Programme Area: Buildings

Project: Building Supply Chain for Mass Refurbishment of Houses

Title: Retrofit and refurbishment case studies

Abstract:

Please note this report was produced in 2011/2012 and its contents may be out of date. This deliverable is number 2 of 7 in Work Package 3. This report presents the findings from a review of completed retrofit case studies, both in the UK and in Germany and France. This deliverables aims to evaluate the cost effectiveness of these recent retrofit projects in terms of supply chain solutions and occupant's perception of the achieved annual savings. It will inform the recommendations made in later deliverables regarding the retrofit interventions to pursue in the UK to improve thermal efficiency in domestic buildings at mass scale.

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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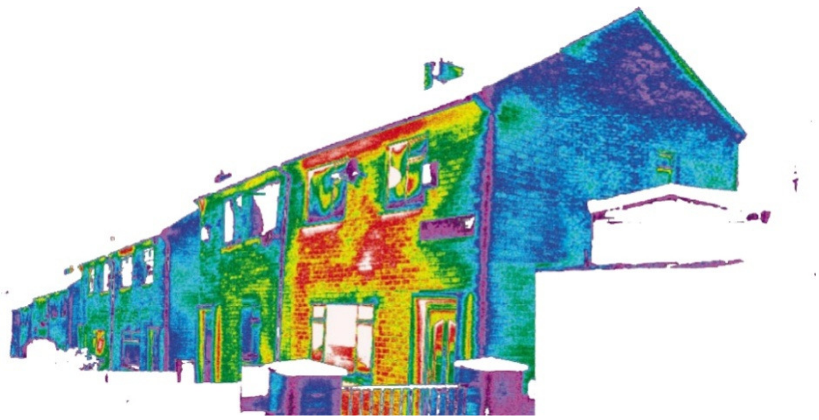


Optimising Thermal Efficiency
of Existing Housing

Retrofit and Refurbishment Case Studies

FINAL REPORT

Submitted by PRP on behalf of the
ENERGY ZONE CONSORTIUM

March 18, 2011

CONTENTS

EXECUTIVE SUMMARY

The case study research presented in this report provides valuable input into the "Optimising Thermal Efficiency of Existing Housing" project, funded by the Energy Technologies Institute (ETI). The project is being delivered by the Energy Zone Consortium, comprising the BRE, EDF Energy, EDF R&D, Peabody, PRP, Total Flow, UCL (Energy Institute), and Wates Living Space.

PRP are a key research partner and leader for this project, which aims to develop strategies to improve the energy efficiency of existing housing stock. This will be achieved by developing mass retrofit solutions for all 26.5 million existing homes in the UK, accelerating the improvement of thermal and energy efficiency in our housing stock. This two-year, £3M project will identify ways in which the refurbishment and retrofitting of residential properties can be accelerated by employing mass production techniques, and create a tool for the analysis of thermal efficiency for different types of housing and the implications of deploying these on a national scale.

This report presents the findings from completed retrofit case studies by outlining the interventions of each case study and common problems in retrofitting projects, including costs, supply and installation issues. Other issues such as skill, supply and process gaps that should have been addressed are presented. Overall, this report appraises the results of different refurbishment projects and provides commentary and analysis of general successes and failures which can be applied to both small and large refurbishment projects in the future.

The selected case studies cover a wide range of building types. Each retrofit project is presented in sufficient detail to highlight the pre- and post- refurbishment condition of the dwellings as well as the issues encountered, actions taken and final outcomes of each project.

BACKGROUND

EXISTING DWELLINGS

Buildings are responsible for 40-50% of the national primary energy consumption in the UK, half of which is used in domestic buildings for lighting, heating and cooling. Most of the UK's housing stock for the next 50 years will be composed of existing dwellings, the majority of which have proven to be inefficient in terms of thermal performance.

Moreover, domestic buildings in the UK are responsible for almost 25% of UK greenhouse gas emissions, 50% of water wastage, and 8% of waste generation, 24% of which is from construction and demolition activity. This fact enhances the importance of making improvements on existing homes in order to improve environmental performance and fuel savings. Considerable reduction in the energy used by existing dwellings will require high levels of refurbishment, a preferable option compared to potentially high levels of demolition.

POLICY

Energy policy in the UK has committed to the proportionate reduction of national CO_2 emissions on a phased basis. The UK government initially endeavoured to reduce national carbon dioxide emissions by 60% below 2000 levels by the year 2050, with real progress by 2020. More recently the UK government has committed to reduce carbon emissions by 80% by the year 2050 (*Climate Change Act*, 2008). Domestic energy use is currently responsible for over a quarter of UK CO_2 emissions and as suchCO_2 emissions from the housing sector should be reduced by an average of 80% to help the UK meet its ambitious long term goals.

NATIONAL LEVEL REFURB: The UK Experience

The report builds on the experience of earlier mass scale refurbishment projects.

The **RETROFIT FOR THE FUTURE** initiative, launched in March 2009 until the end of 2010 by the Technology Strategy Board, was the first program of its kind in the UK to suggest methods to achieve energy conservation in the UK social housing sector. It aimed to help the government meet its goals for greenhouse gas reductions in the forthcoming years.

The **OLD HOMES SUPER HOMES** project was established by the Sustainable Energy Academy to promote the need for retrofitting old housing stock to policy makers. The Academy was able to retrofit old houses and reduce carbon emissions by 70%. The homeowners served as retrofit ambassadors, opening their home to visitors so that others could learn from their experiences. The 36,000 visits so far have inspired others to take similar action to reduce energy bills.

The **WARM FRONT SCHEME** was established in 2005 and provides assistance to eligible households with the installation of heating and insulation measures in order to improve household energy efficiency and to reduce fuel poverty. In 2007, over three million households were estimated to be in fuel poverty, and increases in domestic gas and electricity prices may add a further 1.5 million households. The scheme continues to be underutilized despite changes to the eligibility criteria. Nearly 75% of households entitled to a grant are unlikely to be in fuel poverty, whilst the scheme is only available to 35% of all those households likely to be in fuel poverty, partly because the eligibility criteria include receipt of non-means tested benefits.

The **GREAT BRITISH REFURBISHMENT CAMPAIGN** is supported by UK-GBC (UK Green Building Council), EST (Energy Saving Trust) and WWF (World Wildlife Fund) and aims at producing low energy homes that are cheaper to run and more comfortable to live in. Introduced in 2009, the campaign intends to reduce carbon emissions of existing homes, while also reducing overall demand for energy usage. At the heart of the campaign is a petition to the Government to make it easier and more affordable for people to eco-refurbish their homes.

The **DECENT HOMES STANDARD** was introduced in July 2000 to address the large stock of inefficient social housing. According to the Government, '*A decent home is one which is wind and weather tight, warm and has modern facilities'*. The Decent Homes initiative aims to reduce the number of social housing properties which fail the above Standard by 1/3 by 2004. It also aims make all social rented homes meet the Standard in order to meet the Government's priority to improve people's quality of life in the home. The Government is keen to separate the strategic and day-to-day management of the housing stock. As such, a new financial framework has been adopted that empowers Local Authorities, with the consent of their tenants, to:

- Devolve management of the stock to an Arms Length Management Organization

- Participate in the Private Finance Initiative
- Transfer all or part of the stock to a Registered Social Landlord

To ensure that all social housing tenants have decent homes, the Government employs social landlords. Social landlords need to quantify the level of inadequate housing in their stock, develop an investment strategy to deal with this and measure progress towards its remediation.

Once the Options Appraisal has been completed and an appropriate body has been appointed to manage the Decent Homes programme, work on the stock can begin. The repair, maintenance and improvement requirements are based around four key components:

- Fitness for Habitation
- Disrepair
- Modern Facilities
- Reasonable Degree of Thermal Comfort

Significant funding has been mobilised to improve kitchens, bathrooms and heating systems in order to meet the aforementioned requirements. However, the Government failed to meet their interim target to reduce the number of houses in need by 533, 300, reaching only 350, 000 homes in 2004. The backlog of houses was addressed in the 2010 Spending Review, with the government committing £2.1 billion to the programme from 2011/12.

REPORT OBJECTIVES

This report aims to present the results of case studies undertaken by several consortium partners, bringing together a critical analysis of experiences in designing and delivering retrofit and refurbishment projects at various scales. This will include an analysis of the successes, failures and lessons learned for each of these projects and how these would possibly apply to a large-scale national refurbishment programme.

The objectives of this report are as follows:

- To evaluate the effectiveness of different refurbishment techniques that have been applied to existing dwellings
- To address common obstacles and trends that can provide guidance for future projects
- To present the benefits and drawbacks of various energy efficiency refurbishment techniques and solutions
- To comment on occupant understanding and satisfaction with various interventions
- To appraise the cost effectiveness of chosen refurbishment solutions

METHODOLOGY

Several case studies were selected from the wide range of examples to which the Energy Zone Consortium had access. These have been classified according to the following segments:

Age Band

- pre-1900s
- 1900s-1930s
- 1940s-1950s
- post-1960s

Geographic Location

- England
- Northern Ireland
- Wales
- International (Germany, France)

Information for all the case studies was gathered through a questionnaire survey which was conducted among the consortium partners and led by PRP. The partners directly involved with the present case studies, or had contacts with the relevant case study delivery team were responsible for answering a set of questions in order to provide valuable technical information on each project.

CASE STUDIES

LOW ENERGY VICTORIAN HOUSE (LEVH)	17 St Augustine's Road, London
GREENER HOMES FOR REDBRIDGE	Borough of Redbridge, London
METROPOLITAN HOUSING TRUST	Haringey, London
PERRY STREET DARLASTON	Darlaston, Walsall, West Midlands
BIRCHCROFT SMETHWICK	Smethwick, Sandwell, West Midlands
31 BYRON SQUARE, CAMBRIDGE	Cambridge, England
64 BEACH ROAD, SEA PALLING	North Norfolk, England
ZERO CARBON HOUSE	Birmingham, West Midlands
ECO-ENERGY RETROFIT	Belfast, North Ireland
SELF HEATING SOCIAL HOUSING	Aberdare, South Wales
SOLUTIONS FOR A HOLISTIC OPTIMAL RETROFIT	Newport, South Wales
BASF MEISTERHÄUSER	Ludwigshafen, Germany
HOHENZÖLLERNHÖFE	Ludwigshafen, Germany
BRUNCK QUARTER	Ludwigshafen, Germany
KÖLN	Köln, Germany
ZERO HEATING COST HOUSE	Ludwigshafen, Germany
L'HABITARELLE	Les salles du Gardon, France
SAINT FARGEAU - MAISON PHÉNIX	Saint Fargeau Ponthierry

LOW ENERGY VICTORIAN HOUSE (LEVH)

17 ST AUGUSTINE'S ROAD, CAMDEN, LONDON

Total No. of Units	**1**
Total Floor Area	**260 m^2**
Year of Construction	**1850**
Year of Refurbishment	**2007-2008**
Total Cost (£)	**334,759**

17 St Augustine's Road is a four storey semi-detached Victorian dwelling, which was built in 1850s. After its refurbishment in 2008 the house has been converted to a six bedroom dwelling with social housing tenement. The layout of the house was changed in order to meet the requirements of modern living and provide a comfortable environment to occupants. Because of limitation set by conservation law minimum interruption was allowed to take place on the exterior of the house, while insulation was added internally.

To improve the efficiency of LEVH’s services, the old gas boiler has been replaced by a new oil condensing model, which according to Part L is the best solution to decrease carbon emissions of a house and increase its SAP rating.

There have been 6m² of hot water solar thermal and 3.5 kWp of solar photovoltaic panels integrated on the roof in order to contribute to electricity energy and hot water demands of the house respectively.

Finally, incandescent light bulbs have been replaced by low energy bulbs, in order to save electrical energy and further reduce the CO_2 emissions of the house.

The LEVH is continuously being monitored, to gain hard evidence on how such low energy houses perform in terms of energy consumption and occupant satisfaction. At first a data-logger system was installed in the basement utility room to record the internal temperature and relative humidity occurring in the house and behind the internal insulation boards.

A special system automatically records the electricity being generated by the PV system. Heat meters consisting of a flow meter and temperatures sensor on the flow and return pipes have been installed on the solar hot water system to record the performance and energy used by the central heating system.

The primary objectives of the project were:

- To preserve the heritage of the house
- To reduce the energy consumption of the house
- To raise living standards of occupants
- To provide affordable housing

Intervention	Description	Origin of Materials	Duration of Work	Cost (£)
Wall Insulation	• Kingspan K18 insulated plasterboards of different thicknesses depending on location (45-90mm) • Flexible mastic and expanding foam in junctions and gaps	National	May 2, 2007 to December 31, 2008 (19 months and 29 days)	Donated by Kingspan
Ground Floor Insulation	• Kingspan K3 over concrete basement floor • Insulation around edges to prevent thermal bridges	National		Donated by Kingspan
Roof Insulation	• Kingspan K7 between and above rafters (180 mm) • Breathable membrane above and between the layers for air tightness • Tape added to seal any gaps between insulation boards and membrane	National		Donated by Kingspan
Windows	• Wooden frame hang sash double glazed - argon filled windows with draught proofing	National		30,000
Building Services	• Heat exchange extract fans in bathrooms and kitchen	National		2,000
	• Replacement of gas boiler with oil condensing heating system • Data logging system in basement utility room • System to measure electricity produced by PVs • Temperature sensors on the flow and return pipes on solar hot water system	National		-
Renewables	• 6 m² of solar thermal panels integrated on roof for domestic hot water	National		8,000
	• 3.5 kWp of solar photovoltaic panels integrated on roof	National		31,500

Results and Findings

LEVH has achieved a 76.25% reduction of carbon emissions (Graph 1). Performance rating is only available through calculations that have been conducted during postgraduate survey (Makrodimitri, 2009), using the Parametric Domestic Energy model, which is based on SAP 2005 and has been developed by Robert Lowe and Ian Ridley in 2008. It is estimated that LEVH achieves significant energy demand reduction; DER (Domestic Energy Rating) has been reduced from 73.20 to 9.6 according to the Parametric energy calculator.

Double glazed argon filled windows were transferred to the site ready to be used from the factory because of their special structure (argon filled, low emissivity coating). This ultimately raised costs dramatically.

Energy demand for space heating and domestic hot water has been reduced by 64.77%. Finally the PV panels on roof provide a considerable contribution to electricity demands on the dwelling, generating 59.72% of the electricity consumed in the house (Graph 2). The total reduction of energy demand results in a 67.97% cut in fuel bills.

CO2 Pre refurbishment
CO2 Post-Refurbishment
DER Post refurbishment

GREENER HOMES FOR REDBRIDGE

BOROUGH OF REDBRIDGE, GREATER LONDON

Total No. of Units	**19 (1 additional in development)**
Total Floor Area	**-**
Year of Construction	**Pre-1990 to 2005**
Year of Refurbishment	**2010**
Total Cost (£)	**Total scheme cost = 5 million** **Total works costs = 700,000 (Approx £35K budget available per property)**

The aim of the project is to refurbish 20 vacant dwellings of various ages and condition to higher sustainability levels than the current Decent Homes Standard. Nineteen renovations have been completed, while the sale for the last house fell through and an alternative is being sought at present.

The table below details the most common interventions for all the homes that went above and beyond interventions to meet the current Decent Homes Standard.

Pre and post refurbishment testing was carried out to all properties including, air tightness testing, thermal imaging, spot measurements of temperature, relative humidity and ventilation and before and after EPC certificates. The cost for each refurbishment varied, ranging from £5,713 up to £52,445. All homes were vacant during refurbishment.

The primary objectives of the project were:

- To support other sustainability objectives such as water efficiency, waste minimisation and materials
- To assist the development of standards to measure the sustainability of housing refurbishment
- To test ‘modeled’ versus ‘actual’ performance

Intervention	Description	Cost (£)
Building Envelope	• Top up loft with 250 mm insulation, in between joists and insulate loft hatch to achieve U-value of 0.16W/m2K • Dry lining of all external walls to achieve a U-value of 0.35 • Improved levels of air tightness • Provide airbricks	Approximately 35, 000 per dwelling
Building Services	• A-rated condensing boiler fitted with low levels of NOx • Better controls including new thermostat and programmer in line with CHeSS (2005) • Thermostatic radiator valves fitted to all radiators	
Passive Measures	• Air leakage remedial measures	
Renewables	• 0.53 kWp solar PV installed to provide electricity for lights and appliances • 2 panel solar thermal system and 215ltr indirect twin coil cylinder to existing heating system for hot water	

Results and Findings

Ten of the properties were refurbished to high levels of carbon reduction ranging from 62% to 82%. Ten of the properties were refurbished to Decent Homes Plus standard, resulting in carbon emissions ranging from 7% to 44%.

It was found that one can only achieve an 80% reduction in carbon through major works and at a significant cost above decent homes. In most instances, greater investment in environmental measures resulted in greater carbon reductions and most often, greater savings on energy bills. However, it is clear that the greatest reduction in carbon emissions (60% reduction or more) occurred with the installation of solar PV panels to provide electricity. However, this greatly increased the overall cost of environmental interventions and as a result, the project as a whole. The age of the house made little difference in terms of post-refurbishment performance and total cost.

Other lessons included the importance of always starting with fabric measures first and understanding that the existing condition of older homes means they perform at lower levels of the code Lastly, evidencing 'real' performance is important, as expected performance may vary greatly from actual results.

Next steps include undertaking post occupancy monitoring of whole house energy and water consumption, studying the effects of user behaviour on energy and water consumption and comparing the results against our successful 'Retrofit for the future' carbon reduction projects. The project team also plans to disseminate the findings through a best practice publication containing more details on costs via dedicated web pages.


Metropolitan Housing Trust: Pre-refurbishment


Metropolitan Housing Trust: Post-refurbishment

METROPOLITAN HOUSING TRUST

HARINGEY, LONDON, ENGLAND

Total No. of Units	**300**
Total Floor Area	**32,700 m^2 (approx. 109m^2 per unit)**
Year of Construction	**1919-1944**
Year of Refurbishment	**2004**
Total Cost (£)	**12, 900, 000**

MHT London has a large property base in Haringey where, in 2004, they were faced with 600 hard-to-treat homes with high repairs costs. In response, it was decided to set up the Neighbourhood Investment Unit (NIU), a small regeneration team tasked with tackling these properties, carrying out a whole-house package of works that bring them well beyond the Decent Homes standard. The programme will remove the residents for a period of approximately 14 weeks during renovations.

Since 2004, the programme has achieved high levels of energy efficiency and high levels of resident satisfaction.

The team also involves a Resident Liaison Officer (RLO) who works with residents and the wider community throughout the process. The RLO works to ensure that the residents are involved throughout the throughout, designing their kitchen and choosing the colours for redecoration. The RLO is employed to ensure consistency in service delivery and confidence in running a complex regeneration project. To further combat the effects of fuel poverty, returning residents are provided with a guide to their new home through the best use of the heating system and other key energy saving advice.

The programme is funded mainly through MHT reserves, but topped up with grant funding where available (e.g. through CERT funding). The works are a combination of energy efficiency upgrades, Decent Homes Standard works and general property improvements. Early costs were typically £55k per home, but as the programme developed, this cost has been driven down to £43k per home, achieving the same results.

The primary objectives of the project were:

- To achieve typical carbon savings of 45%
- To deliver cost effective solutions for CO_2 reductions though the primary route of energy efficiency
- To reach CO_2 savings of 140 tonnes/year

Intervention	Description	Origin of Materials	Cost (£)
Building Envelope	• Cavity wall insulation (225mm) • Internal wall insulation (60 mm Kingspan) • Loft insulation (mineral fibre 300mm) • Floor insulation under suspended floors (100mm)	National	43,000 per dwelling
Windows	• Wood sash double glazing		
Building Services	• New boiler with central heating • Thermostatic radiator valves • Time and temperature control and thermostat • Low energy lighting	National	

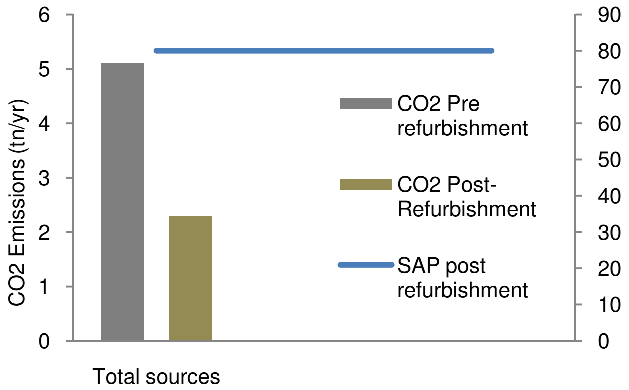
Results and Findings

The Neighbourhood Investment Unit is a project which dealt with several types of old dwellings. To evaluate the energy performance of the refurbished properties were collected, which initially represented the energy consumption and carbon emissions per m² of the retrofitted properties.

The Metropolitan Housing project shows that the refurbished dwellings achieve 45% reduction of carbon emissions in average (Graph 3). SAP rating is not available for this project.

There are no available data for energy consumption per fuel prior to refurbishment. The properties are estimated to consume approximately and average value of 164 KWh/m^2 of primary energy, while achieving SAP rating 80.

Graph 3: CO_2 emissions




Perry Street, Darlaston

PERRY STREET, DARLASTON

WALSALL, WEST MIDLANDS, ENGLAND

Total No. of Units	**51**
Total Floor Area	**5610 m^2**
Year of Construction	**1900-1918**
Year of Refurbishment	**2004**
Total Cost (£)	**25,717.68**

The Perry Street Terraces form part of three streets of 51 properties which were built between 1900 and 1910. Units are typically two bedrooms and a typical floor area of 110m^2. The construction is traditional masonry with solid walls. Floors are suspended timber with air brick ventilation.

Gas central heating, dry lining and loft insulation were installed in 1985. It is possible that the dry lining may not have been adequately ventilated at the time of installation. Air bricks have been added to ventilate the suspended timber floors.

The windows and front doors were replaced in 2004. The windows and rear doors carry uPVC frames. The windows have relatively narrow reveals of 12mm.

Whilst the external appearance of the streetscape has no formal heritage status it is unlikely that external changes to its appearance onto the street would be accepted. The external appearance features a range of window and door features and the eaves are relatively shallow in depth.

Information regarding the environmental performance of mid-terraced houses is presented in this report. The mid terraced houses consist of one storey properties with attic, including five (5) bedrooms in total. Retrofit works took place while the houses were still occupied.

The primary objectives of the project were:

- To upgrade current performance
- To improve ventilation of the suspended timber ground floor.
- To reduce energy bills

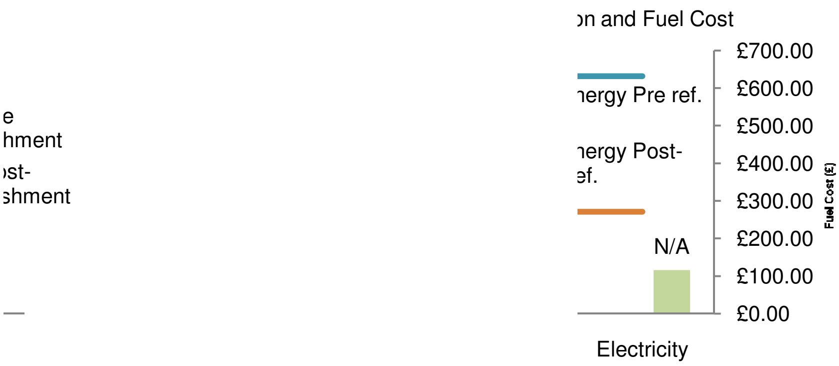
Intervention	Description	Origin of Materials	Cost (£)
Building Envelope	• Internal Wall Insulation and dry lining • uPVC double glazing windows • External doors with insulation and draught proofing • Re-roofing and loft insulation	National	233.80/m²
Building Services	• Installation of gas central heating system	National	

Future Interventions	Implementation Date
Top up roof insulation to 350mm	2010-2015
Low energy light fittings	2010-2015
Biomass Heating with district heat network	2010-2015
Heat metering	2010-2015
EWI	2016-2020
Glazing - upgrade to high performance	2021-2030
Floor insulation	2021-2030
Upgrade to insulated doors	2021-2030
Solar thermal	2021-2030
Heating controls	2021-2030

Results and Findings

The Perry street properties in Darlaston seem to have achieved a 79.31% reduction of carbon emissions (Graph 4). SAP rating is only available for pre refurbishment dwellings performance. Perry Street has received a SAP rating of 64.

There are no available data for space heating, domestic hot water and electricity consumption prior to refurbishment. However, the Perry street dwellings seem to consume similar amounts of energy as the LEVH, while age of properties and construction typology is also very close to the ones of LEVH. Therefore we can assume that both cases have achieved the same levels of energy conservation. The total reduction of energy demand results in 57.07% cut in fuel bills (Graph 5).



Birchcroft Smethwick

Smethwick, Sandwell, West Midlands, England

Total No. of Units	90
Total Floor Area	6750 m^2
Year of Construction	1945-1964
Year of Refurbishment	2010-2015
Total Cost (£)	1,473,390

Birchcroft is a fifteen storey tower block constructed in the early 1960's. The building consists of 6 two bed properties per floor, with typical floor areas of 75m². Each apartment can be accessed via a balcony and lift from a central core. Service ducts are installed across the whole height of the building providing air extract from bathrooms and kitchens.

The construction is a concrete frame with a brick skin and 50-60mm cavity. The cavity has been filled. This has created subsequent problems arising from the retention of wind driven rain.

The window frames and glazing were replaced at the same time. The heating systems are all electric, combining electric storage heaters with an electric immersion storage cylinder for hot water. A quarter of the rooms in each flat currently have low energy light fittings.

The primary objectives of the project were:

- To reach a higher sustainability level than currently
- To further reduce energy consumption of the property
- To conduct post-refurbishment evaluation of energy usage and internal conditions

Intervention	Description	Origin of Materials	Cost (£)
Building Envelope	• Internal wall cavity fill Insulation • Re-roofing and loft insulation (200mm) • uPVC double glazed windows and draught proofing	National	218.28/m²
Building Services	• Gas central heating system	National	

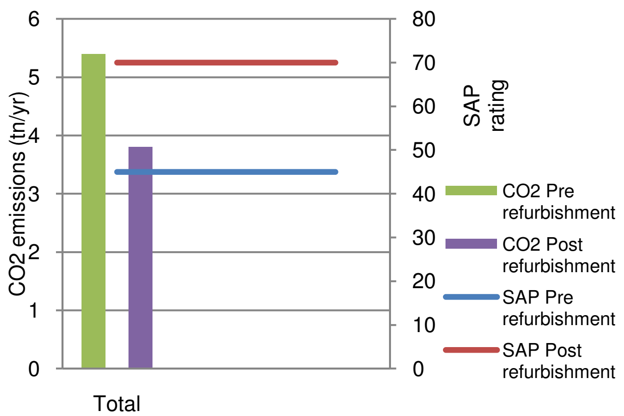
Future Interventions	Implementation Date
Lighting	2010-2015
Gas fired communal boilers	2010-2015
Mechanical Ventilation with heat recovery	2010-2015
Internal heating controls/Heat metering	2010-2015
EWI	2016-2020
Triple glazed windows	2016-2020
Solar Thermal	2021-2030

Results and Findings

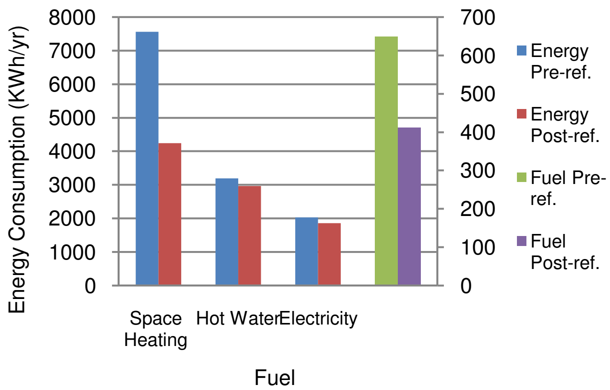
Birchcroft Smethwick properties seem to achieve 29.63% reduction of carbon emissions (Graph 6). SAP rating prior to refurbishment was only 45, while post refurbishment evaluation has upgraded the performance of the dwellings to 70 points of SAP rating.

Energy demand for space heating has been reduced by 43.91%. Energy used for domestic hot water has been eliminated by 7.29%, while electricity consumption received a very small reduction of 8.65%. The total reduction of energy demand results in a 34.46% cut in fuel bills (Graph 7).

Graph 6: Energy Consumption and Fuel Cost



Graph 7: Energy Consumption and Fuel Cost



31

BYRON SQUARE, CAMBRIDGE

CAMBRIDGE, ENGLAND

Total No. of Units	**1**
Total Floor Area	**88 m^2**
Year of Construction	**1947**
Year of Refurbishment	**2010**
Total Cost (£)	**61,450**

The house is a 3 bed semi-detached property on a residential estate in Trumpington, on the outskirts of Cambridge. It was constructed in 1947 and is a British Iron and Steel Federation (BISF) house. It is one of many examples on this estate and originally 30,000 in England and Wales and a further 4,000 in Scotland. Many of these properties still exist with the majority having few energy efficiency improvements other than loft insulation, heating upgrades and in some cases window replacement, installed under the Decent Homes programme.

The house is constructed of light-gauge steel frame and is therefore of lightweight construction with no cavities for insulation in the external walls. The lower storey exterior has a render-on-mesh cladding and the upper storey a profiled steel sheet cladding. The ground floor is of solid construction and has a tiled duo pitch roof. The windows were originally steel framed but at 31 Byron Square, uPVC framed double glazed replacements where installed in 1997.

The upgrade strategy has improved the Energy Performance Rating to A, reduced carbon dioxide emissions to below 17kg/m^2/yr and primary energy consumption to below 115kWh/m^2/yr. The strategy provides substantial improvements to the thermal performance of the external fabric of the house, providing affordable warmth for the occupants. In addition the costs associated with hot water production and electricity consumption will be reduced. The strategy has been developed to be applicable to any house of this type in any location in the UK. The house, regardless of its location, will always have a south and east or west facing roof slope in order to be suitable for the application of roof mounted solar technologies. The heating system proposals are interchangeable with other technologies such as micro CHP, heat pumps, biomass boilers and hydrogen fuel cells. As such, the strategy is not site dependent and is flexible in its approach.

The primary objectives of the project were:

- To demonstrate the applicability of interventions in similar dwellings
- To improve both the comfort and energy efficiency of the homes and those which are similar

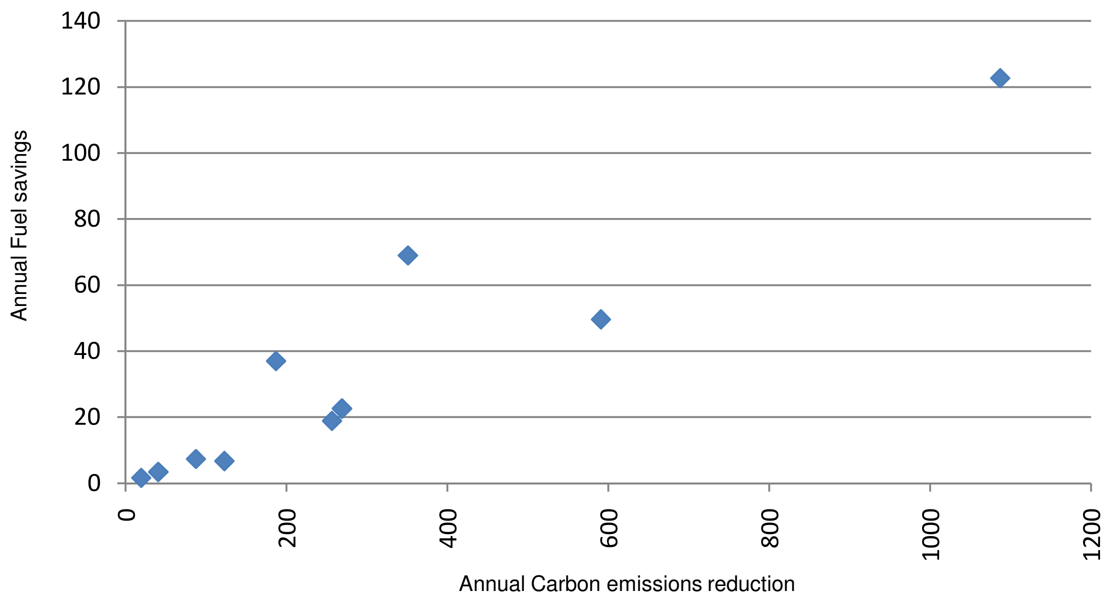
Intervention	Description	Origin of Materials	Duration of Work	Cost (£)
Building Envelope	• External wall insulation	National	May 5, 2010 to July 15, 2010 (41 days)	16, 403
	• Suspended timber floor insulation	National		
	• Roof insulation (350mm mineral wool)	National		388
Building Services	• Under floor heating	National		-
	• New condensing boiler with Zenex gas-saver	-		-
	• Time and temperature zone control	-		-
	• Weather compensator	-		-
	• Flue gas heat recovery	-		905
	• Waste water heat recovery	-		1, 058
Windows	• Double glazed to triple glazed uPVC metal frame windows	National		7, 638
Renewables	• 3.0m^2 solar thermal panels on roof	National		4, 888
	• 2.7kWp, 22.5m^2 PV panels on roof in east-west orientation	National		19, 910

Results and Findings

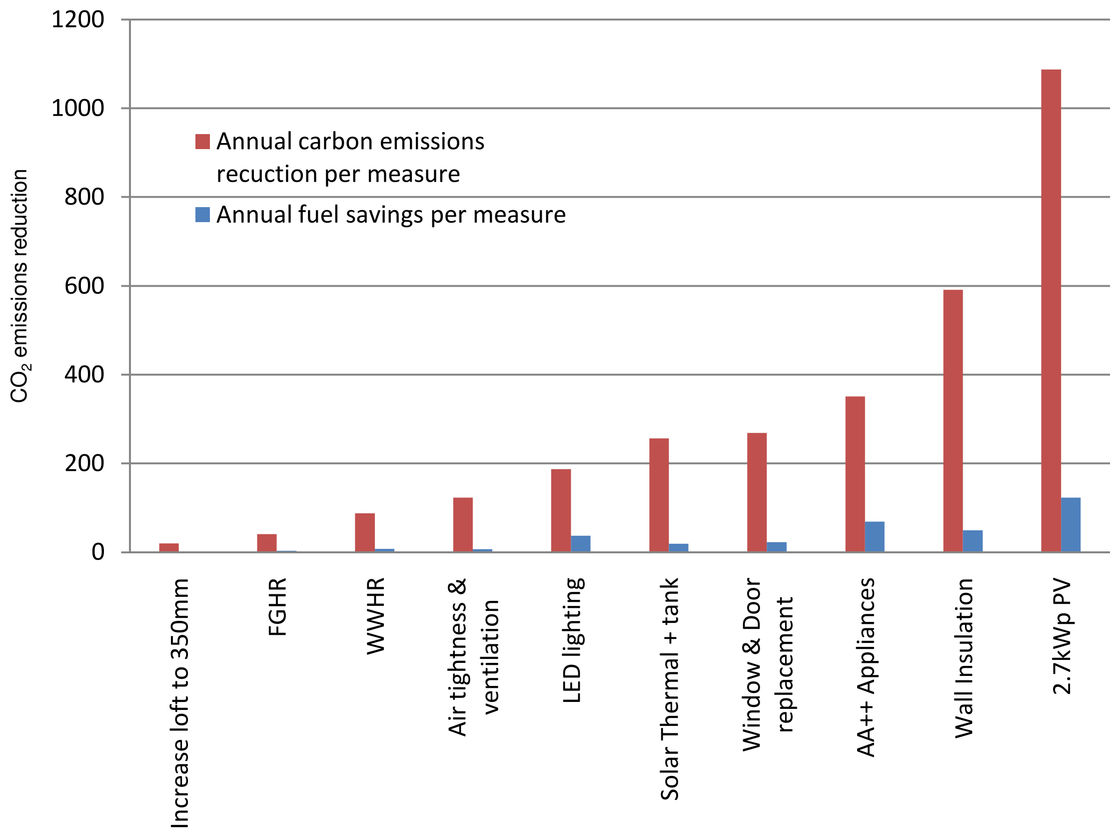
The retrofit project in 31 Byron Square, Cambridge utilizes a number of environmental interventions in order to reduce the annual carbon footprint of the property. It is expected that the flue gas heat recovery will save 207kWh/yr and the waste water heat recovery will save 437kWh/yr in isolation from FGHR.

Graph 8 illustrates that carbon emission reductions are strongly correlated with fuel savings, while Graph 9 shows the exact annual fuel savings and carbon emissions reduction attributed to each measure mentioned above

Graph 8: Annual CO_2 emissions and Fuel Savings



Graph 9: Annual CO_2 emissions and Fuel savings per Intervention



64 BEACH ROAD, SEA PALLING

NORTH NORFOLK DISTRICT COUNCIL, ENGLAND

Total No. of Units	**1**
Total Floor Area	**79.1m^2**
Year of Construction	**1900**
Year of Refurbishment	**2010**
Total Cost (£)	**81,332**

The house is a two bed, three person mid terrace property in the coastal hamlet of Sea Palling in Norfolk. It was built in 1900 and is of cavity wall construction (440mm thick) and although it has some relatively unique layout characteristics, it is a dwelling type which prevails throughout England.

The property sits in a terrace of 5 properties that fronts directly onto the dunes, with the beach and North Sea beyond. The exposed location of the building has led to the use of very substantial building practices which include 440mm thick brick cavity walls, with projecting brick reveals, large tile overlaps and timber sharking boards on top of the rafters. These techniques are generally employed in Scotland and other similar locations in the UK.

Although not officially protected, external insulation would lead to the loss of architectural character with consequential impacts on the larger character of the terrace and hamlet. Internal insulation is therefore proposed with replacement triple glazed composite windows to match the originals. The house has a duo pitch roof, a flat roofed front porch and a single storey rear extension containing a kitchen which does not meet current social housing space standards. The small bathroom is on the first floor and has been formed by taking space from the second bedroom. The heating system is a closed room solid fuel heater.

The strategy will provide substantial improvements to the thermal performance of the external fabric of the house, providing affordable warmth for the occupants. In addition the strategy will ensure costs associated with hot water production and electricity consumption will be reduced. As there is no local natural gas supply, ground source heat pumps are proposed. The proposed strategy has been developed to be applicable to any house of this type in any location in the UK. Where it is not appropriate to use ground source heat pumps, another heating source such as a biomass boiler or air source heat pumps can be used in conjunction with photovoltaic panels on the south, east or west facing roof slope to achieve the required carbon emission reduction.

The primary objectives of the project were:

- To preserve the architectural characteristics of the dwelling
- To illustrate the applicability in other similar dwellings
- To reduce energy bills and carbon emissions

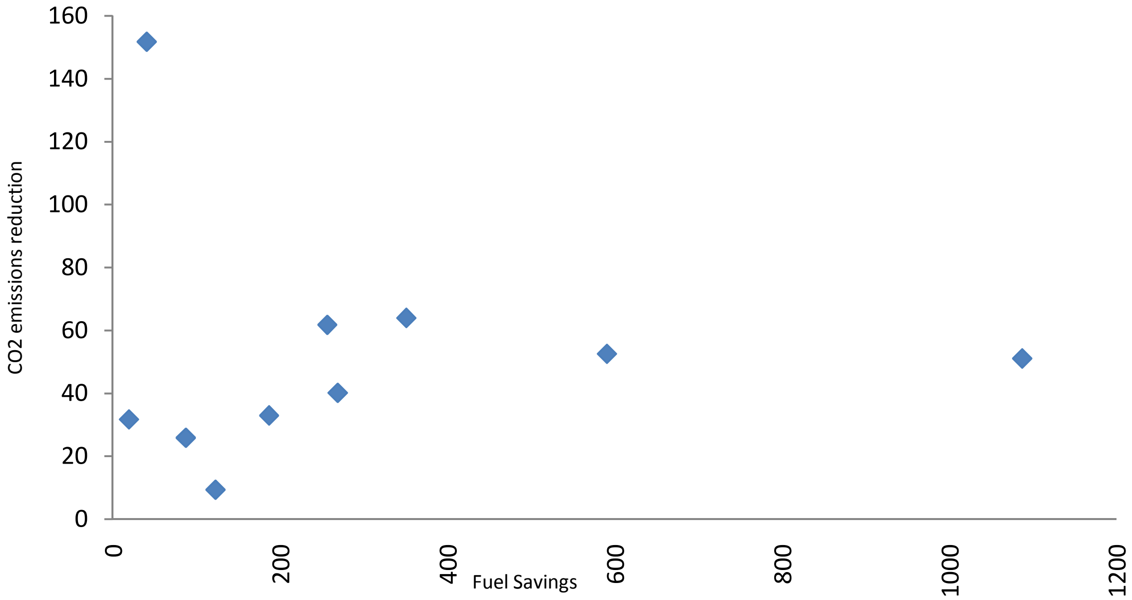
Intervention	Description	Origin of Materials	Duration of Work	Cost (£)
Building Envelope	• Internal wall insulation	National	May 4, 2010 to July 22, 2010 (49 days)	14, 365
	• Insulated dry lining and air tightness	National		3, 760
	• Insulation at ceiling level	National		2, 092
	• Insulation at ground floor level	National		7, 931
Windows	• Upgraded to triple glazed	National		6, 463
Building Services	• Waste water heat recovery	National		917
	• Time and temperature zone control • Weather compensator	National		-
Renewables	• Ground source heat pump installed to under floor/low temperature radiator heating	National		24, 970
	• 3.0m^2 solar thermal	National		6, 263
	• 1.0kWp, 8.3m^2 polycrystalline photovoltaic	National		7, 383

Results and Findings

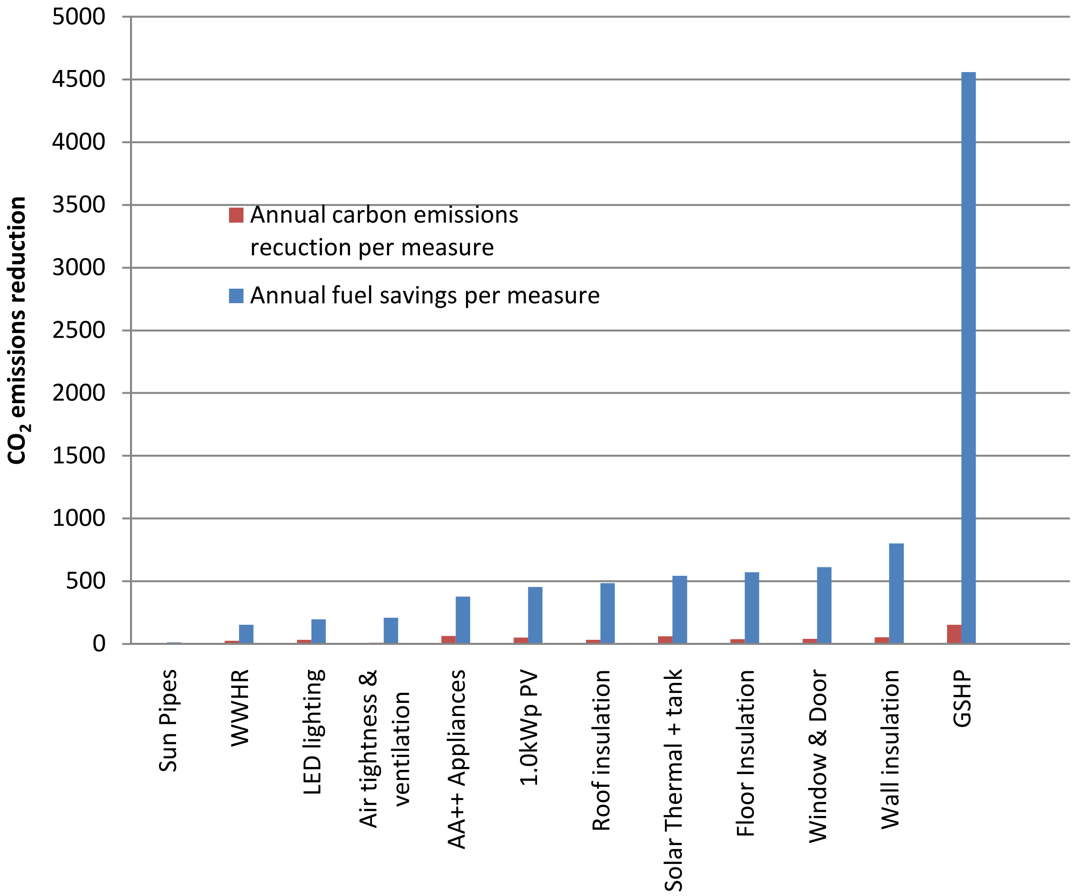
The retrofit project in 64 Beach Road, Sea Palling utilizes a number of environmental interventions in order to reduce the annual carbon footprint of the property.

Graph 10 proves that carbon emissions reduction is not as significant in this project as in the 31 Byron Square dwelling in Cambridge, while Graph 11 shows the exact annual fuel savings and carbon emissions reduction attributed to each measure mentioned above. For example, although saving a significant amount of carbon emissions, AA++ appliances do not seem to save relevant fuel cost, which might be attributed to occupant behaviour.

Graph 10: Annual CO_2 emissions and Fuel Savings



Graph 11: Annual CO_2 emissions and Fuel savings per Intervention




Zero Carbon House: Pre-refurbishment


Zero Carbon House: Post-refurbishment

ZERO CARBON HOUSE

BIRMINGHAM, WEST MIDLANDS

Total No. of Units	**1**
Total Floor Area	**204m^2**
Year of Construction	**Pre-1850**
Year of Refurbishment	**October 2008- November 2009**
Total Cost (£)	**-**

The refurbishment of an existing 1840 house in Birmingham has both doubled in size and has been upgraded to level 6 of the Code for Sustainable Homes. Electrics, space and water heating are all net zero carbon renewable energy, with no fossil fuels used.

At the time of design only one prototype building had achieved this standard, at the Building Research Establishment in Watford. The scheme is believed to be the first and only UK retrofit to the Code 6 standard. As well as requiring very low energy use and zero carbon emissions - ie 100% renewable energy with no fossil fuels - the Code also measures eight other areas of sustainability including water, pollution and ecology.

Advice and a system of membranes and accessories for achieving the level of air tightness essential to the very low energy design were imported from the Republic of Ireland, as they were not available in the UK. The scheme achieves more than 10x Building regulation standards.

The three-storey unfired clay block load-bearing structure is a UK first. As a result, the house has a very high thermal mass, which is considered the simplest, least expensive way of ensuring buildings will not overheat in predicted hotter summers. In addition, it has hygroscopic qualities, which regulate internal humidity, and has extraordinarily low embodied energy. Earth walls at Cobtun (Associated Architects, RIBA Sustainability Award 2005) were calculated as having 0.00016 or 1/6,000 of the embodied energy of other materials. The house was unoccupied during renovations.

The primary objectives of the project were:

- To create a zero carbon house to level 6 (the highest level) of the Code for Sustainable Homes
- To upgrade a 170-year old existing building to the same standard as new builds
- To inspire others - through the use of space, light, materials - that green does not have to be dull

Intervention	**Description**	**Duration of Work**
Building Envelope	Internal wall (outside to inside) • Brick (225mm) • Void (20mm) • Breather paper (1mm) • Warmcel® (350mm) • Airtight membrane (1mm) • Plaster (15mm)	October 2008 to November 2009 (1 year and 1 month)
	External wall (outside to inside) • Render (10mm) • Neopor (280mm) • Brick (225mm) • Plaster (15mm)	
	Solid concrete floor (top to bottom) • Rammed earth screed (75mm) • Limecrete (100mm) • Rockwool (250mm)	
	Double gabled roof (outside to inside) • Slate, Batten, Felt, Rafters (185mm) • Breather (1mm) • Warmcel (450mm) • Airtight membrane (1mm) • Batten (20mm) • Plasterboard (12mm)	
Windows	• Triple glazed and draught proofed	
Building Services	• Mechanical heat recovery ventilation system serves every room for winter use • In summer there is mixed-mode natural ventilation	
Passive Measures	• South/west glazing admits useful winter heat gains; existing mature ash tree provides summer shading • The hygroscopic clay blockwork helps regulate internal humidity • High thermal mass 200mm dense clay blockwork walls, rammed earth floors and 215mm existing brickwork all store passive heat gains	
Renewables	• 8.8 m2 of evacuated tube solar hot water collectors • 35.6 m2 (5.04kWp) solar electric PV panels • A 7kW high efficiency clean-burn wood stove for top-up heating & hot water • An 850/1000 litre cylinder collects and stores heat from the solar panels and stove	

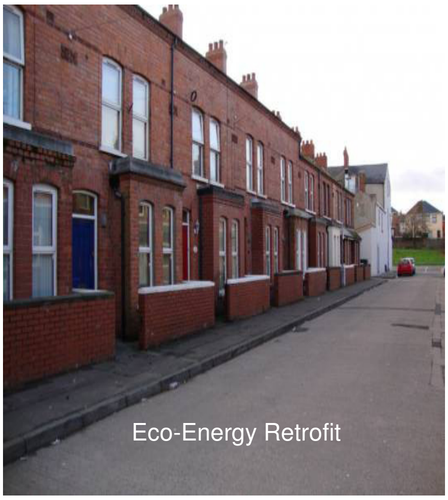
Results and Findings

Results for this case study were limited in terms of cost valuation, carbon emission reductions and fuel savings. However, a few results are included below.

The refurbishment achieved the following U-values: wall=0.11, roof=0.08, triple-glazed windows=0.65 w/m2/degC.

Overall, thermal bridging<0.03 and heat loss parameter= 0.55. A mechanical heat recovery ventilation system serves every room for winter use, reclaiming up to 93% of waste heat.

The air-tightness that is achieved is N50=0.34, using moisture-sensitive and vapour-permeable airtight membranes.



ECO-ENERGY RETROFIT

BELFAST, NORTH IRELAND

Total No. of Units	**1**
Total Floor Area	**85 m^2**
Year of Construction	**1896**
Year of Refurbishment	**May 2010**
Total Cost (£)	**-**

The project involved the refurbishment of an existing mid terrace solid wall house built in 1896, is located in North Belfast and owned by Grove Housing Association. It is already relatively energy efficient having an RD SAP rating of 57 (band D) compared to the average in Northern Ireland of 50. This house is part of a terrace of mixed social and private dwellings, so external wall insulation cannot be used. Internal wall insulation, Passivhaus windows and doors and good air tightness will secure the thermal envelope.

The tenants were accommodated in an alternative unoccupied house within the existing stock during the retrofit. Future small scale retrofits will have access to a spare house in order to keep accommodation costs low.

The primary objective of the project was:

- To achieve a 3 litre house status (less than 30kWh/m^2/yr)

Intervention	Description	Duration of Work (days)
Building Envelope	• Combination of aerogel and phenolic internal insulation installed on external walls • Edge insulation to minimise thermal bridging between floor slab and walls • Internal insulation plywood substructure cut to encompass floor/ceiling joists between floors with taped joints to provide an air tight seal • Services penetrations through airtight barrier sealed with gaskets, tape or airtight sealant and windows sealed to wall/airtight membrane • Replacement floor slab on top phenolic insulation will have edge insulation to minimise the thermal bridge to the adjoining walls • Flanking insulation installed on the internal party walls to minimise thermal bridging and prevent condensation • Aero-cell and closed cell foam insulation inserted around the face and sides of window/door frames to minimise thermal bridge	May 1, 2010 to November 1, 2010 (185 days)
Building Services	• Natural gas system boiler coupled to a 145 litre DHW hot water cylinder • Mechanical ventilation heat recovery system will recover the heat in the stale exhaust air • The MVHR summer bypass option will draw fresh outside air and supply it into the house in the summer. • Replacement of existing attic ceiling to allow for the installation for a combination of different types of insulation to achieve a U-value of 0.10 W/m2K • Standby killer electrical circuits installed in each room enables appliances to be switched off from one central switch	
Passive Measures	• Rear south facing windows are small and shaded by adjoining houses and yard walls • Passivhaus windows with narrow frame widths to provide maximum glazed area	
Renewables	• 1.72 kWp of roof mounted PV array	

Results and Findings

As this case study is part of the Retrofit for the Future program, the monitoring of results post-retrofit remains in the beginning stages. Forecasted results have been made available, though they will not be presented here, as they remain unreliable. Definitive results are expected in the coming months and for the next two years of the program.

However, some predictions have been presented by those involved in the project. The rear south facing windows are small and shaded by adjoining houses and yard walls. PHPP predicts available solar gains of 2.8kWh/m2/year.

The PV output was calculated manually using a PV yield for Northern Ireland of 850kWh/year per kWp. The 8 module 1.720kWp array has a predicted annual yield of 1.720kWp x 850 = 1.462kWh.

A combination of aerogel and phenolic internal insulation installed on the external walls to achieve a U-value of 0.15W/m2K. The replacement of existing concrete floor (which has no insulation) with a concrete slab over phenolic insulation is expected to achieve a U-value of 0.10 W/m2K. The removal and replacement of the existing attic bedroom ceiling to allow for the installation for a combination of different types of insulation is expected to achieve a U-value of 0.10 W/m2K. Passivhaus windows with a U-value of 0.8 will be installed.

Self Heating Social Housing

SELF HEATING SOCIAL HOUSING

ABERDARE, SOUTH WALES

Total No. of Units	**1**
Total Floor Area	**73.7 m²**
Year of Construction	**1896**
Year of Refurbishment	**2010**
Total Cost (£)	**£150, 000 (maximum available from Retrofit for the Future)**

The target for this project is to create the UK's first PassivHaus retrofit using low/zero carbon technology and to reduce the CO_2 generated from a Cornish Type 1 system-built semi-detached property owned by RCT Homes by 100%.

The planned occupancy will be a small family 3-4 people in full-part time work with children in school on weekdays. The house will be unoccupied during renovations.

The dwelling is expected to switch to mains electricity and as such, the effects of space heating and domestic hot water heating via electricity as the primary fuel will be monitored. Space heating will be provided by an air-to-water heat pump, boosting a thermal store. The use of SolarWall® technology will provide warm air as a feedstock to the heat pump, reducing the energy load on the conventional heater.

Part of the passive solar strategy will be the inclusion of conventional shading systems e.g. roller blinds, overhangs etc. reduce excessive solar gains. Night purging may be required during heat waves. Existing thermal mass from the existing precast concrete frame will help moderate summer heat fluctuations

Air tightness products will be used where necessary using high performance tapes and 'intelligent' vapour checks, both of which can help buildings achieve the high levels of air tightness required for Passivhaus buildings. As such, thermal bridging analysis will be undertaken for all primary junction interfaces. Junctions assessed include: Ground floor junction, external corner, party wall, party roof, party floor, eaves, verge, window jamb, head and sill, door jamb, head and threshold.

Whole house modelling was undertaken using SAP+ extension sheet. Dynamic simulation may also be used to assess the impact of the proposed solar-wall combined with the heat pump heating system.

The primary objectives of the project were:

- To create the UK's first PassivHaus retrofit using low/zero carbon technology
- To reduce the CO_2 generated from a Cornish Type 1 system-built semi-detached property by 100%

Intervention	Description	Duration of Work (days)
Building Envelope	• Airtight membrane over roof structure sealed to outside face of Inner OSB SIPS. • Internal plasterboard walls parged to provide continuous air barrier with membrane • Suspended floor air barrier sealed directly to masonry wall • Party wall will have a parging coat to ensure air tightness and mitigate thermal bypass. • Continuous insulation in the form of SIPS • Excellent moisture resistance of OSB integrated into the SIPS coupled with sealed joints also serves as an air and moisture barrier	March 1, 2010 to May 31, 2010 (92 days)
Building Services	• Use of SolarWall® for space heating in conjunction with an air to water heat pump • Air to water heat pump also to provide hot water via a wet system underfloor/radiant heating • Fully controlled mechanical ventilation with heat recovery	
Passive Measures	• Window sized for maximum daylight and passive solar gains. • Shading strategy has been considered to prevent summer overheating risk	
Renewables	• 1.52KW P.V array circa 8m^2.	

Results and Findings

As this case study is part of the Retrofit for the Future program, the monitoring of results post-retrofit remains in the beginning stages. Forecasted results have been made available, though they will not be presented here, as they remain unreliable. Definitive results are expected in the coming months and for the next two years of the program.

SOLUTIONS FOR A HOLISTIC OPTIMAL RETROFIT (SHOR)

NEWPORT, SOUTH WALES

Total No. of Units	**1**
Total Floor Area	**58 m^2**
Year of Construction	**1980**
Year of Refurbishment	**June 2010**
Total Cost (£)	**150, 000 (maximum available from Retrofit for the Future)**

The project takes a team based approach aiming to develop an integrated, technologically robust and people focussed approach to the retrofit. The house is owned by Charter Housing Association and was built in the 1980s. The dwelling is an end of a terrace 2 storey house with a lounge, kitchen, two bedrooms, bathroom and a garden. Three adults presently live in the house. The property was purchased from the private sector in 1980s and is below space standards for social housing. Lack of amenity and living and storage space has been addressed through the retrofit.

A lot of energy is currently being wasted as a result of heat lost through the building fabric and via draughty windows and doors.

The works were undertaken during the summer of 2010 and the tenants remained in situ. The occupants will be give guidance on the use of the new systems to ensure the control systems are easy to use.

The primary objectives of the project were:

- To take a team based approach to the project
- To develop an integrated, technologically robust and people focussed retrofit

Intervention	Description	Duration of Work (days)
Building Envelope	• Robust detailing and double-sealed doors • Internal dry lining incorporated with built in storage in bedrooms, triple glazed windows and doors • Maximize roof insulation	June 7, 2010 to August 13, 2010 (67 days)
Windows	• Triple glazed and double-sealed windows	
Building Services	• Ground to water heat pump using radiators with evacuated tube collectors which feed into unvented cylinder with solar coil • This will use a ground loop in a 80 metre bore hole • A mechanical heat recovery system will be installed in the loft • Positive input ventilation	
Passive Measures	• Rear extension has a roof light and glazed bifolding door positioned to maximize day lighting	
Renewables	• Renewable energy from GSHP, solar thermal and PVs • 2.1kW Photovoltaic panels	

Results and Findings

Energy savings have been made through modifications to the form and space, fabric and systems in order to achieve 80% carbon reductions required.

As this case study is part of the Retrofit for the Future program, monitoring remains in the beginning stages. Forecasted results have been made available, though they will not be presented here, as they remain unreliable. More definitive results are expected in the coming months and for the next two years of the program.


BASF Meisterhäuser - Pre refurbishment


BASF Meisterhäuser - Post refurbishment

BASF MEISTERHÄUSER

LUDWIGSHAFEN, GERMANY

Total No. of Units	**20**
Total Floor Area	**2,150 m^2**
Year of Construction	**1850-1899**
Year of Refurbishment	**2001-2004**
Total Cost (£)	**-**

The project involves the refurbishment of twenty pre-1900s shared semi-detached houses in Ludwigshafen, Germany. These units can be divided into two groups of ten (10) units of 75m² and 140m² gross floor area each with two and four rooms per unit (including bedrooms, dining rooms and/ or living rooms) respectively. All units were unoccupied during refurbishment.

Accurate analysis of the building fabric took place before refurbishment and measuring sensors were installed in clinker facing brick to enable temperature and moisture levels to be measured after refurbishment. Passivhaus Institute Darmstadt was in charge of operating the monitoring program for 2 years after the refurbishment project was completed.

The primary objectives of the project were:

- To protection a historic monument
- To apply EPS vapour permeable insulation to the internal wall surface
- To participate in the DENA (German Energy Agency) showcase project “Niedrigenergiehaus im Bestand ” (low-energy house in modernization)
- To achieve the KfW 60–Standard (demand of primary energy < 60 kWh/m²a), which is the half of the energy demand ordered by law for refurbishment of existing buildings.

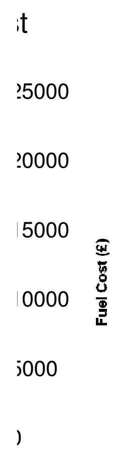
Intervention	Description	Origin of Materials
Building Envelope	Internal wall insulation (outside to inside) • Clinker brick (120mm) • Brickwork (240mm) • EPS (80mm) • Gypsum plasterboard (12.5mm) • Vapour barrier • Gypsum plasterboard (12.5mm)	Local
	Roof structure renovation (outside to inside) • Sarking board • Planking (21mm) • EPS/Rafters (400mm) • Vapour barrier • Plasterboard 2x (25mm)	Local
	Floor insulation (top to bottom) • Wood pavement (10mm) • Floating floor screed (45mm) • Impact sound insulation (70mm) • Insulation (70mm) • Concrete (140mm) • Insulation (100mm)	Local
	• Cellar ceiling insulation • Draught proofing	Local
Windows	• Triple glazed uPVC	Local
Building Services	• Installation of energy efficient boiler with central heating • Ventilation system with approx. 80 % heat recovery • Solar thermal panels • Smart meters	National
Passive Measures	• Modification of layout • Renovation of plumbing units • Annex balconies	National

Results and Findings

The case-study demonstrates that the achievement of 60 KfW–standard with this building type is technically possible but not cost effective. As a result, future "Meisterhäuser" projects have been developed to achieve only the energy standard required by current legislation.

BASF Meisterhäuser has achieved 80% reduction of carbon emissions ASAP rating system is not available in Germany at the moment (Graph 12).

Energy consumption attributed to space heating has been reduced by 83%, which resulted in 81.82% reduction in heating fuel cost (Graph 13). Unfortunately there are no available data for energy used for hot water before the retrofit project and for electricity consumption both before and after refurbishment.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25000
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Fuel Cost (£)

HOHENZÖLLERNHÖFE

LUDWIGSHAFEN, GERMANY

Total No. of Units	**7**
Total Floor Area	**700 m^2**
Year of Construction	**1919-1944**
Year of Refurbishment	**Current**
Total Cost (£)	**-**

Ludwigshafen, Germany loses inhabitants annually and the local housing market is very weak. Uncomfortable apartments have proven difficult to rent, even if they are part of beautiful and historic buildings. Therefore, it was been recently decided that the "Hohenzöllernhöfe" had to be refurbished.

The project entails the refurbishment of seven 1900 - 1920 multi - storey shared houses in Ludwigshafen, Germany. These units consist of four storeys of 100m^2 each. All units were unoccupied during refurbishment.

LUWOGE, the housing company of BASF, conducted research on 180 apartments (18.000 m2) dated since 1923. The project was supported by the German government. The buildings are protected ancient monuments. Experiments took place on one building to examine the performance of different types of internal wall insulation, in order to achieve conserve the external facade.

During renovations, different internal insulation systems will be monitored to collect data regarding the humidity levels at the joints of walls and wooden ceiling constructions. Calculations have been completed for one building with 7 units out of 180 in total. The other units will be renovated in the same way. The refurbishment of the first group of buildings will be completed by the end of the year.

The primary objectives of the project were:

- To protect a historic monument
- To apply thermal insulation to the internal wall surface, in order to conserve the historic external facades
- To collect sufficient data about humidity levels at the joints of walls and wooden ceiling constructions

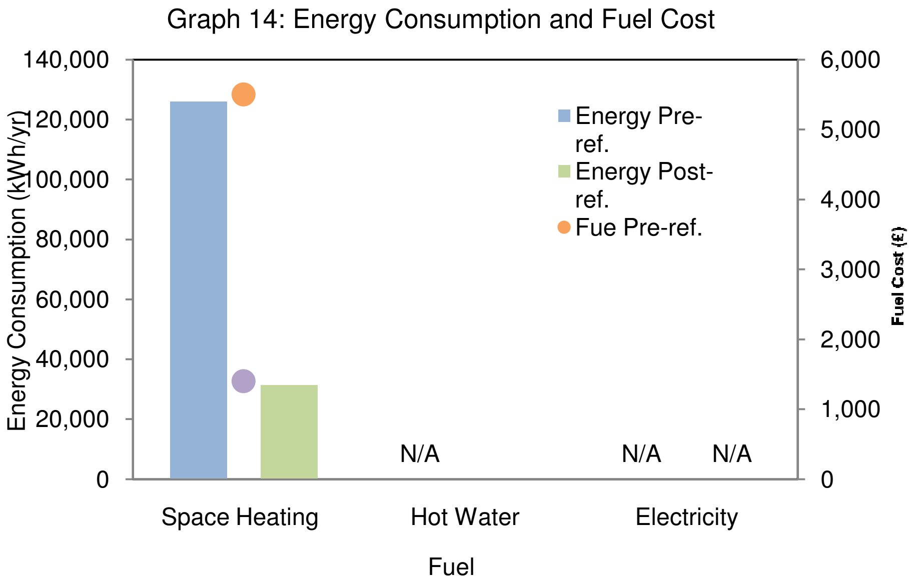
Intervention	Description	Origin of Materials	Duration of Work (days)	Cost (£)
Building Envelope	• Internal wall insulation at the front of the building • External wall insulation at the rear of the building	Local	In progress	40-135 £/m^2 (insulation)
	Roof insulation (outside to inside) • Sarking • EPS (300mm) • Planking (21mm) • Rafters/insulation (140mm) • Vapour barrier • Battens (30mm) • Plasterboard (12.5mm)	Local	In progress	40-135 £/m^2 (insulation)
	Floor insulation (top to bottom) • Timber floor board (24mm) • Fill (60mm) • Concrete (140mm) • EPS (200mm)	Local	In progress	40-135 £/m^2 (insulation)
Windows	• Replacement of double glazed windows with uPVC triple glazed windows and draught proofing	Local	In progress	-
Building Services	• New ventilation system with < 85% heat recovery • Room thermostat • Thermostatic radiator valves	National	In progress	-

Results and Findings

Costs for energy before and after refurbishment are related to the rates in the year of construction. Energy cost before and after refurbishment depend on the year of construction. All costs are construction costs only, excluding additional costs such as planning. Necessary costs are separated from those that were installed solely for energy saving. Necessary costs are those for elements that had to be refurbished anyway; i.e. roof sealing or windows. In Germany, energy usage for domestic appliances is not required to be recorded.

Hohenzöllernhöfe has achieved a 75% reduction in energy consumption for space heating, and fuel bills have become cheaper by 75% as well (Graph 14). Unfortunately, there are no available data for energy used for hot water and electricity consumption both before and after refurbishment as the project is still in progress.

The SAP rating system is not available in Germany at the moment, while figures about carbon emissions for either pre-or post-refurbishment are not available for this case study.


Graph 14: Energy Consumption and Fuel Cost
Energy Consumption (kWh/yr)
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
6,000
5,000
4,000
3,000
2,000
1,000
0
Fuel Cost (£)
Energy Pre-ref.
Energy Post-ref.
Fue Pre-ref.
N/A
N/A
N/A
Space Heating
Hot Water
Electricity
Fuel

BRUNCK QUARTER

LUDWIGSHAFEN, GERMANY

Total No. of Units	**9**
Total Floor Area	**700m^2**
Year of Construction	**1945-1964**
Year of Refurbishment	**1997-2001**
Total Cost (£)	**780,000**

In the 1990s the layouts of the apartments in Ludwigshafen's Brunck Quarter (the BASF housing settlement/workers' housing estate) were found inadequate to meet the needs of modern living and regulations standards. 30% of the apartments were unoccupied before refurbishment. Implementation of the refurbishment project (9 Multi - storey (three storeys and attic) shared houses with 78m^2 floor areas of flats) started in 1997. LUWOGE drew up a comprehensive development program. It included modernisation of old buildings to meet the specific targets of energy consumption, the demolition of derelict buildings and the construction of new ones.

After completion of retrofit project in April 2001, the Kaiserslautern Technical University monitored its thermal performance and fuel consumption for a period of three years.

The primary objectives of the project were:

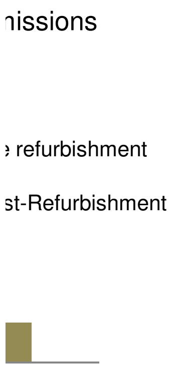
- To protect a historic monument
- To apply EPS vapour permeable insulation to the internal wall surface
- To participate in the DENA (German Energy Agency) showcase project “Niedrigenergiehaus im Bestand ” (low-energy house in modernization)
- To achieve the KfW 60–Standard (demand of primary energy < 60 kWh/m^{2}a), which is the half of the energy demand ordered by law for refurbishment of existing buildings.

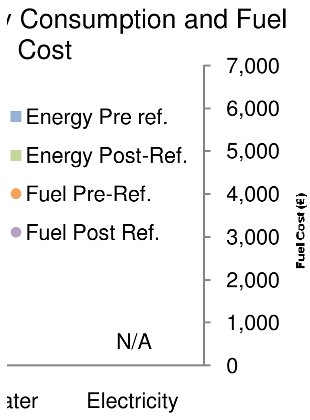
Intervention	Description	Origin of Materials	Cost (£)
Building Envelope	External wall insulation (outside to inside) • Plaster (15mm) • EPS (200mm) • Plaster (15mm) • Brickwork (300mm) • Plaster (20mm)	Local	51,700
	Floor insulation (top to bottom) • Timber floorboard (24mm) • Fill (60mm) • Suspended concrete (160mm) • EPS (200mm)	-	-
	Roof insulation (outside to inside) • Sarking • EPS (200mm) • Planking (21mm) • Rafters/Insulation (100mm) • Vapour barrier		
	• Insulate cellar ceiling	-	-
Windows	• Triple glazed uPVC and draught proofing	-	-
Building Services	• Repair tasks, non-energy-related measurements (e.g. modification room layout) • Ventilation system with 85% heat recovery • Thermostat installed • New boiler installed • CHP system installed	National	728,300

Results and Findings

Brunck Quarter, Ludwigshafen has achieved an 85.71% reduction of carbon emissions, while a SAP rating system is not available in Germany at the moment (Graph 15).

Energy consumption attributed to heating space has been reduced by 85.71%, which resulted in 82.95% reduction in heating fuel cost (Graph 16). Unfortunately, there are no available data for energy used for hot water and electricity consumption both before and after the retrofit project.





KÖLN

KÖLN, GERMANY

Total No. of Units	**72**
Total Floor Area	**4,287 m^2**
Year of Construction	**1945-1964**
Year of Refurbishment	**2009**
Total Cost (£)	**1, 250, 000**

This project entails the refurbishment of a multi-storey building in Cologne, owned by a local housing corporation, which provides shared house accommodation. The building consists of twelve (12) storeys divided into units of 59.5m². The project began in mid 2008 and was finished in late 2009. The properties were occupied during renovation works. Prior to refurbishment the property had performance rating E, while post refurbishment it achieved rating B (energy levels according to EnEV 2007).

The primary objectives of the project were:

- To consider both energy efficiency and economic indicators
- To develop the most feasible refurbishment solution based on the above indicators

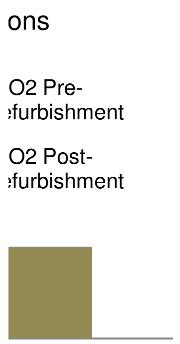
Intervention	Description	Origin of Materials	Duration of Work (days)	Cost (£)
Building Envelope	External Insulation Finishing System (outside to inside) • Plaster (15mm) • Mineralic EFIS (200mm) • Plaster (15mm) • Solid wall (240mm) • Plaster (20mm)	National	120	400,000

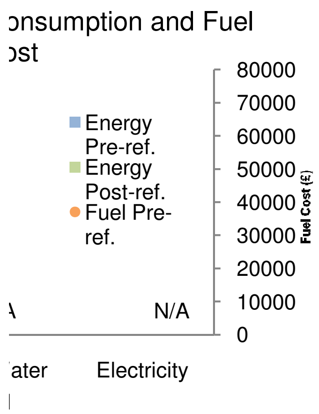
	New flat roof insulation • Bitumen roof sheeting • EFIS (200mm) • Vapour barrier • Concrete (200mm) • Plaster (20mm)	National	90	246, 000
	Ground floor insulation • Carpet (5mm) • Floating floor screed (45mm) • Insulation (30mm) • Concrete (160mm) • EFIS EPS (160mm)	National	10	12, 000
Windows	• Double glazed uPVC gas-filled windows	National	40	308, 000
Building Services	• New heating system	National	10	71,400
Various	• Other works including planning	National	200	212,000

Results and Findings

Köln, Germany has achieved a 62.94% reduction of carbon emissions. SAP rating system is not available in Germany at the moment (Graph 17).

Energy consumption attributed to space heating has been reduced by 70.39%, which resulted in 65.14% reduction in heating fuel cost (Graph 18). Unfortunately there are no available data for energy used for hot water and electricity consumption both before and after the retrofit project.






Zero Heating Cost House: Pre-refurbishment


Zero Heating Cost House: Post-refurbishment

THE LUWOGE ZERO HEATING COST HOUSE

LUDWIGSHAFEN, GERMANY

Total No. of Units	**16**
Total Floor Area	**1750 m^2**
Year of Construction	**1965-1974**
Year of Refurbishment	**2007**
Total Cost (£)	**1, 347, 828**

This project deals with the retrofit of a multi-storey (4 floors) shared house residence building, which includes 16 units in total with 110m^2 floor area each. The property was occupied during the refurbishment work.

The building is well lined with thermal insulation panels made of Neopor®. Neopor® contains tiny graphite particles that reflect thermal radiation and provide the material with a silver-grey hue. The windows are triple-glazed and contain an inert gas between panes.

There is no heating plant installed in the building. The building is capable of generating its own (low) heating loads, using solar energy. The heating system is integrated into the windows frames. The inner pane of the triple-glazed windows includes a thin and invisible metal coating which conducts heat using electricity. When a low-voltage current is applied, the coating heats up like a resistance heater which enables the windows to radiate heat. In order to eliminate heat losses from glazing areas, the outer pane has a heat-reflective coating. Moreover, the spaces between the three panes are filled with an inert gas that conducts heat less efficiently than air. Window heating has not been designed for long-term usage. It is expected to be used only when outside temperatures are extremely low.

PV panel cells on the facade generate electricity, which is fed into the municipal grid. Revenues from this contribution cover the costs for keeping the apartments warm. Solar Panels on the southern side of the roof also cover the need for hot water. A controlled inlet and outlet ventilation system with thermal recovery ensures excellent air quality while utilizing more than 80% heat of the outgoing air.

The first section of construction started in June 2006 and was completed in November 2006. The second section of construction started in January 2007 and was completed in June

2007. After completion, the Zero Heating Cost House turned from a class F (EnEV) into a class A (EnEV) house.

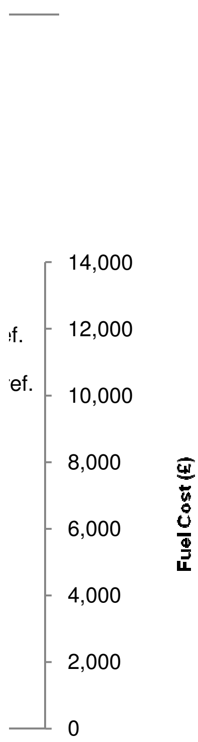
The primary objectives of the project were:

- To illustrate the technical feasibility of the project and reasonable investment costs
- To ensure zero heating costs
- To monitor the effectiveness of the project over the long-term

Intervention	Description	Origin of Materials	Cost (£)
Building Envelope	Exterior wall insulation • Plaster (15mm) • Neopor® (300mm) • Plaster (15mm) • Brickwork (240mm) • Plaster (20mm)	National	111,157
	Basement ceiling insulation • Neopor® (150mm)	National	12,205
	Flat roof insulation (top to bottom) • Bitumen roof sheeting • Planking (21mm) • Air (Rafter) 250mm(200mm) • Rafters/Neopor® WLG 035 (500mm)	National	118,131
	Base area on soil insulation • Styrodur® (250mm)	National	30,514
	• Dry lining, including rebuilding	National	52, 309
	Ground floor insulation • Wooden pavement (10mm) • Floating floor screed (45mm) • Insulation (30mm) • Concrete (160mm) • Neopor® WLG 035 (160mm)	National	-
Windows	• Triple glazed uPVC windows and heating system fitted on window frames	National	338,265
Building Services	• Installation of new ventilation system with heat exchanger	National	183, 081
Renewables	• Solar panels on south façade ($60m^2$)	National	33, 129
	• PV panels facing south ($500m^2$)		

Results and Findings

The Zero Heating Cost House, Germany has achieved an 80.445% reduction in carbon emissions. SAP rating system is not available in Germany at the moment (Graph 19). Energy consumption attributed to heating space has been reduced by 62.96%, which results in 73.33% reduction in heating fuel cost (Graph 20). Unfortunately there are no available data for energy used for hot water and electricity consumption both before and after the retrofit project.



L'Habitarelle: Pre-refurbishment


L'Habitarelle: Post-refurbishment

L'HABITARELLE

LES SALLES DU GARDON, FRANCE

Total No. of Units	**77**
Total Floor Area	**4,300 m^2**
Year of Construction	**1945-1964**
Year of Refurbishment	**2006**
Total Cost (£)	**-**

"L'Habitarelle" is located in Les salles du Gardon, France. The retrofit project deals with the refurbishment of 77 accommodation units, all of which are two stories and range in size from 25m^2 to 80m^2 though the majority are approximately 50m^2. All the flats were occupied during refurbishment.

- 17 flats of 61m^2 (T4), on first floor
- 1 flat of 73m^2 (T5), on first floor
- 41 flats of 54m^2 (T3), including 16 flats on first floor and 25 on second floor
- 9 flats of 25m^2 (T1), on second floor
- 1 flat of 67m^2 (T4), on second floor
- 8 flats of 80m^2 (T4), on second floor

The primary objectives of the project were:

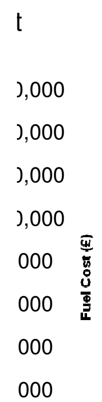
- To prove the feasibility of such a retrofit project
- To illustrate efficient solutions and reasonable investment costs

Intervention	**Description**
Building Envelope	• External polystyrene wall insulation (80mm) • Roof glass wool insulation between rafters (200mm) • Suspended concrete floor polystyrene insulation (125mm)
Windows	• Double glazed uPVC windows in wood casement
Building Services	• Replacement of initial coal stove heating system with air source heat pump and direct electricity • Time and zone temperature control system Ergdom (adaptive energy managing system)
Renewables	• 136m^2 of PV panels on south slope of roof for 21,531 KWh/year

Results and Findings

L'Habitarelle has achieved an 89.45% reduction of carbon emissions. (Graph 21) SAP rating is not available.

Energy demand for space heating has been reduced by 89.04%, which results in a 60.32% reduction in heating fuel cost (Graph 22). Unfortunately there are no available data for energy used for hot water after the refurbishment project's implementation and electricity consumption both before and after the retrofit project.




Maison Phénix: Pre-refurbishment


Maison Phénix: Post-refurbishment

SAINT FARGEAU - MAISON PHÉNIX

SAINT FARGEAU PONTHIERRY, FRANCE

Total No. of Units	**1**
Total Floor Area	**86 m^2**
Year of Construction	**1965-1974**
Year of Refurbishment	**2006**
Total Cost (£)	**-**

This project includes the development of a single family dwelling with 86m² of gross floor area. An extension of 135 m² has been added to the original dwelling. External insulation has been applied on walls, while the initial electric heating system has been replaced with WAHP (Warm Air Heat Pump) with time and temperature zone control. The renewable energy strategy also includes the installation of solar thermal panels on the roof.

The primary objectives of the project were:

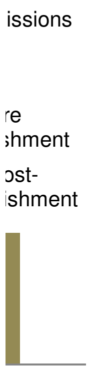
- To illustrate the potential to extend measures to more of the housing stock
- To create a reference building for future retrofits in terms of technology and cost

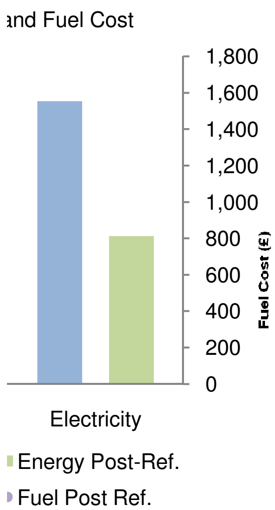
Intervention	Description
Building Envelope	Existing building- interior and exterior insulation (outside to inside) • Polystyrene (80mm) • In situ concrete (45mm) • Polystyrene (100mm) • Plaster 50 mm
	Extension- interior and exterior insulation (outside to inside) • Polystyrene (80mm) • Polyurethane (50mm) • Mineral wool (120 mm) • Plaster (13mm)
	Roof- between rafters (200mm)
Windows	• Double glazed gas-filled in wood casement
Building Services	• Replace direct electrical heating system with reversible heat pump • Double twin controlled mechanical ventilation system installed • Time and zone control data system
Renewables	• Thermal solar for domestic hot water

Results and Findings

Saint Fargeau Maison Phénix has achieved a 50% reduction in carbon emissions (Graph 23). SAP rating is not available.

Energy demand for space heating has been reduced by 53.56%. Energy for water heating is limited by 23.42%. Finally the PV panels on the roof contribute considerably to electricity demands on the dwelling; Electricity consumption has been reduced by 47.71% (Graph 24). The total reduction of energy demand results in a 44.66% cut in fuel bills.





DISCUSSION

LESSONS LEARNED AND MAJOR TRENDS

The case studies examined in this report have similar experiences in terms of common obstacles, successes and failures, and lessons learned. The most common trends are outlined below in order to provide guidance for future retrofitting projects.

MOST EFFECTIVE INTERVENTION(S)

The majority of the projects experienced the greatest success in improved thermal efficiency through the use of wall insulation and improvements to the building's envelope. This is a common trend in many retrofit projects, as improving insulation is most often the most cost-effective intervention.

However, there were varying degrees of success depending on the type of insulation used. For example, aerogel insulation proved difficult to use and significant lead-in times resulted from the limited number of suppliers.

The use of internal and external insulation will also vary widely, depending on the individual dwelling, heritage constraints and the occupancy of the building. Though it is most effective to use both internal and external insulation simultaneously, the present state of the building and cost constraints will determine the resulting interventions.

LEAST EFFECTIVE INTERVENTION(S)

Despite playing a role in a building's envelope, the replacement of windows proved often to be the least effective and the most difficult intervention during the retrofit process. Overall, windows have a relatively low impact on energy saving and were the most common issue according to those involved in the case studies.

This is largely the result of very few manufacturers who can guarantee necessary U-values and long lead times for procurement. The difference in performance between double-glazed and triple-glazed windows is also small despite the large difference in cost. As such, high performance windows are often not the most cost-effective intervention. There are also problems with very high performance windows that are often intended for Passive House standards that are manufactured without trickle vents. This is a problem as older homes require a degree of natural ventilation and breathability to prevent the build-up of moisture. As such, such high performance windows remain most useful and cost-effective in new buildings rather than retrofit projects.

NEW TECHNOLOGY DIFFICULTIES

Given the relatively new nature of a number of interventions and products, difficulties were anticipated by those involved and should be expected in future retrofit projects.

For example, the technical details of new heating windows in the Luwoge Zero Heating Cost House proved more difficult than originally expected, with a slightly higher consumption of energy than expected. As such, this technology is not to be used in future projects.

New insulation products, such as Aerogel, also presented unique problems because of difficulties in transport and installation. Those involved with Cambridge and Sea Palling explained their hesitation in using this type of insulation again in future projects.

New technologies also often lack warranties because they are considered experimental products, which should be considered by the project team.

CUSTOMER ACCEPTANCE

Most home owners and tenants were excited about the projects, though their overall knowledge of the retrofit process and expectations varied greatly.

Projects also tended to proceed more smoothly and with less stress if the properties were empty or the residents were decanted during the retrofit process. Though this is not always possible, it is a potential time-saver and prevents the project from becoming very stressful for the tenants and contractors alike.

There must also be a sufficient level of communication between parties, including the tenant so that tenant expectations are realistic from the beginning of the project. This means the inclusion of tenants in discussions with the design team and contractors at an early stage. This will help motivate the customer to undertake the measures, reduce potential misunderstandings, and will help the process of tenant handover following the completion of the project.

A less common problem but one that should still be addressed is the issue of aesthetics. One project found it difficult to sell the house after refurbishment because it was less desirable than newer houses in the surrounding areas. For all future projects, it is important to consider location in order to meet or surpass the standards set in the dwelling's surroundings.

However, the most important step will be the enabling of customers to maximize their thermal efficiency by educating on important behavioural changes and how to use any new technologies. User manuals and improved 'toolbox talks' are especially important for present and future occupants and will help reach efficiency goals.

LEVEL OF EXPERTISE

A project's success is heavily dependent on effective installation of proposed interventions. Given the fact that many of the interventions are relatively new experienced trades people tend to be few or in need of additional training. In some cases, where there was a high degree of construction team inexperience, important details were missed, such as the lack of thorough insulation and sealing which led to detrimental cold bridging.

As a result, a good site manager is essential to a project. Such an individual would be helpful in maintaining communication between parties and addressing any concerns or problems in the early stages of the project. For example, the BASF Meisterhauser and Brunck Quarter projects had trade's people specially trained by project management, as many of the techniques were non-standard.

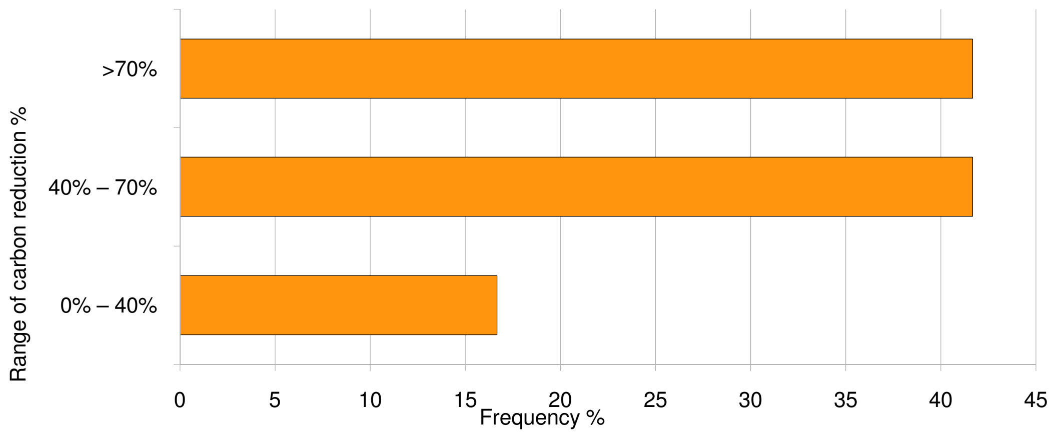
AVAILABILITY OF MATERIALS

Many of the projects faced issues with the availability of materials, which have the potential to create significant delays and increases in cost for the overall project. Remaining flexible in terms of potential long lead-in times for the ordering and delivery of materials is especially important, and the potential for delay should be considered into the project plan. Such problems may include few product manufacturers, distance between project site and manufacturer and long lead-in times for popular products. However, if no new innovative products are used and products are readily available 'on shelf', minimal delays can be expected.

COST IMPLICATIONS

Most of cases which had conclusive data on post-refurbishment emission reductions achieve either satisfactory (40% - 70%) or large carbon emission reductions (>70%) (Graph 2).

Graph 2: Carbon emissions reduction percentages

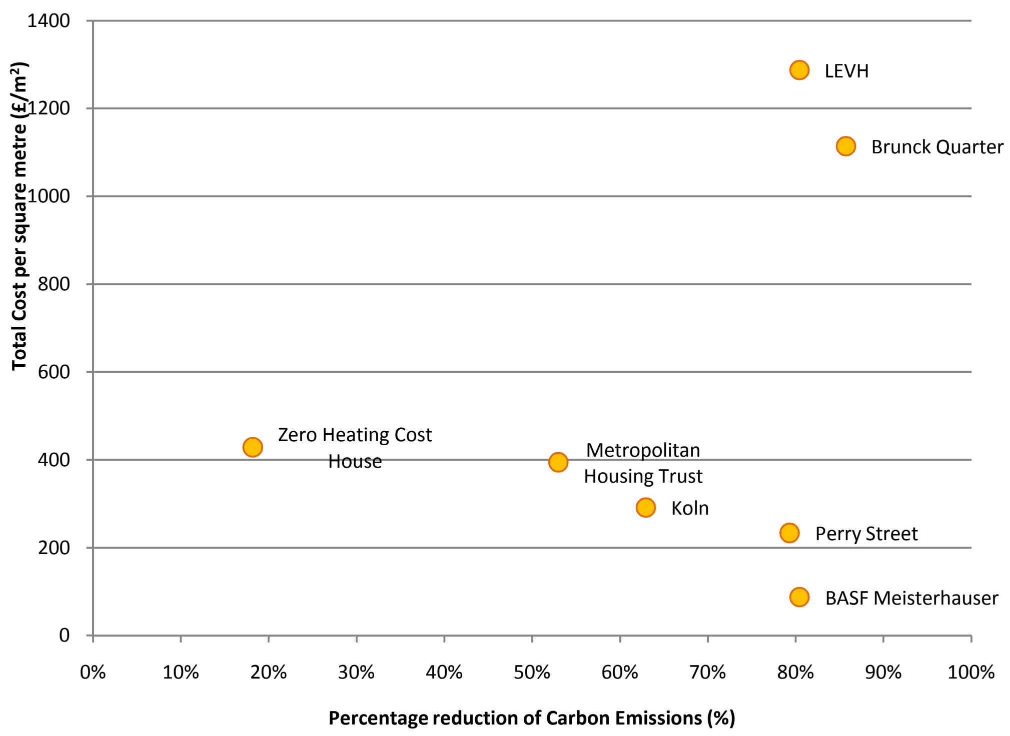


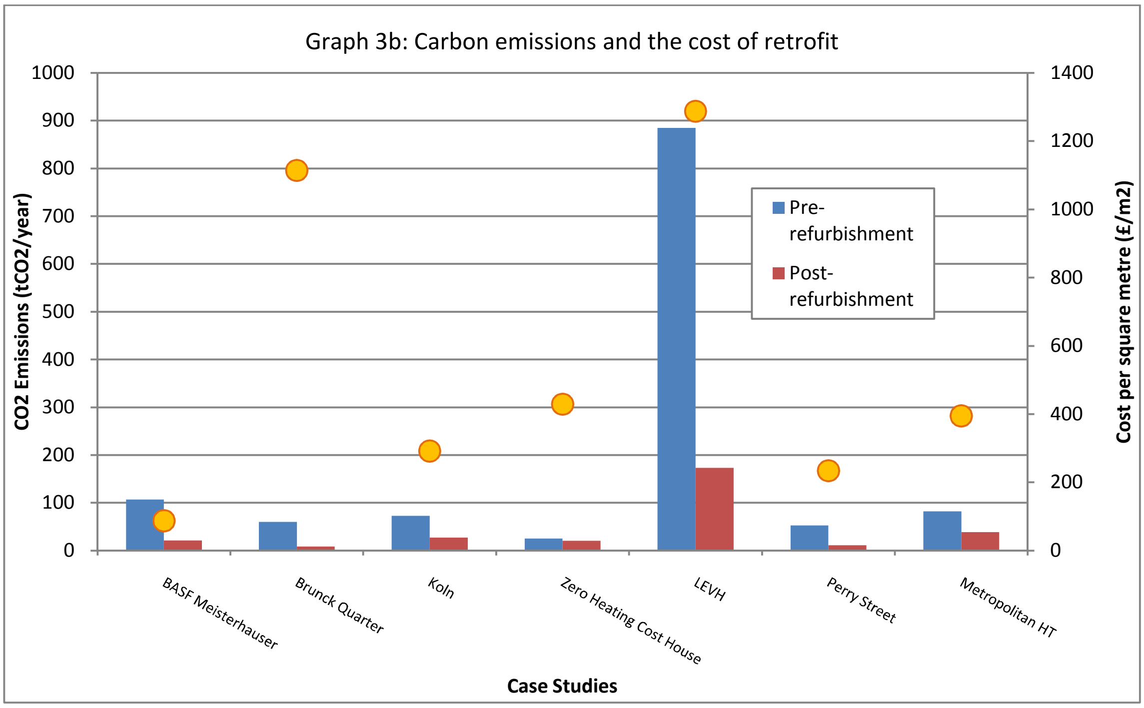
The total cost of refurbishment is highly dependent on the scale of repair works. For example, the Low Energy Victorian House (LEVH) and Brunck Quarter case studies achieve over 80% CO_2 reduction, due to environmental measures. However, this comes at a significant trade-off in terms of cost as such large reductions can only be achieved with significant investment. This can be seen in Graph 3a, where a group of case studies with conclusive post-refurbishment results are compared in terms of final costs.

Interventions that were the most cost-effective appear to be case studies that were large projects that included a number of dwellings or flats and significant floor area (m^2). These are the projects located in the bottom right of Graph 3a, where the greatest percentage of carbon emissions is achieved with the least investment. Projects such as BASF Meisterhäuser, Perry Street, Koln and the Metropolitan Housing Trust all achieved reductions of over 50% and were projects with over 2, 000m^2 to renovate.

However, the cost for non-thermal improvements such as general repairs or replacement of old structural elements dramatically raised the cost of refurbishment and accounts for almost a third of the total cost. The refurbishment of the Brunck Quarter, in Ludwigshafen, included a change in internal layout as part of passive improvements, as well as the aesthetic modernization of external features. However, in most of the other projects, any thermal and passive improvements, and in some cases, renewable technology installation appears to be more cost-effective by a large margin.

Graph 3a: CO_2 reduction vs. Cost per square metre





HOW DOES THE SCALE AFFECT THE NATURE OF INTERVENTIONS?

Based on these case studies, it appears that "mass scale" projects tend to receive limited detail in refurbishment tasks compared to individual dwellings. Most of the mass scale retrofit projects employ Decent Homes and Environmental Improvements mainly with regards to the building envelope (e.g. wall/roof/floor insulation, windows/doors replacement and draught proofing etc.). In contrast, the Zero Carbon House project (Germany), the refurbishment standard is accelerated to the top of sustainability scale including very detailed work including renewables integration and innovations regarding the heating strategy, which also utilises the passive characteristics of the dwelling.

SUMMARY AND CONCLUSIONS

Buildings account for over 50% of total greenhouse gas emissions. Upgrading old and inefficient buildings to meet the principles of bioclimatic design is an effective way to reduce energy consumption in industrialized countries. (Smith, 2005). The retrofitting of old properties is currently taking place in most of the countries of the developed world.

ROLE OF FINANCIAL INCENTIVES

As most of the projects were started by organizations or groups, government funding played a less important role than it would with individuals seeking to retrofit their homes. As such, financial incentives have the potential to initiate individual home owners to renovate their homes. However, financial incentives did help to provide a certain standard toward which to strive in order to receive some funding.

Certain partners suggested the creation of incentives where none are available to individuals. These include energy saving related prize draws for those who sign-up for a scheme, discounts on energy bills and incentive payments for contractors that prevent potential profit fall-out. Finally, the analysis of the case studies reveals that mass-scale refurbishment projects can be more cost effective. Limiting the cost of retrofit can release funds to be spent in other areas, such as new initiatives in heating and the integration of renewable technologies.

ROLE OF PILOT PROJECTS

While there are problems associated with the case studies presented, such projects are essential for improvements to be made in the retrofitting process. The first hand experiences of partners involved with the case studies provide necessary guidance of what works and what does not for future retrofit projects. Single projects and immature technologies will only become mature and drop in price if they are tested in pilot schemes presented in this report. This is evident in the continuing work for the Metropolitan Housing Trust, where the partners have witnessed the cost of delivery drop as the project has progressed. Only with further retrofit projects can common problems be discovered and best practices can be established.

IMPORTANCE OF FLEXIBILITY

Since few successful precedents exist for retrofit projects, obstacles are likely to arise as new interventions and technologies are used. However, the key to the success of the case studies presented stems from the ability to remain flexible as obstacles present themselves. It is impossible with older buildings to plan every detail, as there will likely be unforeseen issues that arise, such as partly rotten beams, issues with dampness or delays in product delivery. It is therefore necessary to adapt planning to these discoveries.

COST

Most old dwellings require further repair works in addition to environmental improvements. The repair and replacement of older materials and services account for a significant rise in total retrofit cost. A reduction in fuel cost is not always guaranteed to be significant in relation to the cost of the refurbishment project. Therefore, careful designation of retrofit tasks should be conducted before implementation of measures to ensure the overall effectiveness of the project in total.

Appendix 1: Retrofit Database Review

The increased interest in the retrofit and refurbishment of UK's existing housing stock has led to a wealth of information, ranging from retrofit guides for the construction industry, flyers and leaflets for homeowners, and perhaps the most valuable and interesting - publicly-accessible databases on completed and on-going retrofit projects. This section examines these online resources and sets out a commentary on the value of these databases to the current research.

RETROFIT FOR THE FUTURE www.retrofitforthefuture.org

In 2009 – 2010, the Technology Strategy Board implemented a £17m programme known as Retrofit for the Future (RfF), to kick-start the retrofitting of the UK's social housing stock.

AECB – (The Sustainable Building Association, was asked to develop appropriate energy performance targets for the competition and provide ongoing support and guidance. The RfF programme was split into two phases, Phase One saw 194 design and feasibility studies developed, while Phase Two took 86 of these studies and funded the implementation of the retrofits proposals. All 86 RfF projects that were accepted for Phase Two funding are included in this database.

Database features:

- Standard project data sheet for all projects
- Energy demand measured through PHPP or SAP2005.
- Includes basic energy data pre-development and forecast post-development.
- Projects in early stages of development and as such measured data to corroborate with forecasts are limited.
- There is limited breakdown of data by intervention which would have been useful to understand which interventions have been most effective on different building types.
- No U-values or technical data of interventions provided.
- There is no cost data at present, which would be helpful to aid discussions on cost-effectiveness on different interventions.
- It would be useful if all the project data could be provided as an excel database to allow for greater data analysis, aggregating results by property and construction type.
- A brief analysis of some of the reported data suggests a wide variation in the levels of electricity/gas/CO_2 reductions achieved across the different developments, ranging from50-90%.
- There are some instances where reported data shows increases in electricity/gas/CO_2. It is unclear if this is misreported data or whether it reflects a change in servicing strategies from gas to electric.

Example project data sheet

Graphs | Images | Figures | Description | Strategies | Building

Fuel use

	Pre-development	Forecast	Measured
Electricity use	2896.74 kWh/yr	1840.41 kWh/yr	-
Natural gas use	70164.27 kWh/yr	4181.76 kWh/yr	-
Oil use	-	-	-
LPG use	-	-	-
Wood use	-	-	-
Other Fuel	-	-	-

	Pre-development	Forecast	Measured
Primary energy requirement	807 kWh/m^2.yr	86 kWh/m^2.yr	-
Annual CO_2 emissions	148 kg CO_2/m^2.yr	18 kg CO_2/m^2.yr	-
Annual space heat demand	-	31 kWh/m^2.yr	-

Renewable energy

Electricity generation	Forecast	Measured
Renewables Technology	-	-
Other Renewables Tech	-	-
Electricity consumed by generation	-	-
Primary energy requirement offset by renewable generation	86 kWh/m^2.yr	-
Annual CO_2 emissions offset by renewable generation	18 kg CO_2/m^2.yr	-
Renewables Technology	-	-
Other Renewables Tech	-	-
Electricity consumed by generation	-	-
Primary energy requirement offset by renewable generation	86 kWh/m^2.yr	-
Annual CO_2 emissions offset by renewable generation	18 kg CO_2/m^2.yr	-

Calculation and targets

Whole house energy calculation method	PHPP
Other whole house calculation method	-
Energy target	Retrofit for the Future
Other energy targets	-
Forecast heating load	16 W/m^2 demand

Airtightness

	Date	Result
Pre-development air permeability test	-	-
Final air permeability test	-	-

SUSTAINABLE ENERGY ACADEMY www.sustainable-energyacademy.org.uk

The Sustainable Energy Academy promotes education and action to reduce the carbon footprint of buildings and communities. They are currently spearheading Old Home SuperHome - a network of exemplar, old dwellings which have undergone an energy-efficiency retrofit. The aim of the SEA is to create a network of homes that are local and publicly accessible to nearly everyone in the country.

Database features:

- Overall CO_2 reduction post-development as a percentage
- There is no breakdown of energy use by gas/electricity pre/post development provided which would be useful in understanding the effect of the different interventions.
- There are no figures on renewable energy production (where technologies applied)
- Unclear as to how CO_2 reductions were measured, NCM or measured energy bills
- There is variable detailed information on the level of interventions (see table below) which makes comparison between different projects and building types more difficult.
- There is no cost data at present which would be helpful to aid discussions on cost-effectiveness of different interventions.
- Whilst the data provided is useful for individual householders, the level of data completeness makes the database of limited value to industry in terms of which measures are most effective.

Example project data sheet

Hove, BN3	**London, Hackney, Henry Road**
Owner(s): Oliver Heath *House Type:* 1960s detached 3 bedroom house. *Carbon saving:* 62% *Measures installed:* • Velfac double glazed windows. Argon filled with u values of 1.11 • Cavity wall insulation, and 30 mm of external insulating render, U value to .51 wmk • Additional 30mm kingspan under exterior cladding • 40 mm foam insulation beneath underfloor heating system • Windows, doors, loft hatch and chimneys sealed with draft proofing materials • Whole house heat recovery system, Vaillant, RecoVair 275 system, with efficiency of 95.3% • Vailent EcoTec condensing boiler fitted, external weather compensator • Underfloor heating on ground floor, radiators on first floor. good controls and thermostats • Ritter Solar panels, 3 sqm evacuated tubes • Charnwood Cove 4kW wood burning stove • 7w LED down lighters to ground floor living spaces • Low energy fridge/ freezer, dish washer, washing machine, induction hob • Low flow taps, dual flush loos, bath diverter to reuse grey water • Effergy electricity monitor in daily use.	*Owner(s):* Linda Fitzgerald Moore *House Type:* Victorian 3-storey semi-detached *Carbon saving:* 63% *Measures installed:* • Double Glazed new sash windows glazed with low E glass (argon filled), U=1.5 • Internal wall insulation 50 and 60 mm Celotex, none on stairs; average U = 0.6 • Roof insulated U=0.29 • Floor insulation Celotex under raised floor, kitchen only • Gas condensing boiler, radiators and programmable TRVs • 2sqm solar thermal panels for domestic water heating • 1.6KWp photovoltaic panels • Low energy lights • 2 X 1600 litre rainwater tanks for toilets and washing machine use • Cornices rebuilt

DASH - METROPOLITAN HOUSING TRUST LONDON www.24dash.com

Known as the London Neighbourhood Investment Unit, this was MHT's programme to bring all Haringey properties up to the Decent Homes standard with an emphasis on energy efficiency.

Typical interventions include:

- 300mm Loft insulation
- 100mm floor insulation under suspended timber floors
- Cavity wall insulation (where applicable)
- 60mm internal wall insulation
- Double glazed windows (often double glazed timber sash windows due to conservation area restrictions)
- Sound insulation between flats
- Complete electrical rewiring
- Necessary structural works
- Complete central heating upgrade including A-rated condensing combi boiler, TRVs and roomstats
- Low energy lighting
- New carpet or laminate flooring
- Water butts and garden improvements where appropriate
- Resident-designed kitchen and bathroom replacement and complete redecoration in colours of residents' choice

Typical results achieved:

- SAP rating of 80
- Primary energy use of 164 kWh/m^2 per year
- Carbon emissions 2.3 tonnes per year

Database features:

- States that projects typically achieve a CO_2 reduction of 45%
- There is no breakdown of energy use by gas/electricity pre/post development provided which would be useful in understanding the effect of the different interventions.
- There is variable detailed information on the level of interventions, which makes comparison between different projects and building types more difficult.
- There is no cost data at present which would be helpful to aid discussions on cost-effectiveness on different interventions.
- Whilst the data provided is useful, the level of data completeness makes the database of limited value to industry in terms of which measures are most effective.

Example project data sheet

None available on the website but the submission to the Europe Housing Awards has a good summary of the project:

http://www.housing.org.uk/Uploads/File/our%20views/Environment/Case%20Studies/MHP.pdf

DECENT HOMES STANDARD www.decenthomesstandard.co.uk

According to the Government, **'A decent Home is one which is wind and weather tight, warm and has modern facilities'.** The Government made it their priority to reverse the decades of neglect and this standard was to be the cornerstone for improving people's quality of life in the home.

The repair, maintenance and improvement requirements are based around four key components:

- Fitness for Habitation
- Disrepair
- Modern Facilities
- Reasonable Degree of Thermal Comfort

Database features:

- None available on the website.
- Suggested that data collection is carried out on the properties to inform the programme and aid industry research. Data collection could follow the Retrofit for the Future project data sheet.

HOW DO RETROFIT MEASURES DIFFER FOR THE DIFFERENT REGIONS?

From a holistic point of view ,each region provides different level of interventions to retrofit projects:

Wales: Decent Homes standard and very few Environmental Improvements

Northern Ireland: Environmental Improvements and Passive measures

England: Decent Homes standard, Environmental Improvements and Renewables

Scotland: Environmental Improvements, Renewables and Passive measures

France: Environmental Improvements, Renewables and Innovations

Germany: All (Decent Homes standards, Environmental Improvements, Renewables, Passive Measures and Innovations)

Appendix 2: Overview of Measures Adopted by Retrofit Projects

This report was produced in the context of assisting the decision-making for retrofit measures that could prove beneficial for the UK towards the ultimate goal of this project: a conceptual frame work to inform legislation and provide guidance for an efficient refurbishment projects.

The case-studies in this report vary in terms of retrofit measures that have been adopted to achieve improved living standards or energy efficiency.

Separate categories were identified for the different measures used for the set of retrofit projects. These categories are listed in Table 1 in increasing environmental impact of interventions:

Category 1: Decent Homes Standard

The repair, maintenance and improvement requirements are based around four key components:

- Fitness for Habitation
- Disrepair
- Modern Facilities
- Reasonable Degree of Thermal Comfort

The standard requires refurbishment of housing facilities (i.e. heating, showering, ventilation etc.) and replacement of old elements (i.e. floor covers, roof re-tiling, new kitchen and bathroom units etc.) in order to make homes wind and weather tight, warm and with modern facilities.

Category 2: Environmental Improvements

Improvement measures towards increasing the thermal efficiency of dwellings by ensuring air tightness (e.g. draught-proofing of windows, doors), minimum heat losses (e.g. wall, rood, floor insulation, double/triple glazing) and efficiency of mechanical services (e.g. heating, heat recovery ventilation systems)

Category 3: Renewable Energy Resources

Retrofit measures which engage the integration of renewable technologies and contribute to the energy demands of the house. Photovoltaic panels are usually integrated on roof level facing south and are connected to the local electricity grid to benefit from reduced electricity tariffs. Sometimes the renewable resources take advantage of the local terrain and utilize local wind or water patterns.

Category 4: Passive Measures

The Passive House concept requires the house to be very well-insulated, air-tight and heated by passive solar gain and/or by internal gains from people, electrical equipment, etc. Energy losses are minimized. Any remaining heat demand is provided by an extremely small source. Avoidance of heat gain through shading and window orientation also helps to limit any cooling load, which is similarly minimized.

Category 5: Innovations

This category includes the measures which go beyond the standard sustainable retrofit techniques and represent any innovative solution set to raise the efficiency of the structure (e.g. energy management system, heating controls), achieve maximum utilization of local weather conditions (e.g. solar radiation) and/or take actions towards future proofing of the retrofit project by conducting post-refurbishment evaluation of the structure's performance (e.g. monitoring systems)

TABLE 1: SUMMARY OF RETROFIT MEASURES	
Category 1: **Decent Homes Standard**	• Renovation of roof structure • Pipe work restoration • Interior improvements (carpeting floor, painting, redecoration) • Modernisation of staircases/entrances/external features • New kitchen & bathroom fitted • Test electrics, boiler, central heating • Window restrictors • Remove carpets to provide hard board • Add smoke and carbon monoxide detectors • Provide air-bricks • Replace glass transom with Perspex fittings • Provide privacy locks, built in wardrobes, mirror and shower curtain • Infill gaps in staircase risers
Category 2: **Environmental Improvements**	• Wall insulation • Ground floor Insulation • Roof Insulation • Double/Triple glazed windows • Insulation of pipes • New heating system - Boiler replacement • New ventilation system with heat recovery • Energy efficient Lighting bulbs • Air tightness measures – Draught proofing • Heating controls and metering • Water saving (Flow restrictions) • A+ appliances • Develop Floor Ventilation
Category 3: **Renewable Energy Resources**	• Ground Source Heat Pumps (GSHP) • Biomass Heating • Solar Thermal Panels • PV panels on roof • Micro-hydro Generating Plant
Category 4: **Passive Measures**	• Modification of layout • annexe balconies • Natural Ventilation strategy • Heat gains from south facing windows • Resize and relocate windows to maximise day lighting
Category 5: **Innovations**	• Heating system fitted on Window frames • PV panels on façade • Energy Management System • Monitoring system