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: ZA019L
Property number: TSB077, TSB078

Author:
Gentoo Sunderland

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:

Technology Strategy Board
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Final Report

Project information

- **ZA reference number:** ZA019L
- **Location of property:** Tyne & Wear, NE37
- **Lead participant details:** Gentoo Sunderland, Akeler House, Doxford Park, Sunderland, SR3 3XR
- **Date report issued:** January 2012

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1. Project details and directory

Project Partners & Participants:

Role	Organisation	Contact Details
Point of contact		
Project Management	Gentoo Sunderland	Address: Akeler House, Doxford Park, Sunderland SR3 3XR Tel: 0191 525 5000 Website: www.gentoogroup.com
Property Owner		
Client/Property Owner	Gentoo Sunderland	Address: Skyline Centre, Houghton le Spring Tel: 0191 525 5000 Website: www.gentoogroup.com
Design Team		
Architect / Certified Passivhaus Designers	Devereux Architects	Address: Devereux Architects, Milburn House, Dean Street, Newcastle upon Tyne NE1 1LF Tel: 0191 233 2950 Website: devereuxarchitects.com
Engineer	Alan Clarke, Services	Tel: 01594 563 356
QS	Gentoo Sunderland	Address: Akeler House, Doxford Park, Sunderland SR3 3XR Tel: 0191 525 5000 Website: www.gentoogroup.com

Contractor		
Main contractor (includes direct labour for all packages other than subcontractors listed below)	Gentoo Construction	Address: Akeler House, Doxford Park, Sunderland SR3 3XR Tel: 0191 525 5000 Email: Website: www.gentoogroup.com
Roofing Sub-contractor	John Flowers Roofing	Address: 2 Monument Park, Pattison Ind Estate, Washington, Tyne & Wear NE38 8QU Tel: 0191 418 6888 Email: info@johnflowers.co.uk Website: www.johnflowers.co.uk
Insulated Render	EAGA/Carillion Energy Services	Address: Unit 4, Whitehouse Business Park, Peterlee, Durham SR8 2RT Tel: 0191 288 9940 Website: http://insulation.carillionenergy.com
Windows/Doors	Warmseal	Address: Westway Ind Park, Throckley, Newcastle upon Tyne NE15 9HW Tel: 0800 321 7011Website: www.warmseal.co.uk
MVHR Commissioning	Green Building Store	Address: Heath House Mill, Heath House Lane, Golcar, Huddersfield HD7 4JW9HW Tel: 01484 461 705 Email: info@greenbuildingstore.co.uk Website: www.greenbuildingstore.co.uk
Scaffolding (including design)	ISL	Address: Interlink Scaffolding Ltd, Hownsgill Park, Consett, County Durham, DH8 7NU Tel: 01207 593 829 Email: isl@interlinkscaffoldingltd.co.uk Website: www.islscaffolding.co.uk
Air Testing & Installation of monitoring equipment	Apex Acoustics	Address: Design Works, William Street, Gateshead NE10 3JP Tel: 0191 423 6372 Email: info@apexacoustics.co.uk Website: www.apexacoustics.co.uk
External Works	Anwen Construction	Address: Eldon Road, Aycliffe Ind Park, Newton Aycliffe, County

		Durham, DL5 6UL Tel: 01325 321 000

2. Introduction

Gentoo is well aware of the UK Government's commitment to reduce CO_2 emissions by 80% by 2050. As an RSL with a stock of over 29,000 homes, Gentoo is also aware of the contribution it can make to achieving this target as housing amounts for 27% of all CO_2 emissions. Gentoo had already embarked on a number of low carbon housing developments covering new build as well as refurbishment when the TSB Retrofit for the Future competition was launched in 2008.

The Retrofit Reality competition to kick start the retrofit market via innovative whole house refurbishment solutions struck a real chord with Gentoo who saw it as a means of learning lessons which could benefit its own wider stock refurbishment plans into the future. At that time, Gentoo had commissioned a team to deliver a large scale new build Passivhaus development in the north-east and so used the team to apply the same principles to housing refurbishment.

Gentoo's proposals involved a comprehensive range of measures such as low energy lighting, solar thermal, energy saving appliances, a new heating system incorporating mechanical ventilation via an MHVR unit with 80% efficient heat resourcing and water saving measures. In conjunction with this, a comprehensive consultation and education process with the customer was created to make sure they were committed to the project. The customers actively participated in the project before, during and after the retrofit works to maximise the learning to be gained. Energy consumption is measured over a 2 year period via remote data collection.

The summary of the original (design stage) aims and objectives are as follows (for each of the two properties involved):

House	**Space Heating Demand Kwh/M^{2}yr**	**Whole Home Primary Energy Demand Kwh/M^{2}yr**	**Overall Carbon Emissions Kwh/M^{2}yr**	**Calculate Reduction %**
TSB077 and TSB078 (78m^2 per property)	50	107	21.8	78.2

The above targets gave a rise to a number of sub-objectives including:

1. Demonstrating that the concept is replicable: it was considered desirable to ensure that customers could remain within their home whilst the retrofit is being undertaken thus

avoiding as much as possible any additional costs and disturbance associated with decanting.

2. Ensuring that the retrofit should not unduly compromise the space standards, or indeed the quality of life, provided by the existing building.
3. Building upon the knowledge of the existing team by retrofitting the building using super insulation techniques.
4. Maintaining continued support from the Local Planning and Building Control Officers.
5. Ensuring that the technologies to be employed are (a) simple, (b) proven, (c) require little or no maintenance, (d) can be cost effectively maintained when maintenance is required and (e) make as few demands of the building occupants as possible (thus increasing acceptance by the occupant).
6. Ensuring that the technologies to be employed have potential for additional benefits such as: (a) improving indoor air quality and indoor humidity, (b) improving stability of energy costs, whereby occupants are less exposed to rising fuel bills, (c) helping to improve health and wellbeing, (d) helping to improve acoustic comfort as well as thermal comfort and (e) helping to reduce fuel poverty.

3. Occupants

TSB077

Two adults in their 50s, and their 2 nephews (aged 31 and 30) living in. The customer also has pets. The couple have lived in the property since 1994. They were decanted to a nearby property during works, with the majority of belongings going into storage.

TSB078

The tenant is in her 20s and lives alone. The property was void before and during retrofit, with the tenant taking occupancy in November 2011.

4. Dates

Event	Date
Project start date (when was the first proposal discussed or agreed)	June 2009
Planning application submitted (if appropriate)	5th February 2010
Planning permission granted (if appropriate)	31st March 2010
Building Regulations application submitted (if appropriate)	22nd April 2010
Building Regulations approval granted (if appropriate)	6th May 2010
Contract for work let / signed	February 2010
Occupants moved out (state if they remained or property was empty)	TSB077 – 23rd April 2010/TSB078 remained Void
Start on site	7th June 2010
Completion of retrofit (Internally 12 October 2010)	*11th March 2011
Occupants moved in	TSB077 – 14th March 2011/TSB078 – 28th November 2011
Monitoring system commissioned and operating properly	5th April 2010
Building defects corrected	11th March 2011
Building services and controls operating correctly	11th March 2011
Practical Completion Certificate issue	*12th October 2010

*The internals were completed on 12 October 2010. Due to excessively low temperatures commencing at the end of October 2010, the external render coat could not be applied and the associated external paving completed. Scaffolding had to be dismantled and re-erected over Christmas. The render could not commence again until the end of February 2011.

5. Pre-retrofit property

Gentoo selected 3 differing property construction types for each project to test the effects of retro fitting measures in each scenario and to provide a sample of the different property types within Gentoo's 29,000 housing stock. For this project Gentoo chose:

TSB077/TSB078: This house type of traditional cavity wall construction was built in 1960. There are 20,000 of this house type or very close derivatives of this within Gentoo's existing stock. Because these homes use cavity wall construction, the fundamental concepts underlying the proposed retrofit could easily be applied to a large proportion of the 16 million cavity wall homes that exist in the UK. The design approach of an external thermal envelope means that it could also be applied to other house types both traditional and non-traditional and so could be applicable to a vast proportion of the UK's social housing stock.

Property selection was based on the following criteria:

- Pair of semi-detached homes
- Representative of a large proportion of Gentoo's stock
- Owned by Gentoo
- Customers suitable for participation
- Customers willing to participate
- No adjacent owner occupiers where possible
- Suitable orientation for Solar Thermal
- Different area of city than other retrofit projects
- Configuration of properties and adjacent properties suitable for work to be carried out

A detailed desktop study was carried out to select the most appropriate properties, in consultation with the local housing management staff.

It was decided to select a traditional property which was due to have internal modernisation works carried out in the near future, so as to have the retrofitting works carried out at the same time to minimise disruption and reduce preliminaries costs. This led to the selection of a particular housing estate. Properties were then analysed for roof slope and orientation suitable for solar panel installations.

Energy consumption records prior to Retrofit - the customers signed a formal agreement to allow access to previous, current and future utility bills. Each property had air tightness tests carried out prior to retrofit and each property had pre-retrofit energy consumption bills recorded by Apex Acoustics, the company employed to carry out the monitoring. Pre- retrofit energy consumption will be compared to post-retrofit energy consumption over the 2 year monitoring period. The results will be used for the final PHPP calculation to determine the actual carbon saving percentage.

6. Design

Design Intent

The design development process assessed the social housing stock and developed a holistic 'whole house' approach to the design. This integrated approach sought to optimise the entire system so as to achieve multiple benefits, rather than addressing isolated components for singular benefits. Critical to the design process has been a cohesive interdisciplinary design team and early engagement with the building contractor. This holistic design approach together with the integrated design team and early involvement of the contractor was able to achieve the overall CO_2 reduction required by this competition.

Technical Summary

The principles and techniques are outlined below:

1. Super insulation 270mm thick – the standards of insulation proposed generally go far beyond those of the current UK Building Regulations. The only limits being lifecycle costs and site restraints.
2. Thermal bridge minimisation and reduction – poorly designed construction details can result in high levels of thermal bridging. Thermal bridging poses specific challenges when undertaking low energy refurbishment projects. If this issue is not addressed adequately then poor surface temperatures can result, leading to elevated risk of condensation and undesirable heat loss.
3. As a result of determining that it is undesirable to decant tenants, and owing to the fact that new kitchens had been installed, the design and construction team sought to reduce heat loss from the existing floor by employing an innovative perimeter 'skirt detail'. The detail minimises heat loss and serves to minimise the risk of condensation.
4. Excellent air tightness (design to target <1 ach/hr@50pa) – the strategy for achieving excellent air tightness was based upon the concept of encapsulating the existing building with a new external air barrier. This served to reduce the number of awkward junctions and interfaces whilst allowing easy access by the construction team. This approach sought to minimise disruption to building occupants.
5. Hygienic ventilation (0.3-0.4 ach/hr) – had been provided by mechanical supply and extract, thus avoiding the uncertainties that arise from natural ventilation whilst seeking excellent indoor air quality.
6. Heat recovery – the provision of the ventilation system enabled heat recovery to be incorporated so as to reduce ventilation heat losses and, through helping to prevent draughts, improve thermal comfort.
7. Window technology – the intention had been to utilise triple glazing. However, the supplier that had been engaged during the early stages of the project proved unable to offer the products within the budget that they had stated (the cost doubled). This led the team to seek a supplier that could offer products within the limited budget; unfortunately the thermal performance of the component was also reduced, i.e. the design moved from triple to double glazing. It is interesting to note that in this case the proportional impact upon the energy balance was limited. The reasons for this were found to be i) the heat loss via the ground floor accounts for a large proportion

of the total heat loss, ii) with regard to solar gains versus losses, the fact that the glazed area of the south facade was larger than other elevations assisted with the energy balance, iii) the g-value, and thus the solar gains, improved whilst the u-value increased; as a consequence the available solar gains served to offset some of the increased losses.

8. Efficient household appliances and lighting – these were selected to reduce primary energy demand and to reduce the cooling load that arises during the summer months.
9. Water efficiency measures – introduced to reduce hot water demand. Low flow showers and taps are amongst the measures that should be implemented. Reference has been made to the AECB Water Standards in an effort to ensure that the reduced flow rates remain realistic and practical.
10. Owing to the suitability of the buildings orientation, solar thermal hot water with a super insulated hot water tank was specified to reduce primary energy consumption. The water efficiency measures serve to improve the solar fraction of usable energy.
11. Passivhaus Planning Package (PHPP) – used to assess energy performance and overheating risk.
12. Consideration was given as to how minimise and prevent thermal bypass mechanisms. Additional attention was given to the installation of insulation, party wall bypass, wind-washing and convective looping. This aspect of retrofit is not currently considered within Building Regulations.
13. The architects developed a quality assurance system that was incorporated onto the detailed drawings so as to assist the contractor during the construction process. They also undertook regular site inspections and prepared site reports that highlighted the successes, challenges and lessons learned.

<u>Challenges Summary</u>

1. Site constraints impacted upon what could be achieved. This included the need to maintain usable alleyways linking between the front and rear of the houses. To allow access via wheelchair and/or wheelie bin, it was determined that the narrowest acceptable dimension was 750mm between face of building and party fence. This limited the extent to which homes could be thermally upgraded.
2. Accessibility, canopies and external services – retrofitting the existing building externally meant that ramps, steps, canopies, rainwater pipes and other service risers imposed specific challenges. If these particular details are not addressed then significant heal loss can result. Whilst this incurs capital costs, the benefits from reducing thermal bridging are significant.
3. Integration of the cylinder for the Solar Thermal and the MVHR system required the creation of new space within the property. This introduced costs and complexity that could potentially have been avoided in larger properties.
4. Air tightness – the particular challenge was identified at roof level where the complexity of the existing structure, services, penetrations and interfaces meant that it would be difficult to improve the standard of air tightness. To reduce complexity, the air barrier was formed by taking a reinforced membrane over the top of the existing roof structure. This was then bonded to the external parging that forms the air barrier externally.
5. Risk of cross-contamination from boiler flue to mechanical ventilation considered in

detail. We referred to Dutch standards as there was no detailed UK guidance; these are now adopted into an EN standard. The solution adopted in these properties was to locate boilers in a familiar location in the kitchen and the MVHR in the loft, ensuring good separation of terminals.

6. Use of gas cooking in house with air permeability standard precluding any open vents. Checks against relevant British Standards indicated that the room sizes were deemed sufficient to provide combustion air for cooking. MVHR will provide a good level of ventilation while running, and all kitchens were provided with open-able windows for times when MVHR is not running.
7. Managing the energy modelling in PHPP was complicated with the need to re-analyse for total primary energy and carbon emissions for each specification alteration, e.g. to windows, or individual choice of white goods.

7. Construction

Organisation and management of the project:

Procurement

The management of this contract has been carried out by Gentoo Construction's own directly employed site management with a mixture of Gentoo Construction's own operatives and subcontractors. A tender was put together by Gentoo Construction using labour rates tendered material prices and subcontractor's prices and preliminary items including overheads and profit to arrive at a Contract Sum. The first Contract Sum was well in excess of the budget which required a value engineering exercise targeting windows, external doors, roof and programming to get the project within budget.

Contract Type & Structure

The work was let under the JCT05 With Quantities Contract. Gentoo Construction were Principal Contactor utilising the specialist experience of their direct labour to achieve air tightness, the new roof structure including beams and Mechanical and Electrical works, which were an integral part of the ethos behind the project. Certain trades were subcontracted as follows:

Subcontractors

Subcontractors were employed for five trades which were:

- External Insulated Render – Eaga
- Windows & External Doors – Warmseal
- Roof Coverings – John Flowers
- External Works – Reinstatement – Anwen Construction
- Scaffolding – ISL

Specialist Installers

- 270 thick external insulated render – Eaga
- Air tightness barrier – Gentoo Construction
- Taping – Eaga

- Taping Training – Green Building Store
- MVHR Unit commissioning – Alan Clark and Green Building Store
- Air tightness measuring – Apex Acoustics
- Monitoring equipment – Apex Acoustics

Specialist Installers and Equipment Suppliers

The external insulated render system was supplied by PermaRock. The MVHR system, although installed by the Main Contractor's direct labour, was commissioned by the Green Building Store. Air Testing and the installation of monitoring equipment were carried out by Apex Acoustics, a company specialising in these areas, who were able to provide valuable advice throughout the process. The initial proposed window and door specification necessitated a specialist supplier. A Value Engineering exercise on this element concluded that the additional cost of the windows and doors at the initial specification was not justified by the improved performance and that the CO_2 emission reduction targets could potentially be achieved with a lower specification. A reduced specification window was then sourced and fitted by a mainstream supplier, aided by air tightness training and coaching from the design team.

Specialist Equipment Suppliers

- MVHR Units – Vortex
- Solar Thermal Panels – Veridian
- Air tightness tape – Green Building Store

Site Supervision

Gentoo Construction engaged one of its own Project Managers (Site Agent) for the scheme. In addition to this, Gentoo Construction employed a Building Surveyor to administer the contract and to deal with issues regarding the existing properties and adjacent owner occupiers. The Design Architect provided a Clerk of Works service and visited the site regularly and produced Site Visit Reports with Actions and Photographic record.

The Project Manager (Site Agent) kept both a video and photographic diary of the scheme. The Project Manager (Site Agent) also maintained close contact with the occupiers and a liaison service was also provided by housing staff from the local area office who provided daily visits and assisted the occupier in completing a daily diary.

Role of Architect/Design Team

The Architect, Devereux Architects and the Engineer, Alan Clarke designed the scheme to Passivhaus principles. They were also employed to oversee the project on site, provided a Clerk of Works service and produced Site Visit Reports that highlighted the successes, challenges and lessons learned). The design team were also responsible for commissioning, snagging prior to handover and will be engaged to provide snagging after the defects liability period.

Lessons Learnt

A Wash-up meeting for this project was held shortly after the works were completed with members of the Property Owner's Team (Housing Management from Gentoo Sunderland), Design Team (Devereux Architects) and the Contractor (Gentoo Construction). The wash-

up meeting was to discuss the project in general with particular emphasis on the lessons learnt. The following conclusions were arrived at:

1) Property Selection/Customer Issues

- Housing Management could have been involved earlier to bring greater benefits in the following areas
  - the property selection
  - local issues affecting properties
  - informing Customers what they will go through and what they will get in the end
  - choosing suitable customers to participate
- Full Health & Safety assessments need to be carried out, to make sure that issues such as disability, presence of young children etc. are fully appreciated
- Locate suitable pair of properties including issues like ease of access, suitable construction, suitable orientation
  for solar thermal
- Customer's willingness to participate – comprehensive briefing given covering all aspects of the works and related issues
- Customer's circumstances can change, e.g. illness or pregnancy. Flexibility required in Management and property choice
- Adjacent Private Owners- Full Briefing, consultation needs to be carried out early. Possible Party Wall Act implications need to be built into programme. Scaffolding impinging on Private Owners' land needs to be considered.
- Customer turnover – properties naturally become void
- Customers need to be well supported throughout the process – a lot of work going on with customer in-situ. A detailed briefing with all facts needs to be carried out at the start of the process.
- Restricted access needs to be taken into account (due to scaffolding and thick insulation), e.g. access for bins
- Maintenance need to be involved earlier in the process. The Asset Management database should be notified early that these are not ordinary properties.

2) Design Stage

- Accurate physical survey of properties carried out at an early stage, e.g. distance from gable wall to boundary requires exact measurements to ensure that required clearance is there to install thickness of external wall insulation, render finish and scaffold and still allow minimal access.
- Full structural survey required
- Introduce main subcontractors into early design process to establish the requisite quality standards with regards to achieving air tightness. Discussions should include the condition of the existing walls to take the insulated external render:
  - How flat are the walls? Are the existing walls sufficiently flat/smooth such that the EWI system will achieve intimate contact with the wall surfaces, thereby optimising conditions for achieving minimal air leakage (thermal bypass) behind the insulation?
  - If the walls are not sufficiently flat, can they be levelled? If yes, how, and what cost (materials, labour, timescale, etc)?

- If walls are not flat and levelling is carried out, what impact will this have on other building elements, such as soffits and fascias, window/door openings etc?

- Roof design – insulated roof structure with I beams chosen in order to utilise loft space for MVHR kit. This was expensive and involved a crane to lift the I beams. Removing the roof caused weatherproofing and security issues. Consideration should be given to insulating the loft and moving the MVHR units elsewhere
- External Render – overall thickness of up to 300mm means that gullies and drains had to be relocated
- Render thickness gives problems to scaffolding design & access
- Design solution to prevent cold bridging at ground floor meant extending render to top of foundation and proved expensive. Trench required meant hard dig and restricted access – reducing depth of boot insulations would reduce cost
- Initially the design team designed and specified all the elements in order to achieve the target of reducing carbon emissions by 80%. Various Value Engineering Exercises were carried out on most elements. The best example of this is the window and external door specification. A triple glazed window was initially specified with dramatically low whole window 'U' Values. Confusion from the supplier over the exact requirements led to a substantial price increase between initial budget costings and firm quotes. Further investigations revealed that there was a vastly diminished return in terms of carbon reduction on very highly specified and highly expensive windows compared to the 'A' rated windows from a mainstream supplier which were used on the finished project. It was found that one of the key issues around achieving air tightness was around the windows, which was achieved through the use of proprietary tapes and sealers under supervision from the Architect.

3) Pre Construction

- Programming – careful estimation is needed of the complexity of the project and learning time required to achieve air tightness etc. All three Gentoo TSB projects were programmed to run concurrently managed by a single Project Manager. However, this was changed to consecutive programmes to allow for a learning curve, the Project Manager to run one project (two properties) at one time and to allow for a single, thoroughly trained squad of operatives to be used. Need to build into the Phase 1 programme enough time to pilot a pair of properties that are empty. Need also to look at time of year work is carried out – especially with removal of roof and insulation and render work in low temperatures.
- Suppliers – general feeling is some of the suppliers have cornered the market with this specialist type of work and have put on a cost premium to reflect this. Need to consider more traditional suppliers who may wish to enter this market as well as those specialist suppliers
- Briefing – a more thorough briefing is required for all staff and subcontractors to reinforce that this is no ordinary scheme and strict tolerances need to be achieved in order to achieve the air tightness. Any additional training required should be carried out prior to the start of the scheme in order to prevent delays in sourcing training when needed. The Passivhaus model requires much closer attention to issues such as air tightness, continuity of thermal insulation, etc., than is usually achieved on more 'routine' projects. Having the site operatives 'buy in' to these concepts is

beneficial in terms of ensuring that some of the installation problems that were encountered on site are quickly overcome.

- Training – arranged and carried out prior to construction phase. Special consideration in the requirements to achieve air tightness – parge render coat, heat cutting of insulation with no open joints, taping etc.
- Security – needs to be carefully considered. Roof needs to be carefully programmed in to be on and off in a day. Although done on this scheme, potential weather problems need to be allowed for.

4) Construction Phase

- Site Supervision – constantly required by contractor or consultant due to complexity of scheme and tolerances required to achieve air tightness. This time needs to be built into programme as well as a more accurate understanding of the timescales from the preferred installers prior to formulating the programme.
- Structural Survey – full intrusive survey must take place during design stage and prior to construction. This needs to point out deficiencies in the existing structure such as voids, unevenness of existing roof structure and unevenness of existing walls. All of these problems lead to difficulties in achieving air tightness.
- Air tightness – general difficulty of educating and getting operatives and subcontractors to work to achieve the tight tolerances required to achieve required air tightness. As previously stated training before the start of the scheme. Also difficulties with existing buildings – out of square, gaps etc.
- External Insulation – thorough briefing for operatives required and general buy in from management, prior to commencing construction. This needs to take account of practice of subcontractors for moving operatives around. Contract Clause should be inserted to prevent operatives being moved once trained. Tight supervision is required to ensure heat and not saw cutting of insulation is carried out, gaps are to a minimum and the correct gap sealer and tape is used, especially around corners and openings. Also need to protect parge coat from rain and ensure parge coat achieves a continuous air tight barrier.
- Windows – an experienced local window supplier struggled to cope with the complexity of the schemes and the air tightness requirements, despite a thorough briefing and pre-order in-depth subcontractor interview. Window subcontractor was familiar with requirements but appears to have had limited experience of this type of work. Despite providing a sample with special condensation holes that did not detract from achieving air tightness, a standard window with special seals was produced which required additional time to seal and the standard condensation holes and additional taping.
- Site Management – imperative continuity maintained.
- Roof Insulation – cutting needs to take allowance for dimensional tolerance of roof structure. Also needs to be carefully cut against I beams. This issue is obviously specific to site conditions and the proposed design solution
- Window Openings – further out of square than anticipated, window design needs to take account of this
- Render Boot Trench – time taken to hand dig needs to be accurately assessed
- MVHR Unit – should be properly commissioned by a specialist before being used
- Duct Work & Grilles – need protection. Full drawing layouts should also be provided

as more specialist than normal.

- Pro-clima Tape cannot be applied in damp conditions
- Parge coat required to be completely smooth to take account of air tightness
- Communication of design approaches: for example, electricians need to receive the full design information to enable existing radiator systems to run at reduced temperature to suit high insulation levels.
- It became apparent that wiring standard plumbing controls have evolved into a fairly failsafe routine, e.g. dual thermostats on hot water cylinders are pre-wired so there is only one way to connect them up. New controls were added
- Pipe insulation is familiar to installers, but quality of installation has not generally been a high priority on domestic projects. Here, pipe heat loss was a known factor in the energy consumption, and required addressing properly, but there was difficulty in getting installers to take a more serious approach to installation – strong briefing on quality and tolerance requirements is necessary.
- Insulation of intake and exhaust ducts with vapour tight insulation is necessary to avoid condensation and to meet the energy standard as determined by PHPP. The best materials currently available in the market were hard to work with and it was difficult to get an adequate result. Although this job historically falls to mechanical installers, in the end it proved that carpenters were better equipped for the cutting & jointing required. In the long run, we hope to see alternative approaches to dealing with this issue, preferably by the use of ductwork actually fabricated from suitable insulation material
- Commissioning – on-site set up of non-standard technologies was very beneficial as it brought in expert supervision and picked up installation faults that may otherwise have gone unnoticed. Maintaining a regime of commissioning should be considered for all such projects, though of course the expertise could be brought in-house with suitable training.

5) Generally

- Housing Management (as Property Owner) need to be brought in at the initial design stages
- Consideration needs to be given to decanting customers due to amount of work being carried out to their homes
- A great deal of time and effort had to be put into managing and achieving the desired standard of quality assurance. This highlights the fact that the industry lacks the appropriate skills for achieving retrofits. Luckily, the contractor was motivated and determined to succeed. As a consequence, this served to foreshorten the skills development process; had this not been the case then the challenge would have been far greater
- Time needs to be allowed for training
- Corrective Thermal bypass risk: Party wall risks had been designed out to as great a degree as possible. The remaining risk related to workmanship. Despite attempts at awareness building, it proved difficult to address all aspects. A major part of this problem arose from the discontinuity of subcontract labour and the subsequent loss of acquired skills and knowledge. This particularly applied to the subcontractor responsible for installing the external insulation. Research identified by the design team suggests that a 2mm gap behind the insulation adds over 12% of the thermal

transmission, a 7.5mm gap increases heat loss by over 20% and a 15mm gap increases heat loss by over 52%. Constant site supervision and stringent QA procedures are essential to prevent this.

- Supply Chain Issue – At initial Bid Stage, prospective suppliers and their costs need to be carefully vetted as replacement at a later stage in the process can cause severe delays.

8. Commissioning and occupancy

Both of the properties in ZA019L were empty during the Retrofit works, one void and one decanted. Had they both been occupied, daily visits would have occurred, both from the site team and a tenant liaison officer from the local area office to provide support for the occupier whilst the Retrofit works were taking place. The occupier would have kept a daily diary of their experience of living through the Retrofit works, assisted by the Tenant Liaison Officer.

Customers had initial discussions with Gentoo concerning the benefits of the Retrofit works and what they would gain from this. An information leaflet was then devised which was explained to the customers through joint visits by Gentoo staff. This seemed to work well as it enabled Gentoo to talk to the customers and answer any specific questions. Prior to this, a lot of work and discussion was completed with Gentoo housing management and maintenance staff in agreeing what information needed to be included in the information leaflet. There was also a requirement to train and brief appropriate staff along with Gentoo's standby service and the Customer Service Centre to enable them to answer any queries they received from customers. This part of the retrofit programme was a steep learning curve for all the staff involved in the programme. It was important to get this right as this change was about educating staff and customers concerning the benefits of the retrofit programme. There was also a lot of coordination between various parts of the Gentoo Group once works were on site which was very challenging.

9. Costs

Projects costs as estimated at Design Stage and Final Post Construction Costs (all inclusive of VAT):

Item Stage	Design Stage Materials	Design Stage Labour	Post-construction Materials	Post-construction Labour	Comments
Management and administration					
Design		25,645		25,645	
Construction overall					
- Prelims	9,700	6,372	15,941	23,050	Extended programme incurred additional costs
- Fabric measures					
- Windows and External Doors	13,086	2,309	6,830	1,580	Revised window specification reduced costs from design stage;
- External Wall Insulation and render inc below ground work	22,260	3,928	20,447	4,145	Insulation specification varied
- Roof Works	12,084	5,179	19,511	6,757	Redesign to roof
- Building Services (conventional)	4,326	4,900	5,984	6,360	Electric shower added
- Low / zero carbon technologies	9,493	2,373	7,582	3,596	
- White goods / appliances	4,632		3,237		Specification varied
- Consequential costs					Additional costs for extra taping & obtaining level surfaces to achieve air tightness
- BWIC Window Installation	1,662	1,108	1,937	3,123	
- BWIC M&E Installations	2,090	3,135	3,115	7,806	
- Internal redecoration					Full decoration added as variation to contract
Occupant temporary housing					
Monitoring equipment	10,492		11,047		
Monitoring and reporting service		920		920	
R&D Costs (please detail)					
Stat Fees		1,186		1,080	
SUBTOTAL	89,825	57,055	95,631	84,062	
GRAND TOTAL	**146,880**		**179,693**		

Please note:
All post-construction costs include VAT at 15%. The additional cost of the change in VAT from 15% to 20% is in addition to these costs

The materials column is inclusive of plant.

Some of the proposed works were omitted at design stage due to their impact in terms of CO_2 emissions reduction being disproportionate to cost. In many cases, the major cost was not the works themselves, but the consequential costs. A good example of this is insulation to solid ground floors. To install the requisite level of insulation would require a new staircase, alterations to upper floors, new internal & external doors, damp proofing and other associated minor works. This element of the works was therefore not carried forward past the option appraisal stage.

Although the specification and therefore the cost of the windows were reduced overall, substantial consequential costs incurred in relation to windows. These were mainly due to the air tightness and insulation requirements and were therefore integral to the success of that element and the project as a whole. The thickness of the external wall insulation necessitated a cill detail on site which varied slightly from the original design, with an associated cost.

Further consequential works were carried out in terms of builder's work in connection with the mechanical & electrical installations. These were originally included at a traditional level. It was decided during the site works that, due to the extensive mechanical & electrical works and works to reveals and soffits, full internal decoration was required, which is included as a variation in the breakdown above.

After much deliberation at design stage, it was agreed by the project team that making good to areas disturbed by the works would be sufficient in terms of finish. Once the works were under way and the extent of the disturbance to the building became clear, all parties agreed that the finished product should include full decoration to all areas, and flooring and ceramic wall tiling to wet areas. The MVHR system installation in particular requires so much builder's work that to leave the sitting tenant without full redecoration would not be appropriate.

The initial specification for white goods and appliances was revisited once the project was on site. The 'diminishing returns' rule also applies here – whilst a substantial improvement on CO_2 emissions on standard appliances can be achieved through the purchase of 'A' rated appliances, the very lowest emission appliances are much more expensive than even 'A' rated appliances for proportionately less improvement in performance.

10. Wash-up meeting

A wash-up meeting was held on 16th May 2011. The attendees were:-

Head of Project Management	Gentoo Sunderland
Senior Architect	Devereux Architects
Contracts Manager (Energy)	Gentoo Construction
Project Manager	Gentoo Construction
Project Manger	Gentoo Construction
Quantity Surveyor	Gentoo Construction
Head of Construction	Gentoo Construction
Head of Operations (Central)	Gentoo Sunderland
Head of Operations (Washington)	Gentoo Sunderland
Neighbourhood Housing Manager	Gentoo Sunderland

The main purpose of the wash-up meeting was to discuss Lessons Learnt and this has been included in Section 7 of this report.

11. Doing it again

The basic design of super insulation, air tightness, mechanical ventilation and provision of solar thermal has been very successful and this design principle would be used in doing it again. However, from the experience gained, a number of changes to processes or methods of construction would be considered. These are:

- To improve the experience for occupants remaining in their homes, the work would need to be carried out more swiftly, with a more realistic programme
- Ensure the earlier integration of the maintenance team
- Ensure the earlier integration of the housing management team
- Develop subcontracts that will ensure continuity of labour
- Closer integration of suppliers
- Provide an increased level of on-site training for trades and spend more time on training generally
- In the case of M&E installers, provide initial talk through of the design drawings, and emphasis on differences and special requirements. This does require that the same operatives remain on site.
- Careful consideration needs to be given in relation to any temporary works required
- Daytime decanting of occupants into a Respite Centre can help facilitate works on site and minimise customer disruption
- Consideration of pre-fabricated roof cassettes rather than the built up roof structure used
- Rigorously adhere to the quality criteria established at the beginning of the project

The design process provided by Devereux Architects and Alan Clarke Services was excellent and would be difficult to improve. The Architect's commission could have been extended to include more site visits given the nature of the works.

The construction process could have been improved from the initial programming. The difference in construction standards from the UK 'norm' was not appreciated enough. More time could have been programmed from the start of the project to act as a pilot and to understand the methodology and complexity of construction. More time early on should have been devoted to briefing and training operatives and management.

Although the properties were not occupied during construction, the properties in Gentoo's other Retrofit for the Future projects were partly occupied. Daytime decanting could have been considered using a temporary Respite Centre. Commissioning was carried out mainly through an 'Understanding the Retrofit Project' do's and don'ts leaflet with a briefing carried out by the Housing Management staff. Involvement of the Architect or Services Engineer may have also added value.

Potential Efficiency Gains on Larger Schemes – It is generally agreed that the low carbon technologies used in this project will come down in price once they are more widely used in terms of materials. It is also reasonable to assume that repeated installations would reduce installation times and therefore costs. Supervision costs and programme times would also be reduced if any future project were to be carried out on several neighbouring houses concurrently.

One of the keys to making this project replicable would be to use pre-fabricated components for the roof. This project used bespoke roofing details in order to form the super-insulated envelope at roof level. Although not feasible on this project given its small scale, there may be opportunities for the use of pre-fabricated components. The roof cassette option was considered at design stage but discounted on the grounds of both the additional cost extra over construction on site and that the condition of the existing trusses may make installation difficult. Economies of scale would apply should super-insulated roof cassettes become more widely used; however, their installation may well often necessitate the replacement of the existing roof structure in order to take the new loadings.

Other key areas which make the project replicable are more suppliers involved in supplying key components, hence reducing cost, which would happen in time and a proper understanding by the industry of the tolerances required to make this type of Retrofit work.

12. Business benefits

Gentoo and their main partners in this project, Devereux Architects and Alan Clarke Services, feel the experience gained in delivering this project will vastly increase their knowledge base of this type of work. This will benefit each partner when competing for future low carbon refurbishment of existing stock. Gentoo and their partners feel that the innovation used on this project has led them to understand that whereas we need to look at a whole approach to reducing CO_2 emissions, there has to be a focus on build-ability and quality as well. Improvements in quality will help to achieve the air tightness requirements more efficiently and improving quality will result in general benefits anyway. Gentoo have now developed a bespoke quality assurance system in order to ensure this new and different approach to construction in the UK can be delivered consistently.

The experience gained on this project will also benefit the retrofitting of Gentoo's own 29,000 housing stock, potentially giving greatly improved savings for our own customers. The learning gained will enable us to train our own workforce on the most efficient retrofitting techniques. An example of this is the return to wet plaster on a low carbon new build development to achieve the requisite air tightness including Code 6 houses built using traditional construction.

The knowledge gained of the procurement of the specialist materials and services required and the skills gained by both site management and operatives are transferable to other areas of the business, therefore benefitting the organisation in general. The challenge will be to disseminate this knowledge to other areas of the organisation. The skills learnt on

Retrofit are transferable to every project together with the unique thinking processes required.

Gentoo have used the knowledge gained from the Retrofit project to help deliver its Energy Saver Bundle (ESB) project in CESP qualifying areas to provide customers with energy efficient heating systems, double glazing and PV. The drive is to do all this work to each property within 2 days.

It is difficult to estimate the number of business leads generated by this project. Gentoo are currently talking to and/or working with a number of external clients on reducing carbon on hard to treat solid wall properties. Gentoo have acquired
a solar panel manufacturing company, Romag and the installation of PV has become an added focus in CO_2 reduction of housing stock. The TSB project has further raised Gentoo's awareness of the Green Agenda in relation to existing housing stock and enabled it to examine the further opportunities available. Gentoo Construction has recently become MCS Accredited through this awareness.

All of the partners within the TSB project feel it is difficult to say what effect the TSB project would have on business over the next 5 years. Certainly, if the treated properties are monitored effectively for a period of several years then the data obtained should prove to be extremely useful in validating the technologies and methods adopted in each case. Monitoring of the treated houses is also under way with the Energy Savings (EST) and, together with the other TSB Retrofit Futures schemes nationwide, this monitoring will be a useful guide as to how existing housing could be improved to a much higher (lower energy/lower carbon) standard that might address 'zero carbon' challenges in the future. Gentoo and its partners on this project are now better placed to understand these challenges and to be ready for exploitation of a growing market for this higher standard of building energy performance.

13. Additional Information

One of the major lessons learnt from this project is the feeling that the construction industry is generally unaware of the techniques and skills required for producing low carbon retrofit projects. This will require a major change in mindset for the industry that can only happen through education and training at grass roots level by the Universities, Colleges and trade bodies. The challenge will be for organisations such as Gentoo and its project partners, who wish to drive the Green Agenda forward, to work with these educational establishments to ensure the required changes happen.

Gentoo have commissioned Camco to analyse initial post-retrofit energy data collected by Apex. They have produced an early indication report which shows that for TSB077 gas consumption has reduced by 67%, electricity consumption reduced 41%, carbon emissions reduced by 58% and overall energy costs reduced by 55%. However, these are early indications and should be viewed with caution due to the limitations in extrapolating data within 1 year and during the summer. These figures are considered to be pessimistic and are expected to improve during the remainder of the two year data measurement period.