Technology Strategy Board
Driving Innovation

Retrofit for the Future

Project final report

Cover note

This report was prepared by the collaborative project team for this Retrofit for the Future project, to provide fuller context on their experiences and the particulars of their retrofit's specification, construction and occupation.

The authors were encouraged to include honest, transparent and constructive comment, garnered from multiple perspectives across their team. All views are taken to be an accurate account from the time.

There may have been further modifications to the property after this report was produced. It is therefore possible that a small minority of statements will no longer be valid.

Although minor modifications have been made to this report by the Technology Strategy Board, these were only to ensure the privacy of individuals, including the residents, and compliance with the Data Protection Act.

This report may contain links to other websites, such as for project partners or the retrofit project. The Technology Strategy Board is not responsible for the content of those websites.

This report has already proven to be a valuable source of information for the technical and cost analysis reports published by the Technology Strategy Board which are available at: www.retrofitanalysis.org

Retrofit for the Future Project Final Report

Project number: ZA343S
Property number: TSB036

Author: ECD Architects Ltd

The work reported here has been funded by the Technology Strategy Board under the Small Business Research Initiative (SBRI) under the Retrofit for the Future programme. This project is one of nearly 90 projects funded under the programme. Further information on the programme can be found at: www.innovateuk.org/retrofit

Technology Strategy Board
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SBRI
Government challenges.
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Final Report

Project information

- **ZA reference number:** ZA343S
- **Location of property:** RG20, Berkshire
- **Lead participant details:** ECD Architects, Studio 3, Blue Lion Place, 237 Long Lane, SE1 4PU
- **Date report issued:** February 2013

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1. Project details and directory

Role	Organisation	Contact Details
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Landlord	Southern Housing Group	Fleet House, 59-61 Clerkenwell Road, London, EC1M 5LA Tel 020 7553 6413 Switchboard 08456 120 021 www.shgroup.org.uk
Architect	ECD Architects Ltd	Studio 3, Blue Lion Place, 237 Long Lane, SE14PU 020 79397500 www.ecda.co.uk
Engineer	Carter Clack	49 Romney Street, Westminster London, SW1P 3RF 0207 233 0303 mail@carterclack.co.uk
QS	Keegans	Studio 2, 193-197 Long Lane, London, SE1 4PD 0207 199 0900 www.thekeegansgroup.com
Main contractor	AD Construction Group	Jacob House, 2-4 Powerscroft Road Sidcup, Kent, DA14 5DT 020 8269 6377 Web: www.theadgroup.co.uk
Sub-contractor - heating	ICE Energy	
PV installer	Solar Technologies/ British Gas	Unit 29, Romsey Industrial Estate, Greatbridge Road, Romsey, Hampshire, SO51 0HR 01794 830154 www.solartechnologies.co.uk
Supplier - windows	Green Building Store	Heath House Mill, Heath House Lane, Golcar, Huddersfield, HD7 4JW 01484 461705 www.greenbuildingstore.co.uk
Supplier – external insulation	Rockwool	26-28 Hammersmith Grove, London, W6 7HA, 0845 241 2586 www.rockwool.co.uk
Heat recovery ventilation	EnviroVent	EnviroVent House, Hornbeam Business Park, Harrogate, HG2 8PA 01423810810

		www.envirovent.com
Intelligent heating controls and monitoring equipment	Wattbox Ltd	The Techno centre, Coventry University, Technology Park, Puma Way, Coventry, CV1 2TT www.wattbox.com

2. Introduction

TSB036 is a formerly 3-bedroom semi-detached house located in RG20, Berkshire, which is both owned and managed by Southern Housing Group. The property forms part of an estate built in the 1950s, largely comprising two-storey properties of masonry construction with facing brick elevations and tiled roofs.

The proposals sought to carry out a deep retrofit with tenants living in the property during the works retrofit. This approach demanded external upgrades where possible to minimise disruption, but the retrofit strategy would be further constrained by the need to ensure measures were acceptable to the planning authorities, given that they were to be carried out to only one of the semi-detached pair. Refurbishment work would also be extended to a former coal shed on the side of the property which had previously undergone a basic conversion for use as a bedroom.

The proposed retrofit solution was intended to address major comfort and affordability issues being experienced by the tenants. Mould growth, thermal discomfort and fuel poverty were identified as particular issues needing to be addressed along with the carbon reduction targets. Despite significant investment in the refurbishment of this property in recent years, it had not provided a sustainable solution - conventional comfort standards had become unaffordable for the tenants and living in the property was posing a risk to health in some rooms. Retrofit for the Future offered the opportunity to implement a radical whole house solution which would address these problems once and for all.

3. Occupants

The current tenants, had been living in the property for 14 years and have two children. The tenants worked part time and often from home. They remained living in the property throught the retrofit works. One of their children suffers from a health condition which requires an ordered and consistent home life, and would be particularly challenging for retrofit with residents in-situ.

The make-up of occupants before and after the retrofit:

Age band	Number before retrofit	Number after retrofit
Under 5 years	0	0
5-16 years	1	1
17-21 years	1	1
22-50 years	2	2
51-65 years		
Over 65 years		
Please state if (yes/no):	**Before retrofit**	**After retrofit**
Married couple / partners		
Couple / partners with children	Yes	Yes
Any disabled persons		

4. Dates

Event	Date
Project start date (when was the first proposal discussed or agreed)	01/05/2009
Planning application submitted (if appropriate)	23/04/2010
Planning permission granted (if appropriate)	01/07/2010
Building Regulations application submitted (if appropriate)	Under notice
Building Regulations approval granted (if appropriate)	
Contract for work let / signed	18/10/2010
Occupants moved out (state if they remained or property was empty)	Occupants remained
Start on site	18/10/2010
Completion of retrofit	18/05/2011
Occupants moved in	n/a
Monitoring system commissioned and operating properly	April 2011
Building defects corrected	June2011
Building services and controls operating correctly	June2011

5. Pre-retrofit property

The property is a two-storey semi-detached house featuring a tiled roof with rendered gable end and brick chimneys, with a single-storey flat-roofed side extension formerly used as a coal shed. The house type is typical of many suburban and rural locations in the UK. The front of the building faces broadly north-west, with the rear garden elevation facing south-west – the surrounding land comprises a small front garden, driveway leading to a prefabricated flat-roofed garage and a substantial garden backing onto the local school. The external walls are constructed from cavity-walled masonry capped with 'Finlock' concrete gutters, which bridge the two leafs. The external wall cavity had been filled with insulation prior to the current tenants occupying the property – site investigations confirmed a mineral wool fill. The roof structure comprises rafters on propped purlins and ridge beam built into load-bearing internal and external walls – a 'shoulder' in the roof section is created because the first floor ceiling level is higher than the external eaves. In contrast, the former coal bunker is constructed from solid brick masonry with a concrete flat roof and felt waterproofing.

The village, and therefore the dwellling, has no connection to the natural gas network. Originally, the house was heated by a coal-fired back boiler supplying radiators and a hot water cylinder. The tenant reported that this system kept the house 'warm and cosy'. Subsequently, the coal-fired back boiler was replaced by electric radiant panel heaters and the hot water cylinder was provided with an electric immersion heater, timed to use Economy 10. Other recent changes included the installation of uPVC double-glazing, 150mm glassfibre insulation to the loft space and upgrades to bathroom/kitchen fittings carried out as part of the 'Decent Homes Standard' works. Mechanical extract fans had been fitted in the bathroom and kitchen.

Subsequent to these 'improvements', the tenant reported that comfort standards were poor, electricity bills were high (£1087 for the winter qtr 08/09) and there was mould growth in all bedrooms. In the main house, the pattern of mould growth related to the 'Finlock' concrete gutters which created a significant cold bridge. An attempt to introduce an insulated skirt around the perimeter of the loft area has failed to remedy this problem. In the extension, sever mould growth was largely due to significant cold bridging in a room that was not originally intended for habitation.

6. Design

Our approach to energy saving and CO_2 reduction was to follow a lean-clean-green hierarchy: seeking to minimise heat losses from the property's thermal fabric and ventilation method; to supply residual space and water heating using replicable, low carbon technology; to minimise lighting and appliance energy loads; and finally to consider microgeneration using proven, renewable energy systems. Ambitious reductions in CO_2 emissions and primary energy use of 16 $kgCO_2/m^2/yr$ and 110 $kWh/m^2/yr$ respectively were calculated in the SAP 2005 Extension. Due to the constraints of retrofitting a semi-detached property with a fixed heat loss surface-to-floor area ratio, a heating demand of 57 $kWh/m^2/yr$ was predicted. The electrical demand was intended to be met in part by on-site power generation from a roof-mounted photovoltaic array on the garden side.

The package of measures employed to meet these targets included the following:

- Rockwool Rockshield over-cladding to all external walls,
- XPS external insulation below DPC,
- internal PUR insulation to sloped ceiling areas
- Rockprime top-up blown loft insulation,
- GBS Ecopassiv replacement windows and doors,
- Envirovent humidity-responsive heat recovery ventilation, coupled with a retrofit air tightness strategy,
- ICE Energy ground source heat pump and storage system, with radiator and hot water distribution,
- roof-mounted polycrystalline photovoltaic array
- Wattbox monitoring system,
- LED replacement lighting in the extension, and
- A+ rated appliances.

External wall insulation comprising 220mm of vapour permeable stone wool insulation finished with a silicone render coating improving the thermal fabric to give a U-value of 0.15 W/m^2K whilst allowing any moisture within the existing structure to migrate freely through the overcladding. The white render finish has precedent in the area and was acceptable to planners. Below DPC 180mm of XPS insulation was extended down to footings level. At ceiling level, Rockprime blown stonewool insulation was installed to a depth of 420mm to achieve a homogenous insulation layer that achieves a U-value of 0.1 W/m^2K. A replacement loft hatch and ladder were also included. 200mm PIR rigid insulation boards were added to the flat roof area and integrated with the external wall insulation. To combat the cold bridging problem from the Finlock gutters, internal insulation and dry lining was added to all sloped areas in the upper floor rooms. The solid concrete ground floor slab remained uninsulated as to do so was considered impractical.

A parge coat was added to the entire wall finish to improve the building's air tightness, with proprietary sealing tapes at window and door junctions. Inward-opening windows and doors were supplied by the Green Building Store from their Ecopassiv range, which combines ultra low U-values with 100% FSC Pure timber. The specification included a window Uw value of 0.75 W/m^2K and a glazing Ug value of 0.60 W/m^2K.

To provide adequate ventilation and remove excessive moisture, mechnaical ventilation with heat recovery was introduced. This was installed in the loft space in a purpose designed access deck above the new insulation. The EnergiVent Q system offered a number of

innovations: vapour tracking controls and inlet valves; intelligent, energy saving zone controls; DC motors; wireless remote user interface; 5 year filters, and a modular design allowing greater ease of installation. Ventilation in the downstairs WC was provided via a prototype single-room heat recovery ventilation unit called RetroVent.

Heating was provided by a ground source heat pump from ICE Energy – this had to be located outside the property in an insulated cabinet because of a lack of space inside the dwelling. The ground coupled collectors were arrayed under the rear garden. Hot water was distributed via a conventional radiator system, retrofitted to each room.

At roof level, eight 175 kWp PV panels were installed with the inverter mounted in the loft space, accessible from the deck., to provide electricity for the heatr pump and for general use.

In the single-storey extension all lighting was replaced with LED technology. In the kitchen, an A++ rated cooker and fridge/freezer were provided, requiring alterations to the kitchen layout.

Finally a Wattbox was installed to monitor performance from the property.

7. Construction

The project was procured under a single JCT Intermediate Building Contract between Southern Housing Group and Architectural Decorators Ltd. The contractor was selected from SHG's framework.

Architectural Decorators provided a dedicated site manager to the projects who supervised all site activities, ensuring that the works were carried out safely in accordance with activity-specific risk assessments and method statements. AD Ltd also employed a Resident Liaison Officer (RLO) to provide the main point of communication between the contracting team, the social landlord and tenant. Direct labour was used to undertake stripping out and demolition, groundworks, roofing, alterations to building fabric, installation of airtight tapes, dry lining, tiling, plumbing, fittings, electrical works and decoration. Materials and products were procured by AD Ltd from manufacturers and suppliers nominated by the architect.

Specialist contractors were employed by AD Ltd to install the following:

- external wall insulation (EWI)
- loft insulation
- external doors and windows
- GSHP central heating and plumbing
- photovoltaic panels
- mechanical ventilation with heat recovery
- intelligent building monitoring system

Regular monthly site meetings were held to record progress of the works and carry out inspections and valuations. These were chaired and minuted by the architect, attended by representatives of the social landlord, the RLO, the CDM Co-ordinator, the contractor's project manager and the site agent.

Prior to practical completion, snagging was undertaken by the architect, a representative of the social landlord and the tenant.

There were many lessons to be learned from this project, particularly relating to delays that caused practical completion to be delayed over three months. The works programme was based broadly on the following installation sequence:

- removal of extension gutters and window cills
- excavation of foundations
- GSHP collectors and radiators
- timber work (gable extensions, loft platform)
- GSHP unit and cylinder
- internal insulation and chimney fill
- MVHR and ductwork
- PV
- windows and doors
- parge coat and sealing tapes
- flat roof insulation
- external insulation

This sequence was designed to allow heating to be provided from the GSHP over the Christmas shut down and the air tightness test to be carried out once all the services penetrations had been formed, but before the external insulation was applied.

The first critical delay to the programme occurred because of a delay in delivery of the GSHP cabinet. With the commissioning date of the heating system due just before

Christmas, it was considered too great a risk that the tenants might be left without heating over the break so a new date was set for January 24th. Temporary portable gas heaters were provided. Unfortunately this date was also missed by the AD Ltd's plumbing subcontractor causing a further delay of a month in commissioning. The delay in the heating meant the existing hot water cylinder could not be removed which in turn meant the ventilation system could not be completed. The original loft hatch position had to be reconsidered to improve head heights, requiring a new penetration in the ceiling and patch plastering to the old. It proved too difficult to match the existing Artex pattern to the tenant's satisfaction, so a skim coat of plaster was applied. However, a combination of high humidity caused by the gas heaters and the lack of ventilation (due to an incomplete MVHR system and the newly air tight dwelling), caused all bedroom ceilings to fail, causing even further delays. The problem was removed once the GSHP and MVHR were finally commissioned and all bedrooms were over-boarded with plasterboard. This demonstrates the importance of sequencing retrofit works appropriately and highlights that delays in one aspect can lead to unforeseen complications in other areas.

Other delays contributed to the overall three month contract over-run as follows:

- lack of availability of extra-long insulation fixings for the 220mm EWI thickness
- delivery of a wrongly-dimensioned side door (200mm short) delayed the completion of the parge coat and air tightness test
- EWI subcontractor went into administration, leading to a delay whilst the replacement sub-contractor mobilised
- incorrect window cills were installed and had to be replaced prior to completion of the EWI
- incorrect specification of replacement soil to the rear garden after the GSHP installation required a delay and eventual substitution of topsoil and turf

It is fair to say that these delays added to the stressful situation experienced by the tenants during the retrofit. This created tension between the residents and the contractor's site team. Complaints listed included:

- slow progress on internal decorations
- poor communication on progress/delays
- missing AD Group site staff when the windows were delivered (meaning one of the residents helped to unload the units)
- excessive dust as a result of using incorrect dust sheets
- damage to vacuum cleaner and kettle after use by subcontractors
- noise transfer via the incomplete HRV system
- substandard lighting levels in the ground floor bedroom due to incorrect LED supply
- obtrusive pipework at the bed position in the ground floor bedroom

Where the tenant lives through a retrofit, attention to detail is very important so that inconvenience is minimised. Small details such as whether boxing out to cabling impeded the bed position in the ground floor bedroom had much more significance in the smooth-running of relations on site than would be the case for a family moving into a void property.

8. Commissioning and occupancy

Commissioning was carried out to the ground source heat pump and to the heat recovery ventilation system. The heat pump commissioning was carried out by a specialist team from the supplier/ installer, ICE Energy, in a single day without problem. However, the original commissioning date was postponed twice because of problems with the installation of the external insulated housing and the radiator pipework – each time the revised date was set several weeks hence due to heavy demands on the commissioning team.

Balancing the ventilation system was completed at the first attempt. Design alterations were carried out during the ductwork installation due to concerns over cross-talk between the ground floor bedroom and the living room. Minor problems occurred during the defects liability period due to faulty installation of the condensate pipework, which was easily rectified.

A home user guide was provided to the residents to aid understanding of how the changes affected their home. It is fair to say that the tenants were particularly interested in engaging with the retrofit measures and technologies. Living through the retrofit meant that they had a greater understanding of the changes to their property and paid attention to understanding appropriate use of the technologies installed.

9. Costs

Item Stage>	Design stage Materials and labour	Post-construction Material and labour	Comments
Management and administration	16,098.00 + VAT	16,098.00 + VAT	
Design			
Construction overall	111,947.78 + VAT	123,567.61 + VAT	
- Prelims	11,909.34	13,700.00	
- Fabric measures	48,273.10	60,239.55	
- Building services (conventional)	N/A		
- Low /zero carbon technologies	40,001.60	41,428.06	
- Consequential costs	N/A		
Occupant temporary housing	N/A	N/A	
Monitoring equipment	7,000.00	8,200.00	
Monitoring and reporting service	Incl.	Incl.	
R&D costs	N/A	N/A	
Contingency	4763.74	N/A	

10. Doing it again

1. Given the same funding opportunity, we would specify a broadly similar specification again. Most of the materials and components employed have proved to be robust and effective, if expensive. One area of improvement would be in the heat recovery ventilation component, where we would prefer a higher specification based on more in-depth knowledge of designing such systems.
2. Many of the problems arose because of small design issues that hadn't been fully resolved by the time the contract was commenced. A good example of this is the GSHP cabinet which had been assumed was a standard product offered by ICE Energy but was in fact a bespoke item supplied by another company. Planning the sequence of works is often crucial and having strict controls on site to achieve key deadlines can significantly reduce the risk of consequential delays.
3. The GSHP is a very expensive solution to providing small amounts of heat in a deep retrofit scenario. An alternative system based on ASHP may have been more appropriate. All components were generally considered to be expensive but this is most likely due to the one-off nature of the project and the need to import from the Continent.
4. Many of the programme problems arose because of small design issues that hadn't been fully resolved by the time the contract was commenced. A good example of this is the GSHP cabinet which had been assumed was a standard product offered by ICE Energy but was in fact a bespoke item supplied by another company. Other seemingly insignificant design decisions like leaving the loft hatch in its original position had significant knock-on implications. Better communication and a more effective approval process for subcontractor design/supply elements would improve the retrofit process – if we had been given an opportunity to review fabrication drawings for window and cills perhaps the delivery errors may not have occurred.
5. Planning the sequence of works is often crucial and having stricter controls on site to achieve key deadlines would have significantly reduced the risk of consequential delays. The site team were very remote from their normal area of operations and this isolation also contributed to chain-of-command errors being made on site. Given more experience of this type of work, we can foresee that Contractors' programming and supply chain control can get tighter, reducing the impact on tenants and social landlords. Whilst many low-carbon technologies or products are sourced from the Continent, the risk of substantial delay if there are mistakes in the delivery specification that have to be rectified.
6. Expertise in the commissioning of technologies such as heat recovery ventilation and heat pump technology is limited within the industry. More operatives skilled in such work are required if the industry is to scale up.

11. Business benefits

ECD continue to work in the retrofit sector, building on their experience from the R4tF projects. At least two small-scale retrofit opportunities have arisen directly from the R4tF projects. Approximately 50% of the practices' work load currently stems from this sector, including a number of large, hi-rise retrofit opportunities, equivalent to a turnover of around £3,000,000 over 5 years.