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: ZA028A
Property number: TSB010

Authors: RCT Homes & BRE

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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Final Report

Project information

- **ZA reference number:** ZA028A
- **Location of property:** Aberdare, Wales, CF44
- **Lead participant details:** RCT Homes Ltd
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- **Date report issued:** October 2011

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1. Project Directory

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Contractor		
Main contractor	Jistcourt (South Wales) Ltd	Jistcourt House, Seaway Parade, Port Talbot, SA12 7BR Tel: 01639 822200 Website: www.jistcourt.co.uk/index.php
Sub-Contractor – M&E	ETS Ltd	Tel: 01656 743436 Email: sales@electrotechnicalservices.co.uk
Sub-Consultant – Airtightness	Melin Energy	Tel: 01269 591160
Sub-Contractor - Timber	Vale Timber Frame UK Ltd	Tel: 01639 711472 Email: info@valetimberframe.com
Sub-Contractor - Steel	Tata Steel	Tel: 01495 724 321
Supplier - External Insulation	Brickshield	Tel: +44 (0) 845 2412586
Supplier - Windows & Doors	Solar Windows Ltd	Tel: 029 2085 8989 Email:info@solarwindows.co.uk

2. Introduction

This Retrofit for the Future project stemmed from existing relationships between RCT Homes, the BRE and the other design consultants through previous work to look at the existing properties on an estate of houses managed by RCT Homes. This work had been looking at both new build and refurbishment potential in the area to improve the housing quality for tenants.

The TSB "Retrofit for the Future" call therefore provided the opportunity to investigate the capacity to retain and enhance the existing housing stock in greater detail, and to a higher performance standard, than had previously been considered, and as such was agreed as being a call that should be pursued.

RCT Homes' goal for the project was to better understand the capacity of the Cornish Type 1 houses in their ownership to be refurbished and therefore to achieve a low carbon building. This goal would give them a better understanding of how this existing stock should be managed and enhanced going forward, which in turn helps RCT Homes to undertake long term asset management.

3. Executive Summary

The ZA028A project took an unoccupied system built Cornish Type 1 property and addressed the challenges of how to reduce the building's energy demand whilst bringing the building back into beneficial use. The focus of the refurbishment was on fabric improvements together with an innovative steel solar collector linked with an air source heat pump to provide heat and hot water.

The completed project achieved a 68.3% reduction in carbon emissions over the original building performance as measured using the SAP methodology. Notably, this makes no allowance of the performance of the steel solar collector, hence it is likely that the actual performance is in excess of this, and should equate to space heating bills of less than £10/month. 68.3% improvement represents an extremely high level of performance enhancement for any refurbishment, and is especially notable considering no electrical renewable energy generation equipment, and no 'mainstream' heat renewables, are installed in connection with this project.

Whilst a success in the performance achievements, the project has demonstrated that the extensive level of refurbishment required to achieve this significant fabric improvement would be financially unviable without considerable additional funding. The project therefore highlights it is unlikely that the Cornish Type 1 property can be economically refurbished to the levels of carbon reduction/energy performance that are considered necessary achieve the UK requirement of 80% carbon reduction by 2050.

4. Occupants

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

The property (TSB010) had been unoccupied prior to the refurbishment works being undertaken for a period of many months. This was the result of a tenant moving out, and once vacant, some vandalism to the property rendering it uninhabitable without refurbishment/repair. Consequently, the “Retrofit for the Future” property did not require any occupants to be moved out or to live around the refurbishment (the latter would have been practically impossible given the scope).

TSB010 therefore remained vacant throughout the planning and construction works associated with the delivery of the “Retrofit for the Future” project. Upon completion, new residents have been selected by RCT Homes.

Simultaneous with the refurbishment of the retrofit property, the neighbouring property was also refurbished as this forms the other half of the pair of semi-detached houses and it would have been visually unacceptable to the planning authority not to undertake this. Whilst not part of the project, the external envelope and internal fabric of this second property has had similar works undertaken to the “Retrofit for the Future” project. Prior to works, the second property had one occupant, an elderly resident who had lived there for many years. RCT Homes approached him and he agreed to relocate to an improved property elsewhere with RCT Homes’ portfolio, which occurred in August 2010. Upon completion, the second property was placed back into the RCT Homes portfolio of properties and subsequently a new tenant has been housed within the property.

5. Dates

Event	Date
Project start date	November 2009
Detailed Design development & drawings	November 2009 - February 2010
Detailed Cost Plan produced	March 2010
Project/Client company lead change of personnel	March 2010
Cost Cutting exercises & drive for sponsorship	April -August 2010
Lead designer company change	June 2010
Survey of Neighbours	July 2010
Planning application submitted	August 2010
Planning permission granted	September 2010
Bat Licence application submitted	November 2010
Bat Licence approval granted	January 2011
Building Regulations Notice application submitted	February 2011
Building Regulations Notice approval granted	March 2011
Contract for work let / signed	March 2011
Occupants moved out (state if they remained or property was empty)	Property was empty
Start on site	April 2011
Completion of retrofit	September 2011
Occupants moved in	October 2011
Monitoring system commissioned and operating properly	
Building defects corrected	Final Certificate due September 2012
Building services and controls operating correctly	Final Certificate due September 2012

The “Retrofit for the Future” project has been successfully delivered on site, although somewhat later than had originally been hoped. This is largely unrelated to the complexities of the technologies and processes intended in the scheme, but rather to more mundane difficulties that are commonplace risks to any construction project. The pre-construction delays can be summarised as:

- **Cost.** Once the detailed costing for the work was undertaken, the predicted project cost considerable exceeded the TSB and RCT Homes funding combined. There was therefore considerable effort and redesign required to maintain the project aims but reduce the overall project costs.

- **Personnel Changes.** The original project champion within RCT Homes left in March 2010, which delayed the normal process of the cost exercises. To a lesser extent, there was also a delay associated with the lead designer’s employment move from Gaunt Francis Architects to BRE, although RCT Homes’ decision to transfer the project as well minimised this issue.

- **Bats.** Once the scheme costs has been reduced, in some cases through free/cost issue pledges from suppliers, the planning application was submitted. As part of this, a bat survey was undertaken which identified previously undiscovered (and unexpected) bats dwelling in the house loft space. A more extensive survey and relocation measures were therefore required, which further delayed the project delivery.

6. Pre-retrofit property

TSB010 forms half of a pair of semi-detached Cornish Type 1 properties. The Cornish Type 1 house design was conceived by Beresford & Tonkin and typically manufactured by Central Cornwall Concrete & Artificial Stone Ltd between 1946 and the 1960's, although the precise date of construction for TSB010 is not known. The house type is designated as "defective" by the BRE's Non-traditional Houses book, as a result of horizontal and vertical cracking in the concrete columns and ring beams, together with high rates of carbonation and significant levels of chloride. The Cornish Type 1 construction was originally formed by precast reinforced concrete columns set approximately 3' apart, each formed with two vertical rebates or slots in their sides. Precast concrete panels were then slotted into the columns to form the external walls to ground floor, with a ring beam then formed to cap this construction. The first floor mansard was then constructed from timber framing and, typically, tiled.

TSB010 had undergone a previous refurbishment before being the subject of the "Retrofit for the Future" project, and it is believed this occurred in the 1990's. At this time, the external precast concrete panel from the original system was removed, the concrete foundation extended, and an external brick wall constructed to the underside of the ring beam, including 50mm of cavity insulation to the ground floor. It is likely that during these refurbishment works the original roof finish was replaced with the metal 'tile effect' sheet roofing that the property was found to have prior to the "Retrofit" project commencing. The 1990's refurbishment also replaced the original windows with uPVC, double glazed units in the original structural openings of the building envelope and probably upgraded the heating system - this is only presumed as they appear to have been stolen whilst the property was vacant.

The property fell vacant in the 2000s, and once empty suffered both vandalism and theft. As a result of being a damaged, vacant property, no pre-refurbishment meter readings are available for this particular property (note that similar properties on the estate could give some guide as to what these may have been should this work be commissioned). Visual inspections were undertaken as part of the design process, including photographs, which show the extremely poor state of repair of the property. These also demonstrate the extent and size of holes in the building fabric that would negate any chance of an airtight envelope.

The property was selected for the "Retrofit for the Future" project for several reasons, including the state of disrepair noted above that meant it required some investment from RCT Homes anyway. This consideration combined with the imperfect orientation of the building footprint; the team agreed early in discussions for the project that it would be unrepresentative to choose a "perfect south" property, and hence TSB010 gave an orientation that precluded any solutions being overly 'solar' reliant, and hence hard to replicate. The property is also in a prominent location within the estate, and would provide a positive local landmark once refurbished.

7. Initial Design

The Retrofit for the Future project was conceived as a highly insulated, air-sealed extensive refurbishment of the property, incorporating mechanical ventilation with heat recovery, an air source heat pump and high performance triple glazed windows. This original design concept included a number of unusual features:

Steel Solar Collector. From the inception of the project, Tata (ex Corus) Steel have been a project partner, with a view to demonstrating the use of their solar collector in a domestic setting. The Tata Solar Collector is essentially a perforated steel sheet, finished in a dark colour, with an enclosed air void behind it. When exposed to solar radiation, the steel heats up. Air is then drawn from the void behind the steel (and replaced through the perforations), and this air is pre-heated before entering the building. The Cwmbach design looked at the challenges of incorporating this solar collector into domestic buildings, both technically and architecturally. Although the precise technical layout was not known at the outset of the project, the concept design was always to use the pre-heated air in conjunction with an air source heat pump and mechanical ventilation & heat recovery system for the house.

Mansard Roof. The Cornish Type 1 properties are typified by a mansard roof design. From the earliest design concept, due to significant concerns about airtightness and thermal bridging details around this element, the proposals were to replace this first floor with a 'traditional' vertical wall & pitched roof construction. The design concept was therefore to form a new timber frame construction from first floor deck level, which was envisaged as Structural Insulated Panels (SIPs).

"Ringfence" Insulation. From the earliest stages, it was known that the refurbishment would not be able to improve the insulation of the ground floor slab; clearly below the slab was inaccessible, and above the slab the floor to ceiling for the ground floor restricted all but the most nominal insulation installations. The design team therefore proposed forming a "ringfence" of vertical insulation installed around the outer perimeter of the property down to a depth of 500-600mm. The intention, subsequently backed by thermal modelling, was to lengthen the heat loss path and thereby reduce heat losses through the ground floor slab.

Beyond these notable elements, the overall scheme was designed to fit and enhance with the surrounding neighbourhood. The ground floor external wall insulation was finished with brick slips throughout, with this terminating at first floor deck level. From first floor, metal cladding ran vertically as far as the relocated eaves & gutter detail (now at a more common second floor ceiling height), where matching coloured cladding was then used to provide a steel roof for the property. Internally, every effort was made to achieve the Welsh Government's Housing Quality Standards, and this was largely responsible for the conversion of the property from an undersized three bedroom house to a broadly compliant two bedroom property.

8. Design Development & Construction

The following chronicles the key events during the lead up to construction and the refurbishment of the property. Key items are highlighted, with ongoing changes and developments noted in between.

Design Team Appointments & Roles. As noted in “Dates” above, there was one personnel change at RCT Homes and a change of lead design company (to maintain the same lead designer) between the initial conception of the project and the start on site. Apart from the delaying effect, these changes did not change the scheme concept and hence are noted for completeness only.
Also worthy of note is that the design team appointments were based on a ‘standard’ scope, with the services only designed to a schematic layout for use by the contractor and subcontractors, which will be picked up later.

Concrete Retention. The original scheme design envisaged the retention of the post and ring beam concrete construction typical of the Cornish Type 1 property, despite its known “defective” status. This means that the property will not be suitable for mainstream mortgage products, but for RCT Homes this was not a concern (indeed it could be argued would be preferable). However, the Structural Engineer was unable to underwrite the loading of the new timber frame being installed from the first floor deck upwards using solely the original structure. To overcome this, the existing posts and ring beam were retained, but standard blockwork infill included between the posts and packed to the underside of the concrete ringbeam, effectively therefore providing a new load path to supplement the original posts and uniformly support the existing ring beam.

Procurement of Contractor. After the above design evolutions, a contractor was appointed. With consideration for the size of the contract, and based on prior experience of a number of contractors, RCT Homes choose to approach Jistcourt Construction directly and invite them to be the contractor for the scheme, on the basis that they were already on RCT Homes’ framework of possible contractors. RCT Homes had confidence that Jistcourt could deliver the scheme effectively, as well as being aware through other ongoing contracts the likely overheads and preliminary costs that would accrue. RCT Homes also took the view that Jistcourt would be keen to remain on the RCT Homes framework for future (larger) projects and therefore considered it unlikely that Jistcourt would be very far away from a competitive price. From this point of the design process, therefore, Jistcourt were on board as main contractor, and sub-contract packages were developed with prices being sought from the supply chain.

Timber Frame Package. Once the contractor was on board, one of their first tasks was to look at the sub-contractor packages, and most notably the new timber frame that would form the first floor and roof structure. Initially, some difficulties were experienced in getting responses for a small, bespoke project such as this from an industry that was largely busy, which resulted in some prices returned higher than expected. A review of the requirement for SIPs was undertaken, and the timber package relaxed to allow for both closed and open panel timber frame construction being acceptable (with insulation & membranes therefore to be site applied).

Cladding Colour. The original design used dark grey metal cladding to the first floor walls and roof. However, discussions during the planning process highlighted that the planning authority would not grant consent based on these colours, citing concerns over the match with the surrounding area. Following consideration of the need to retain a dark colour for the effectiveness of the Steel Solar Collector, a dark brown metal cladding colour was agreed, and the design amended to reflect this.

Bat Boxes. As a consequence of the planning process, a detailed bat survey that had been required revealed the presence of bats in the loft space. As a protected species, a specialist ecologist was bought into the team and proposed mitigation measures to allow the works to proceed once the bats had been removed, on the provision of permanent bat boxes within the final design. The design was therefore amended to include four bat boxes integrated into the first floor metal cladding, with a design that ensured they had minimum visual impact but would provide excellent environments for roosting bats. These design amendments were signed off by the planning authority and adopted into the design going forward.

Construction Contract. Having amended the design as necessary, the scheme then proceeded to a formal contract with Jistcourt (prior involvement had been delivered through a limited Letter of Intent). The contract selected was the preference of RCT Homes and Lee Wakemans, who had worked together successfully using this contract previously. It was also felt to be a more balanced division of risk between client and contractor, although noted as having a relatively high administrative burden.

Site Supervision. Prior to finalising the works on site, RCT Homes asked Jistcourt to appoint a specific Site Agent for this project based on previous experience and their confidence in him to deliver the project. Once this was determined, the Site Agent attended some of the design meetings and was able to understand the importance of achieving performance targets such as airtightness.

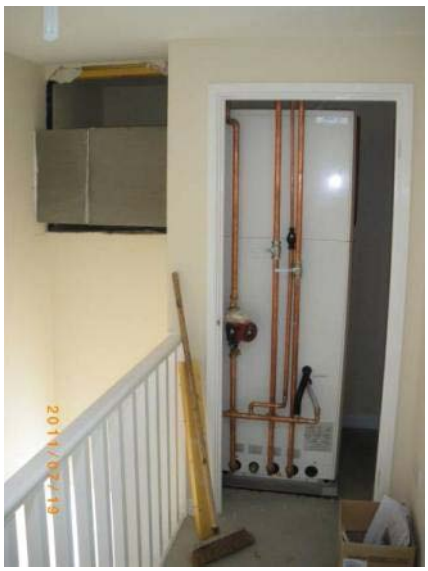
Airtightness Measures. A key target from the outset of the project was to achieve an airtightness of $1m^2/h/m^3$ or better, which formed an important part of achieving the energy target. The Site Agent was aware of the need for this and the design included the use of an Intellio airtightness membrane and sealing tape. Once the building envelope had been formed, the Site Agent programmed several days

within the building where he thoroughly sealed the envelope, whilst work progressed externally with the remainder of the construction. In retrospect, this attention to airtightness was invaluable and certainly contributed to the achieved airtightness performance.

Brick Slip Amendments & Render Colour. The original project specified brick slips to the ground floor. However, Jistcourt raised legitimate concerns over the brick slip spacing around the window openings, none of which were sized to brick dimensions. There was concern that this could cause an excessive number of cut bricks and an untidy finish. After a number of design options were considered, including vertical stack bonded brick slips, RCT Homes felt the preferred solution was to incorporate a render band at window height, which therefore removed the majority of the coordination issues between opening sizes and brick dimensions. This changed required a reversion to the Planning Authority, who accepted this after some negotiation and on the basis of a brick-coloured render band to be visually 'lost' within the brick slips.

Subsequent to this, no acceptable match for the brick slip colour render could be found that was of an appropriate type for the installation. A further discussion and sign-off ensued about the changed colour of the proposed render band that resulted in some site delays due to coordination and agreement of colours with the Local Authority.

Landscaping Works Incorporated. Mid-way through the site works, RCT Homes took the view that the previously excluded landscaping works should be undertaken through the contract. A concept landscape plan was therefore produced and integrated into the works, and a revised programme agreed.



MVHR & Air Source Heat Pump. The original design had selected and specified a Dimplex air source heat pump and heat recovery unit. This remained key to the design delivery as few other units could be found that provided the same function, performance and physical component size. This lack of choice did cause challenges during construction, including a requirement from Dimplex that one of their certified sub-contractors should be used for the installation (at a higher cost than the prior sub-contractor price). When on site, the installation itself did not accord with the schematic design, with the unit installed at right angles to its intended position as no consideration for a "right hand" or "left hand" unit had been made, as well as changes to the connections to the Steel Solar Collector and the studwork boxing formed above the staircase. These amendments also included a new door from the front bedroom having to be installed in order to allow reasonable service access to the Dimplex unit. This unit therefore proved problematic during the site works, partly as a result of the

commission for a schematic services design appointment that (in turn) meant the precise installation details were left to the sub-contractor and not planned in detail beforehand.

Ring Fence Insulation. Immediately prior to the landscaping works, and after the 'above DPC' building envelope was completed, Jistcourt excavated the perimeter in order to install the "ring fence" of below ground insulation. This was envisaged at concept stage as a vertical continuation of the external wall insulation lengthening the heat path. Upon excavation, it was discovered that the foundations had been extended further than expected (and further than the trial holes showed). This would require considerable cutting back to allow the insulation to be installed vertically, hence the detail was amended to allow an offset, forming a short width of horizontal insulation across the top of the existing foundation before returning this down as originally designed.

Following on from the detailed design amendment for the below ground insulation, the works on site proceeded without any further amendments. The revised completion date, incorporating the landscaping works, was achieved as anticipated, allowing for commissioning and hand over to RCT Homes.

9. Commissioning and Occupancy

Below is an extract from RCT Homes' newsletter about the occupation of the house:

Originally built in the 1940's, the house had been empty since May 2002 and was in state of disrepair when RCT Homes chose it to receive the green overhaul using grant funding from TSB Technology Strategy Board, a Government funded agency. This work was more than simply a makeover. The process of 'retrofitting' involves making significant structural changes to an existing property to bring it up to modern standards. Completed by RCT Homes' contractors Jistcourt over nine months, the work included more than half of the original building being taken down which included removing all of the internal walls and first floor, before it was rebuilt to exacting environmental standards.

As part of the rebuild, innovative technologies were installed in the home which include an air source heat pump, which transforms energy from solar radiation gathered by the specialist wall panelling into warm air, and to heat water for radiators and domestic use ; the walls, floors and roof were insulated to a very high specification; and triple glazed argon filled windows throughout the property to help maximise energy efficiency in the home. Additional features include a high efficiency light transmitting skylight on the upstairs landing to minimise the need for electric lights.

All of these additions mean that the building is now virtually air tight and the SAP rating has dramatically improved. SAP ratings provide a simple means of reliably estimating the energy efficiency performance of dwellings, the energy efficiency rating of the property is 83 which equates to much lower running costs, and also has a CO2 rating of 84 making the property at Cwmbach extremely environmentally friendly.

The residents moved into their new home after their application to transfer from a one- bedroom flat was successful.

They explain, "The space in the house is great and we have never had a garden before – my boyfriend is already planning to build a park! It does feel different to a normal house – it is much warmer and, because of the triple glazing, it is so much quieter."

As part of the process of letting out this 'green home' all applicants needed to outline how they would be committed to maximising the green potential of this home. "We understand the importance of recycling and do our best to recycle wherever we can. We also don't touch any of the boiler or temperature controls as we know that the heating will know when it needs to come on."

The RCT Homes Project Manager, says, "Renovating this house into an energy efficient home which is cheap to run and utilises all the latest technology, was a test of our expertise and available technologies given the state it was in just 12 months ago. The end result is a modern home that will allow the family to live comfortably with technologies that should also reduce their fuel bills. We knew this was going to be a big challenge as we were working with a lot of technology – however to go back and see how well the residents have adjusted to the new home makes it all worth it."

10. Costs

Item Stage>	Design stage		Post-construction		Comments
	Materials	Labour	Material	Labour	
Management and administration					
Design	-	£19,820	-	£19,820	
Construction overall	£48,690	£85,772	£51,009	£92,330	
- Prelims	£6,954	£,39,405	£7,788	£44,134	Extended contract period due to Client changes, including external works.
- Fabric measures	£26,111	£39,166	£27,596	£40,995	Consequential improvements resulted in slight increases to labour and materials.
- Building services (conventional)	£1,744	£1,165	£1,744	£1,165	A significant amount of materials were contributed to the project at discounted rates from the supply chain.
- Low /zero carbon technologies	£11,431	£6,036	£11,431	£6,036	Including solar wall and air source heat pump.
- Consequential costs	-	-	-	-	
Occupant temporary housing	-	-	-	-	Property was previously unoccupied.
Monitoring equipment	£2,450		£2,450		EST monitoring costs.
Monitoring and reporting service	-	-	-	-	RCT Homes to monitor post contract.
R&D costs (please detail)	-	-	-	-	Included within design fees.

Note the above cost table relates to the retrofit property only and is intended to identify the costs associated with the “Retrofit for the Future” refurbishment.

11. Wash-up meeting

A wash-up meeting was not held, but individual team members were interviewed by telephone and the results of this have been included in this report.

12. Doing it again / Lessons Learnt

The overarching lesson learnt from the project is that achieving this level of carbon reduction on a Cornish Type 1 property is likely to be more costly than demolition and construction of a new house on the same plot. Without significant financial motivation to proceed on a refurbishment route, RCT Homes will not be undertaking refurbishments of Cornish Type 1 houses to this level of performance. However, the individual ideas and approaches used collectively in the Retrofit for the Future project can be disaggregated, and have been reviewed below.

Lesson - Occupant issues aside, some properties would be better to redeveloped than refurbished.

Key Personnel Appointments. Delays in the project prior to site occurred due to changes in client and lead designer roles; it would be preferable to avoid these changes in future projects.

Lesson - Maintain continuity of Project Team.

Scope of Design Services. Problems with the installation of the whole house ventilation system can be traced back, at least in part, to the M&E Consultant's appointment only relating to schematic design rather than full design of the system. In retrospect, given the complex nature of the installation, the limited 'room for manoeuvre' within a house and the importance of a high performance and good quality outcome, engaging the services engineer to provide an accurate full design (at least for this key MVHR system) may have avoided the issues on site and helped with the coordination challenges in the building.

Lesson - Engage Services Engineer for full design of key M&E elements.

Cost Developments & Reductions. Time was lost with the project due to cost cutting as the original scheme estimate was higher than the available budget from RCT Homes and TSB. Whilst this was overcome, some of these savings were achieved after the appointment of the contractor. It is felt that the early appointment of the contractor therefore added value to the delivery of the project, and would be repeated (possibly even earlier).

Lesson - Appoint Contractor as early as possible.

Procurement of Contractor. The procurement of the contractor (direct invitation to a particular contractor within an existing RCT Homes framework) led to a successful outcome and allowed input in the process during the detailed design stage.

Lesson - Open book working with Contractor can deliver benefits on overall project cost.

Steel Solar Collector. The solar collector is installed and consideration is currently being given for monitoring to establish its performance. It is difficult without these results to identify the success of the component, other than to observe that, architecturally, it has a lower impact than other renewable solar collectors when designed as an integrated part of the elevational treatments.

Lesson - Steel Solar Collector definitely worthy of further consideration when integrated into cladding design.

Air Source Heat Pump & MVHR. The installation of the Dimplex unit caused challenges during both the design and construction stages., This was due in part to the lack of alternative options on the market, as well as to a lack of detailed design information. Earlier and more detailed engagement with Dimplex may have reduced this problem, especially if alternative products were also available (accepted this may not always be possible).
Lesson - Thoroughly coordinate key equipment between supplier technical team, design team and contractor.

Bats & Bat Boxes. The discovery of bats in the building led to the development and installation of new bat boxes, which are a new design integrated behind the first floor cladding. A bat licence was required for these works, which caused delays to the project. Undertaking the more detailed bat survey earlier in the design development would have enabled a faster route through the statutory requirements and led to site faster.
Lesson - Undertake site ecological surveys earlier in the design process.

Site Management & High Airtightness. Much of the successful delivery of the Retrofit project can be traced back to the Site Agent, who understood the especially high demands of the project and was able to attend some of the design discussions prior to the start on site. Armed with this understanding of the design rationale, the Site Agent was then able to monitor (and in some cases personally deliver) the key building details during construction.
Lesson - Appoint a good Site Agent as early as possible and ensure they understand the design rationale.

Ringfence Insulation. The below ground installation of insulation was hampered by the unexpected foundation beyond the building perimeter. A more detailed site investigation may have demonstrated this, and hence allowed more design time to produce an alternative solution, or omit the detail. As a principle, the ring fence insulation appears to work based on the thermal modelling. Unfortunately no post-occupancy monitoring of this particular element is proposed, hence this cannot be demonstrated from the finished build.
Lesson - Undertake more extensive site investigations for concealed elements.
Lesson - Consider 'ring fence' insulation in future, but include for post-completion monitoring of the detail.

External Insulation & Brick Slips. The issue of brick slip dimensions and window sizes remains a challenge for external wall insulation, given even existing openings that are a brick dimension are unlikely to remain so after the insulation has been installed. Detailed consideration for how the brick slips are set out around the window openings should therefore be considered as soon as the brick finish is proposed and, should no acceptable detail be identified for this, then brick slip finishes should be avoided.
Lesson - Avoid brick slips unless an acceptable detail to accommodate non-brick dim. openings can be agreed.

13. Business benefits

RCT Homes. Although financially there have been few benefits, RCT Homes is still proud to have completed such a challenging project which demonstrates many new technologies. The main benefits to RCT Homes include enhancing our reputation to tenants and other parties - the properties have generated great interest and have been viewed by parties ranging from representatives of the Welsh Government to delegates from the European social housing sector. This has served to raise RCT Homes' profile.

The project has also demonstrated new ways of working in partnership with a diverse range of consultants, contractors and suppliers all ultimately focussed on completing the project and achieving the original design brief, as well as some exceptional achievements by the main contractor - which include a steadfast determination to reach an air-tightness of 1 or less! This level of collaboration has demonstrated useful benefits for future schemes. RCT Homes have also acquired a great deal of knowledge from the project, in particular modern methods of retrofitting non-traditional housing, which has future business benefits. The project has also allowed supply chain development - RCT Homes now has knowledge of suppliers who can provide specialist technology, equipment and materials beyond the traditional supply chain appropriate to social housing.

Jistcourt (South Wales) Ltd. The benefits to ourselves include significant gains in experience: we are now able to project and market ourselves as having a practical working knowledge of low carbon and sustainable technologies. We also now use the completed project as an example of our build quality, and have an understanding of how to achieve a very high level of air tightness within the building envelope. We have also extended our knowledge of applying practically and efficiently the unfamiliar technologies required. The project also enabled an enhanced level of co-operation, with constant contact between Employer, Designer and ourselves, we were able to co-ordinate with a high degree of efficiency the constantly evolving scheme requirements, via the unfamiliar specialist supply chain members, to deliver a successful outcome. All of these improvements provide us with business benefits derived from the scheme that will assist us in marketing and delivering future low carbon refurbishment projects, a sector we envisage will grow in future.

Tata Steel. Tata’s involvement in the project from the outset has delivered a number of business benefits. These include the demonstration of a potential application of a steel based transpired solar collector in conjunction with an air source heat pump and thermal storage. This is a novel application in the UK and this practical example will contribute further information to the potential inclusion of air source heat pumps into the Renewable Heat Incentive, and possibly even enable the inclusion of steel transpired solar collectors. The project has also been a beneficial vehicle to demonstrate the aesthetically pleasingly refurbishment of a residential building using steel based products: This is a significant new potential market for Tata products and this project provides supporting material and images to help access this. Initial access to this market is likely to be through Registered Social Landlords, and this project also provided business benefits through the experience of working alongside RCT Homes and hence allowed an understanding of the priorities and requirements for this type of client. Lastly, an ongoing monitoring project is being considered to capture further data from the steel transpired collector that will provide an evidential basis for the potential creation of a new renewable product for the domestic market based on this technology.

Lee Wakemans. The project has enabled Lee Wakemans Ltd to develop a database of cost information based upon market tested prices to enable us to prepare more accurate cost plans and estimates for similar projects. Alongside this, the experience of working on the project has assisted in developing Lee Wakemans' understanding of sustainable construction methods within the residential sector, putting us in a good position to bid for work of a similar nature with other Housing Associations, enabling us to expand our client base. Lastly, the marketing of the project by RCT Homes has helped to promote Lee Wakemans and the services which we provide.

BRE. As the Building Research Establishment, BRE is at the forefront of developments in construction and especially around delivering low carbon. In order to maintain this position, BRE undertakes a continual engagement with cutting-edge projects by providing assistance, directly undertaking or monitoring the work. This project forms a part of this ongoing process and provides valuable, practical experience of the challenges of low carbon refurbishment. Maintaining this level of expertise and the company's position at the forefront of the construction industry is therefore the primary business benefit for BRE. Secondarily, as a direct result of the work on this project, a further project has been commissioned from BRE by RCT Homes to apply the lessons learnt in a cost effective fashion to a further 60 Cornish Type I properties.

Smith Ecology Ltd. This project moved away from traditional building design and yet bats still had to be accommodated. The fact that we were able to provide a good solution enhances our reputation in this field. Furthermore, the nature of the project meant that it was necessary for us to learn about the constraints of modern high energy efficiency building design, especially the need for an airtight envelope and non-traditional cladding and take this all into account in finding a solution for the bats. This experience of designing a new bat roost module that could be fitted into the building without compromise to energy efficiency should prove useful on future projects. Post development monitoring of the bat roosts is yet to be carried out and the degree of success that we find will inform future developments in this area.