will become prone to Overheating due to high insulation levels, particularly lightweight structures. Air Conditioning systems cost four times as much to run as heating systems. Consideration has to be given to the impact this will have.	Phase change materials (PCMs) can significantly reduce this effect because they provide thermal mass to absorb and store this heat. This type of technologies has been included within a variety of projects. - BRE, Victorian Terrace Project - Somerset House, London Micronal® PCM is made of polymer capsules containing a special wax mixture which stores latent heat. When the temperature rises over a defined temperature threshold of 23°C, the wax melts and the phase change material absorbs heat. When the temperature drops, the wax solidifies, and heat is emitted. Through intelligent temperature management, Micronal® PCM contributes to an improved indoor climate, more comfortable living conditions and better energy efficiency.

NOTE 8	Insulation Products
EPS  	**Description** Polystyrene enriched with graphite, which reflects infrared radiation. Foams made of Neopor are silver grey colored. With Neopor the effect of heat radiation by means of infrared absorbers or infrared reflectors is neutralized for the first time. **Special characteristic** ▪ Very good thermal conductivity (0,032-0,035 W/mK) ▪ Low weight, low water absorption. ▪ Up to 20 % improved insulation effect versus conventional EPS. ▪ Neopor is an extremely cost- and eco-efficient insulation material. **Typical applications**

	▪ External walls, especially EIFS ▪ Flat roofs and pitched roofs ▪ Internal insulation ▪ Ceiling insulation ▪ Floor and Perimeter insulation ▪ ICFs – insulating concrete forms ▪ Impact sound insulation ▪ … and much more …
Polyurethane Insulation  	**Description** Polyurethane insulants are produced from two main system-components: Isocyanate + Polyol. According to the formulation they foam up to a predefined quality. Available as rigid boards or as spray foam **Special characteristic** ▪ Very low thermal conductivity (0,024– 0,032 W/mK) ▪ Very good mechanical properties and temperature stability. ▪ Very good adhesive properties ▪ Elastopir-systems have an outstanding fire performance ▪ Various board sizes are possible ▪ Easy to handle and fast to install ▪ Spray foam is adaptable to each shape and cavities are easy to fill **Typical applications** ▪ Metal faced sandwich panels for facades and roofs ▪ Insulation boards for walls, roofs and floors, SIPS ▪ Spray foam applications ▪ Technical insulation, e.g. pipe insulation, hot water tanks