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

greenstructures

Building Magazine Sustainability Awards: Highly Commended

Best Carbon Reduction Project 2008: Winner

Environmental Best Practice 2009: Gold Winner

Environmental Best Practice 2009: Bronze Winner

The City of London Best Sustainable Building 2009: Winner

Built Environment & Architectural Heritage: 2009 Green Champion

Best Eco Project 2009: Highly Commended

Best Retrofit Innovation 2010: Winner

FINAL REPORT

Retrofit For the Future Project
ZA217T - TSB065

The work reported here has been funded by the Technology Strategy Board under the Small Business Research Initiative (SBRI) under the Retrofit for the Future programme. This project is one of nearly 90 projects funded under the programme.

Further information on the programme can be found at: www.innovateuk.org/retrofit

Technology Strategy Board
Driving Innovation

SBRI Government challenges. Ideas from business. Innovative solutions.

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1. Project Details / Directory

ZA217T – TSB065 - London NW10

Role	Name & Position	Organisation	Contact Details
Property Owner			
Housing Association		L&Q Group [London & Quadrant Housing]	Address: Osborn House, Osborn Terrace, London SE3 9DR Tel: 0844406 9000 x 2182 Website:www.lqgroup.org.uk
Design Team			
Design, Architecture & Engineering		Green Structures Ltd	Address: Unit A, Swan Island, Strawberry Vale, Twickenham, Middx. TW1 4RP Tel: 020 8744 0246 Website: www.greenstructures.co.uk
Contractor			
Main contractor		Green Structures Ltd	[as above]

2. Introduction

This property is located in the London Borough of Brent. The house is a typical late 19th century brick built Victorian-style mid terrace. It is also a typical example of a “hard to heat” home, which represents a total of 36% of all homes in the UK. Therefore the solution developed for this single terrace house can be taken and applied to all similar houses across the board to bring affordable heat and comfort to the average home.

The project seeks to address four particular challenges:

1) Cost Challenge: We have selected products and technologies based on their future potential cost relating to economies of scale and not current cost. This does inflate the current cost of Retrofit, but provides the greatest future cost saving potential.

2) Planning Challenge: Our chosen solutions should not only be acceptable to planners but also to general public. Our Renewable Heat sources are quiet and discrete, generating no fumes or vibrations, with minimal disruption to integrate into the built environment

3) Process Challenge: Development of modular Whole House Retrofit procedures allows for the most efficient techniques to be matched with the most appropriate dwellings. Once standardised, these Retrofit Packages will provide a decision making tool for Social Landlords, contractors and householders, improving efficiencies and reducing costs

4) Scale up Challenge: There are no limits to scale up capability of our methods and techniques. The factors limiting the speed of scale up are the speed of installer training and availability of finance.

5) Occupancy Challenge: The volume of retrofitting likely to be required to meet long term carbon reduction targets is such that it will be impractical to decant all those affected. The methodology must facilitate retrofitting generally within occupied properties.

3. Occupants

The property is occupied by two tenants who remained in residence throughout the retrofit.

4. Dates

Works began on site at the end of May 2010 and finished in mid-December.

Green Structures will be running energy efficiency testing and prototype systems monitoring for two years from the March 2011.

5. Pre-Retrofit Property

The house is a typical late 19th century brick built Victorian-style mid terrace.

The building consists of two levels at the front and back of the house, with the back levels located slightly lower than the front.
The external walls are tradition 9-inch solid brick; all of the floors are timber construction; the main gable roof is conventional framed in timber at an angle of approx. 30 degrees facing north and south.

The plot has a small front courtyard 3m long and a backyard 12.3m long with a storage shed. The ground floor of the property has an access ramp at the front as well as at the back.

The ground floor accommodates a hall, a living room, a lounge room, a toilet, a staircase to the first floor and a kitchen on a rear annex.

The first floor comprises a corridor leading to a master bedroom, a single bedroom, a toilet, a bathroom and a third bedroom used as a laundry / storage room at the back of the property. There is an access hatch to the roof loft at the mentioned corridor.

6. Design

Green Structures design concept was to achieve maximum carbon reduction by minimising the energy input to the building, consistent with acceptable levels of occupier comfort and convenience.

The design strategy focused on:

Super insulation - the building walls were insulated externally with a total of 120mm of rigid polyisocyanurate foam [PIR] finished with a render system topcoat.

A new 'warm' roof was installed, incorporating an innovative combination of both rigid foam between the rafters, and multi-foil insulation blanket on top. The multi-foil was wrapped around the roof, to overlap behind the top of the wall insulation below.

All windows were replaced with triple glazed units, to minimise the fenestration U-values.

The soil stack serving the toilets, bathroom and kitchen was relocated inside the building envelope, rather than remaining external.

The suspended timber floor at ground floor level was insulated with spray foam. It was intended that the foam be applied via a remotely operated vehicle [ROV], procured from China. However, our bankers were unable to overcome internal administrative difficulties in issuing a Letter of Credit, so it was not possible to secure the delivery of the ROV within the project timescales. The underside of the floor was eventually insulated by more conventional [spray foam] means.

Considerable attention was paid to the detailed installation of all of these elements, to assure the insulation effectiveness and achieve maximum air-tightness throughout the property.

Heat recovery ventilation – a mechanical ventilation system was specified to ensure adequate comfort levels within the property, once the super insulation and associated air tightness levels were achieved, whilst minimising the amount of heat rejection via stale air.

Fitting of a solar thermal device – given the building's orientation, the rear portion of the roof was well suited to the installation of solar thermal collectors. However, as a terrace property, the roof area was relatively small.

Solar thermal was selected in favour of solar PV, as the thermal efficiency is in the order of 4 or more times higher; for a given collector area, in equivalent conditions, solar thermal may make a greater contribution to the building's energy requirement than PV.

Solar accumulator heat storage – one of the key issues in utilising solar thermal power [and indeed most forms of renewables] is the variability of supply. Green Structures have developed a heat storage solution, incorporating phase change materials. This will allow any solar energy not only to be used directly to contribute to the building's heating or hot water requirements, as with any conventional solar thermal installation, but will also contribute to longer term heat storage. Once charged, this heat store is designed to hold in excess of 3 days requirement, thus buffering the supply against demand.

7. Construction

Green Structures undertook the lead contractor role for the retrofit, under direct instruction from TSB. In addition, a series of refurbishments were identified by the building owners which were not directly associated with the retrofit per se. These were also taken on board by Green Structures, under separate instruction from L&Q Housing, to proceed in parallel with the retrofit.

The external wall insulation system was specified as the Structherm NSC-2 [non-structural cladding, system 2]. Structherm's policy is to only supply this product system via a network of agents, who are appointed as approved installers. On recommendation from Structherm, Astley Facades were retained as a specialist subcontractor, to undertake the insulation work.

A general building contractor was also engaged to complete the re-roofing works, plumbing and electrical refurbishment, installation of new windows and doors, refurbishment of the kitchen and bathroom, as well as general redecoration.

The building was fitted with a management and control system [BMS] by a further specialist subcontractor, Climatrol, with whom Green Structures had a previous relationship on other private-client projects.

Green Structures' own labour was directed to the installation of the solar thermal system, the thermal store, mechanical ventilation heat recovery system and associated air supply & exhaust ductwork.

Initially, the bulk of the work was the responsibility of the general building contractor, particularly removal and replacement of the roof. The works progressed under the supervision of a visiting architect from Green Structures without full time site management. This subsequently proved to be an unsatisfactory arrangement, especially once other contractors were due on site.

The programme suffered a number of setback and delays, including the failure of a subcontractor to attend site as scheduled and agreed, incorrect installation of measures once they did arrive on site, poor performance by the general building contractor, and extended lead times for key elements including the windows & doors, and the replacement kitchen.

Green Structures appointed full-time site management to address project control issues, but continued to encounter delays and disruption. The general contractor was subsequently dismissed, and the refurbishment and redecoration, partial rewiring, and final elements of the insulated render, were all completed by Green Structures directly.

8. Commissioning and occupancy

System commissioning has proven highly problematical, due to a number of factors:

The mechanical ventilation heat recovery unit at the heart of the system was not originally designed to work with anything like the thermal store built by Green Structures. In consequence, it was not possible to 'balance' the system in the conventional way, which in turn meant there was a lack of technical support available from the manufacturer in the UK. Green Structures eventually located detailed product documentation on a European website, but only in German. Thanks to Google Translate, the general gist of the document was eventually understandable.

The MVHR was further compromised by the behaviour of the tenant, who opened windows despite repeated explanations that this was against the principles of the building's insulated and air tight design, and also the design of the MVHR system operation, and would effectively guarantee no heating in the building.

The ventilation system was originally installed using proprietary flexi-duct throughout the loft area. The loft is a relatively confined space, particularly with the addition of the large thermal store. The flexi-duct proved vulnerable to accidental damage or disturbance, leading to duct leaks which again disrupted the system performance. The flexis were replaced with rigid duct in early 2011.

The BMS system failed to operate at all in the initial stages, as it was not possible to establish any communication link via the system's GSM modem. This was attributed to the new roof construction; the foil insulation essentially created a Faraday Cage, isolating the GSM signal. After much debate, a separate external aerial was specified and installed, and remote communication was finally initiated.

The project was completed in early December 2010, one of the coldest Decembers on record, and one with very little sunshine. Regardless of the manufacturer's predicted 'averages' for monthly solar gain, there was essentially nil contribution to the building heating from the solar thermal system.

During the coldest of the winter months, when minimal solar thermal is available, the space heating requirement has to be met by an in-line electric duct heater. The property relies on a pre-pay key meter for the electricity supply, and the tenant is unhappy at the change in electricity bills, relative to pre-retrofit (this despite the absence of a gas bill). Prior to the retrofit, the property had gas heating which has now been completely removed. At 2kW, the duct heater has less capacity than a typical domestic electric fire, yet has the capability to ensure the system provides comfortable heating levels throughout the house. Clearly, this also has some impact on the property electrical bill assuming no electric heaters were previously in use.

The performance of the system continued to be erratic, up to mid-February 2011, not least because the tenant was unhappy with the cost of operation, specifically electricity cost, and would turn the system off, apart from a brief period in the morning and evening when the immersion heater ran to provide hot water. This is achieved relatively simply, by knocking out a single MCD breaker on the main consumer unit, next to the front door. This action isolates the electrical supply to the loft and all the equipment therein, including the inline duct heater, the solar thermal system circulation pump, the BMS and its embedded data logging system.

Since mid-February 2011, appropriate comfort levels were being achieved, with apparently minimal electrical power input. The prototype system will require further monitoring, and fine-tuning of the operational parameters.

9. Costs

The final project costs were substantially over the original budget;

Management & Supervision – the failure of the general building contractor to perform to specification and schedule was a major source of cost over run, not least because Green Structures were forced to engage additional staff to take over the day to day supervision of the work. A site manager was engaged on a full time basis to handle these issues. An office-based project manager took over the role of the visiting architect in coordinating suppliers and contractors, and resolving interface differences between trades, and systems.

Prelims – the site programme extended by some 10 weeks, leading to significantly increased costs for welfare provision, skip hire, furniture storage, etc.

Direct Labour – the programme over-run, and taking over direct control of works which should have been completed by others, resulted in additional direct costs to Green Structures.

Variations – additional costs were incurred as part of the building refurbishment, rather than essential parts of the retrofit, such as whole-house rewiring. In the main, these costs were borne by the property owners, L&Q, from their own resources and did not affect costs against the retrofitting budget.

Design Choices – elements of the design resulted in significant work elements, and associated costs, which were potentially disproportionate to their end value to the project in terms of carbon reduction. The decision to relocate the soil stack within the building envelope, for example, intended to minimise the potential for air and thermal losses associated with pipe penetrations, was particularly significant, in hindsight, as this resulted in the requirement to completely refit two toilets, the bathroom and the kitchen which would otherwise have been able to remain largely untouched.

Innovation – the development of the thermal accumulator storage unit was more costly than anticipated. Practical issues with construction, and interfacing to the other systems being installed, incurred more time and labour on site than originally expected. Resolving the issues which arose also required more design and drawing time, further increasing the cost expenditure relating to innovation.

A summary of the principal costs is given below. By way of information, we have attempted to proportion the cost of each work element under four headings:

- Retrofit Specific – costs integral to the essential elements of the retrofit
- Forced Works – incidental costs, not directly included in the retrofit, but incurred as a consequence of particular design decisions
- Elective Works – additional work, refurbishments or improvements, not directly included in the retrofit, but undertaken at the tenant / landlord behest to avoid further disruption at a later date. Such costs were borne by L&Q as variation costs.
- Experimental Technology – costs particularly associated with the new technological innovations which Green Structures have introduced to each specific project

In general, it may be seen that the retrofit-specific works account for around half of the total expenditure actually incurred.

	Total Expenditure	*Retrofit Specific*	*Forced Works*	*Elective [non-retrofit]*	*Experimental Technology*
SUBCONTRACT COSTS:					
Subcontract - general builder	**£ 20,000.00**	*£ 9,500.00*	*£ 2,000.00*	*£ 7,000.00*	*£ 1,500.00*
Subcontract - external Insulation	**£ 6,000.00**	*£ 6,000.00*			
Subcontract - plumbing works	**£ 6,000.00**		*£ 1,500.00*	*£ 3,000.00*	*£ 1,500.00*
Suncontract - electrical	**£ 4,000.00**	*£ 1,000.00*		*£ 3,000.00*	
Subcontract - BMS installation	**£ 10,000.00**	*£ 5,000.00*			*£ 5,000.00*
MATERIAL COSTS:					
Roof replacement	**£ 6,000.00**	*£ 6,000.00*			
Window & door replacement	**£ 11,000.00**	*£ 11,000.00*			
Underfloor [spray] insulation - timber floors	**£ 1,500.00**	*£ 1,500.00*			
Underfloor insulation - replace kitchen floor	**£ 1,000.00**	*£ 1,000.00*			
Floor finishes & carpets	**£ 4,600.00**		*£ 2,100.00*	*£ 2,500.00*	
Replacement kitchen	**£ 8,900.00**		*£ 1,900.00*	*£ 7,000.00*	
Energy efficient appliances	**£ 2,000.00**	*£ 2,000.00*			
Replacement bathroom	**£ 9,500.00**		*£ 2,500.00*	*£ 7,000.00*	
Electrics, rewiring, lighting	**£ 3,000.00**	*£ 1,500.00*	*£ 500.00*	*£ 1,000.00*	
MHRV & ducting	**£ 3,000.00**	*£ 3,000.00*			
Thermal accumulator [incl PCM]	**£ 5,000.00**				*£ 5,000.00*
Solar thermal system	**£ 5,000.00**	*£ 2,500.00*			*£ 2,500.00*
Plumbing fittings [incl tanks]	**£ 3,000.00**	*£ 900.00*	*£ 800.00*	*£ 400.00*	*£ 900.00*
Regulatory valves & actuators [BMS]	**£ 2,000.00**				*£ 2,000.00*
External fascia cladding	**£ 1,200.00**	*£ 1,200.00*			
Consumables & sundry materials	**£ 10,000.00**	*£ 5,000.00*	*£ 2,000.00*	*£ 2,000.00*	*£ 1,000.00*
GREEN STRUCTURES COSTS:					
Overhead [35% activity @ 10 months]	**£ 35,000.00**	*£ 20,000.00*			*£ 15,000.00*
Design, detailing, procurement & management	**£ 17,500.00**	*£ 7,000.00*	*£ 5,000.00*	*£ 2,000.00*	*£ 3,500.00*
Direct labour & on-site supervision	**£ 32,500.00**	*£ 9,500.00*	*£ 4,000.00*	*£ 9,000.00*	*£ 10,000.00*
Technical development [thermal store]	**£ 8,000.00**	*£ 4,000.00*			*£ 4,000.00*
PRELIM / SUNDRY COSTS:					
Prelims - furniture storage	**£ 2,000.00**		*£ 2,000.00*		
Prelims - skips / waste removal	**£ 3,000.00**	*£ 2,000.00*	*£ 500.00*	*£ 500.00*	
Prelims - welfare provision	**£ 1,200.00**	*£ 1,200.00*			
Prelims - tenant reimbursements [curtains etc]	**£ 1,500.00**			*£ 1,500.00*	
Prelims - fees [building control]	**£ 700.00**	*£ 700.00*			
Prelims - scaffold / access	**£ 3,000.00**	*£ 3,000.00*			
Prelims - hire equipment / tools	**£ 800.00**	*£ 800.00*			
		£ 105,300.00	***£ 24,800.00***	***£ 45,900.00***	***£ 51,900.00***
TOTAL:	**£ 227,900.00**				*£ 227,900.00*

10. Wash-up meeting

A project wash-up was held in December 2010 at L&Q head offices.

Green Structures identified five key headings as learning points:

Technology Innovation & Prototyping – by definition, the project was intended to be innovative, with unique features including things which hadn't been done before [e.g. thermal accumulator heat storage] and processes or products applied in a manner for which they had not originally been designed [e.g. MVHR system]

Core Competences – both the supply chain management and the initial project management were heavily design orientated, with insufficient commercial focus. As the works progressed, the refurbishment aspects and issues grew disproportionately, overshadowing the retrofit itself. Effort was diverted from implementing 'good' technology, to cosmetic issues [such as kitchen work top colours or tap styles]

Procurement – neither suppliers nor subcontractors were felt to perform especially well on the project implementation.

Human Factors – Green Structures had no previous experience in the social housing sector, prior to this project. The works were completed with the tenant in residence throughout, who was allowed almost unrestricted expression of choice in relation to [cosmetic] design elements

Random Factors – it is in the nature of refurbishment work that unexpected elements are thrown up once work begins. This was compounded by allowing last minute variations and changes.

11. Doing it again

The key headings from the wash up meeting identify the principal aspects which would be changed on future similar projects:

Technology Innovation & Prototyping – Conceptual designs need to be expanded in detail, to identify and resolve limiting factors and potential conflicts between system elements, before materials arrive on site.

The innovative products we have developed need to be engineered to production level, to reduce the cost and complexity, and further improve performance.

Systems should be 'kitted' off-site, to ensure completeness, and confirm key interfaces, before any installation work is attempted

Core Competences – Field based site and project management is essential where the works contain significant innovation. Ideally, the same site team would be re-engaged, preserving the tacit knowledge gained from previous experience. The scope of works should be thoroughly assessed, to ensure the principal focus is on works essential to the retrofit, rather than general refurbishment

Procurement – System 'kitting' as above should reduce unforeseen delays and enhance the continuity of progress on site. Processes will be re-engineered to eliminate the requirement for major package subcontractors [e.g. external insulation / render will be done in-house in future]. Less reliance will be placed on trust [that suppliers or contractors will do what they say they will do] and more emphasis on progress chasing.

Human Factors – Future designs will be re-engineered to essential elements only, offering tenants a pre-determined 'palette' of choices, preferably of readily available standard stock items, e.g. specific kitchen ranges from a national supplier. This should speed up decision making and reduce procurement lead times.

Random Factors – by definition, these are largely beyond a team's knowledge or control at the outset. Suffice to say that it is important to recognise that it is reasonable to expect the unexpected, especially in an existing building refurbishment situation. Project plans may not reflect this directly, but the sequencing and duration of activities should be wary of wild optimism, and err more on the side of caution where it is practicable to do so.

12. Business benefits

Green Structures anticipate that our future business effort in the retrofit sector will be focused on product design and development, and associated consultancy, rather than on direct contracting; we will seek to secure future competitive advantage and profitability through partnering, licencing of intellectual property for our innovative designs, advising on best-practice detailing and disseminating the tacit knowledge and practical experience gained to date.

Much of the future retrofitting work, and indeed much of the future growth in the UK economy, is expected to be undertaken by SMEs. To this end, Green Structures are already in discussion with The Federation of Master Builders, for example, exploring opportunities to partner with them and contribute to the development the retrofit-specific skills for FMB-member companies throughout the country, and have already presented at one FMB-arranged seminar.

As a result of participation in R4F, and the product development work we have undertaken to support our contribution to this programme, we have been granted registered designs, with one patent application relating to the Passive Heat Recovery Ventilation Unit [PHRVU] approved, and two more on the Thermal Accumulator which are currently in the closing stages of evaluation by the IPO. Once these bear fruit, we intend to engage with Venture Capital to secure support for significant further growth through technology led products with a potential market in many of the UK's 25 million homes, and the further 160 million throughout the EU.

We have established a further pipeline of energy and built environment related projects, including more than 10 patentable inventions that are now being developed; progress remains slow, due to the overall size and resources of the company, although the prospects are extremely promising.

We have submitted further responses to funding calls, recently securing funding to support a further project relating to inter-seasonal energy storage, directly based on concepts introduced on our R4F work.

Green Structures were selected to participate in the Innovation Future Zone at the 2011 Ecobuild exhibition, resulting in further contacts and opportunities for business development; we are now developing a passive climate control system with PodPassive which will be submitted as a Proof of Concept TSB application in July 2011. We have further engaged in discussion with Buro Happold, exploring opportunities to leverage their extensive capabilities and move forward on our product development.

During the course of the Ecobuild exhibition, we were pleased to host a German trade delegation visit at one of the R4F project sites, establishing further contacts with potential suppliers and future partners. We have also hosted four further groups as part of the Open City FLASH programme, sharing our experiences and making new contacts.

The company has received a great deal of positive exposure from our involvement in R4F, resulting in further opportunities for promotion and collaboration; as part of the Buildings for the Future Innovation Awards, we have secured two collaborative projects with the University of Sheffield [from a total of ten available awards] looking in detail at the mechanical engineering and material properties relating to localised heat storage & usage, which will result in a substantial academic contribution to our new product development process.

In February 2011, we were invited to join the UKTI Trade Mission to Israel [Renewable Energy Conference] making a number of worthwhile contacts. As a direct result of this mission, we are now in the process of setting up a collaborative joint venture energy incubator with partners from Imperial College, London.

We were subsequently invited back to Israel by the British Embassy to present at the EU-Israel Workshop on Innovation and Start-ups. We have now filed a pan-European collaborative application for a fringe event coinciding with the EU Innovation Convention, due to be held in Brussels in December 2011.

Green Structures are unlikely to directly pursue any significant further retrofit work in a general contracting capacity, except by way of future technology demonstrators. We are still very interested to form partnerships or collaborations with more mainstream contractors who would have appropriate construction capacity to undertake retrofitting on a larger scale. However, it must be noted that the company is now also involved in a wide range and depth of interests, projects, products, partnerships, and collaborations that would simply not have been possible without participation in the R4F programme.

13. Additional Information

Over the course of this project, a great deal of time and effort was spent on tenant issues and concerns. Retrofitting with the tenant in-situ is challenging. Whilst the tenant may have agreed to the works in the first instance, it was not their idea; change is being done ‘to’ them, rather than ‘by’ them. This raises a raft of human factors issues in respect of the psychology of construction management as a process, residents’ personal choice, and control of their own home.

Difficulties in the commissioning period have already been discussed. Green Structures have attempted to assess whether the electrical consumption was indeed excessive as reported by the tenant, or whether there was any technical basis for complaint. Given the lack of consistent data, it has not been possible to come to any absolute conclusions at this point.

With hindsight, one area of concern is the extent of thermal bridging which is actually occurring, as opposed to that expected. As the house was insulated in isolation, but is part of a terrace, therefore the boundaries of the new insulation and the interfaces with adjacent properties are at best a compromise. We believe this may potentially be more detrimental to the building performance than was originally anticipated, although Green Structures currently lack the measurement capability to make any firm determination if this is actually so.