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: ZA636L
Property number: TSB075

Authors:

Town and Country Housing Group

Climate Consulting

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.

Final Report

Project information

- **ZA reference number:** ZA636L
- **Location of property:** TN2, Tunbridge Wells
- **Lead participant details:** Town and Country Housing Group, Monson House, Monson Way, Tunbridge Wells, Kent TN1 1LQ
- **Date report issued:** 09/12/11

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1. Project details and directory

Role	Organisation	Contact Details
Project Lead	Town and Country Housing Group	Address: Monson House Monson Way Tunbridge Wells Kent TN1 1LQ Tel: 01892 501684 Website: www.tchg.org.uk
Registered Provider	Town and Country Housing Group	Address: Monson House Monson Way Tunbridge Wells Kent TN1 1LQ Tel: 01892 501684 Website: www.tchg.org.uk
Project Manager	Baily Garner	Address: 146-148 Eltham Hill London SE9 5D Tel: 020 8294 1000 Website: www.bailygarner.co.uk
Engineer	Bryant and Reina	Address: Bryant & Reina 70 Pavilion Road Folkestone CT19 5RL Tel: 01303 248648 Website: *www.bandrgroup.co.uk*
Sustainability Consultant	Climate Consulting	Address: Climate Consulting Ltd Stephenson House 2 Cherry Orchard Road Croydon CR0 6BA Tel: 020 8633 9823 Website: *www.climate-consulting.co.uk*
Main contractor	Jenner	Address: Century House Park Farm Rd Park Farm Industrial Estate Folkestone Kent CT19 5DW Tel: 01303 255 444 Website: http://www.jenner-group.co.uk/
Subcontractor – ventilation	Passivent	Address: Passivent Limited 2 Brooklands Road

		Sale Cheshire M33 3SS Tel: 01732 850770 Website: www.passivent.com
Subcontractor – electrical and heating	Bryant and Reina	Address: Bryant & Reina 70 Pavilion Road Folkestone CT19 5RL Tel: 01303 248648 Website: *www.bandrgroup.co.uk*
Solar thermal	Solar UK	Address: Commonswood Farm Hastings Road Northiam East Sussex TN31 6HY Tel: 01892 526368 Website: http://www.solaruk.com
Supplier - windows	Windowplan House	Address: Knight Rd Strood Rochester Kent ME2 2AH Tel: 01634 711119 Website: www.windowplan.co.uk
Heating Controls	Heating Save	Address: 589 Great North Rd St Neots Cambridgeshire PE19 7GJ Tel: (0)1480 223923 Website: www.heatingsave.co.uk
Wood Stove	Specflue	Address: 8 Curzon Road, Chilton Industrial Estate, Sudbury, Suffolk CO10 2XW Tel: 0800 90 20 220 Website: http://www.specflue.com
Heat Bank	DPS Tanks	Address: 1-3 Wealdstone Rd Sutton Surrey SM3 9QN Tel: 0845 2411 441 Website: http://www.heatweb.com/

2. Introduction

This project addresses the refurbishment of a 1950s, three bed property in Tunbridge Wells. Although refurbishment to "Decent Homes" standards had already been carried out, the property still suffered major problems with damp, cold floors and high energy bills. A solution has been developed which applies multiple energy reduction measures and low carbon energy technologies to provide a 'whole house' solution, aiming to reduce carbon emissions to 18 $kgCO_2/m^2a$ and primary energy consumption to 110kWh/m^2a.

The project aims to minimise energy demand through very high standards of insulation, reduced air permeability and heat recovery ventilation. The use of a multi-source heating and hot water system is intended to provide low carbon heat from solar thermal (primarily in summer) and a wood stove (in winter). A lot of attention was also placed on the importance of ventilation, particularly seeking to reduce maintenance requirements of ventilation systems whilst maintaining high air quality levels within the dwelling.

3. Occupants

The occupants were the same before and after the retrofit and they occupied the property throughout the retrofit works.

To be more specific, the property is occupied by a family with young children. They are regularly in and out of the property. They had a baby just before the works started and like to maintain a high temperature at the property.

The family has a prepayment meter and are aware of their consumption. They have many electrical appliances which are heavily used.

The make-up of occupants before and after the retrofit:

Age band	Number before retrofit	Number after retrofit
Under 5 years	3	4
5-16 years		
17-21 years		
22-50 years	2	2
51-65 years		
Over 65 years		
Please state if (yes/no):	**Before retrofit**	**After retrofit**
Married couple / partners	Yes	Yes
Couple / partners with children	Yes	Yes
Any disabled persons	No	No

4. Dates

Event	Date
Project start date (when was the first proposal discussed or agreed)	1st June 2009
Planning application submitted (if appropriate)	3rd June 2010
Planning permission granted (if appropriate)	6th August 2010
Building Regulations application submitted (if appropriate)	n/a
Building Regulations approval granted (if appropriate)	n/a
Contract for work let / signed	31st August 2010
Occupants moved out (state if they remained or property was empty)	Remained in occupation
Start on site	31st August 2010
Completion of retrofit	4th February
Occupants moved in	N/A
Monitoring system commissioned and operating properly	1st June 2011
Building defects corrected	12th April 2011
Building services and controls operating correctly	n/a

5. Pre-retrofit property

The house is a 1950s 3 bedroom property on an estate of 120 almost identical properties in Tunbridge Wells. The house is of a cavity wall construction, with a cold loft space. Most of the ground floor is suspended timber, except the kitchen and bathroom which are of solid concrete construction.

The property was chosen due to its replicability across the UK's social housing stock and the fact that it is typical of properties owned by Town and Country Housing Group.

Another factor present when deciding on which property to retrofit was the presence of cooperative tenants who were willing to work with the project team to carry out the works while they remained in situ. The residents stressed that they were particularly interested in having a wood burner installed. However, issues did occur on site which extended the construction programme significantly, not least the arrival of a baby before commencement and then the arrival of some puppies in the kitchen delaying access to this area!

The property was monitored for approximately a year prior to the retrofit works. Specifically the internal temperature, humidity and CO_2 levels, as well as the electricity consumption were recorded.

6. Design

The initial design for this property put a strong emphasis on highly insulating the building envelope and improving air tightness.

Wetherby external wall insulation was planned for the external walls with render. However, as this was a semi-detached property the planning department felt that it would stick out and be conspicuous due to the step in the insulation from the other adjoining property. Furthermore despite the estate being a not particularly architecturally notable and typical 1950s council estate (nor in a conservation area) the planners did not want us to change the character of the existing house and wanted it to blend in. It was hoped we might show how we could improve the character but it was not accepted. Therefore brick slips to closely match the existing were required along with a full planning application taking 8 weeks to determine (plus extra fees). This may point towards the attitude of planners in future.

In the end approval was given that allowed render to the sides and rear of the building with slips on the front. (The completed step between the two houses has proven to be less than conspicuous; in part masked by a rainwater down pipe). The eaves detail was deep enough not to require further works to alter and maintain the overhang. The periphery of the walls were excavated (once the main works were done including brick slips) for the future installation of the EPS, to dramatically reduce thermal bridging around the perimeter at and just below ground (floor) level.

External windows and doors were to be upgraded with triple glazed units. The loft space was to be insulated with a combination of mineral wool and solid batt insulation; the ground floor was planned for a combination of overlaid aerogel insulation to solid floor slab areas, and insulation batts installed between timber floor joists to all other ground floor areas with suspended floor structures. All service penetrations and gaps were to be sealed and the suspended ground floor over boarded to improve air tightness.

Following the improvements to the building fabric, a wood burning stove (resident choice) with back boiler and solar thermal panels (rear south facing roof) were to be installed, connected to a thermal heat bank and being backed up by the existing gas boiler. The heating and hot water system would be controlled by a connected programmer control centre, which would automate and regulate the heating and hot water supply from the lowest carbon source. These controls are as complicated or as simple as the resident wants – they can be used by enthusiasts in a detailed way to fine tune and drill through information or, alternatively, just simply controlled by using one or two push buttons (which is preferred by the resident in this case).

The original radiators for the house were retained for practical (less disruptive) and cost saving reasons, and because it was felt that they were within design parameters.

Ventilation was to be supplied by a combination of a standard MVHR system, with automatic boost facility when the hot water or oven is in use; and a SolarVenti (non SAP assessed), dehumidifier panel, which is non mains connected and has a fan that is photovoltaic powered, providing heated dry air to the property whilst removing stale damp internal air. The consultants acting for the SolarVenti suppliers claim that monitoring has shown it produces 1100 kWhrs per annum of free energy in the form of pre-heated fresh air to the property (variable depending to an extent on weather conditions). It is particularly productive in spring and autumn.

Extra vents to meet Building Regulations Part J were installed behind the wood burner, entering the property through the suspended timber floor in the main living room where the

burner is situated.

Interestingly, towards completion, the property had a number of days of extra unplanned monitoring by Cranfield University, due to a chance meeting via the Zero Carbon Hub's Ventilation and Indoor Air quality Sub Group. Funded by the Gas Safety Trust and championed by a leading academic, this work aimed to monitor air quality in airtight, gas-supplied properties, particularly in relation to carbon monoxide levels, particulates and VOCs. The positive feedback was that there were no issues to report. It has to be noted that airtight levels approach Passivhaus standards.

Generally the majority of the designed works were carried out to plan. A few unforeseen issues occurred which affected progress and required reprogramming of works or alteration to the initial design.

The initial issue which affected progress was the result of one of the resident's dogs producing a surprise litter of puppies the day before commencement on-site. These occupied a portion of the kitchen area (which required the aerogel insulation to be installed to the floor slab) for the first 7 weeks of the works. As the property is quite small, this had a significant effect on progress.

Prior to commencement it was realised that it would be problematic and would result in a waste of gas to use the existing combination boiler as the backup for the new system with the thermal heat store. The combi boiler was not designed for such a use with stored water and therefore it became clear after consultation with the manufacturers that it might be possible but risky to retain it. It was therefore agreed to remove the existing 'A' rated Ideal boiler and supply a new, open vented system Worcester Bosch boiler to link to the heat store as this was a better match for the thermal store technology. The location of the old boiler was in a cupboard in the third bedroom (where the new thermal store was to be located) but it was evident that a previous boiler had been located in the kitchen. The new gas boiler was relocated in the kitchen in a new cupboard to match the existing units as there was already a space for it.

Initially it was believed that the only ground floor area with a solid floor was the kitchen, for which it had been planned to use aerogel insulation, with the remaining suspended timber ground floor being insulated between the floor joists. While on site it was discovered that the bathroom floor was also solid and therefore it was agreed that this area would also be overlaid with the aerogel. There was however one further issue, in that we could not raise the height of the bath, due to the low ceiling height. It was therefore decided to insulate this area below the bath with mineral wool insulation so as not to create a cold bridge.

It was found when taking up the existing floorboards in the living room to install the insulation that they were surprisingly tongued and grooved, which made removal much more difficult (and perhaps part explains why the existing air tightness level was actually better than existing building Regulations(8)).

Care had to be taken not to generate too much dust especially with a baby and children living in the house. Even so, these works were able to be done whilst the residents were out during the day. It was done in 'strips' and programmed in such a way that circulation areas were always there to allow access through the house if necessary. These works caused less of an issue in practice than expected and were finished in a couple of days.

Further issues were experienced with regards to installing the aerogel to the kitchen floor slab. It had been planned that the insulation could be installed to the floor without raising the level of the kitchen units. This was, however, realised not to be the case, as appliances would no longer be able to fit below worktops in their original spaces. The result of this was

therefore the need to raise the kitchen units, worktop, sink, supply and waste pipe work as well as adapting the splash back tiling.

It was realised that, despite it being advised for social housing tenants not to use the loft space for storage, this would evidently happen once the works were completed, due to the large amount of belongings being stored in this area by the resident previously. For this reason, as we did not want the mineral wool installation being unduly compressed by belongings and reducing its performance, we decided to provide cross support over the joists and overboard the insulated area to protect its performance.

The initial plan to use a standard Mechanical Ventilation and Heat Recovery (MVHR) system was rethought during detailed design phase, when it was realised that this system would be heating incoming air as well as the SolarVenti system providing the same effect. Thought had to be given to ensure the single SolarVenti inlet was not in close proximity with an inlet or outlet for the MVHR, and didn't 'clash'.

The MVHR system originally chosen did not have an automatic summer bypass, and manually changing the settings and relying on the residents to do it every year would be an undesirable extra task. It was thought that in the summer months, no mechanical ventilation would be provided unless it was heated, which would not be wanted in a highly insulated house. A different MVHR system was therefore investigated which operates on a seasonal/ temperature control basis. The iHybrid system has been developed by Passivent to operate throughout the year; however, when the outside air temperature is above 9°C, fresh incoming air is not passed over the heat exchanger to heat the air. Once the temperature drops below 9°C, the incoming cool, fresh air passes over the heat exchanger and this air is heated by the exhaust warm, stale air being extracted from the property. The main MVHR unit had to be installed in the loft for space reasons and therefore a loft ladder allows access for filters to be checked and cleaned as necessary in future.

The location of the 300 litre thermal store cupboard required some thought. This is a large cylinder and in the end placing where the existing boiler cupboard was situated (thus reducing lost floor space) was decided upon. We even discussed locating the thermal store in the loft outside the main insulated body of the house but this proved too much of an engineering challenge (particularly as the thermal store is large and very heavy once full – 400kg).

There had been discussions initially about connecting the MVHR system to the top of the thermal store cupboard located in the third bedroom, to remove and utilise the excess heat given off in this area. The venting of the cupboard, however, did not occur during the initial construction works and it was believed by the plumber that the thermal store would be insulated to an extent to prevent heat loss. This has been found to not be the case and this area is experiencing significant overheating (mainly from ancillary pipework even though lagged) thus confirming the suspicion of the client. It was therefore decided later on to return to the original plan and install an additional extract duct to the top of the cupboard to allow this heat to be utilised for heating the incoming fresh air in the MVHR system in winter months, and vented externally in warmer weather. It is hoped this will be a useful adaptation that will equalise temperatures in the home.

The cupboard itself was constructed using a double hinged panel to open up the whole cupboard completely (rather than a fixed side panel) so that if necessary access could be gained to the rear of the tank.

The MVHR system also had West Energy 'demand controls' fitted to boost the extract facility automatically when the cooker or hot tap / shower is used. This proved to be easy to install and a success.

The SolarVenti non mains-connected passive ventilation system was originally designed with

the panel on the side of the house to be more discreet. However, on site it became clear that it would have to be located on the rear slope of the roof below the solar hot water panel, with the ducting routed through the loft to the stairwell to achieve the maximum benefit and solar gain for the preheating of the positive input ventilation. Although the actual panel that gets heated by the sun is quite large the installation of this system was relatively simple once the new design had been agreed.

There was much discussion about putting a porch on the front entrance of the house to reduce air leakage to the main living area, however, after some design work it proved not to practical or viable within the budget. This was due to the slope down to the front of the house and the proximity of the entrance in relation to the external side access foot path to the garden, which would have been significantly impaired.

Prior to start on site a workshop with presentations was held for TCHG maintenance and other staff, mainly focusing on wood burner technology but also introducing the whole concept of the house. South East Wood Fuels, Specflue and Milborrow Sweeps (complete with brushes!) were in attendance. Furthermore, a design team meeting with all suppliers and consultants was held at the house with the residents in attendance. This was a very successful meeting with a great deal of learning, knowledge sharing and enthusiasm generated between all participants.

7. Construction

- **Procurement:** The main contractor was appointed due to the strong relationship held between them and TCHG, their familiarity with the project from Phase 1, and their passion to be at the forefront of the sustainability and retrofit markets.
- **Contract type:** the chosen route was a 'JCT 2005 Intermediate Form of Contract' as it offered a more comprehensive format than a Minor Works Contract, but could still be used with the build schedule produced for the final stage bid also offering some flexibility.
- **Contract structure:** One main subcontractor was employed for M&E. Specialist installers and subcontractors for plastering and the application of the external wall insulation system were also employed.
- **Specialist installers:** The M&E subcontractor engaged specialist installers for the installation of the solar thermal panels, the wood stove, the heating control system, the MVHR and the solar ventilation system.
- **Specialist equipment suppliers:** Specialist equipment was chosen based on its performance.
  The following were procured by the M&E contractor:
  1. LaZer2 solar thermal system
  2. 5kW Merlin wood stove with back boiler
  3. iHybrid ventilation system
  4. A large 'Heatbank' thermal store provide by DPS (now bought by Specflue)
- **Site supervision:** A site manager was appointed who performed periodic visiting inspections
- **Role of architect/ design team:** An architect was not appointed in this case. It was the role of the design team, which consisted of the project manager, the engineer and the sustainability consultant, to supervise onsite and sign off works.

The main lessons learned on site and during the duration of the project are as follows:

- Due to the high number of subcontractors involved in the project, management proved to be challenging for the lead contractor. The coordination of all contractors involved was assisted by a site visit that took place before the works started, where all the contractors met and discussed the integration of each system.
- Cold weather caused an unexpected delay in the installation of the external render system, and should be considered in future.
- A combination of innovative and practical thinking is required for the successful completion of the retrofit. Examples of this approach were the selection of mineral wool insulation for the bathroom floor and the application of glass wool insulation in the eaves, based on the fact that glass wool was easier to install and would minimise thermal bridging compared to the higher specification phenolic board that had been initially considered. The eaves details in particular were discussed between Baily Garner, Jenners and CEN; including how to insulate the eaves in a way that was practical for installation, allowed ventilation of the loft to continue and maximise heat losses. The conclusion was that using phenolic board in the void would be so difficult to install it ran the risk of leaving gaps for heat loss. Instead, plywood boarding was applied to the rafters to prevent the mineral wool being applied to the void from

blocking ventilation to the loft space. The board also held the mineral wool in place.

- A degree of flexibility in the design strategy of the works should be adopted in case the actual construction type of the property is different than the one originally assumed.
- The installation of MVHR can be a challenge to older properties in terms of getting the duct runs in, and the management of the loft space, bearing in mind residents are used to using loft spaces for storage. There was some negotiation with the resident on this to ensure everything could be accommodated and that the resident was happy they still had storage room.
- Achieving the higher air tightness was a challenge with residents in situ, particularly for the upper floor which ideally should have been completely hard boarded over. The original target was not met and, in the opinion of the person carrying out the air tightness testing for BSRIA, achieving just below 5 was more realistic than the target of 2 for this property. It is clear that decanting the residents at extra cost and carrying out much more extensive works would have been the only way to approach below 2, and especially Passivhaus standards. Incorporation of the BSRIA testing into the actual work programme was not as easy as hoped and it is felt this could have been improved upon with more help from the BSRIA administrators.
- The cooperation of the occupants is essential in order for the retrofit works to run smoothly and on schedule. Some temporary works were needed inside the property (e.g. the installation of a temporary Santon Premier 175l hot water cylinder in the loft (with backup electric immersion heating) whilst the main heating system was out of action to accommodate the needs of the occupants. Also the use of a Big Yellow Store storage facility nearby for much of the resident's not immediately required belongings helped to make life easier for everyone.
- The installation of the monitoring was a challenge and delays in installation caused some disruption to the programme resulting in the solar hot water being commissioned and then de-commissioned, before being re-commissioned again.

In terms of the triple glazing it was found on site that the original suppliers (Sheerframe) and their fabricators needed double the lead in period of the chosen supplier (Liniar). Previous experience of Liniar also pointed to an excellent after sales service which has proved to be the case. There were significant issues with the supply of the front door from the manufacturers Masterdor – subsequently found to be due to the closure of a factory due to difficulties in the market and the credit crunch.

In terms of the energy management system provided by Heatingsave, this has worked and clearly has benefits to offer if it runs correctly, but a number of updates were needed to the firmware as there were initially 'bugs' in the system, leading to problems with the heating system use. These were easily resolved but were an extra inconvenience. Changes to the relay messages that operate the circulation pumps on the heating circuits, to ensure that pumps were not operating too frequently during sleeping hours for the residents, were also needed; otherwise the residents were complaining that their sleep was being affected due to operation noise.

The large 300 litre thermal store is very noticeable and looks quite daunting in terms of the amount of ancillary pipe work (particularly with all the extra monitoring equipment). It has been found that if immersion heaters are needed for any reason it requires more than one 3kW immersion to heat the tank in a reasonable period of time (one immersion takes 4 hours

from cold and a lot of electricity, 2 takes 2 hours from cold). Some discussion and thought as to at what level in the tank the inputs from each heating element should be situated was required, taking into account heat stratification in water; bearing in mind the 3 No evacuated tube solar hot water panels will still produce heat in winter months (although obviously less) when the wood burner back boiler may also be producing heat.

The tank uses standard plate heat exchangers (provided by SWEP) which should be readily available going forward and it is hoped that it won't require removal for a very long time offering a life span and life cycle cost advantage over standard cylinders. A hard water lime control element was plumbed into the system for good measure. The size of the tank dictated the fact that 3 No. panels and not one was specified to meet the energy assessment requirements as advised by CEN (now Climate Consulting). Usefully the thermal store system has an automatic venting system to prevent stagnation and overheating. Also the Heatingsave controller and Heatbank thermal store were found to be very complementary with DPS; Specflue remarked that they had been looking for some while to find a controller like the Heatingsave unit to co –ordinate all the heating elements so effectively.

8. Commissioning and occupancy

The handover process was significantly facilitated by the fact that the residents of the property were involved throughout the retrofit. After completing the works a run-through and a demonstration of all the systems was provided. The occupants were made aware which system controls shouldn't be changed; to ensure that no mistakes will be made, the controls of the heat store bank that should remain constant are located separately from the heating controls that can be manipulated by the user.

To enhance the occupants' education and secure the long-term success of the project a simplified home user guide was created – although it took time to improve it to the desired extent with input from the various participants. The home user guide includes an explanation of the function of each system and their interdependence, as well as maintenance instructions and information on how to address any malfunctions that might occur. General and behavioural energy saving tips were appended to the end of the guide. In fact the resident was engaged and interested enough to pick up everything during installation in any case.

The controls of the heating control system can be accessed remotely by the supplier and developer of the technology. Any queries of the occupants regarding the heating controls can possibly be resolved this way. The Heatingsave heating control system did require some updating of firmware for electronics after problems were experienced by the resident – for example it was turning on circulation pumps needlessly during the night, causing some noise, and although not high level this disturbed the residents sleep. Operation of equipment during sleeping hours should be avoided. The problem was easily rectified once identified.

Some useful data was taken from the extra monitoring provided by the Heatingsave unit for the plumbing installations, and remote access was initially provided via a broadband connection and hub. This was data related to when and how much the solar hot water was delivering during the day. However, this system relied on the resident maintaining a broadband subscription. The resident subsequently cancelled their subscription for financial reasons and data was no longer accessible remotely. This reduced the effectiveness of the measure. Monitoring that requires broadband connections are not a good fit for social housing on a larger scale in the main (unless the resident is motivated); for these financial reasons and also sometimes due to interference. It is still possible to take information from the hard drive provided on site by Heatingsave, but this is much less convenient. The EST monitoring is obviously providing its own data (although, at first glance of what has thus far been received, this could be better in terms of presentation from the monitoring company).

It has become clear that one of the residents does like to live in relatively warm conditions – 23 to 25°C – all year round (demonstrating that any over heating has to be significant). She has even complained of being cold in the living room and yet when asked over the phone and on site she acknowledged that the digital thermometers (one on the room thermostat and one on the smart meter) were showing 22°C. She has accepted that heating to this higher temperature would lead to higher bills, and that this is not an efficient way to run the house. It was discussed with Specflue whether when the wood burner is not being used it

might act as a ‘cold radiator’ and perhaps the extra associated vents were causing some cooling but this was dismissed as not being at all a significant factor.

The house is occupied by two adults and four children (a high density), and they tend to wake up early and wash early in the morning before sunrise. It is hoped the thermal store is storing enough energy overnight to negate the need to use the gas boiler to heat the store and this appears to be the case. We do know that the solar hot water is not able to add to the store until about midday on a sunny day as there is already too much heat in the store. The resident says they are manually turning on the gas boiler as they feel it is necessary before daylight hours and this may be affecting when the solar hot water becomes effective. It is hoped over time the resident will come to understand that manually switching on the gas boiler is not needed; initial monitoring suggests the gas boiler only used 250kWhrs during the last 12 months which suggests it’s use is still greatly reduced however.

LED GU10 bulbs replaced the 9 no existing GU10 bulbs in the kitchen (saving 20 watts per bulb, and liked by the resident in terms of brightness) and CFLs were already used elsewhere in the property. A new shower was installed in the bathroom to reduce hot water usage.

The feedback from the resident is that they love the wood burner and it appears that the reason for this is the more direct radiant heat that this produces which is obviously a personal preference. A leaflet on the different types of wood and how they burn was produced for the resident. It has to be said the annual cleaning of the flue has had to have been built into the annual maintenance programme – and there was some discussion on the obligations surrounding this in addition to the gas boiler annual check. In future TCHG will only prefer to entertain this wood burner solution in rural, off gas grid areas where there is a local economy match. There are many log supply chains and discussions were held with South East Wood Fuels about sustainable supply in the area; the resident has since responsibly chosen to source kiln dried logs.

The residents also like the simplicity of using the SolarVenti system (and on/off and fan speed knob located on the stair well), and despite the background hum it produces (which is not unpleasant) in full operation they leave it on all the time (even in the Summer). The thought that it is not using electricity appeals to them. Some discussion has taken place as to how to actually monitor this kit (tiny tag located in the duct, local weather data etc) as it has been claimed that it produces 1100 kWhrs of energy per annum in terms of pre-heated air but it is not SAP assessed. There is a separate consultant who has offered to do this but at a price not budgeted for. It was hoped BSRIA might help but it appears this is not in their remit.

In terms of the external cladding, the resident requested external security lights and so fixings for these and TV aerials were strategically placed around the external walls to avoid undesirable DIY installations.

Finally, the TCHG’s Assets Team was provided with a run-through of the operation of the installed technologies to ensure that their maintenance staff are well-educated and informed on how to address any malfunctions that might occur.

9. Costs

Item Stage>	Design stage Materials	Labour	Post construction Material	Labour	Comments
Management and administration		£11,957.55		£14,067.72	
Design		£8,050.00		£8,050.00	
Construction overall					
- Prelims	£4,996.00	£7,625.32	£2,450.00	£8,482.12	
- Fabric measures	£12,202.10	£21,929.66		£34,593.41	Materials and Labour costs combines in contract documents for PC stage
- Building services (conventional)	£444.00	£3,712.00		£4,948.00	Materials and Labour costs combines in contract documents for PC stage
- Low /zero carbon technologies	£11,025.00	£14,231.60		£23,301.40	Materials and Labour costs combines in contract documents for PC stage
- Consequential costs		£150.00		£3,945.00	
- Contingency		£5,000.00			Contingency covering costs associated with consequential costs at PC stage
Occupant temporary housing	£960.00	£900.00	£280.00	£600.00	Resident belongings only – No Decant
Monitoring equipment	£2,500.00		£3,596.58		
Monitoring and reporting service		£1,500.00		£1,500.00	
R&D costs (please detail)					

10. Wash-up meeting

A wash-up meeting was held on the 11th of February 2011. Attendees from the following were organisations and companies were present:

- TCHG
- Jenner Contractors
- Bryant & Reina,
- Climate Consulting
- Baily Garner
- Specflue
- HeatingSave
- DPS Tanks
- Solar UK
- Gas Advisory Services
- Passivent

All of the points discussed in the meeting have been covered elsewhere in the report.

11. Doing it again

Definitely do again: One of the issues that were made clear was the effect of the energy efficiency measures that were applied to the building envelope on the thermal comfort of the occupant. Following the insulation of the ground floor and the installation of triple glazing in particular, there was an increase in ambient temperature and the residents noticed an improvement in comfort; especially regarding the feel of the floor and the temperature in the kitchen. An extra benefit of the triple glazing was the improvement in sound insulation, so it is something that we would definitely do again. The panel-by-panel installation of the living room floor insulation was also something that we would definitely do again, as it was quick and less disruptive for the occupant.

Definitely not do again: As the project proved to be successful, there isn't anything that we definitely wouldn't do again – although the use of wood burners is only likely to occur in rural off gas areas. It would be preferred not to use such a large thermal store in future if possible, and options for this have been explored.

Reduction of costs: In order to reduce costs, the replacement of the windows with energy efficient triple glazing could have been avoided, as this was an expensive measure. However it was deemed necessary and proved to be one of the most successful measures, as explained above.

Improvement of the design process: A Passivhaus approved architect could have been appointed to oversee the design process (and to carry out some checks on site). However, it was not deemed necessary as there weren't any major changes to the shape and form of the building. Another reason was that the overall cost of the project would have been significantly higher if a Passivhaus approved architect had been appointed.

Improvement of the construction process: The adverse effect of the weather had more of an impact than initially predicted. Another issue that came up and should be considered in order to improve the construction process is the selection and management of the subcontractors involved. Identifying contractors able to undertake multiple measures would lead to a more streamlined process. This is also an issue from a maintenance viewpoint.

Improvement of the commissioning and occupancy process: As the occupants were interested in the works and involved throughout the process, the occupancy process ran relatively smoothly and was well managed by the main contractor (with a dedicated workman who stayed with the family throughout the process gaining their confidence almost becoming a friend of the family). Better integration of the BSRIA testing into the build programme – dictated by BSRIA which meant the joint attendance opportunity with the contractor was missed. The installation of the monitoring equipment was delayed due to supply issues causing a problem with the commissioning of the solar hot water system – and it did create a call out issue which had to be rectified.

Large volume heated hot water storage tanks and ancillary pipe work do give off more incidental heat than is often appreciated in highly insulated situations when dedicated tank

insulation and lagging has been overwhelmed, and the position of these, or how this issue might be mitigated, needs to be carefully thought about.

An increase in efficiency would be expected from a larger scale of retrofit works in similar properties, as the process would be more streamlined, and all of the lessons mentioned above would have been assimilated.

It is also envisaged that the comparative economic and environmental cost per dwelling would be lower. Specialised subcontractors and installers would be able to complete their work in a number of properties in a single day, thus reducing any travelling costs and carbon emissions due to travelling. Additionally, as larger quantities of technologies and insulation materials would be required, delivery costs would be lower.

In order for the replication of works to be successful at a larger scale, a comprehensive plan of works and strong central project management would be essential. The selection of reliable and cooperative subcontractors would be required. Finally, additional occupant education and training would be desired to inform the users of the environmental and economic benefits associated with the retrofit, and to guarantee that they would fully benefit from the works. The fact that the long term benefits outweigh any temporary disruption in their daily lives would have to be highlighted to obtain their full support.

12. Business benefits

A number of lessons that would benefit future business were learned over the course of this project. In terms of innovation and the use of technology, it was made clear that the interdependency of the installed building systems and their relation to the energy efficiency measures has to be taken into account in the formation of the design strategy. For example, the success of the MVHR is to a great extent based on the high level of insulation on the building envelope and the increase in air tightness.

As one of the aims of the design team was to 'futureproof' the dwelling for climate change, overheating, which is not typically taken into account, was a concern: a specific reason being the presence of a number of heat sources and the associated piping in such a well insulated envelope. To address this, an MVHR which operates on a seasonal basis was selected, leaving the option of natural ventilation during the heating season. TCHG now has a continued dialogue with Passivent and we are looking at an agreement for mainstream stock and new builds. Similarly, West Energy Controls have been specified in standard employers' requirements when MVHR is specified. Future work with Wetherby is planned as we were impressed with this insulation product and excellent quality of finish. We have now profiled our existing stock to look for future EWI improvements that can be made.

SolarVenti are still in touch and using the feedback to help in product development. The thermal store suppliers, Specflue (formerly DPS), stated they were very interested in further work alongside Heatingsave, who say they are working on a non broadband based GSM monitoring version. The main plumbing contractor, Bryant and Reina (now Reina Group), have stated that they have carried out 13 installations of the thermal store on the back of the ZA636L project; mainly in large private houses (which is probably a more appropriate match up).

Beneficial press coverage was received after a local MP with a particular interest in such projects and activities visited the completed property with the local press in attendance

In terms of making the process more efficient, the importance of obtaining the cooperation and support of the occupants was evident throughout the process. It was worth investing some time to keep residents up to date and involved, as well as making sure that the works were, to a reasonable extent, organised around their schedule. A number of leads with RSLs and developers, as well as local authorities, were presented because of the Retrofit for the Future project. For Climate Consulting in particular, a potential business benefit of £100,000 over the course of five years relating to the emerging retrofit market has been estimated.