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: ZA448M
Property number: TSB063

Author – Roland Hill Ltd

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Technology Strategy Board
Driving Innovation

SBRI
Government challenges.
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Innovative solutions.

Final Report

Project information

- **ZA reference number:** ZA448M
- **Location of property:** Cumbria, CA6
- **Lead participant details:** Roland Hill Ltd, Brayton Domain, Aspatria, Wigton, Cumbria, CA7 2BD
- **Date report issued:** August 2011

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1. Project details and directory

Role	Organisation	Contact Details
Lead Partner	Roland Hill Ltd	Address: Brayton Domain Aspatria Wigton Cumbria CA7 2BD Tel: 016973 20483 Website: www.rolandhills.co.uk
Housing Authority	Riverside Carlisle	Address: English Gate Plaza Carlisle Cumbria CA1 1RP Tel: 01228 882827 Website: www.riverside.org.uk
Architect / Engineer	Roland Hill Ltd	As above
QS	Roland Hill Ltd	As above
Main contractor Carried out directly the following activities ▪ building ▪ electrical ▪ heating inc solar ▪ plumbing ▪ all joinery ▪ roofing	Roland Hill Ltd	As above
PV installer	CBJ Electrical Ltd	Address: CBJ Electrical Services Warwick Mill Warwick Bridge Carlisle CA4 8RR Tel: 01228 564407 Website: www.cbjconsultants.co.uk

2. Introduction

The dwelling is located in a small market town just North of Carlisle. The whole of the town is off the natural gas national grid which means that fuel poverty can be a major problem with families in this area. Riverside Housing own a large number properties in the area and are looking for effective solutions to heating these properties long term.

The approach with the property has been a fabric first approach. The challenge therefore, for this project is to upgrade the existing fabric and achieve deep cuts of about 60% in CO_2 emissions by fabric measures first. We wanted to demonstrate that this approach was best carried out with internal insulation to the property using vacuum insulation panels. These should give excellent U-values in a reduced thickness compared to the use of traditional insulants. Again this was an aspiration because the adjoining property and its brick built nature. The proposed technologies for further reductions can also be easily scaled up and replicated in different areas of the region and the country.

By using the above approach with an off gas property it is hoped to produce a leading example of how these properties can be retrofitted.

3. Occupants

The property had the same tenants before and after the retrofit. They were decanted from the property whilst the retrofit was being carried out. They were housed in another property that is owned by Riverside during the duration. Whilst it was possible to house them nearby they could not be accommodated in the same area as where the project house is located. This caused the tenants some problems with logistics for work etc. In addition the temporary house did not have carpets and the tenants felt that the house was of a lower standard than the one they had left.

Please state 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	0	0
17-21 years	0	0
22-50 years	0	0
51-65 years	2	2
Over 65 years	0	0
Please state if (yes/no):	**Before retrofit**	**After retrofit**
Married couple / partners	Yes/~~No~~	Yes/~~No~~
Couple / partners with children	~~Yes~~/No	~~Yes~~/No
Any disabled persons	~~Yes~~/No	~~Yes~~/No

4. Dates

Event	Date
Project start date (when was the first proposal discussed or agreed)	13/4/10
Planning application submitted (if appropriate)	Not Required – permitted development
Planning permission granted (if appropriate)	Not Required
Building Regulations application submitted (if appropriate)	Not Required
Building Regulations approval granted (if appropriate)	Not Required
Contract for work let / signed	13/4/10
Occupants moved out (state if they remained or property was empty)	22/10/10
Start on site	23/10/10
Completion of retrofit	25/2/11
Occupants moved in	26/2/11
Monitoring system commissioned and operating properly	15/6/11
Building defects corrected	1/6/11
Building services and controls operating correctly	1/6/11

5. Pre-retrofit property

The property is a ‘typical’ early 1950s semi detached 2 bedroom end terraced house. The house has an approximate floor area of 65m^2 spread over the two floors. The property is brick built with a cavity, approx 50mm wide, which was insulated with mineral fibre in the late 1980s. Riverside have had a systematic campaign of filling all the cavities of the properties that they own. The roof of the property still had the original tiles. These were still assessed to be sound and were not upgraded.

The whole area is off the main gas grid. There are a number of houses owned by Riverside in the area. Therefore there was a desire to consider how in the future these off gas properties can be upgraded and the occupants kept from slipping into fuel poverty. The methods of heating the properties vary. Most, however, have either economy 7 storage heaters or are solid fuel heating. Properties with of either these two heating types were considered. A significant proportion of the properties in this area are two bedrooms therefore it was decided to try and concentrate on one of these. The final criterion for choice was ideally an end terrace property. Because there are three outside walls to these propertiesthey tend to be the harder properties to heat and / or cost more to run for the tenants.

The property was not monitored in any way before the retrofit took place and unfortunately there was no chance to look at past fuel bills etc. This was due to the tenants only having been in the property less than a year. In addition the electricity meter was pre-paid so they did not have past bills and the main heating fuel was coal, which was paid for with cash. This means there is no base to compare new results with. The property which was originally going to be used would also not give representative results if the fuel bills were compared. This property was electrically heating using Economy 7 storage heaters.

6. Design

Early in the process, after the contract award, the original property chosen had to be removed from the scheme. This was because the tenant in the house, at 75 years old, did not feel that they could go through the upheaval of moving out etc required for the project. After some weeks, the property that was finally retrofitted became available. This was on the same small estate as the original house. However the first house had a roof that pointed due south. On the new house the roof points just south of east / west. This meant that slight changes had to be made to the solar PV to make this effective for the poorer orientation. However the calculated reduction in the output was not thought to be significant enough to increase the size of the array fitted to the roof.

The basis of this design has always been a fabric first approach. The idea was to make the building envelope as efficient as possible before any heating elements and controls were added. Because the property was of brick construction and an end terrace it was felt that external insulation was not possible because of the 'step' that would result at the property junction and the distinct change in aesthetics of the building. Internal insulation was then looked at but many of the 'traditional' forms of insulation were prohibitive for use because of the amount of internal floor space that would be lost. The concept of vacuum insulation panels was chosen because of its exceptional thermal conductivity properties. This is a material that has been used very little in the UK but that has great potential. After searching for manufacturers, Vacupor Vacuum Insulation Panels were chosen as they were the only ones on the market in the UK with third party accreditation. To afford protection to the Vacupor panels a 40mm timber stud frame was placed in front of them. The stud then had plasterboard fixed over it and was skimmed, providing a service void for electrics etc to be run in. It also means that when new tenants move in, pictures and light shelving etc can be fitted without the insulation being compromised. Although this method did add to the thickness of the wall, for the U-value required this was still considerably less than for a PIR based solution. Vacupor was also to insulate the floor. The original concrete floor was removed, partly because it was found to have been covered with asbestos tiles, and vacupor was laid under the floor with a screed finish over it.

Heating in this property was provided by a new concept – driven primarily by an air source heat pump. A larger thermal store to hold water for the central heating in the house is housed in a 'pod' in the garden, separate to the building. This allowed the unit to be built off site and then delivered complete. On the roof of the 'pod' are solar thermal panels which are oriented directly to south. The heat pump then runs over night on cheap rate Economy 7 electricity to fill the store with hot water. The house then draws down from the store through the day to heat the house. This is not the most efficient way of running the heat pump from a carbon view point. However with the vastly reduced cost of the electricity it has been calculated that this will be the cheapest way of heating the house – thereby helping to reduce the problems of fuel poverty. The design originally consisted of an 8kW heat pump (capable of delivering water at 55 Deg C for the heating and 65 Deg C for the DHW). The DHW is stored in a 200 litre tank which was supplemented by solar thermal panels. The water was then to be delivered to the house on a closed loop. Within the house there was a small plate heat exchanger to deliver the water to the taps in the house. This meant there

were no problems with legionella as DHW was effectively delivered on demand. During the commissioning phase however it became apparent that the configuration of this layout was not ideal so the design was altered The original 1500 litre thermal store was replaced with a unit that was 1000 litres. At the same time the heating system was altered from being open vented to being an unvented system. On the DHW side there had been a problem where the plate heat exchanger meant that there was too much heat loss between the tank and the taps. This was compounded by the fact that the heat pump would only raise the DHW in the tank to just over 60 Deg C. As a result, the plate heat exchanger was removed and the supply of the hot water was changed from the heat pump to the immersion heater running overnight on Economy 7. At the time of writing this report the DHW side is working well. However the weather has meant that the heating side has not been fully tested.

In terms of energy saving designs there were a few minor areas that were altered. These are described below:

1. Portions of the bedrooms were within the slope of the main roof due to the height of the ceilings. The amount of insulation in this slope had to be reduced slightly from what was planned initially so in this area the target U-value was not met. This was because the thickness of the insulation required would have impinged on the internal window reveals in each of the bedrooms. The area of this part of the roof is approx 10% of the total roof area so it was felt that giving a more aesthetically pleasing feel within the property was preferable.
2. Originally it was assumed that the cavity wall insulation would be in a good state of installation but when the original windows were removed to be replaced with the triple glazed units it was found that quite a lot of the insulation had slumped or not been installed very well. This was left untouched As it was felt that the amount of work required to rectify this properly would have impacted on the programme too much to warrant the improvement.
3. Originally the exterior doors were to be proprietary insulated composite doors. However ‘good’ doors were on long lead times and did not have low u-values. Timber doors were developed that were filled with vacuum insulation panels that give a theoretical u-value well below 1.0 W/m^2K.

7. Construction

For the organisation of the contract from the TSB in this project, Roland Hill Ltd was the lead, designer and contractor. Therefore the approach to the procurement etc was not in a standard method or route.

- Procurement – It was always understood from the outset of the project, between the RSL and Roland Hill that Hill's would act as principle contractor and designer for the project.
- Contract type – Because the project was not being 'fronted' by the RSL they did not want to have a formal contract in place to cover the works. It was completed on a letter of understanding between the RSL and Roland Hill Ltd.
- Contract structure – One of the main benefits of this project is that Roland Hill directly employs all the trades used, with the exception of specialist installers – see below. The company is also registered under MCS for installation of solar thermal panels and air source heat pumps so this was also undertaken. Meetings were held between the RSL and Roland Hill Ltd.
- Subcontractors – the only specialist work that was subcontracted was the installation and commissioning of the solar PV panels. Weather conditions in January when the equipment was installed meant that more than one trip to the site was required by the subcontractor to install and commission. Their work was hampered by the extreme cold and snow on the roof.
- Specialist installers – The only specialist installer required was for the solar PV installation, to ensure that the system met the full criteria of the MCS accreditation. This company was directly employed and instructed by Roland Hill.
- Specialist equipment suppliers as below:
    - Vacuum Insulation Panels. This was procured by EnviroHomes Ltd directly from Porextherm and imported from Germany. On investigation this is the only VIP that could be found to be readily available with third party accreditation that would be accepted by the local building control. There are others available but these were either without accreditation or the support from the manufacturer was felt to be poor.. The application of the panels was so straightforward that the manufacturer did not need to visit the site for any specific training. The panels were protected by the inclusion of a 40mm timber stud in front of the panels. This allowed for services to be run and pictures etc to be hung to the wall without compromising the insualtion. The only place where this did not happen was up the stairs on the gable end of the property where the stairs were very narrow. Here Vacupor was adhered straight to the existing wall and plaster board then adhered to the Vacupor panels and then directly skimmed. This gave an exceptional U-value in approx 30mm. The compromise is that individual panels are at risk of puncture if, for example, pictures are hung in future years. The current tenants understand this and will not hang pictures – however it is a possible problem with future tenants.
    - Solar thermal panels. These were supplied from Sundwell Solar (manufactured in the UK). Roland Hill have used these in the past and found

them to be very reliable and excellent in their performance. With experience they appear to outperform other more common panels. These were fitted to the heating Pod that was positioned in the garden. There are a number of advantages to this –

  - They are fitted in the factory
  - There are no working at height issues
  - The pipe runs to the DHW tanks are exceptionally short.

- Site supervision – Site supervision was again by Roland Hill direct labour. Because of the closeness of the site to the head office of the company the supervision was carried out by visiting inspection – at least once a day.
- Role of design team – The design team and the contractor were the same company so the designers were retained on the project for its duration. Designers and engineers visited site at regular intervals – at least twice weekly – which ensured that work was interpreted and carried out as envisaged. It made sure that any installation issues could be discussed on site with the trades directly before work on that particular element had commenced. There was also close liaison with other suppliers, especially with EnviroHomes who supplied the Vacupor vacuum insulation panels. This close approach meant that the correct material was specified and ordered in the correct manner.

The programme for the work over ran from that originally predicted. This was due to two main factors

→ Scheduling of labour became a problem as Roland Hill won several contracts at the same time as mobilising this project. Because of the nature of this particular project it was felt that own labour rather than subcontract was preferable so there were some problems getting the correct trades when required. There is now a greater understanding around this type of full scale low carbon retrofit which means that in future projects it would possible to subcontract more of the work if required.

→ The weather during the end of the contract made working in the house difficult. At times temperatures during the day were as low as -10 Deg C, with no heating available. This meant that there were times when the site had to be closed or when output from those on site was affected by the conditions.

8. Commissioning and occupancy

Setting to work, testing and commissioning of the equipment went smoothly overall. There was an original plan to have all the commissioning carried out within approximately three days as a block. This was initially achieved and the tenants moved in. However it became apparent early on that there were problems with the thermal store principle of the heating system. In addition to equipment problems, which were finalised to be over capacity of the thermal store, there were problems for the tenants in understanding the technology. The concept of running the ASHP over night on Economy 7 was not understood– in fact it took 6 months from them moving back into the property for them to have the tariff at the property changed. Roland Hill had felt that they had understood the concept, however, looking back, this was not true. More time spent explaining this more radical heating system was required for the tenants' full understanding (maybe because they were used to a coal fired boiler and heating system). A knock on effect of this lack of understanding was that the tenants then started to try an 'improve' the system whilst we were not there. Settings on the ASHP were altered which in the end compounded the problems we were having with the equipment. Once this was realised, it informed the partial redesign of the system and the reduced size of the thermal store. The removal of the heat exchanger from the thermal store was also carried out to make the system simpler with fewer components to complicate the system.

Other than the issues with the heating system mentioned above, the re-occupancy was very straightforward. The tenants that occupy the house now were in the property before the retrofit and whilst the works were being carried out they were shown round the property on a number of occasions to have the design rationale and principles explained to them. During this time we took on board any specific comments they had and involved them as much as possible, for example paining the house in colours specified by the tenant. Before the tenant moved into the property a training / appreciation session of approx 2 hours was held with them. This went through the following systems:

1. ASHP heating concept and controls
2. Solar thermal Panels
3. Solar PV panels
4. Extraction Systems
5. Low Energy Lighting
6. Controls and monitoring system
7. Instrument positions and what they read
8. Limitations of any equipment or systems

Spending time with the tenant had benefits overall but it is felt that we had them involved in the retrofit at the house too early. During the time that the ground floor slab was removed, the floor boards were up for heating piping / re-wiring etc the house did not feel like their home any longer which meant that they were very dispirited with the whole process. This caused problems for a few weeks with their morale and subsequent visits to the house.

Immediately following this initial training the tenants moved in. For the first couple of weeks or so they were left to 'getting used to' the house and the equipment and control systems. Manuals and instructions etc of all the systems and controls had been left in the house. After this initial settling period a further 'top up' training session was carried out. This followed a

similar agenda to the first session carried out prior to the tenants moving in. It was during these follow up sessions that the problems with the heating system were identified.

So far the tenants in this property have fully embraced the house and all the systems within it. They are showing friends and family around the property on an impromptu basis and are proud to be involved in the whole process. Key to this has been the involvement they felt during the final stages of the retrofit and prior to them moving in. However his would be caveated by the fact that they were discouraged during the retrofit period because of the degree to which the house was dismantled. This has coloured what they have said to people as to whether they would recommend it to others.

9. Costs

Item Stage>	Design stage		Post-construction		See Numbered Notes Below
	Materials	Labour	Material	Labour	
Management and administration	N/A	5000	N/A	6945	(1)
Design	N/A	7000	N/A	6347	(2)
Construction overall					
- Prelims	2000	6000	2733	5768	(1)
- Fabric measures					
o Floor insulation	2085	3872	4173	2927	(3)
o Wall insulation	3123	6111	4067	6761	(4)
o Windows & Doors	7898	3020	3259	5983	(5)
o Roof	800	1395	712	1354	
- Building services (conventional)	8500	7000	9159	10361	(6)
- White Goods	4650	N/A	2494	N/A	(7)
- Low /zero carbon technologies					
o Thermal Store Heating	9000	9500	8765	10658	(8)
o Solar PV	N/A	6000	N/A	6276	(9)
- Other					
o Heat Recovery	2000	500	2274	635	
- Consequential costs					
o Decoration	N/A	N/A	812	1358	
o Modifications to Thermal Store Heating	N/A	N/A	2225	3548	(10)
Occupant temporary housing	N/A	4000	N/A	3687	
Monitoring equipment	12595	N/A	9357	N/A	
Monitoring and reporting service	N/A	15000	N/A	9547	(11)
R&D costs (please detail)					

Please note all costs above exclude VAT. This has been done because under HMRC rules there will be a mixture of 5 & 20% VAT. Excluding VAT here keeps them on a 'level playing field'.

(1) The project overran the original timescales for a number of reasons and this meant that the overall costs for this were over that originally budgeted.
(2) It was estimated there would be more work to do on designs after contract award than was required in reality.
(3) Costs for the insulation under the floor were more than budgeted. Also this cost includes for screed etc for reinstating the floor slab.
(4) The material costs for the insulation were a little more than budgeted. However there were extra costs here because of the timber stud work put over the insulation to afford it more protection. This had not been budgeted for in the original costs.
(5) Originally it was planned to buy the new triple glazed windows required for the project. However these were eventually made in-house. This accounted for the differences between the budgeted and actual labour and material splits. Extended delivery times quoted from the original manufacturers necessitated the final manufacture of the units within our own joinery shop. This was part of the reason the project overran on time.
(6) Changes in specification from the design period to the actual installation caused differences in the costs in this area.
(7) More cost competitive suppliers for the white goods were found after the phase 1 period.
(8) These are the costs for the new air source heat pump, thermal store heating system. As this was a format for ASHP the cost were greater then first estimated.
(9) This element was subcontracted. The reduction in cost was due to the falling cost of PV systems that has occurred over the months of the project
(10) The costs here were for modifications to the heating system external to the building following initial start up problems with the thermal store size.
(11) A PC sum for this portion of the project was originally included – actual costs were less than those estimated.

10. Doing it again

What would you definitely do, not do, or do differently if you were doing it again

1. Definitely do again – the use of the Vacupor Vacuum Insulation, in both the walls and floors was a big way to making the house very well insulated but without losing large amounts of internal floor area.
2. Definitely not do again – because of the orientation of the property the addition of the solar PV panels did not have the effect that might have been hoped for. Therefore they did not really give the return that would have been expected for the capital outlay.
3. Reduction of costs – in a house that was not particularly treated with air tightness membranes the benefit of the mechanical ventilation was marginal.
4. Improvement of the design process – the design process was not too problematic as the house was to be vacated for the construction phase of the project. If the tenant had been in residence at the time of the retrofit then a different approach to the whole of the work would have had to been taken. This may have resulted in some of the work not being carried out in this case due to the disruption involved to the tenants.
5. Improvement of the construction process – time was lost on site by not having everything to hand or not having definite delivery dates for equipment. This led to problems with scheduling labour and the construction period being extended longer than was intended. For fast turn rounds on construction, projects possibly should not be started until all the equipment and components were available.
6. Improvement of the commissioning and occupancy process – integration of the all the technologies together especially with the bespoke control and monitoring system was not perfect, especially with the later problems encountered with the thermal store size on the heating system. However it is felt that this would become more ‘slick’ the larger number of retrofits were carried out including all these technologies. In this particular property more attention to making sure the tenants really understood the equipment going into the house would have alleviated a considerable amount of the problems later encountered.

Significant efficiency gains could be made with the Vacupor vacuum insulation if a large number of similar properties could be tackled in one project. Here time was required to measure the house accurate to have the correct amount of panels delivered so there was no waste. With similar houses one could be measured and spot checks carried out on each of the other houses to check for regularity. All other areas would benefit from larger project sizes – all the renewables etc. In addition management costs per house would significantly reduce for larger projects as would all the other preliminaries.

Key to making larger projects run more efficiently would be close coordination between designers and the early involvement of the tenants. This would involve both overview and detailed briefing sessions and management of their expectations of the work to be carried out.

11. Business benefits

One of the main lessons learnt is how important it is to look at a whole project solution and how the integration of differing technologies can affect the final outcome. The time spent with tenants for training and familiarisation is another aspect of this. Time was spent with them, but arguably this should have been more. However it is felt unlikely that this time could be spent with every tenant if this was being rolled out over a larger number of properties. In addition the couple who occupy this house are very amenable and enthusiastic about the project, wanting it to work. In reality, unfortunately, not every tenant might be this enthusiastic.

Other lessons learnt are based around the Vacupor insulation - this would take considerably less time to fit than was estimated on this project as it was easier to fit than originally predicted.

The profile of Roland Hill Ltd, and evidence of its capabilities has been significantly raised through the project in the region in which it operates. EnviroHomes Ltd, the supplier of the Vacupor, has seen a significant up turn in the number of retrofit enquiries for its product which has led to increased sales of the product.

Roland Hill is forecasting to receive approx £10m of retrofit business over the next five years.
EnviroHomes is estimating an total increase in sales of approx 300% over the next five years this equating to a total in crease in sales of approx £6.5m