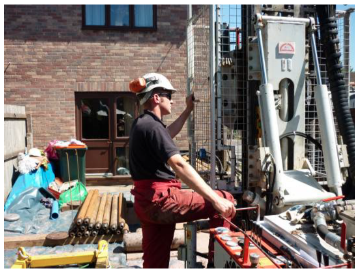
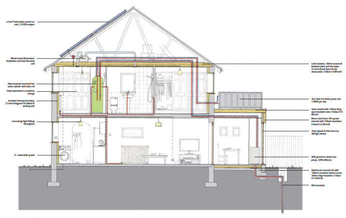
Low Carbon Retrofit

Solutions for a Holistic Optimal Retrofit (SHOR) - 1980s Urban Semi-detached House





Low Carbon Retrofit : Solutions for a Holistic Optimal Retrofit (SHOR) - 1980s Urban Semi-detached House

a. **Year of output**: 2009-2011

b. **Type of output**

vii. Building design

c. **Title of the output**:

Low Carbon Retrofit : Solutions for a Holistic Optimal Retrofit (SHOR) - 1980s Urban Semi-detached House

Funders/Clients

Technology Strategy Board Technology Strategy Board

Charter Housing Association

1. Each of the following is required **where applicable** to the output:

a. **Co-authors**:
Heal A

b. **Interdisciplinary research**

The panel should note that this is the product of interdisciplinary work involving a range of research partners and industry.

c. **The research group**

Design Research Unit of the Welsh School of Architecture (DRUw)

Aims and objectives

The TSB brief was that each of the *low carbon refits* of existing low-rise social housing twill meet the UK government's target for reducing greenhouse gas emissions of 80% by 2050, while also cutting energy use dramatically.
Programme applicants were asked to develop whole house retrofit solutions that would result in deep cuts to CO_2 emissions whilst also significantly improving energy performance. Applicants were required to take a 'whole house' approach, i.e. to consider a household's energy needs and carbon dioxide impacts as a whole, and establish a comprehensive package of measures to reduce them.
The team set out to achieve a successful retrofit scheme which was innovative through an integrative, technologically robust, holistic, people focused approach to achieve carbon savings rather than being seduced into a technological short term quick 'quick fix'.

Methodology

The scheme involved close collaborative working with a team located within the Welsh School of Architecture including Architects (DRUw), Environmental Specialists - Centre for Research in the Built Environment (CRiBE – Lannon, Jenkins, Patterson) and Sustainable Design Specialist with particular expertise in human factors – BRE Centre for Sustainable Design (SUDoBE – Tweed) as well as the Social Housing Provider – Charter Housing Association's tenant satisfaction and maintenance team and their supply chain. To achieve the objectives a decision-making matrix was developed and used by the project team during regular meetings to identify the optimal, practical and replicable low carbon solution for this property. Property survey and analysis, modelling, and design and expertise of the various team members all contributed to this collaborative process.
Four aspects of the property were considered:
FORM & SPACE - to reduce energy demand, improve daylighting and address lack of living space and amenity
FABRIC - to reduce heat losses and draughts and improve occupant comfort
APPLIANCES - to reduce energy demand from white goods and lighting
SYSTEMS - to provide energy from renewable sources
Each of these was valued against CARBON SAVINGS, WHOLE-LIFE COSTS, BUILDABILITY, REPLICABILITY and COMFORT CONDITIONS.

Dissemination

This has taken place in three main ways as follows:-

- through demonstration through construction and post occupancy .
- through the Technology Strategy Board Retrofit for the Future programme websites - Retrofit Analysis and in particular 'Retrofit Revealed The Retrofit for the Future projects – data analysis report'
- Solutions for a Holistic Optimal Retrofit (SHOR) - 1980s urban end of terrace house TSB http://retrofitforthefuture.org/viewproject.php?id=96#building
- through RIBA publication in a forthcoming book on best practice in low carbon retrofit 2013

Authorship

Wayne Forster DRUw (Principal Investigator)
Amanda Heal DRUw (Design Research Associate)

In collaboration with the following partners
Charter Housing
CRiBE
SUDoBE

Statement of Significance

TSB Retrofit for the Future Competition winner 2009

Statements of Support

1.1 Introduction

1.1.1 Context

During 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 AECB has developed this database as an education and dissemination tool, incorporating both the RfF projects as well as new and refurbished *domestic and non-domestic* low energy buildings. TSB provided grant funding to support the development of the low energy buildings website.

RfF projects

Programme applicants were asked to develop whole house retrofit solutions that would result in deep cuts to CO_2 emissions whilst also significantly improving energy performance. Applicants were required to take a 'whole house' approach, i.e. to consider a household's energy needs and carbon dioxide impacts as a whole, and establish a comprehensive package of measures to reduce them.

1.1.2 Dwelling type and research aims

The building provided by Charter Housing Association was a 1980s urban semi-detached (end terrace) two bedroom three person house in Newport, South Wales. Ground Floor: Small entrance hall open to kitchen, lounge with door direct to garden.

This comprised of

First Floor: 1 double bedroom, 1 single bedroom, bathroom. 58m2 internal floor area.

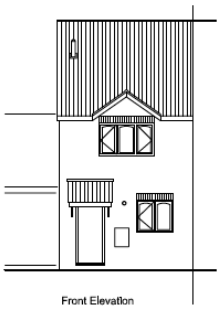
Construction: Brick-block cavity wall, with uninsulated cavity, uninsulated concrete slab floor, tiled timber truss roof, loft insulation in poor condition, timber double-glazed windows in poor condition, gas central heating.

The dwelling was purchased as part of housing stock from private developer by the housing association during the recession of the 80's- the house does not meet space standards usually required of new-build social housing. It was lacking in living and amenity space and this presented an additional challenge to the retrofit team – particularly architecturally. Many authorities/housing associations were encouraged purchase stock from private sector at this time in order to alleviate the sector and for rapid provision of 'social housing'- replication is applicable to both public and private sector housing. 31 houses on the estate belonged to Charter Housing.

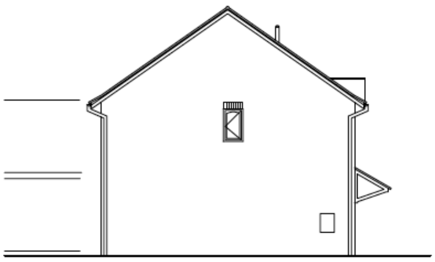
In terms of typicality the house type represented a particular era in public sector housing - 8.5% dwellings in England and Wales were constructed 1981-1990 = 1,997,500 dwellings. Of these, 352,500 belong to LA or RSLs.

The ambition was for the solution and design method to be particularly useful for properties where amenity and space standards are an issue, whether the property is terraced, detached or semi-detached.

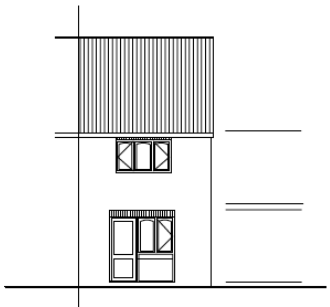
Aerial view of property – note that North is directly up the page



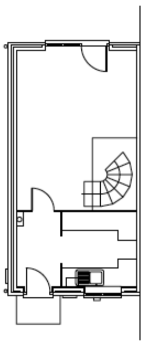
Front Elevation



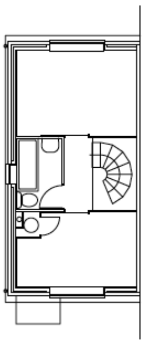
Side Elevation



Rear Elevation



Ground Floor Plan



First Floor Plan

Rev	Revision note	Date
-	-	-

Do not scale. Use figured dimensions only. Subject to site survey and all necessary consents. All dimensions to be checked by user and any discrepancies, errors or omissions to be reported to the Architect before work commences. This drawing is to be read in conjunction with all other relevant materials.

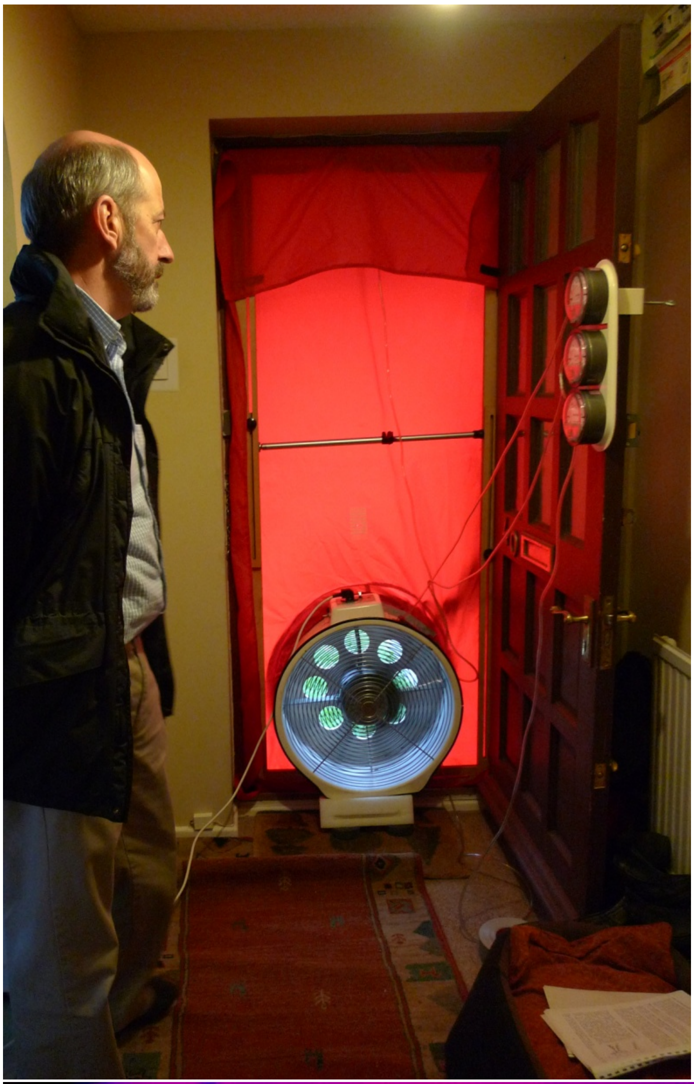
1082 TSB Retrofit: The Turnstiles
Client:
Dwg name: Existing Plans & Elevations
Dwg no:
Scale: 1:100 @ A3
Rev:
Date: 28.10.09

wsa

dru^w

Design Research Unit Wales
Welsh School of Architecture, Bute Building, King Edward VII Avenue
Cardiff. CF10 3NB t: 02920 874430 f: 02920 874926 www.dru-w.co.uk

The existing end of terrace house




14.6°C
14
12
10
8.2°C

Report N°: DAT-EST-TSB060	he Turnstiles - T1		
Date:	31/03/2010	Airtightness Engineer:	P Sharpe
Accreditation Body:	ATTMA	Registration Number:	0005
Client:	Energy Savings Trust	Plot N°:	
Region:		Developers Type:	
Address:	21 Dartmouth Street London SW1H 9BP	Development Name:	
		Development Address:	Turnstiles rt iNR
Telephone:	020 7227 0361		
Facsimile:			
Test Results at 50 Pascals		Q_{50}: Airflow (m³/h):	1617
Measured Air Permeability (m³/(h.m²)):	9.68	Design Air Permeability (m³/(h.m²)):	10.00
Did the dwelling achieve the required air permeability as specified in the SAP calculations?			YES

Testing the existing building fabric prior to design

1.2 Research aims

The Retrofit for the Future competition was designed to address the challenge laid down by the UK Government's target to reduce greenhouse gas emissions by 80% by 2050. The competition was co-ordinated by the Technology Strategy Board with the endorsement of the Department for Communities and Local Government and the Homes and Communities Agency.

Retrofit for the Future acted as the catalyst for the retrofit of public sector housing with an ambition of achieving an 80%

reduction in the in-use CO2 emissions of each property.

1.2.1 Aims and objectives

As well as the carbon savings prescribed in the TSB competition we set out to achieve the following aims:-

Space standards - A major constraint of the project was the small size of the property. Solutions that improved living and storage space were favoured, allowing space invasive options such as internal dry lining and ground source to be used appropriately.

Planning consent –design should ensure that this would not be required. The team set this constraint for the scheme in order to save cost and time. The need for individual planning applications where retrofit was likely to be 'pepper potted' across the housing stock was identified as a significant barrier to this kind of retrofit.

Costs - Whilst the main aim of the feasibility has been to meet the carbon reduction targets, this had to be balanced against costs for the project to be realistic. The team has considered the costs associated with supply, installation, maintenance, operation, savings to tenants and economies of scale for potential role-out.

Maintenance - Lower maintenance products were selected where possible e.g. composite window frames. The RSL is satisfied that the solution can be maintained within existing regimes, programmes and skills base.

Tenant education and perception - Good communication with the tenants was identified as being crucial as this would encourage cooperation and commitment but crucially familiarise them with design and technical solutions which hother wise may have been inaccessible despite being selected for amenity and functionality.

Tenants in residence – This was a key aim as if the practicality of keeping tenants in the house could be demonstrated this would eliminate huge logistical issues and costs for the provider

Scale up and mainstream - The method should be flexible and cost effective for large-scale role out.

Supply chain - Solutions should work within the RSL's existing frameworks, supply chains and UK partnerships.

Risk - Through the analysis and design process, risks was to be balanced against innovation.

1.2.2 Research method

The research was to be conducted through design, construction and post construction evaluation based on a collaborative approach involving an integrated design and construction team and tenants.

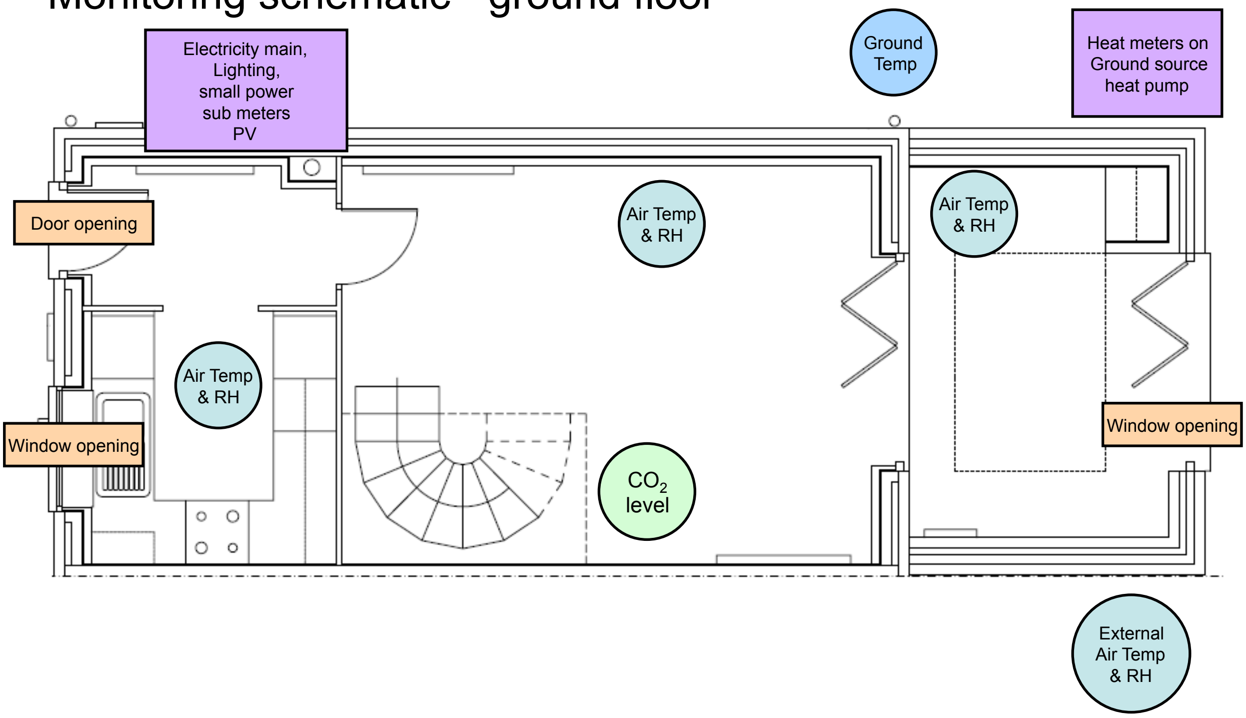
The competition process involved two stages – feasibility and if then selected design and construction and a period of monitoring the building performance in use

For this particular project this would involve the following :-

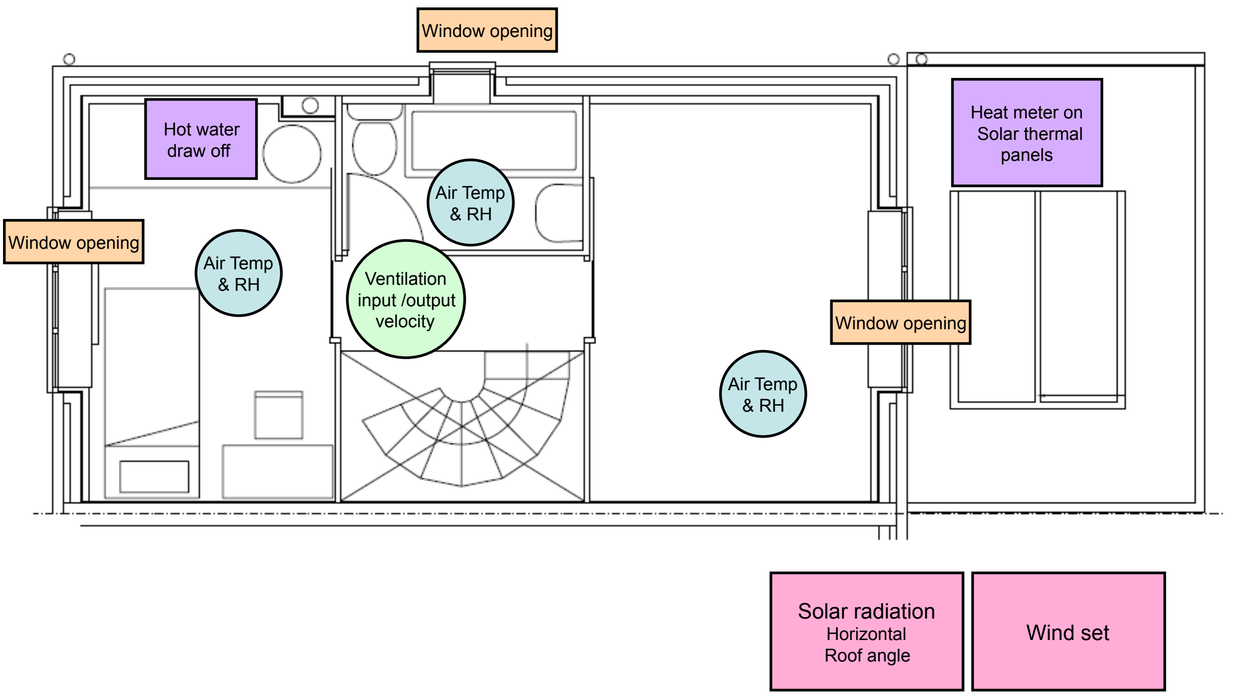
Team approach: An innovative team approach was taken to establish the most appropriate technical solution for the property and its tenants. The whole project team worked together closely throughout the processes of analysis, design, modelling, costing and construction and post construction. Tenants were also consulted and involved on a number of occasions. This collaborative process has been documented and has led to a solution that achieves exemplary performance standards and pushes the boundaries of sustainable retrofit for social housing in the UK. The team has chosen to adopt an innovative process rather than opt for risky technologies that, in reality, may not perform to expected standards. A combination of state-of-the-art standard products achieves a solution that is realistic within the supply chain.

Integrated solutions: A rational design approach has been taken which addresses the lack of amenity space in the property, deals with the external envelope and provides innovative but appropriate technologies that will be operable by the tenants. The following aspects were considered:
FORM & SPACE - BUILDING FABRIC - APPLIANCES - SYSTEMS.
Each were analysed in terms of CARBON SAVINGS - COSTS - BUILDABILITY - COMFORT & CONDITIONS

Monitoring schematic - ground floor



Monitoring schematic - first floor



Retrofit for the Future SHOR 1980 semi detached

Option/Measure	ITEMS TO MODEL	Accepted/Rejected	COST	Carbon emission	Cost	Carbon saving	cost saving	Householder impact	Supplier	Notes	File
As built				**73.06**	**£415.32**					**This is the SAP as built**	
Doing the best we can	**Fabric insulation, heat pump solar thermal triple glazing**			**16.99**	**£148.43**	56.07	£266.89				
Form and space											
Open-plan living space		Rejected - no C impact.									
Add openings		Rejected - no C impact /security issue									
Light well/sun tube	sun pipe lighting above staircase		Approx. £600							Little C reduction. Amenity.	
	Rooflight above stairs		Approx. £600							Carbon increase. Amenity.	
Storage space	Wardrobes on external wall in bedroom with insulation materials within									Need to include plan of furniture layout for residents to see. Same as dry lining	
Living space in roof	2.5mx2.5m space	TEST	Approx. £8,000	65.02	£408.51	8.04	£6.81			Combines well with rooflights	
Draught lobby		TEST		72.93	£414.69	0.13	£0.63				Set 1
Conservatory	Double glazed single storey conservatory - full width of property	TEST								Prone to vandalism	
	Double glazed double storey conservatory - full width of property	TEST									
Stair well	Alternatives to spiral staircase - Dog leg	Dog leg								Not that replicable as not in that many houses. No C reduction. Amenity only.	
Fabric											
Walls	Cavity - already present, quality to be checked	Baseline fig. without CW.								Cavity wall is present. Blown fibre, not setting. 8 years old. Satisfactory.	
	External cladding	TEST		49.93	£304.24	23.13	£111.08			Negative amenity and would need planning permission	set 3
	Dry lining on all walls	TEST		49.93	£304.24	23.13	£111.08				set 3
Roof	Loft insulation - 250mm	TEST		70.13	£401.21	2.93	£14.11			This is more than 250mm	set 1
Floor	Insulated floor	TEST								Decant/disruption.	
Windows	Double glazing non pvc	TEST		69.55	£398.45	3.51	£16.87				set 1
	Triple glazing non pvc	TEST		68.18	£391.93	4.88	£23.39				set 2
	Modification to back window - bottom panel to be converted to superinsulated non pvc panel.									Possible condensation issue with panel on back window. Prefer UK suppliers where possible.	
Doors	Double glazed and draught proofing.									Done with the windows	
	Triple glazed and draught proofing.									Done with the windows	
Systems											
space/water heating											
Radiators	Convector heater to heat wall surface to provide radiant heat.	Rejected as not SAPable								Internal wall - energy reduction. External wall - comfort.	
Underfloor	Underfloor heating	TEST		76.44	£431.58	3.38	-£16.26			Unlikely due to lack of C impact and hard surface comfort by residents.	set 2
Air to air heat recovery											
Energy source/boiler	New boiler suggested. Boiler in roof space - maintenancevs space	TEST		52.31	£306.79	20.75	£108.53			Combi with 90.7%	
	Boiler with solar with intelligent weather compensating equipment	TEST		50.23	£299.54	22.83	£115.78				Set 3
	Ground source for hot water and heating	TEST		43.54	£405.01	29.52	£10.31			Is ground source possible in area - need to check with BGS.	set 4
	Ground source with solar top up and PV to run pump.	TEST		41.63	£386.26	31.43	£29.06			Radiator sizes need to be checked for appropriateness.	set 4
Instant or storage											
Hot water conservation											
Insulate pipes, cylinder											
Shower, spray taps											
Mechanical Ventilation											
Heat recovery	Mechanical heat recovery system	TEST		73.73	£422.71	0.67	-£7.39				set 2
Ventilation	Ventilation in bathroom and extractor in kitchen	TEST		74.4	£421.75	1.34	-£6.43				set 3
Lighting											
Light fittings/lamps	all energy saving lightbulbs										
Renewables											
Solar water											
PVs											
Wind											
Ground source											
Appliances & Controls											
White goods	Washing machine									The results for this are in the extended spread sheet not SAP	
	Fridge freezer									The results for this are in the extended spread sheet not SAP	
	Energy saving lighting									The results for this are in the extended spread sheet not SAP	
Controls system											

Design decision matrix

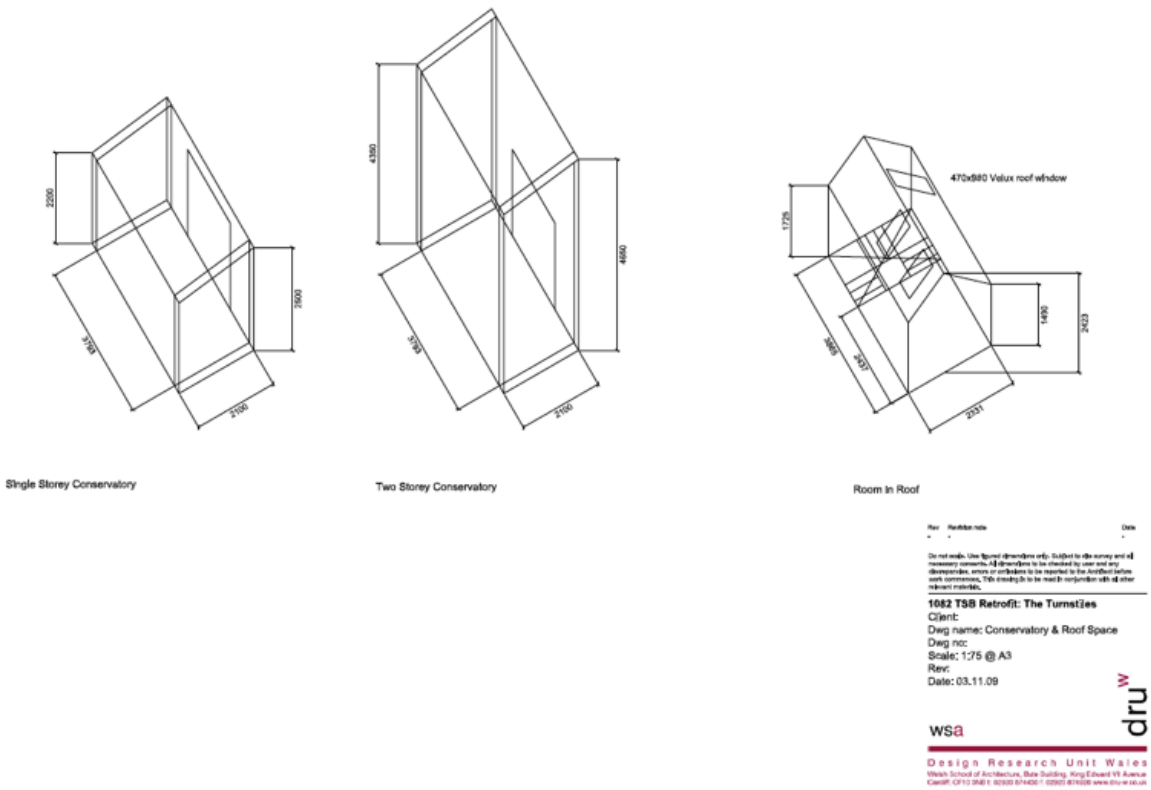
1.3 Design Solutions

The carbon savings calculations were made for each individual option considered using Builddesk Energy Design 3.4. The assumptions made regarding the measures to be implemented are as follows;

Positive input ventilation from loft space with trickle vents within the windows will be fitted.
2KWhp Photovoltaic panels will be fitted on the building.

Form and Space: 6m2 living space in roof with rooflights that also improve daylighting to stair and living room; single-storey solar extension to rear of property for amenity space and thermal buffer; built-in storage with incorporated insulation to gable wall.

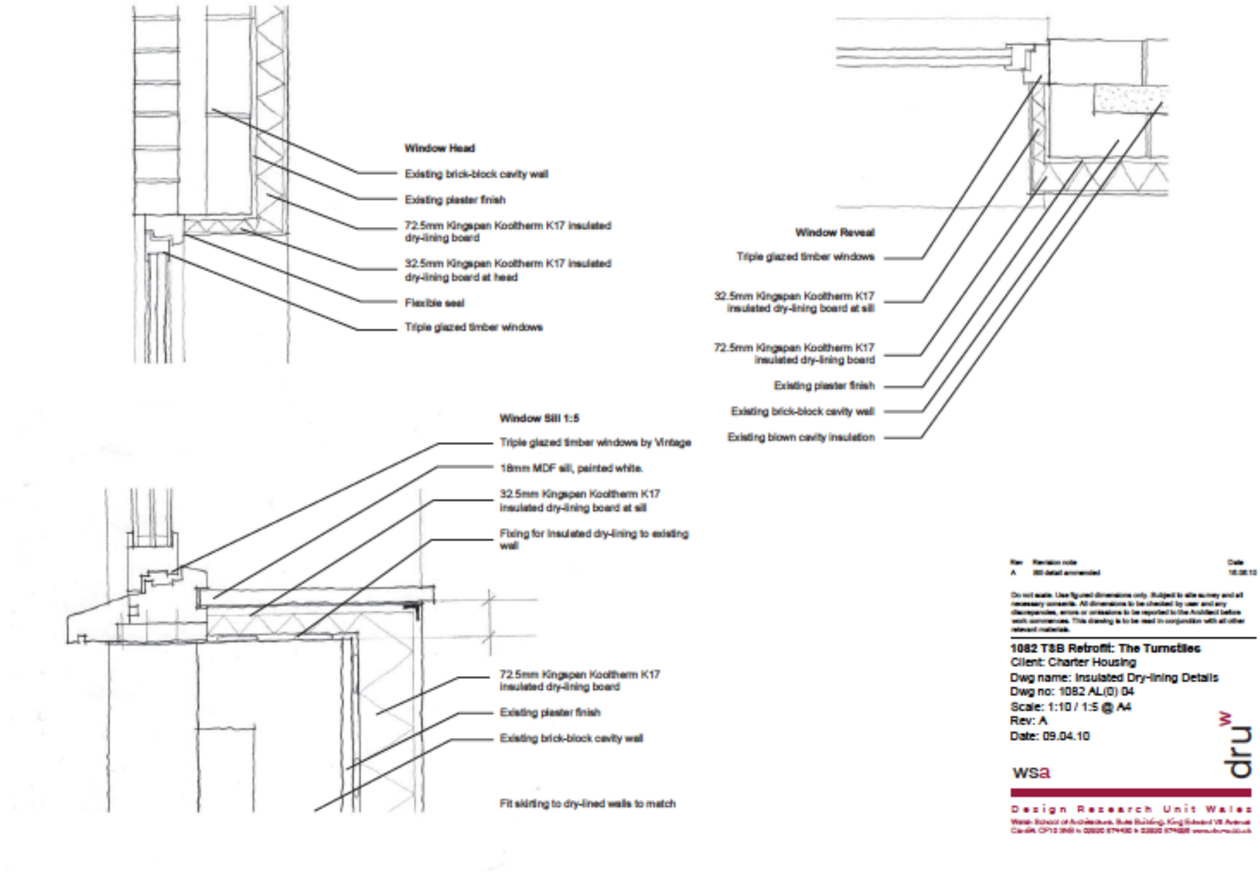
- living space in roof – (2.5mx2.5m) which is insulated and roof lit with three double glazed Velux windows - U Value 1.40.
- a single storey solar space extension full width of the property, with a triple glazed pitched roof and a triple glazed end wall. This extension will have walls and floor with a U Value of 0.15
- storage space - wardrobes backing onto external wall in main bedroom which incorporate insulation materials.



Early analytical drawings exploring potential space improvements

Fabric: Dry lining internal walls; highly insulated roof/loft; UK manufactured triple-glazed windows and doors with improved air-tightness and composite frames for low maintenance.

- dry lining and insulation on internal walls - U Value 0.19
- loft insulation - U Value 0.19
- triple glazed non-pvc windows - U Value 0.90
- Improve the air tightness to 2 $m^2/(m^2h)$ by robust detailing and fitting new glazing and doors



Drawn details showing internal insulation details for existing fabric

Fitting new window and preparing reveal for insulation

New conservatory space constructed using prefabricated walling elements

Systems: A ground-to-water heat pump (electric) with efficiency: 320.0 %, using radiators on a standard tariff will be installed. The controls will include time and temperature zone control. This system will be placed within the new amenity space. The hot water system will have evacuated tube collectors (2.88m2) mounted on the building which will feed into unvented cylinder with Solar Coil.
Positive input ventilation from loft space with trickle vents within the windows will be fitted.
2KWhp Photovoltaic panels will be fitted on the building.

Ground source heat pump installed at rear of the property

Existing supply chains: The project builds on established supply chains and frameworks in place at Charter Housing to allow continuity and familiarity in supply, installation and maintenance.
All manufacturers, suppliers and contractors are UK based and local to Newport where possible, promoting local economy and reducing carbon emissions related to transport.

Product selection and sourcing of labour:

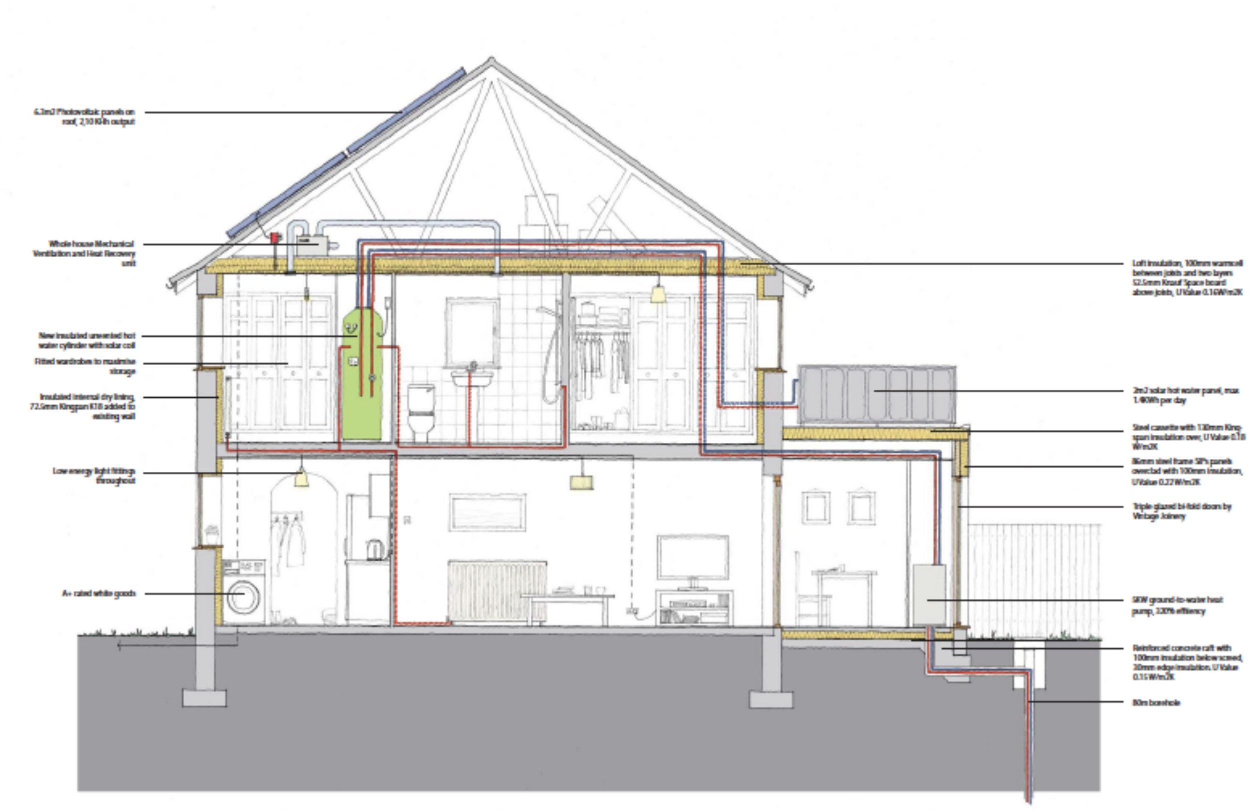
Worcester Bosch – these are existing partnering supplier to the social landlord. They are manufacturers and suppliers of renewables and traditional boilers with a proven track record, operating from a zero-waste factory in Worcester. They have designed and will supply the ground source/solar system and monitoring.

Heat Force - Approved supplier and installer of renewables and existing maintenance contractor. Already has expertise in renewables field.

CWE Electrical: Existing partnering contractor, familiar with renewables.

Charter appointed Contractor: Building contractor using local labour, with existing framework, UK based, experienced in social housing.

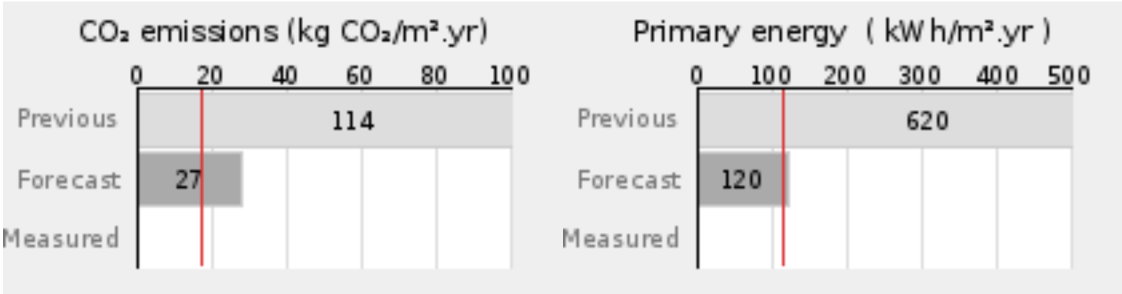
Green Building Store: UK manufacturers of composite timber triple-glazed windows with 0.9 U-value. The company are keen to work within the social housing sector and have offered up to 25% discount for larger scale role-out installations.
Each prototype had its own set of test criteria that developed progressively from the previous study.



Schematic showing integration of all energy saving and energy producing measures

1.4 Predicted results

The existing property and carbon savings for each individual option were modelled using Builddesk Energy Design 3.4. The team compared the individual carbon savings against capital costs for each measure to calculate the price per tonne CO2 saved.



The resulting reductions in tenant energy bills were also evaluated. These are outlined below for the selected options:

Fabric:
- Dry lining and insulation on internal walls: 8.46 £/tonne (Saving: £111.08 /year)
- Roof insulation: 60.20 £/tonne (£14.11 saving/year)
- Triple glazed windows: 107.86 £/tonne (Saving: £23.39 /year)

Form and space
- Living space in roof : 26.27 £/tonne (Saving: £6.81 /year)
- Solar space extension: 123.97 £/tonne (Saving: £9.19 / year)

Sysrem
- Ground-to-water heat pump with solar: 29.96 £/tonne (Saving: £29.06 /year)
- 2KWhp Photovoltaic panels: 65.35 £/tonne

1.5 Results and research outcomes

The following chart shows emissions in kg CO_2 / m2 / year for each of the properties we have analysed. Three of the properties achieved reductions beyond the 80% target of 17kg CO_2 / m2 / year. The same three properties also had primary energy consumption of less than 115kWh / m2 / year. A further ten properties achieved CO_2 reductions equivalent to 70% – 80%. A further thirteen achieved CO_2 reductions equivalent to 50% – 70%.

The results from the monitoring of the property indicate that the retrofit was one of the best performers from the TSB retrofit programme. Results indicated that a consequence of the improved performance was that residents tended to heat the dwelling to levels well above previous comfort levels. If this was reduced by 1degree than the target performance of 8)% reduction would easily be reached.

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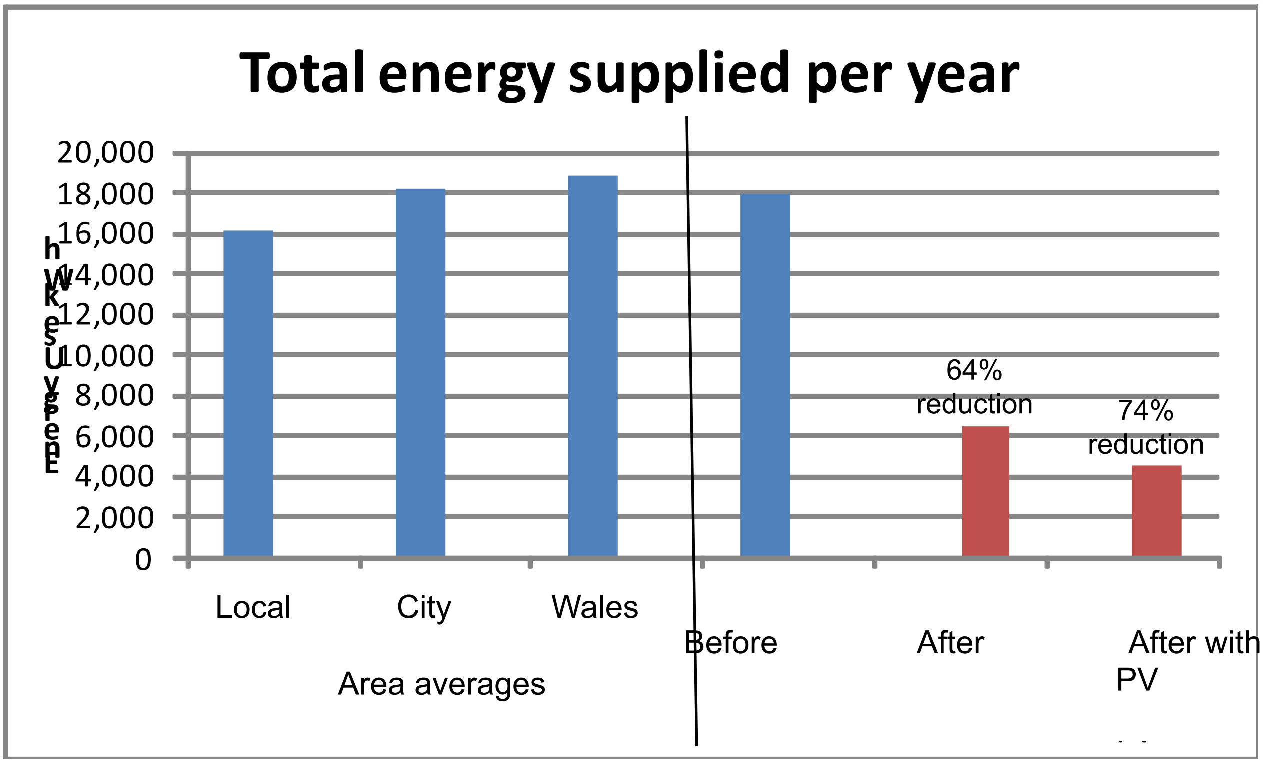
Energy demand



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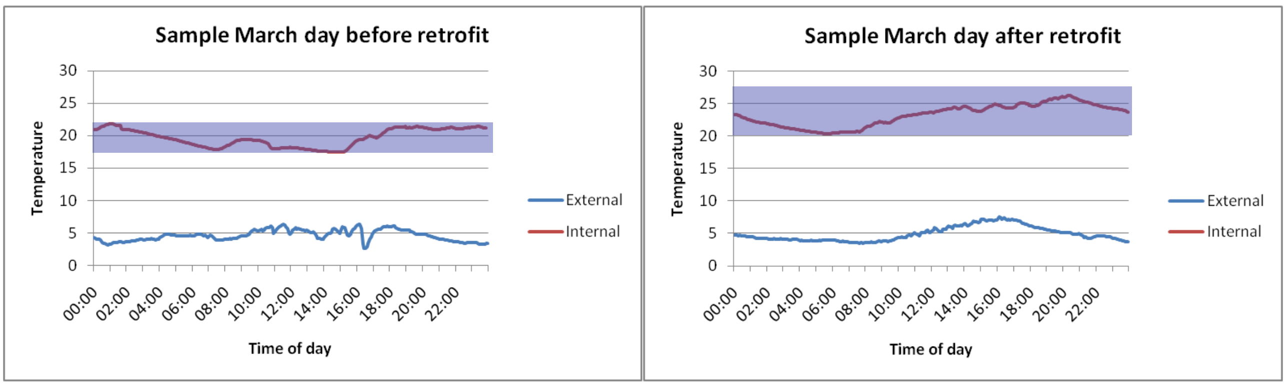
Internal temperatures before and after retrofit



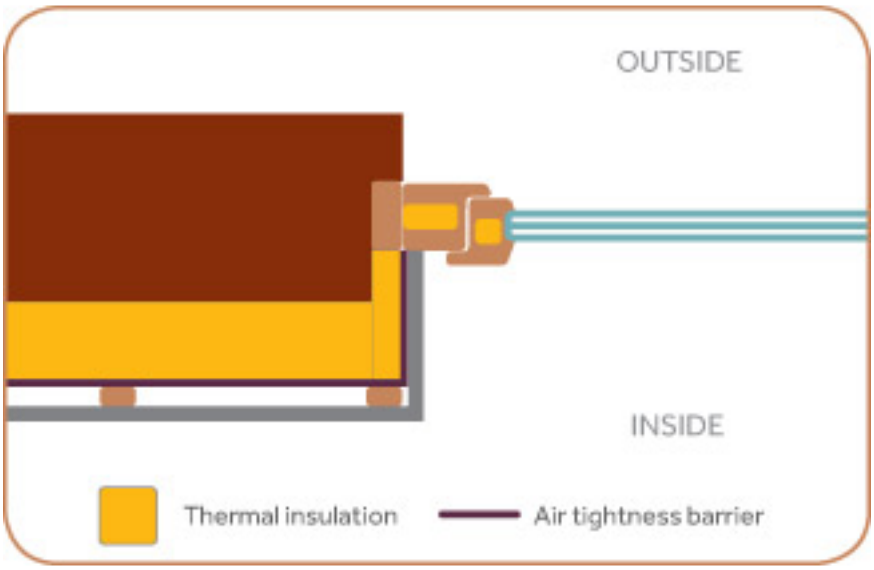
1.5.1 Form and Space:

The living space in the roof proved to be too expensive to execute but the single storey solar space extension full width of the property, with a triple glazed pitched roof and a triple glazed end wall was constructed and proved vital both in terms of supplementing much needed space but also to accommodate services. The overall floor area of the house (58m2) was increased by 20%

1.5.2 Fabric

Internal wall insulation.
Whilst the advantages of keeping the tenant in the house is recognised the detailing and installation of the internal insulation requires a great deal of care.
Intermediate floors, where floor joists are built into external walls: not only is it difficult to insulate this zone, addressing air tightness continuity is particularly tricky with the risk of failure quite high if moist internal air is permitted to condense on cold joist ends, potentially leading to rot and structural failure.
Internal partitions and party walls, where they are tied in to the external solid wall: returning the insulation back into the room may help to alleviate cold bridging in these locations.
Junctions with windows: where possible, consideration should be given to overlapping the window frame to further improve energy efficiency of these elements. Window boards will most likely need to be extended or replaced also. If at all feasible, window replacement should take place concurrently with IWI as the replacement windows can then be located closer to the plane of the insulation to reduce thermal bridging at the edges.
Fixtures and fittings such as bathroom fittings, kitchens, cupboards and radiators all have to be removed and relocated. It is important to take advantage of this opportunity when these elements are being replaced anyway.
Internal building services such as waste pipework, wall-mounted boilers, flues, vents and telecommunications equipment will all have to be removed and relocated on the face of the dry lining.

Windows



The new window frames were designed with a wider frame to accommodate the internal insulation enabling the reveal to be effectively insulated.

1.5.3 Systems
The absolute carbon reduction targets set in the competition resulted in a quite complicated set of technical solutions. The dwelling was not ideally oriented to carry a pv array and consequently the

building is now cluttered with renewable technologies – although of course the ground source is very discreet.
As a dwelling becomes better insulated and properly ventilated building services solutions shuld become simpler.

Timers

Pumps

Thermostats

Displays

In the analysis of energy saving measures in this house, we estimate that the new internally insulated dry lining offered best value. In terms of cost savings and carbon dioxide emissions. Whilst the ground source heat pump provides the highest overall savings the high capital cost means that the economic pay-back period is prohibitive.
Additionally, the additional sun-space does not contribute much to he energy savings, however the benefit of much needed living and amenity space justifies the expenditure.

Vital statistics table

Characteristics	Before	Target	Measured
Primary energy [kWh/m²/year]	620	120	155
Space heating kWh/m²/year	224	59	–
Airtightness [m³/m²h @ 50 Pa]	9.68	–	7.73
Type of glazing	double	triple	triple
CO_2 emissions [kg CO_2/m²/year]	115	28	29.3

1.6 Evidence of artefact

End of terrace retrofit

Side and rear elevations – solar access to renewables over new conservatory

View from living/kitchen room through to new conservatory which provides much needed buffer space and location for ground source heat pump

Rooflight to maximise day-lighting over conservatory


CALOREX 5000
GROUND SOURCE HEAT PUMP
POWER
ECONOMY
HIGH
PROGRAMMER LIVE
HEATING
IF LIGHT SHOWS, PRESS RED BUTTON
HEAT PUMP
FERNOX
buddy
sales@fernox.com
www.fernox.com

New refitted kitchen now daylit, insulated internally and with triple glazed windows

Significant Appendices

Appendix II

Retrofit Revealed
Technology Strategy Board 'The Retrofit for the Future projects – data analysis report"
www.retrofitanalysis.org

Retrofit insights: perspectives from
an emerging industry
The Institute for Sustainability
http://www.instituteforsustainability.co.uk/latestpublications.html

Baeli, M Retrofit for the Future Case Studies RIBA Publications
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