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: ZA611X
Property number: TSB032

Author:
Bolton at Home

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
Driving Innovation

SBRI
Government challenges.
Ideas from business.
Innovative solutions.

Final Report

Project information

- **ZA reference number:** ZA611X
- **Location of property:** BL4, Bolton
- **Lead participant details:** Bolton at Home, 1-3 The Courtyard, Calvin Street, Bolton.
- **Date report issued:** 4/11/11

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1. Project details and directory

Role	Organisation	Contact Details
Project Lead	Bolton at Home	Address: 1-3 The Courtyard, Calvin St, Bolton BL1 8PB Tel: 01204 335386 Email: Website: www.boltonathome.org.uk
HA	Bolton at Home	Address: 1-3 The Courtyard, Calvin St, Bolton BL1 8PB Tel: 01204 335386 Website: www.boltonathome.org.uk
Architect	Broadway Malyan	Address: Riverside House 2a Southwark Bridge Road London SE1 6DX Tel: 02072614200 Website: www.broadwaymalyan.com
QS Contractor	Wates Living Space	As below
QS Client	Bolton at Home	As above
Main contractor Wates Living Space	Wates Living Space	Address: Wates House, Station Approach, Leatherhead, Surry, KT22 7SW Tel: 01372 861000
Sub-contractor – electric	Aspect Plumbing & Heating LTD	32 Leeds Road, Knowsley Industrial Park, Liverpool, L33 7SE Tel: 0151 545 1888
Sub-contractor - heating	Aspect Plumbing & Heating LTD	32 Leeds Road, Knowsley Industrial Park, Liverpool, L33 7SE Tel: 0151 545 1888
PV installer	Aspect Plumbing & Heating LTD	32 Leeds Road, Knowsley Industrial Park, Liverpool, L33 7SE Tel: 0151 545 1888
Supplier - windows	Remploy Building Products	Bardsley .Oldham. OL8 3JB Tel:- 0161 627 3355
Internal wall insulation	M & H Joinery Ltd	Cotton House, Old Hall Street, Liverpool, L3 9TX Tel: 08707 542600

2. Introduction

This project intended to be a "tenure-neutral" whole house solution that could be applied to all semi-detached houses, particularly in an area of the UK that needs regeneration. The architects approached the social landlord, who they had worked with before, to enter the Retrofit for the Future competition; to see what the results of an extreme retrofit might be and to take from it some of the potential learning and techniques to apply to other properties owned by the social landlord.

1. Occupants

The occupants were new after the retrofit; the property was empty beforehand. After retrofit the property was advertised in the normal way, which did not outline the extent of the work completed so as not to attract tenants who were pro-energy saving. The chosen tenants had a child with a health problem that it was felt would benefit from this type of property.

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

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

2. Dates

Event	Date
Project start date (when was the first proposal discussed or agreed)	July 2009
Planning application submitted (if appropriate)	N/A
Planning permission granted (if appropriate)	N/A
Building Regulations application submitted (if appropriate)	N/A
Building Regulations approval granted (if appropriate)	N/A
Contract for work let / signed	Nov 2010
Occupants moved out (state if they remained or property was empty)	empty
Start on site	June 2010
Completion of retrofit	April 2011
Occupants moved in	June 2011
Monitoring system commissioned and operating properly	April 2011
Building defects corrected	April 2011
First Air Test	April 2010
Final Air Test	May 2011

3. Pre-retrofit property

The property is a semi-detached 1950s property with a masonry cavity wall that already had retrofitted insulation of the cavity, approx 50mm. The floor area is 95 m²; although we had no energy bills available we predicted that the property used 4412 kWh per year for electricity, and 15212 kWh per year of natural gas for heating and hot water. SAP modelling suggested that CO2 Emissions were 61 kg CO2/m² per year, with a primary energy requirement of 314 kWh/m² per year. The property was chosen as it was unoccupied and represents a house type that is prolific throughout the area.

4. Design

The original design for the property was based on retrofitting the entire envelope to a very good thermal performance (as exceeding u-values of 0.15W/m2K for opaque elements if possible), before combining a series of technologies, including a ground source heat pump that does not require a separate water tank, ventilating windows, mechanical ventilation with heat recovery and photovoltaics.

Energy demand would first be reduced through a mixture of experimental external insulation, internal superinsulation and low air permeability (3m3/m2.hr). The property would become “all-electric”, as opposed to the use of gas for heating (which should be minimal) and hot water. It was intended that this three-bedroom family property would occupy a family of five, including school children and “inactive” adults, who would be able to control the property’s technologies using a simple controller that also acted as data monitoring system.

After the property became unoccupied by the original tenants (who had decided to emigrate) we entered into more detailed site investigation. We discovered that there would be difficulties in using ground source heat as originally planned, due to the make-up of the ground; we were also disappointed to learn that our passive ventilation strategy, via the "ventilating windows" that use passive stack principles, was inadequate. Installers and suppliers told us that they were no longer confident that these windows performed as intended and we had to rethink how we would bring air leakage down to a very low level and provide adequate ventilation.

We therefore opted for standard Mechanical Ventilation with Heat Recovery (MVHR) that we hoped could be connected to an exhaust air heat pump. However, rough calculations showed that with the Coefficient of Performance that could be achieved by the air heat pump, as opposed to the original ground source design, we would not get close enough to our target levels of CO2 reduction. We also didn’t think we could make any greater demand reduction impact after using external insulation on the flank wall and internal insulation on the front, back and party walls to achieve u-values of 0.15W/m2K.

Further fabric works showed diminishing returns, both in terms of energy saving and money investment. We therefore opted for triple-glazed units without trickle ventilation and were left to consider how we could meet the heating and hot water demand without a heat pump and fairly limited (though quite typical) roof space for solar technologies. We decided to use photovoltaic-thermal (PV-T) panels combined with a heat pump as a hybrid solution. Although this technology has never been used before in this context we felt that it would be worth testing it to meet all of our heat and power needs, which had increased slightly due to the MVHR. We felt it was an innovative approach and one that could be truly replicable for properties that had limited ground space and simply needed more than a heat pump could provide.

Other elements of the retrofit remained as designed – we introduced a draught lobby, insulated the loft and suspended timber floors, heavily reduced thermal bridging and air leakage, and installed the controls and monitoring system.

5. Construction

- Procurement: negotiated with a framework partner
- Contract type: standard JCT
- Contract structure: main contract with direct labour covering most trades plus some sub-contractors
- Sub-contractors: One
- Specialist installers: engaged via a main contractor
- Specialist equipment suppliers: varied; procured by Broadway Malyan Architects
- Site supervision: site agent permanently on site.
- Role of architect/design team: The architect was retained to oversee construction and carry out any iterative modelling required for the decision making.

Lessons learned on site:

- Window and door lintels were cracked and needed replacing for air tightness.
- Living room floor joists had been installed the wrong way round and needed replacing so that new hardwood flooring could be fitted.
- The roof and batons needed replacing to withstand solar array loadings.
- The outhouse larder required insulating internally to stop thermal bridging. It also required an exterior roof and insulation to stop thermal bridging.
- The exterior air vents needed removing.
- All floor joist interface with inner wall needed insulating to ensure air tightness.
- All sockets, light and power, required insulating pads fitting to their back boxes to ensure air tightness.
- Increased window sills were needed to accommodate new windows fitted to out leaf of brick with added insulation to cavity.
- The ground source heat pump was not suitable because of the house being in a mining area, and was therefore changed to an air source heat pump.
- The inside larder wall had to be moved to accommodate loading of new boiler above.
- Plaster removed from internal walls revealed large cracks and defects.
- Bathroom shape was altered to accommodate the new boiler.
- Boxed in pipes going from the air source heat pump to the boiler in the upstairs bathroom condensed, causing damp, and therefore required lagging.
- The Thermalite block needed to be fitted to the outer ground leaf of brickwork to stop thermal bridging.

6. Commissioning and occupancy

Commissioning was undertaken of the air source heat pump and solar thermal panel electrics. They were found to be wired the wrong way round, so the solar gain wasn't credited on the meter; this was soon rectified.

The Wattbox has been problematical in that new software was needed.

Training was provided on the Wattbox controls, and setting the thermostat on the new boiler. The tenants needed instruction on how to drill fixings into the internal wall insulation, so as not compromising the air tightness. A copy of the tenants' user manual is attached.

7. Costs

Please find attached the Bill of Quantities, Appendix 1.

8. Wash-up meeting

A wash up meeting was held at the address with the project lead and the architect, August 2011.

9. Doing it again

1. **Definitely do again**
   Work as a genuine team to solve problems as the project went on. It would have been very difficult to achieve the air permeability targets we had set for ourselves without a co-ordinated effort.

2. **Definitely not do again**
   Rush some elements of the site work – for example, the capping to the external wall insulation at the front and back elevations is not aesthetically what was planned but was a result of not being able to extend the brickwork as designed due to the over-onerous labour input needed on site to tooth the bricks out.

3. **Reduction of costs**
   The PVT, whilst being cheaper and more space-effective than using both PV and solar thermal separately, needs to go down in price; this will hopefully happen with mass market penetration.

4. **Improvement of the design process**
   A lot of the survey work of the existing property was carried out by both the contractor team and social landlord, which sometimes gave different results. This slowed down the time on site and led to more rushed design decisions.

5. **Improvement of the construction process**
   More time to investigate and guarantee costs before the contract was put in place would have been useful.

6. **Improvement of the commissioning and occupancy process**
   More time to iron all the glitches out before occupancy.

Efficiency gains in a larger programme of retrofits

External insulation would be far more cost-effective, quicker and more efficient if many homes were insulated in a co-ordinated programme.

Replication at scale

Works would be much less expensive. The heating technology for example has to be equivalent in price to current gas systems.

Having engineers skilled in the interaction of other technology associated with their installation.

10. Business benefits

The design team gained a lot of experience in using a new technology, and having the chance to try out this innovation in the context of the TSB programme was key. Several other retrofit projects and dissemination opportunities have arisen as a result of the project.

The designers expect to continue this kind of work, particularly whole house retrofit, with the benefit of monitoring the post-occupancy data from this project.

11. Additional Information

Bolton at Home want to increase their knowledge of how tenants interact with the new technology used in this project; it is for this reason that a research project has been commissioned with Salford University. The project will study tenant behaviour over the project period, monitoring energy use and changes in behaviour.

Appendix 1

Bill of quantities

31/03/11 FINAL ACCOUNT					FORECAST FINAL ACCOUNT				APPLICATION
					Retrofit	Decent Homes		%	
Item	Work Element	Qty	Unit	Rate	Total			Complete	
1	PRELIMINARY WORKS/SUBSTRUCTURE								
	Strip & clean up incl removal of fitted wardrobes, pipe boxings, wall vents, cables, downspouts, tv aerials and the like				500.00			100%	500.00
	Full damp proof course	1	item	1,890.00	1,890.00			100%	1,890.00
	Insulation to ground floor; living room and hall	32	m2	55.00	1,760.00			100%	1,760.00
2	SUPERSTRUCTURE								
2C	Roof								
	Take off existing roof tiles & re-roof	1	item	0.00	0.00				0.00
	New PV roof tiles to south east elevation	0	item	0.00	0.00				0.00
	Supply and install PV panels in lieu of tiles	1	item	13,516.70	0.00				0.00
	Additional rafters to support pv panels				150.00			100%	150.00
	GRP & insulation to rear flat roofed canopy & under cloaking to exposed section of canopy	1	item	1,371.40	0.00				0.00
	Repoint chimney & replace pots	1	item	150.00	150.00			100%	150.00
	Insulation under rafters	95	m2	30.00	0.00				0.00
	Loft insulation	80	m2	8.50		680.00		100%	680.00
	New upvc soffits & fascias	1	item	678.00	678.00			100%	678.00
	Fire stopping to party wall	1	item	50.00	50.00			100%	50.00
	Scaffolding	1	item	850.00	850.00			100%	850.00
2E	External Walls								
	External insulated render to gable wall only	1	item	6,000.00	6,000.00			100%	6,000.00
	Internal insulation to all external walls except gable end	100	m2	48.50	4,850.00			100%	4,850.00
2F	Windows & External Doors								
	Windows - triple glazed Smart Sash System; supply & fit	1	item	6,856.63	6,856.63			100%	6,856.63
	Composite external doors (single); supply & fit	2	nr	695.00	1,390.00			100%	1,390.00
	Sliding door to form porch, double glazed toughened glass; supply & fit	1	item	990.00	990.00			100%	990.00
2G	Internal Walls								
	New window boards/cills	16	m	10.50	168.00			100%	168.00
	New curtain battens	16	m	4.50	72.00			100%	72.00

2H	**Internal Doors**								
	35mm interior quality white six panel colonial type doors c/w ironmongery	8	nr	75.00	600.00			100%	600.00
3	**INTERNAL FINISHES**								
3A	**Wall Finishes**								
	Skim to internally insulated walls	100	m2	4.00					0.00
	Patch plastering to walls & ceilings **(Provisional Sum)** to include work for rewire								0.00
	Decoration (blown vinyl + magnolia emulsion paint) to all walls , gloss to skirtings, window boards, architraves etc	1	item	1,750.00		1,750.00		100%	1,750.00
	Stripping existing wall paper	1	item	250.00		250.00		100%	250.00
	Ceramic tiling, white 150 x 150mm to kitchen & bathroom only	12	m2	35.00		420.00		100%	420.00
3B	**Floor Finishes**								
	Latex screed and dpm	80	m2	3.50		280.00		100%	280.00
	Vinyl	18	m2	24.50		441.00		100%	441.00
	Coir carpets/underlay	0	m2	0.00	0.00				0.00
	Skirtings	100	m	6.50	650.00			100%	650.00
3C	**Ceiling Finishes**								
	Decoration to ceilings; blown vinyl & white emulsion paint				0.00				0.00
4	**FITTINGS**								
	AAA rated washing machine Candy GOF4625S-80	1	nr	300.00	300.00			100%	300.00
	A rated fridge/freezer Proline TFP 120A	1	nr	150.00	150.00			100%	150.00
	Heat Storage Cooker				0.00				0.00
	Kitchen units, supply & fit	1	kitchen	1,100.00		1,100.00		100%	1,100.00
	Bathroom sanitary ware incl electric shower; supply and fit	1	item	1,381.01		1,381.01		100%	1,381.01
	Pipe boxings, sealant, noggins, patresses, sundries etc	1	item	150.00		150.00		100%	150.00
	Insulated access hatch to roof	1	nr	75.00	75.00			100%	75.00
	Make good cupboard in box bedroom & add in new shelves; incl painting	1	item	150.00	0.00				0.00
5	**SERVICES**								
5A	**Mechanical & Electrical Installations**								
	Full rewire, testing & commissioning, specialist electrical equipment etc	1	item	2,752.91	902.91	1,850.00		100%	2,752.91
	Supply and fit V Phase voltage optimiser	1	item	400.00	400.00			100%	400.00

	meter								
	Standard electric fire complete with surround	1	nr	350.00		0.00			0.00
	GSHP	0	nr	0.00	0.00				0.00
	NIBE/ mechanical ventilation incl additional boxing in	1	nr	19,981.06	0.00				0.00
	Internal plumbing & heating	1	item	4,928.26	4,546.31	381.95		100%	4,928.26
5C	**Builders Work in Connection**								
	Generally	1	item	250.00	250.00			100%	250.00
6	**REFURBISHMENT WORKS**								
	Knock down wall between toilet & bathroom to make into one room; incl m/g	1	item	150.00		150.00		100%	150.00
	Block up kitchen/dining room door; incl skim, decs etc	1	item	100.00		100.00		100%	100.00
	Form new door opening between living room and dining room	1	item	150.00		150.00		100%	150.00
	Demolish larder room in kitchen & block up window; incl skim, decs etc	1	item	250.00	250.00			100%	250.00
	Brick up external coal store door & form new internal opening from utility room	1	item	250.00	250.00			100%	250.00
	Brick up opening to side of newly formed porch (double skin brickwork, no internal finishes)	1	item	150.00	150.00			100%	150.00
	Form cupboard for cylinder in bathroom	1	item	150.00	150.00			100%	150.00
7	**EXTERNAL WORKS**								
7B	**Drainage**								
	Alterations to above ground drainage;				300.00			100%	300.00
	Replacement rainwaterpipes where necessary	1	item	200.00	200.00			100%	200.00
7C	**External Services**								
	Utilities detection survey	1	item	495.00	0.00				0.00
	Measured Works Total				**35,528.85**	**9,083.96**	**44,612.81**		**44,612.81**
	Variations				68,051.59				68,051.59
	Prelims				29,120.00		29,120.00	100%	29,120.00
	Sub-Total				**132,700.44**	**9,083.96**	**141,784.40**		**141,784.40**
	WLS Overheads & Fees			6%	7,962.03	545.04	8,507.06		8,507.06
	Gross Valuation (Excluding VAT)				**140,662.47**	**9,629.00**	**150,291.46**		**150,291.46**
	Less previous payments								86,899.56
	Nett Valuation (Excluding VAT)								**63,391.90**