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: ZA145M
Property number: TSB025

Author:
Cambridge City Council

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

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Final Report

Project information

- **ZA reference number:** ZA145M
- **Location of property:** Cambridge, CB2
- **Lead participant details:** Cambridge City Council, Estates & Facilities, Mill Road Depot, Mill Road, Cambridge, CB1 2AZ, 01223 457960
- **Date report issued:** March 2012

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1. Project details and directory

Role	Organisation	Contact Details
Property Owner		
Local Authority	Cambridge City Council	Cambridge City Council, Estates & Facilities, Mill Road Depot, Mill Road, Cambridge, CB1 2AZ. 01223 457960
Design Team		
Architect	PRP Architects	10 Lindsey Street, London, EC1A 9HP. 020 7653 1200 / 0845 634 3614 lon.prp@prparchitects.co.uk www.prparchitects.co.uk
Engineer	Gawn Associates	
CDM Coordinator	Bottone Associtess	
Contractor		
Main contractor	Hill Partnerships	The Power House, Gunpowder Mill, Powdermill Lane, Waltham Abbey, Essex, EN9 1BN 020 8527 1400 www.hillpartnerships.co.uk
Sub-contractor – electric, heating, general builders	Co-Cox East Anglia Ltd	12 Benfield Way Braintree Essex CM7 3YS
PV installer	Viridian Solar	01480 831501 enquiries@viridiansolar.co.uk
Supplier – windows & doors	Sheerframe	01733 852311
Supplier – LED lighting	PhotonStar LED	02381 230381 info@photonstarlighting.com

2. Introduction

At the outset, our aim was to analyse the technical feasibility and economic viability of reducing carbon dioxide emissions from post war semi-detached houses, built from BISF (British Iron and Steel Federation) construction, by 80%. We developed a whole house solution that exceeded the competition energy and CO^2 emission performance targets. We used the skills of the expert consultants and contractor in our team, whilst engaging with the dwelling tenants and suppliers of innovative construction materials and technologies to develop a solution that is appropriate for this type of house and replicable around the UK. We recognised that the majority of homes that need retrofitting around the country will be occupied during the process, so did not rely on relocating the tenants during the works.

We also recognise that the potential rollout of whole house solutions to the UK's housing stock could damage the character and heritage of our towns and cities. However, it could also be seen as an opportunity to improve the appearance of these areas. We believed that the property had no specific architectural qualities and the external appearance could be enhanced through the installation of the proposed energy efficiency measures. The proposals would therefore not only reduce energy consumption and carbon dioxide emissions but improve the visual aesthetics of the house too. It is hoped that this will enthuse the residents to take greater ownership of where they live and place greater importance on playing their part in reducing emissions from the house.

3. Occupants

The property is occupied by a family of four (two adults and two children). The occupants were the same before and after the retrofit and were in residence throughout the whole process. The property was selected by inviting the tenants in every home of this type in Cambridge to express an interest in the project. Cambridge City Council then visited each keen household and selected the final property using a set list of criteria (with size of household at the top as we wanted to prioritise larger families where the benefits would be larger). This process was invaluable as it helped to ensure that we had occupants who were committed to the project and could also have regular input to ongoing developments.

4. Dates

Event	Date
Project start date (when was the first proposal discussed or agreed)	03.02.10
Planning application submitted (if appropriate)	N.A
Planning permission granted (if appropriate)	N.A
Building Regulations application submitted (if appropriate)	16.03.10 Building Notice submitted
Building Regulations approval granted (if appropriate)	Acknowledged 23.03.10
Contract for work let / signed	14.04.10
Occupants moved out (state if they remained or property was empty)	Tenants remained
Start on site	05.05.10
Completion of retrofit	15.07.10
Occupants moved in	Tenants remained
Monitoring system commissioned and operating properly	04.08.11
Building defects corrected	27.08.10
Building services and controls operating correctly	15.07.10
Programmed completion date (delayed by EWI Kingspan availability and additional works requested by CCC - see above)	30.06.10

5. Pre-retrofit property

The house is a 3 bed semi-detached property (91sqm) on a residential estate in Trumpington, on the outskirts of Cambridge. It was constructed in 1947 and is a British Iron and Steel Federation (BISF) house. It is one of many examples on this estate and originally 30,000 in England and Wales and a further 4,000 in Scotland. Many of these properties still exist with the majority having few energy efficiency improvements other than loft insulation, heating upgrades and in some cases window replacement, installed under the Decent Homes programme.

The house is constructed of light-gauge steel frame and is therefore of lightweight construction with no cavities suitable for insulation in the external walls. The lower storey exterior has a render-on-mesh cladding and the upper storey a profiled steel sheet cladding. The ground floor is of solid construction and the property has a tiled duo pitch roof. The windows were originally steel framed but uPVC framed double glazed replacements were installed in 1997.

The property has a single storey lean-to construction that forms a draught lobby on the kitchen entrance and houses a WC and external storage.

Basic energy consumption monitoring was carried out before the retrofit work began. This found that prior to the improvements being carried out electricity consumption was approximately 5,700 kWh per annum and gas consumption was approximately 18,000 kWh per annum. Total annual fuel bills were in excess of £1500.

6. Design

The following technologies and innovations were proposed to be used in conjunction with established approaches such as mineral fibre insulation to the roof space and low flow taps:

- Photovoltaics: 'Clearline PV' from Viridian Solar (an SME based in Bassingbourn, Cambridgeshire). Solar thermal system is in identical frames as PV for matching aesthetics. Product is under development and not yet on the market and offers separation of roof and electrical trades, clarity of responsibility, ease of installation and low impact appearance.
- Greater than usual thickness of insulated external render - from Permarock UK.
- Greater than usual thickness of Spacetherm insulated drylining - from the Proctor Group.
- Use of Nanogel insulation for the floor.
- Triple glazed windows from Sheerframe window systems (specialising in high performance uPVC windows).
- LED lighting: from PhotonStar LED Ltd (an SME based in Southampton). New product developed for social housing that uses 6.7w lamps and has a much extended life over incandescent or even compact fluorescent bulbs. It will be used with a lighting control system to maximise efficiencies.
- Flue gas heat recovery: the Zenex Gas Saver, innovative use in combination with a solar thermal system.
- Waste water heat recovery system: the Recoh-Vert (subject to detailed design).
- Low-energy decentralised whole house ventilation: Part F type 3.
- Energy display system: Trio + from Green Energy Options (an SME based in Cambridge). This system is under development and not yet on the market. It offers an interactive touch screen interface for educational and awareness use by the occupants with the ability to display energy usage from up to 100 distinct sensors with 2 month memory for all sensors as well as sub-metering of circuits, boiler and micro-generation systems.
- Solar powered doorbell.
- Changes to heated envelope to make the outside WC comfortable and to minimise thermal bridges at the junction of the lean-to part of the building.

Proposals for the retrofit changed in the following areas:

Ventilation
The original phase 1 proposal for a passive ventilation system was substituted at phase 2 with Distributed Whole House MEV (always on low energy extract fans in kitchen and bathroom) as it is our experience that residents do not trust passive systems as they associate the lack of fans with the idea that there is inadequate ventilation, often installing additional fans. It is also very difficult to design a retrofit passive stack system.

Zone control not installed
During the course of the project it was discovered by the contractor that to install zone control would mean completely re-plumbing almost the entire central heating system. Additionally the property itself is relatively small and with large open plan areas that would

not benefit fully from a full time, temperature zone control system. A simple room thermostat, programmer and TRV control system was retained. Although this will have had a slight detrimental effect on the CO_2 emission reductions the targets should still be met.

Some white goods different
The original proposal included A++ 'white goods'. It was found that this specification is not commonly (or indeed at all) available for some product types. The highest energy specification products available within the budget were chosen, in some cases this was A or A+ rated only. The tenant also wished to retain their tumble dryer for which no A rated alternative exists. Instead the tenants were given advice about how much energy a tumble dryer uses compared to line drying. The real-time energy display should confirm this.

Solar Doorbell
Omitted as no suitable product could be located.

Windows
Very high performance windows are often manufactured without trickle vents as they are detrimental to the thermal performance of the window frames (they are likely to be used in Passivhaus performance standard dwellings with very low air permeability and MVHR). In retrofit projects where high levels of air tightness are difficult to guarantee and where MVHR is not specified, the chosen ventilation strategy of distributed whole house MEV can comply with Part F building regulations only with airtightness and dwelling volume ratios sufficient to allow the fans to move enough air. Since the air tightness levels were unpredictable, it was chosen to specify high performance trickle vents in the triple glazed window units to cover the risk of there being insufficient ventilation.

Floor Insulation
The original specification for Aerogel insulation under the floorboards was substituted by a greater thickness of phenolic foam to achieve the same thermal improvement as it was discovered that the available depth for insulation was greater than first thought.

Ceilings
New foil backed plasterboard was installed at 1st floor ceiling level as the original ceiling was unable to support LED lighting fixtures. Sloping ceilings were insulated with Celotex (not Aerogel) to the same thermal specification, as it was not necessary to use such high performance insulation in a relatively unconfined space.

Lean-To
The original intention to exclude the lean-to WC & lobby from the heated envelope was abandoned in favour of improving the construction to a higher specification to bring the effectively outside WC into the heated envelope. The lean-to rafters also had to be replaced to accommodate the new insulation depth.

Waste Water Heat Recovery
It was possible to install WWHR at the property but the original intention to use the shower integrated 'Showersave' unit was changed to a similar system that is suitable for the bath arrangement.

7. Construction

The teams have learnt lessons during the Retrofit process at the property and also through the other two projects that were run in parallel by the same delivery team.

Hill has identified some issues that need resolution; otherwise they could be seen as potential barriers to Retrofit implementation. Part of the challenge has been in delivering a pilot scheme with three individual houses, one of which is in Cambridge. This creates an artificial situation and it can be challenging to understand how this position would extrapolate to a cost-effective volume programme, which is the how the project would be rolled out.

- As constructor, we would highlight the following which were relevant as we delivered this series of projects in 2010, not just the Cambridge project, and are probably similar now:Supply chain issues, where suppliers cannot meet the demands for one house or a small group
- Problems with residents who understandably cannot cope with the invasive nature of the work over a 6 week programme; however, for this type of work, decanting is not a solution
- Education process needed to support the residents to change their lifestyle to gain the maximum benefit from the investment
- Existing maintenance records not being correct; always a problem with working on refurbishment of existing buildings
- Lack of consistency from local authority planners in relation to permitted development rights
- Subcontractors not having the experience to accurately price the works; this will change over time
- Subcontractors working with cutting edge technologies and needing to adapt as required
- Subcontractors who cannot accurately provide the environmental testing results

Many of these will be resolved through experience and repetition but early consideration of these delivery issues alongside funding, incentivisation, resident awareness and quality control is imperative.

From a Local Authority point of view, it was vital that we maintained an excellent relationship with the occupants. We wanted to carry out the works with the tenants in situ as this is a more realistic method of refurbishing properties on a wider scale. Due to the tight time frame in which we were attempting to carry out a lot of work, there were occasions when every room in the house was being worked on with a total of 20 operatives on site. In hindsight, carrying out this level of work in this fashion was not very sensible and we should have re-housed the tenants (at least temporarily during the busiest times).

There is also an issue with contractors sub-contracting the vast majority of the work to a local building company. This company tends not to have the accountability or buy-in to the Retrofit project and ethos, and this can make it harder to stress the importance of air-tightness or other more innovative technologies.

8. Commissioning and occupancy

Commissioning of active equipment was mainly carried out by Hill Partnerships or their sub-contractor. This was generally done to a decent standard and all technologies were explained to both the occupants and the landlord. However, most of the hands-on advice and explanations had to be carried out by the landlord as this proved to be an ongoing exercise and not just a one-off discussion/presentation.

The solar PV and thermal systems were initially commissioned by the contractor's sub-contractor, but we subsequently brought in Viridian Solar (the supplier) to commission it properly and fix some outstanding issues. These systems are now working correctly.

Monitoring of individual rooms/temperatures/appliances has been limited due to issues with the company selected to provide this work. The product from Microwatt seemed to have some faults and only worked for a week or so at a time. Microwatt also did not resource this project as much as was required to successfully deliver the number of projects they had. This was very unfortunate as the product itself gave some excellent data when it did work.

Utility monitoring has gone well, and the landlord has also taken regular meter readings in order to keep a close eye on consumption and to highlight any issues.

9. Costs

Item Stage>	Design stage Material Labour	Post-construction Material Labour	Comments
Management and administration	-	-	
Design	£29,995	£29,995	
Construction overall	£98,670	£98,670	
- Prelims	£5,875	£5,875	
- Fabric measures	£53,315	£53,315	
- Building services (conventional)	£9,755	£9,755	
- Low /zero carbon technologies	£29,725	£29,725	
- Consequential costs	-	-	
Occupant temporary housing	-	-	
Monitoring equipment	£4,020	£4,020	Includes broadband line rental for 2 years.
Monitoring and reporting service	£13,220	£13,220	Includes Cambridge University monitoring work.
R&D costs	-	-	

10. Doing it again

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

Definitely do again

- Wall Insulation
- Deep Cills (moving windows forward into new external insulation)
- Launch event
- Secure products early on
- Undertake research into potential suppliers early on
- Waste water heat recovery (although attributing savings would be better)
- All thermal bridging measures
- Zenex FGHR / Alpha boiler FS1 system

Definitely not do again

- Working with the tenants in situ throughout such a whole house retrofit project was very stressful for the tenants and contractors alike.
- The decision to retrofit rather than rebuild the lean-to containing the WC was in hindsight not the best use of resources. Although a rebuild may have seemed an expensive job, the simplicity of this solution would have perhaps been cheaper overall than the necessarily complex refurbishment.

Reduction of costs (what might you leave out and how would you make things cheaper?):

- Restrict the use of Aerogel (or other premium insulation products such as Vacuum Insulated Panels (VIP) to areas where space is valuable.
- LED bulbs rather than whole fittings.
- Removing old fireplaces (this still should be done but not under a retrofit budget).
- Leasing or borrowing monitoring equipment.

Improvement of the design process (better informed design decisions, more professional input, etc.):

- Allowance for external calculation of savings outside SAP / PHPP - individual heat recovery ventilation, multiple appendix Q measures; time and temperature TRVs, more integration with construction team in terms of practicality of measures and explanation of scope of works.
- Methodology to include tenant behaviour; especially the likelihood of taking up in comfort increases potential savings.
- Use of 'greener' products where possible.
- Modelling to actual tenants to help manage expectations.
- A simple method for calculating thermal bridging, or rules of thumb for existing typical

construction techniques, would improve this aspect of the design process. We chose to use the SAP default value both before and after improvement since it is difficult to calculate for the existing case and is likely to be poor and since, although we have included measures to counter thermal bridging, we have perhaps simply corrected for increased thermal bridging due to better surrounding u-values.

Improvement of the construction process (reduce timescale, smooth operation, etc.):

- Toolbox talks.
- More during construction visits.
- Restriction of sub-contractors (and or closer management of sub-contractors by whole team (including design team).
- Keeping Decent Homes improvements separate from retrofit improvements financially.
- Single organisation for integrated system provision (e.g. heat distribution, heating system, and controls).

Improvement of the commissioning and occupancy process:

- Tenant advice sessions / training similar to that undertaken by RELISH.
- Training of tenant / landlord liaison staff in the retrofit process, the systems installed and their efficient operation and maintenance.

What efficiency gains would you expect from a larger programme of retrofits, eg: 50 homes of similar age and design in a similar neighbourhood?

There would be large efficiency gains from a larger programme of retrofits, but work on this scale cannot really be carried out with tenants in situ. This could mean excessive decanting costs and a lot of upheaval for residents.

What, in your view, would be key to making replication at this scale successful?

- A reliable and straightforward mechanism for decanting residents during the really busy site activity times.
- Whole house plans for every property within the stock, so that work can be carried out when a suitable opportunity arises (major works; between tenancies).
- Market and Policy certainty so that contractors and supply chains can gear up to undertake the millions of necessary retrofits.
- Term agreements for contractors with larger landlords in order to extend the usual range of property services to include whole house retrofit.

11. Business benefits

Cambridge City Council is currently working on a post Decent Homes improvement plan for all of its housing stock. This process has been helped a lot by what we learnt on the Retrofit for the Future project – for example, we have rolled out external wall insulation to the remaining BISF properties on the same estate this year. We have installed solar PV panels on other properties using Viridian Solar and we are actively looking into installing LED lighting and other measures that we discovered during the Retrofit process.

PRP have consolidated their reputation in the retrofit field and have participated in several multi-property (10-30) retrofit programmes as well as production of Retrofit Guides. It is expected that this sector will extend and expand over the next five years and that PRP will continue to develop in this area, with increasing demand.

12. Additional Information

Phenolic foam EWI
A project plan delay occurred in relation to external wall insulation. The incorrect insulation material was originally ordered through a sub-contractor who was ignorant of the purpose of the project. When this came to light, it was discovered that there were considerable lead-in times for the correct insulating material in the widths required for this project. Using the high profile nature of the project to persuade the manufacturers to bring forward the order, the project team were able to expedite this and no significant delay was caused to the overall project. The property was clad in temporary external wall coverings for a significant portion of the project duration.

Boiler / FGHR combination
The original specification of flue gas heat recovery in combination with a system boiler (rather than the more usual combi boiler) proved problematic in terms of supplier. Our initial supplier choice, having stated that this was a viable combination of technologies, went on to state that this could only be provided as an experimental product and therefore without warranty. Again the team were able to locate a second supplier without causing delay to the project.

Aerogel insulation
During the course of the project the manufacturers of the Aerogel insulation significantly increased the price of the product as well as increasing lead-in time estimates. The project team had already secured an adequate supply (in anticipation of long-lead in times and in the desire to complete the project as quickly as possible). Without this, considerable project delay could have occurred.

Windows
A number of window manufacturers needed to be investigated in order to be certain of a supply of windows that fit the design criteria and landlord’s requirements. There are very few manufacturers that can genuinely provide windows with the required whole opening U-value required for the project.

Extensions
In regards to lean-to's and (whether originally constructed or later addition) extensions: the decision to rebuild rather than retrofit should be made at a lower threshold to any decision to retrofit the whole building.

Other
- Smart meter roll-out certainty.
- System 3 ventilation might include heat recovery.
- eTRVs.
- A whole house plan identified with trigger points for compatible potential improvements to be undertaken over a 25 year period with replacement items such as windows and boilers being made at natural cyclical replacement times.
- Less reliance on maximum rooftop solar technologies at the outset, with provision to practical maximum (rather than amount to reach target) included in whole house lifetime

plan.

- Tenant reaction to the retrofit process is unpredictable and one outcome of this project is a greater understanding of tenant expectation management.
- 'Hidden' advantages of works - such as lessening summer overheating, faster wash times from A++ washing machines, better lighting quality from LED lights - need to be identified and communicated to residents and landlords.
- Clearer demarcation of responsibilities (i.e. subcontractors responsible for measuring roof area for suitability).
- Lack of product for solar doorbell a disappointment.
- A solid floor insulation product is needed.
- The issue of potentially claiming funding from the Feed-in tariff (or in the future the RHI) needs to be considered. For new build, the HCA have only recently made clear the boundary between their funding and the FiT. There is too much risk in this area to be able to guarantee funding for renewable energy by deciding early on to arrange funding in any particular way.
- Monitoring organisations that can undertake utility, environmental, and renewable monitoring at a reasonable cost are few and far between.
- Informing neighbours of the nature of the works and the construction timetable.
- A mechanism for provision of energy efficient appliances to tenants. Social landlords do not typically provide tenants with appliances and the provision of these in this project unearthed a number of issues of responsibility.
- A referable guide to energy efficient appliances. Procurement of the required A++ rated appliances was surprisingly difficult considering that the energy rating of appliances is a long established scheme.