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: ZA556B
Properties: TSB095 and TSB121

Authors: Camco
& NCHA

Final Report

Project information

- **ZA reference number:** ZA556B
- **Location of property:** NG22, Nottinghamshire
- **Lead participant details:**

  Nottingham Community Housing Association (NCHA)
  Maintenance Department
  Unit C
  Camberley Court
  Bulwell
  Nottingham
  NG6 8GE

- **Date report issued:** 11th November 2011

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1. Project details and directory

Role	Organisation	Contact Details
Project Leader	Nottingham Community Housing Association	Maintenance Department Unit C Camberley Court Bulwell Nottingham NG6 8GE
Registered Social Landlord	Nottingham Community Housing Association	12/14 Pelham Road Sherwood Rise Nottingham NG5 1AP Website: www.nhca.org.uk
'Design'	NCHA Maintenance Department	As above
Energy Consultant	Camco	The Workstation 15 Paternoster Row Sheffield South Yorkshire S1 2BX www.camcoglobal.com
Main Contractor	NCHA Maintenance Department	As above
Monitoring	Parity Projects	
PV supplier	Dulas	
PV Installer	Run by the Sun ltd	
Window Supplier	Pultec	
Window Installer	Cash & Carry Windows (of Mansfield)	
Spacetherm Supplier	A Proctor Group	
MVHR	Nuaire	
dCHP & ASHP Provider	Baxi	
SHW	AES Ltd	

2. Introduction

This project aimed to improve the carbon performance of a very 'typical' house archetype to the kind of level that might be required to achieve our national 2050 carbon target. In the Retrofit for the Future (RftF) project this was predetermined at 17kgCO_2/m^2/yr for all energy (i.e. regulated and unregulated – or *including* appliance use).

To achieve the very low levels of CO_2 emissions we used very high (energy) standard fabric measures ***and*** low & zero carbon (LZC) technologies.

The project also sought to consider the potential role of the main heating technology (ASHP) and dCHP in houses with a lower level of energy performance, these lower levels of performance being more typical for social housing stock now and into the near future.

TSB095
(During pre-improvement airtightness testing)

3. Occupants

The property was void prior to the retrofit. The former elderly tenant had been largely refusing programmatic upgrades for some time. In this project the property was a change of occupancy so there is a significant disconnect between the 'pre' and 'post' occupancy levels making any 'before' vs. 'after' comparison of actual energy use relatively meaningless.

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

Age band	Number before retrofit	Number after retrofit
Under 5 years		2
5-16 years		1
17-21 years		
22-50 years		2
51-65 years		
Over 65 years	1	
Please state if (yes/no):	Before retrofit	After retrofit
Married couple / partners		
Couple / partners with children		Yes
Any disabled persons		

4. Dates

Timeline of key dates:

Event	Date
Project start date (when was the first proposal discussed or agreed)	May 2009
Planning application submitted (if appropriate)	N/A
Planning permission granted (if appropriate)	N/A
Building Regulations application submitted (if appropriate)	N/A
Building Regulations approval granted (if appropriate)	N/A
Contract for work let / signed	Work undertaken by NCHA's maintenance team
Occupants moved out (state if they remained or property was empty)	Void property
Start on site	c.23rd March 2010
Completion of retrofit	c. July 14th 2010
Occupants moved in	c. July 22nd 2010
Monitoring system commissioned and operating properly	c. 1st Jan 2011
Building defects corrected	c. July 14th 2010
Building services and controls operating correctly	c. 1st Jan 2011

- The property was identified early in RftF bidding process. The level of work required to improve the property to 're-let' standard meant that the cost exceeded the threshold for it to be re-let. Normally it would have entered the 'disposal' process. The property was taken out of 'disposal' and became a 'long term void' while the RftF bid, feasibility, and full bid process progressed. Hence there is a very long timeline between the 'first proposal' and 'start on site'.
- We took a very deliberate decision to follow a typical process for NCHA void properties. So there was no special 'design team' or 'architect' in the project. The 'design' and delivery was kept as close as possible to the standard NCHA process. Hence the work was lead and delivered by NCHA's maintenance team and staff with sub-contractors (and where possible the usual sub-contractors). This was so that learning and also replication would be as direct as possible.
- The slightly unusual nature of the project makes the 'start on site' date a little grey. We were visiting the site and holding meetings etc in February 2010. This allowed for us to start obtaining quotes and even ordering some items. However the real work on site really only got going after the airtightness test (though some initial bits and pieces had started prior to that).
- The 'operating properly' date for the monitoring is a moot point. There have been a number of issues. The critical item that was missing until the turn of the year was the electricity used by the 'ASHP compressor'. Early evaluation of the ASHP was done by taking manual readings from the actual meter – these were not arriving on the website.
- The main building services & controls issue was with the ASHP/heating controls. This required several visits up to the end of 2010. Whether or not these are now operating properly remains under review.

5. Pre-retrofit property

The property was structurally sound. However the tenant had been refusing most programmatic stock improvements for some time, hence in terms of services, décor and detail it was generally in poor condition.

General	**Bathroom (pre)**
The property is a 3 bed semi-detached. The EPC details for the property suggest its age is 1950 to 1966. Brick cavity construction (the internal leaf is also brick). The internal walls are mainly brick/block; it has a solid (concrete) floor, hence, high thermal mass. There is a pitched roof (apex gable) with concrete pan tiles.	
Kitchen (pre)	**External (pre)**

Insulation	**Loft insulation (pre)**
The property already had (blown) cavity wall insulation (CWI) [probably polystyrene beads judging from the loft insulation picture]. Loft insulation was 25mm (the paper backed variety). There was no floor insulation	
It is possible to see how thin the insulation is where the insulation does not reach the edge of the loft. The white material is almost certainly cavity wall insulation beads which will have blown out of gaps at the top of the cavity during installation.	

Windows & Doors	**Side Door [& Windows] (pre)**
The existing windows were double glazed. However there was significant deterioration of the seals and deformation of the frames. This was clearly evident during the initial airtightness testing & thermal imaging. The existing double glazing's performance was surprisingly poor. The existing doors (and glazed panel) had low (thermal performance), being wood/wood composite with single glazing.	
 Window (pre)	

Heating & Hot Water

The existing property had no central heating.

There were open coal fires in the kitchen and some bedrooms and a gas fire in the lounge.

The DHW was provided by an electric emersion heater. The existing tank had thin 'factory foam' insulation and a secondary jacket – but this was not even properly attached to the tank.

Open Fire, Kitchen	**Open Fire, Bedroom**
Gas Fire, Lounge	**HW Cylinder (electric emersion)**

6. Design

Overall
One of the key target points was to achieve carbon emissions of below 17kg CO_2/m^2/year (a RftF target).

To achieve this we started with the building fabric (measures including insulation, airtightness and new doors & windows). We considered the ventilation strategy (open ventilation to MVHR). Finally we used LZC technology for space heating, DHW, and electrical generation (ASHP heating, solar thermal, and PV).

'Design' process
The 'design' (and delivery) was led by NCHA's maintenance team to keep this project as close to the standard NCHA void works procedure as possible. Camco provided support to the process as did suppliers (manufacturers / installers). This was a deliberate choice to place learning where it would be most effective for replication and to try to make the improvement process as relevant as possible (not a separate one-off special). While the levels of expenditure available under RftF are significantly above 'normal' social housing resources, we felt that there would be relevant learning and elements which could be replicated and wanted that opportunity to be directly gained in the core void improvement process and team.

Insulation
Walls
In order to achieve the very low overall CO_2 targets, we decided that we would insulate the walls – though CWI was already in place. Where CWI is already in place the 'easy win' has already been achieved and the cost benefit of further insulation is limited. Hence additional (internal) wall insulation would not normally be cost effective within the resource constraints of social housing. However we needed very high levels of thermal performance for the project. Applying internal wall insulation would support a low 'U' value for the walls and also help in the process of improving airtightness.

We used Spacetherm which is a relatively new product with good insulation at low thicknesses. Though expensive we felt that this was an interesting product with significant replication potential. Spacetherm uses aerogel together with boards of various types. Aerogel comes in 10mm thick sheets so the insulation element is available in 10mm multiples up to 40mm thick. A Proctor Group laminate the aerogel to various construction materials (OSB, MDF, plasterboard, plywood etc) to create the Spacetherm product (insulated board). Because aerogel generates low 'U'-values in thin depths this means that Spacetherm can save internal room space (due to its thin size – say in comparison to mineral wool). The Aerogel is manufactured by US based Aspen. It is imported in to the UK by A Proctor Group who then Manufacture the Spacetherm product.

The pros of Spacetherm are;

- Good level of insulation at a lower thickness
- Damp proof membrane not required as Spacetherm is hydrophobic (BBA certificate)

The cons of Spacetherm

- Cost (approx £150/2m2)

Floor

We decided to use Spacetherm to insulate the (solid concrete) ground floor. Though the product had not been BBA approved for floors (it has for walls), we felt that this was a viable and relatively low risk option. Again, relatively thin floor insulation could have significant replication potential. We took advice from Proctor Group on the use of the product in this way.

Roof

This was very simple, 300mm of mineral wool.

Windows & Doors

We opted for GRP windows with a very high level of thermal performance. As GRP is structurally sound it does not require (metal) stiffening bars (like UPvC does). This means that the frame is not the 'weak link' in the way that it is for typical windows. This allows very good overall U values to be achieved. We were seeking an overall 'U' value of c.1 for our windows. The structural integrity of GRP should also mean that the frame is less likely to warp over time – hence this product may function better for longer than current typical systems.

Originally, Octaveward were chosen to supply the windows and suggested filling the frames with foam to further enhance performance. Unfortunately, Octaveward had to withdraw from the project. However, they referred us to Pultec, who supplied the final product. The foam filled frame windows were not available and thus not used.

The doors were supplied by the window installer (one of NCHA's window & door supplier installer contractors [Cash & Carry windows]).

Heating & Hot Water

ASHP

The ASHP unit used was Baxi's Ambiflow.

This unit was chosen because NCHA have a strong existing relationship with Baxi, and because we also wanted to try Baxi's dCHP unit within the project. So overall we felt that it could be advantageous to work with Baxi as a partner. The Ambiflow ASHP has a significant weakness in that it does not provide DHW. Clearly DHW is part of the overall energy use in a home. This means that units like the Ambiflow are really only relevant as 'off gas' solutions. It would be highly unlikely that a space heating only heat pump would be the best option where gas is available.

In 'design' terms SAP 2005 assumes an efficiency of 175% for an air to water ASHP where radiators are used. This seemed a little arbitrary especially as we were using a very low temperature heating system (at UFH levels). Baxi suggested that they hoped an SPF of 2.7 might be achieved.

DHW & Solar Thermal

As the Ambiflow ASHP is space heating only, we supported the electric emersion DHW system with a solar thermal system (see also Sunwarm below).

Airtightness & Ventilation

Sunwarm

Sunwarm is a positive input ventilation system manufactured by Nuaire. In theory, the unit can draw from inside the loft, outside of the building or via solar thermal panels (with the full system we had identified). The occupier simply selects ‘warm’ or ‘cool’ on their control and the system selects the optimum source from which to draw the fresh air.

We intended to use a full Sunwarm system (not released into the market). This includes ‘traditional’ MVHR and also a solar thermal panel which can support space heating and DHW. Nuaire (Sunwarm manufacturer) were suggesting an overall contribution to space heating of c. 1,500 kWh per year and contribution to DHW of 1,500kWh per year. Unfortunately the use of the full system at TSB095 had to be abandoned.

MVHR

Instead of the full Sunwarm system we ended up using a ‘traditional’ MVHR system to provide ventilation in the property.

Airtightness

We targeted airtightness of 3. To do this we worked on as many areas as possible. We removed the ‘open’ vents, there were no trickle vents in the new windows, and we used an external box for post instead of having a letterbox. We boarded the upstairs floors (to reduce leaks through the floor). We sealed pipe holes, wiring holes and electrical conduits. We had airtightness testing done mid improvement so we could continue to identify and tackle leaks. Much of this work is not rocket science, it is mastic and expanding foam.

Generation

PV

We added PV to provide additional carbon savings from the onsite generation.

dCHP

Domestic CHP was part of the wider remit of the project. This was not installed at TSB095. The primary property for dCHP was TSB121.

The dCHP unit we were interested in was Baxi’s Ecogen. In theory this unit was potentially a step forward in dCHP because it can produce 1kW of electricity at 6kW of heat. This is a better ratio than previous units. Furthermore Baxi were also suggesting that the electricity generation at lower heat output was better than in some previous units. All this lead Baxi to suggest that the dCHP would ‘work’ in summer when there is only the DHW demand. At the time when this project started Ecogen had only been ‘soft launched’ with Baxi partners. The unit can provide additional heat with a second ‘burner’.

7. Construction

Procurement
We intentionally set out to run the work in the same way as void properties are processed in NCHA's core, day to day business. This means that NCHA take the 'designer' and 'main contractor' role. An NCHA 'surveyor' goes to the property, decides what work is required and organises that work. Some elements of the work are done by NCHA's in house team, and other parts are subcontracted in.

In procurement terms some work is undertaken against existing framework contractors, 'special' or different work was done by obtaining quotes and issuing a purchase order.

Contract type
As the project was kept 'in-house' and delivered along the standard process for void properties there was no 'contract' to issue for the house.

Contract structure and specialist installers
Where work in the project was 'typical' or at least semi-typical this was undertaken by installers who are on NCHA's supplier framework[s].

As a simple example this approach was taken to the installation of the windows. The very efficient GRP windows (manufactured by Pultec) were identified and rough costed by Camco (energy consultants for the project). Cash & Carry Windows (an NCHA supplier) then installed the windows as usual under NCHA's process. The actual cost of the windows could have been included as a 'supply & fit' or NCHA could have paid the manufacturer. The key point being that anything that could be done in the 'standard' way was.

For the none-typical elements (such as the PV) NCHA and Camco pooled experience, approached supplier[s] obtained quotes and then issued purchase orders for each individual 'specialist' item &/or installation.

Specialist elements

- Spacetherm:
  - Material supplied by A Proctor Group;
  - NCHA installed. NCHA staff were trained so that they could install the Spacetherm (IWI). This included training from Hilti and A Proctor Group.
- PV: supply and install by Run By The Sun (Kyocera panels from Dulas)
- MVHR: Supplied by Nuaire
- Solar Thermal: Supplied and installed by AES Ltd
- ASHP & dCHP: Supplied by Baxi; NCHA used one of their normal heating contractors for most of the heating system installation work. This was supported by NCHA (they have in house heating system skills & are a Corgi organisation), and Baxi provided additional technical support and guidance.

Site supervision
Site supervision was undertaken by NCHA in line with the standard void process. A member of the Maintenance team leads the job and oversees work on site.

8. Commissioning and occupancy

Occupancy
In addition to the standard letting process NCHA visited the tenant and discussed the systems in the house – and their use.

Commissioning
In the initial stages we had two main commissioning issues. The first of these related to the monitoring. This is described below, but as this is about the TSB project rather than the measures which are the subject in the project this is really secondary. The significant commissioning issue relates to the ASHP.
There have been subsequent 'failures' (ASHP, MVHR & SHW pump). Which are described in section 11 'problems'.

ASHP
AHSP
One of our concerns for this project was that the special nature of the project, together with the extensive monitoring and publicity potential, would mean that we received an unrealistic 'gold plated' service from suppliers which would not reflect real delivery. Baxi were consulted on the design for the ASHP. In addition to the heat pump and controls they were also engaged for radiator sizing etc.

Once the weather began to turn and there was evidence of the heating being used (from the web based monitoring data) Camco took an initial look at the CoP of the ASHP unit. This was complicated by monitoring issues, but it very much seemed that the CoP was significantly lower than might have been hoped or expected. As we resolved elements of the monitoring problems it became increasing clear that the ASHP CoP was significantly below par. It was also clear that internal temperatures in the house were higher than might be expected (23 to 24 degrees). Communication with the tenants suggested that they were having difficulty with the controls. We (Camco and NCHA) were baffled and we called in a Baxi engineer for help. Engaging with this engineer was a breakthrough for the project. It was clear that we then had contact with someone with a more detailed grasp of the ASHP (& dCHP) technologies.

The fundamental problem with the ASHP at that point was with the 'intelligent' control system. Essentially this system measures the external and internal temperatures – and then calculates the heat required from the heat pump to overcome the heat loss and maintain the target internal temperature. While the theory is great – in practice the intelligent control fundamentally failed to understand the energy characteristics of the house. This meant that on our first visit; with a target temperature of 20 degrees, and an internal temperature of 24 degrees (as measured by the controller), the system's response was not only to remain 'on' but to employ the ASHP booster (the direct electric heating part).

The first set of changes to the controller (December 2010) was not enough to rectify the problem (we were nervous about turning the system down too much and making the tenant cold). On the second visit the Baxi engineer was consulting the manufacturer's technical manual as well as Baxi's technical manual – as we continued to reset parameters in the background calculations. The system has been running on the current settings since the

back end of December 2010. Looking at almost a year of data (Jan 1st 2010 to autumn 2011) we are still not getting the sort of SPF that we should. We are currently talking to Baxi to see if we should go back again and review the system to see if there is a reason for the lower than anticipated performance.

Metering

The first thing to say is that Parity have reviewed their approach to 'commissioning' monitoring systems at least partly in the light of lessons from the RftF programme.

The greatest lesson from the project perspective is that there really needs to be a data review (c.1 to 3 months in – or once the heating season is underway). This would allow proper sense checking of all the data. In addition to identifying any missing measurements this would also highlighted any data sets where there might be calibration issues or mis-feeds of the data.

We had a number of issues, including basic problems (like missing data sets) and the more complex issues (like calibration errors).

9. Costs

The table below provides the costs for the measures – on a 'per house' basis. Clearly all of these measures are not in any single house and this isn't the full project costs (these are spread across all the houses in the project). The table provides and illustrates the 'design vs. actual' cost comparison (not the full project cost comparison).

Item Stage>	Design stage		Post-construction		Comments
	Materials	Labour	Material	Labour	
Management and administration					
Design					
Construction overall					
- **Roof access**	**£1,175**				**See DLO Labour below.**
- **Radiators (etc)**	**£2,350**				**See DLO Labour below.**
- **Floor Insulation (0.4)**	**£1,175**				**See DLO Labour below.**
- **Walls (SWI – Spacetherm 0.24)**	**£14,100**		**£15,284.62**		**See DLO Labour below.**
- **Roof (0.13)**	**£293.75**				
- **Windows (1.0)**	**£10,575**		**£9,987.50**		
- **Doors (1.0)**	**£3,525**				
- **Seal fireplace**	**£1,175**				
- **Airtightness (3)**	**£2,350**				**See DLO Labour below.**
- **Air pressure tests**				**£705.00**	
- **Lighting**	**£56.40**				
- **DLO Labour**				**10,907.00**	**Mainly for installation of Spacetherm and airtightness work**
- **Sunwarm (MVHR with solar heating and SHW capability)**	**££6,462.50**		**N/A**		
- **MVHR (traditional)**	**N/A**		**£757.88**	**£1,855.33**	
- **ASHP**	**£6,462.5**		**£3,456.18**	**£2,350.00**	**See DLO Labour below.**
- **dCHP**	**£6,462.5**				
- **SHW**	**£5,875**		**£3,378.13**		
- **PV**	**£14,100**		**£10,439.87**		
- **Appliances**	**£1,762.50**		**N/A**		
Occupant temporary housing	N/A				
Monitoring equipment	**£7,050**		**£8,271.43**		**Also some consultancy time on top of this.**
Monitoring and reporting service					
Electrical (Various)			**£1,895.00**		
- **dCHP**	**£6,462.5**				

10. Wash-up meeting

To date we have not held a wash-up meeting. There have been various follow up sessions during the project which have partly filled the same purpose. It is possible that an 'end of project' meeting will still take place – but this would be timed to include more monitoring results – rather than being focussed around the construction issues.

11. Doing it again

Problems

Construction

- Windows: In the process of inserting the glazing trim a number of the trimming pieces were broken. Pultec (the window manufacturer) said that a slightly different technique ("there's a knack to it") was required compared to UPvC windows. Pultec sent out one of their technicians to replace the broken trims. This could have been avoided by providing (apparently very quick and simple) training to the project's window fitters. However we only learnt this in hindsight.
- Spacetherm IWI: The internal walls of the house were largely semi engineering bricks (relatively hard). The plan was to use a Hilti gun fixing solution (NCHA's team had on-site training from Hilti and A Proctor). However the guns kept jamming (from the dust generated we think). It was reported that the guns were jamming after fixing about 1.5 boards. This lead to so much time stripping the guns that this was clearly unworkable. This lead to a change in approach to a self-fixing screw. It is also worth mentioning that using the full sized boards was challenging, if we were doing this again we would use the half size boards which would be much easier to handle and manoeuvre. At the time we were installing the boards the weather was good, so the (large) garden was used for cutting the boards. Bad weather would have added to the difficulties encountered.
- dCHP: The dCHP unit is heavy. NCHA like to install retrofit 'boilers' on the wall (because on the floor they take up cupboard space – including the room required for maintenance access). To lift the dCHP unit there is a specific lifting device. However British Gas had the lifting device and wouldn't release it. This lead to a very difficult lifting process (including senior NCHA managers). This problem was compounded by the existing wall not being straight. The relatively short standard fixings for the dCHP were not long enough to allow easy fixing of the very heavy dCHP unit onto the curved wall.
- Sunwarm: The Sunwarm solar panel was relatively special kit to be installed by a Nuaire contractor. The contractor did not attend our on-site, pre-start 'get together' day. The lesser level of communication with an unknown technology ended up meaning that by the time they saw the site we had already installed 'too much' PV so there was not enough space left on the roof. The panel's ducting means that it can require significantly more space than the actual size of the panel. So, although the panel would fit in the space remaining on the roof – the ducting needed to miss the rafters and that was why the panels could not be located in the remaining area.
- Timing: There were difficulties in timing for some kit and some contractors/services. With 'standard' items and contractors it is easy to schedule and phase works. With 'specialist' kit/installers timing becomes much more difficult.

Other

- **ASHP:** The operation of the ASHP control system, and the subsequent effort to re-set the controller meant that the ASHP unit was over heating the house and working very inefficiently for months (this is still not fully resolved).

- **ASHP:** There was a very cold period in the first heating season. During this time the condensate drain became completely frozen. This lead to condensate leaking onto the path outside the back door, and freezing on the floor creating a sheet of ice. The unit also required frequent resetting during this period, it was reported that at one point it was reset 12 times in 12 days.
- **MVHR:** After about a year of operation the tenant report that the ceiling in the landing had water dripping from it. This was directly under the MVHR unit. The cause of this problem was that the condensate drain had not been properly connected.
- **SHW:** We think that the SHW pump stopped working after about 3 and a half months (5th November). Initially we thought that this was a metering failure – as there was some heat being shown from the SHW heat meter. However it appears that heat is from thermal syphoning as the overall SHW performance is well below that which would be anticipated.

Good points

- Labour: It is often said amongst architects, consultants and energy specialists that their detailed energy plans all go to pieces when the manual labour on site ignore the way things should be done! In this project we found that actually what can be achieved by the guys (& girls) on site can be very impressive. The work on site was run by the normal process as far as possible. A 'normal' surveyor, 'normal' DLO workers etc.
    - Air tightness example: We had an airtightness target of 3. To achieve this we organised for the site's leader to be present at the air tightness test. We also organised our own additional air tightness tests during the work. Then we largely left them to it. The airtightness testing process provided learning and understanding of how and where leaks occur. The guys on site took up the challenge and set about sealing everything. Not rocket science – just tape, mastic and foam. The second test (when the process was underway) showed relatively little improvement (because there were so many leaks in the house that having sorted half of them still left lots of infiltration routes). However it again showed the guys on site new forms of leaks and more understanding about levels of sealing. The end of project result was 2.42 (from the BSRIA post construction test). We felt that this was a very good result. Many new-build project fail to achieve this standard! It is worth noting that we did not address the interface between the floor joists and walls. This was a deliberate choice as we thought that removing the ceiling or lifting the floor boards wouldn't ever happen in replication (not just for airtightness purposes at least) and we wanted to see what we could achieve without addressing this area. We doubted that we would reach the target of 3, and surpassing it was an impressive result driven by the guys on site. This shows what can be achieved 'on-site' with the right direction, encouragement and incentives.
    - Dry lining details: Traditionally dry lining has a gap at the bottom (i.e. it doesn't go to the floor). Clearly this creates a potential 'gap' in the insulation and also a weak point in the air tightness battle. Our 'on-site' generated solution was to use strips of Aerogel for the Spacetherm to 'sit' on at the floor

level. Thus providing continued insulation and a more robust airtightness detail – while still allowing for some movement.

- Overall thermal performance of the house: The house does seem to function well for the occupiers. It doesn't seem to overheat and the internal temperatures are relatively stable.

Lessons Learned

Construction

- Spacetherm internal wall insulation
    - According to the Spacetherm wall insulation installers, the material was reasonable to work with. However, they would have preferred "half sized" boards (600 x 2400, rather than 1200 x 2400). Smaller boards would increase manoeuvrability indoors and lead to an improved finish.
- Windows: Certainly for our windows it would have been better to provide our installers with some (very simple) on-site training or support.
- dCHP: The weight of the unit means additional resources are needed for wall mounting.
- New / specialist equipment: As much communication as possible helps to ensure smooth delivery (but this is more difficult as 'special' installers are not as readily available.
- Immature supply chains are not fully reliable.

12. Business benefits

Lessons learned in terms of innovation, efficiency or increased opportunities
The project has enabled NCHA to gain valuable experience in retrofitting project work and has also provided an excellent platform to showcase the benefits of retrofitting both to NCHA staff, contractors, and external stakeholders.

NCHA staff received training in the installation of Spacetherm (IWI) (from A Proctor Group] and also training from Hilti. A Proctor Group commended NCHA's staff and NCHA can now install Spacetherm as a contractor to other organisations.

NCHA's window suppliers/installers (Cash & Carry Windows [of Mansfield]) talked to their usual window manufacturers about this project. The suppliers provided details of more advanced UPvC windows with much better thermal performance than their 'standard' products. There would be an interesting piece of analysis work comparing the costs and benefits of the windows used and some of these other products.

Business leads and opportunities
The Retrofit for the Future project has proved to be very useful in forging links with new suppliers, manufacturers & consultants, and also strengthened relationships with existing contractors and consultants. It has also proved to be an exceptional project for showcasing achievements with a great deal of interest from a wide range of stakeholders.

The project has bolstered Camco's experience in low carbon refurbishment, contributing to its leadership in this sector. The project provided an opportunity to build on PassivHaus expertise and using extensive insulation materials. The project also highlighted the barriers of implementing retrofit projects on the ground and importance of the 'human side,' of such projects. This practical learning has supported the high level work Camco is engaged in.

We anticipate that the greater 'value' from the project will really be established when the monitoring results are clearer. This will demonstrate the real impact on measures.

Value of retrofit business over the next 5 years
NCHA is looking very closely at the development of the Green Deal. The work in this project will help NCHA in terms of thinking about actual savings for customers (not just the theory of 'the golden rule').

If the ECO does provide significant funding for solid wall properties than NCHA will have the option of using Spacetherm products if these are appropriate and viable. This could be a service for other organisations as well as being a measure for their own stock.