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: ZA606E
Property number: TSB074

Author(s): Climate Consulting Ltd

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Technology Strategy Board
Driving Innovation

SBRI
Government challenges.
Ideas from business.
Innovative solutions.

Final Report

Project information

- **ZA reference number:** ZA606E

- **Location of property:** CR6, Surrey

- **Lead participant details:**

Climate Consulting Ltd
Stephenson House
2 Cherry Orchard Rd
CR0 6BA
www.climate-consulting.co.uk

- **Date report issued:** 6 February 2012

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1. Project details and directory

Role	Organisation	Contact Details
Project Manager /Energy Consultant	Climate Consulting Ltd	Address: Climate Consulting Ltd Stephenson House 2 Cherry Orchard Road CR0 6BA Website: www.climate-consulting.co.uk
LA	Croydon Council	Address: Asset and renewal division Department of adult services and housing 13th Floor south side Taberner House Park Lane Croydon CR9 1DH Website: www.croydon.gov.uk
M&E Engineer	Bryant & Reina	Address: 70 Pavilion Road Folkestone CT19 5RL Website: www.bryantandreinagroup.co.uk
QS	Jenner Contractors	Address: Century House Park Farm Road Folkestone Kent CT19 5DW Website: www.jenner-group.co.uk
Main Contractor	Jenner Contractors	Address: Century House Park Farm Road Folkestone Kent CT19 5DW Website: www.jenner-group.co.uk
Sub-contractor - electric	Bryant & Reina	Address: 70 Pavilion Road Folkestone CT19 5RL Website: www.bryantandreinagroup.co.uk
Sub-contractor - heating	Bryant & Reina	Address: 70 Pavilion Road Folkestone CT19 5RL

		Website: www.bryantandreinagroup.co.uk
PV installer	MAP Environmental	Address: Gallants Business Centre, Lower Road, East Farleigh, Maidstone, Kent ME15 0JS Website: www.mapenvironmental.co.uk
Solar gain heat pump	Thermal Reflections Ltd	Address: Unit 3 400 Cromwell Road Grimsby N.E.Lincolnshire DN31 2BN Website: www.thermalreflections.co.uk
External insulation	Wetherby Building Systems Ltd	Web: www.wbs-ltd.co.uk
Spacetherm insulation	Spacetherm (Proctor Group)	Website: www.spacetherm.co.uk
Vacuum Insulated Panels (VIPs)	va-Q-tec	Address: Wurzburg, Germany Website: www.va-Q-tec.com
Windows (Manufactured by Liniar Windows Flamstead House Denby Hall Business Park Denby Derbyshire DE5 8JX)	Window Plan Ltd	Address: Windowplan House, Knight Road, Strood, Rochester, Kent ME2 2AH Website: www.windowplan.co.uk

2. Introduction

This project addresses the retrofit of a 1919, 2-bed property in CR6, Surrey. The semi-detached property has solid walls, a complex design and is not connected to the gas grid. The design originally outlined in the proposal provided a solution for addressing very hard to treat houses by reducing primary energy consumption to 87.6kWh/m^2a (a 95% reduction from the baseline) and CO_2 emissions to 18.2kg/m^2a.

The solution involves installing a combination of high-performance external and internal insulation, as well as implementing thorough air-tightness, to greatly reduce whole-house energy demand without compromising on external aesthetics or internal space. The use of very high efficiency appliances reduces energy consumption further, whilst remaining heat demand is met by an air source heat pump and increased electricity consumption offset with a photovoltaic (PV) array.

3. Occupants

The occupant of the property was the same before and after the retrofit, and occupied the property during the retrofit works, apart from a single week when she was abroad on holiday.

Prior to the retrofit works the occupant was provided with a visual energy monitor (OWL), with the aim of helping to educate her about the actual breakdown of her energy use, and allow her to adjust her behaviour accordingly.

The tenant has an acute awareness of electricity consumption, due to her very high bills, but very little understanding of how to reduce her bills. One challenge is that she likes to keep her property well ventilated, regularly opening doors and windows, which results in temperature drops.

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

4. Dates

Event	Date
Project start date (when was the first proposal discussed or agreed)	01/10/09
Planning application submitted (if appropriate)	16/04/10
Planning permission granted (if appropriate)	10/06/10
Building Regulations application submitted (if appropriate)	n/a
Building Regulations approval granted (if appropriate)	n/a
Contract for work let / signed	13/07/10
Occupants moved out (state if they remained or property was empty)	Occupant remained in property apart from w/b 26/07/10
Start on site	26/07/10
Completion of retrofit	Main works completed end of November 10
Occupants moved in	Occupant remained in property
Monitoring system commissioned and operating properly	August 11
Building defects corrected	August 11
Building services and controls operating correctly	August 11
Other key dates? (please add more lines as necessary)	

5. Pre-retrofit property

The property is a two bedroom semi-detached dwelling built in 1919 and is exceedingly hard to treat. It is not on the gas grid and has an aesthetically pleasing front façade. The property is of solid wall construction, with sloping ceilings on the first floor; the ground floor is partly suspended timber and partly solid floor construction. The porch and the bathroom extension were added to the property after the original construction, possibly at the same time as the original house was split into two semi-detached dwellings.

The property was monitored for six months prior to the works commencing on the property. Data on electricity consumption, internal and external temperature, humidity and CO_2 levels were collected. The collected data showed that during the heating season the internal temperatures within the property were very low causing considerable discomfort to the elderly resident. The poor building fabric meant that heating the property and preventing draughts was difficult, and the poorly controlled old storage heaters had to be supplemented with peak rate electric radiators.

The property was chosen as it had been identified as having a poor energy performance and had been in need of improvement works for many years, however the challenges of treating it had led to other properties types being treated instead. It is one of over 3 million solid wall properties across the UK, and, as is common, had been brought up to decent homes standards. The prevailing levels of insulation within the property and high air permeability meant the property was still challenging to heat however, and cold surfaces had resulted in mould and damp problems.

SAP calculations had been carried out. These showed an estimated 155kg $CO^2/m^2/yr$ carbon emission per year; anecdotal evidence from the resident showed the challenges in heating the property, and indicated fuel bills of approximately £140 per month and this was backed up by data from the SAP calculations. As part of Phase 1, analysis of the property using Passive House Planning Package (PHPP) was undertaken.

6. Design

The design strategy and actual installation works are overall the same. The original solution developed aimed to keep the loss of internal space to an absolute minimum, whilst preserving the appearance of the house and making it possible to carry out all works without relocating the tenant.

High-performance insulation was specified to lower the space heat demand to a fraction of its baseline level. The remaining heat load was proposed to be met with a solar gain heat pump, and some of the additional electricity use to be offset with a PV array.

<u>The proposed design strategy was as follows:</u>

The front wall will be insulated internally using Spacetherm aerogel, backed with a vapour barrier to avoid interstitial condensation. This will be wrapped around the side walls to reduce thermal bridging to negligible levels. The side and rear of the property will be insulated with a rendered, phenolic external wall insulation system (EWI). The lowest part of the insulation will be replaced with waterproof extruded polystyrene, which will be excavated into the ground to minimise the ground floor thermal bridge. The roof slates will be removed to allow the installation of phenolic insulation in between the rafters, which will meet the EWI at the soffits. This will also allow the roofline to be extended to cover the rear wall EWI and will facilitate the installation of the PV array. The interior of the loft will have additional phenolic insulation within the rafters, while the sloping ceilings on the first floor will have internal aerogel insulation (eliminating thermal bridges at the rafters). The ground floor will be overlaid with thin vacuum insulated panels (VIPs), and these overlaid in turn with an underfloor heating system which will minimise the risk of perforation of the VIPs. Air permeability will be reduced to a level of 5ach@50Pa through a rigorous work program. Very high-performance doors and windows will be sourced, and where relevant will be moved outwards to minimise shading caused by the EWI. The current porch will be replaced with a larger sun-lounge to maximise solar gains.

A solar gain heat pump will be installed, with collector panels on the unshaded east wall feeding into a “thermodynamic block” in the loft, providing space and water heating across the house. This novel technology uses sunshine, wind and rain to speed up heat transfer to the refrigerant in the heat pump, and shows great promise for application in the UK. Finally, a PV array will be installed on the south-facing roof and major appliances will be exchanged for high-efficiency equivalents.

<u>Changes to the design were as follows:</u>

1. PV installation was reduced from 1.26 kWp (1029 kWh/year or 7 panels) to 1.08 kWp (883.872 kWh/year or 6 panels) due to roof space limitations. The dormer roof was measured slightly incorrectly at the design stage, limiting space for the application of PV.

2. Internal sloping ceiling insulation was not installed, equating to a reduction in insulation from 30mm to 0mm. This was due to a change in opinion of the resident who decided she did not want to lose any more ceiling height as it would make it more difficult to turn over her mattress. When re-modelled, this made little difference to the overall dwelling performance as the roof was also insulated externally at roof level.

3. There was an improvement in the airtightness of the building post-retrofit, from 5ach@50Pa to 4.01ach@50Pa.

4. The solar gain heat pump was removed and replaced with an air source heat pump after a few months operation. This was due to a number of factors including ice build-up on the plates, the aesthetic appearance of the panels, concerns over the operational performance. Unfortunately, this removal took place before reliable data could be collected about the performance.

5. Rising damp was discovered in the under stairs cupboard. A specialist survey was undertaken and a report issued. The recommended works were undertaken and a guarantee issued. Removal and reinstatement of floor boarding was undertaken and installation of additional under floor ventilation. This has had no significant impacts on the project.

The changes are summarised as follows in PHPP and SAP:

PHPP	**Baseline**	**Targets**	**Design**	**Actual**	**Design % reduction**	**Actual % reduction**	**Difference**
Annual CO_2 emissions	359	20	20	21	94.4%	94.2%	0.23%
Total Primary Energy	1470	115	80	90	94.6%	93.9%	0.66%
SAP	**Baseline**	**Targets**	**Design**	**Actual**	**Design % reduction**	**Actual % reduction**	**Difference**
Annual CO_2 emissions	154	17	16	25	89.6%	83.8%	5.81%
Total Primary Energy	1020	115	110	180	89.2%	82.4%	6.82%

It is clear that the changes made little difference to the calculations carried out in PHPP, but had quite a significant difference in SAP. Nonetheless, the changes still resulted in the dwelling achieving a c.94% and c.83% reduction (in PHPP and SAP respectively) for both CO_2 and primary energy.

7. Construction

- Procurement: The main contractor was appointed due to the strong relationship held between them and Climate Consulting, as well as their passion to be at the forefront of the sustainability and retrofit markets.
- Contract type: A standard JCT contract was developed between Jenner Contractors and Climate Consulting, covering the main retrofit works over a 3-4 month period.
- Contract structure: The main contractor had direct labour covering the majority of trades, plus one main subcontractor was employed for M&E. Specialist installers and subcontractors for plastering and the application of the external wall insulation system were employed.
- Subcontractors: The M&E contractor undertook the main M&E work and engaged specialist subcontractors for the solar gain heat pump and PV panels.
- Specialist installers: The following specialist installers were engaged via the main contractor.
  1. PV: MAP Environmental
  2. Solar gain heat pump: Thermal Reflections Ltd
  3. Windows and doors: Windows by Liniar Windows, external doors by Masterdor
  4. External wall insulation

- Specialist equipment suppliers: The PV system, external wall insulation and windows were purchased by sourcing competitive quotes to specific performance specifications. All other special equipment was chosen based on its performance, the majority only having a sole supplier within the UK.
- 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. The energy consultant was retained as project manager. The design team consisting of the project manager, lead contractor and local authority contact were retained throughout. The project manager and site manager were responsible for supervising onsite and signing off works.

Lessons Learnt

Probably the most fundamental lesson relates to undertaking the works in an occupied property. With the resident remaining in the property the time period for the works proved to be longer than was anticipated. Works had to fit around the resident's timeframes and daily routine. Understandably at times the resident found elements of the process stressful and the contractor team reduced work levels or left the site for a while to give her some personal space. It was also important to always leave the site tidy at the end of the day, and ensure sanitary wear and kitchen facilities were fully operational, which created delays. I would suggest that if the property had been vacated the work would have been completed in half the time.

Working with the insulation material:

- VIPs & Spacetherm: The Spacetherm product was very dusty when cutting. Therefore all cutting took place outside.

  It came apparent that we couldn't install VIPs to the floor without a protective layer to reduce the risk of the panels being punctured in the future. We therefore designed a method for layering the VIPs and underfloor heating to provide maximum protection. In addition, on placing an order for the VIP panels, it was decided to order as many of the standard size panels as would fit on the ground floor and to then infill remaining gaps around the edges of the rooms with phenolic insulation. Not only did we think this would have negligible effect on the design u-values, but in practical terms we actually envisaged it having a potentially positive effect as we were concerned that any expensive bespoke sized panels that we ordered may not fit exactly due to errors made in measurements and it is of course not possible to cut the panels as you cut through the vacuum. Furthermore, by infilling phenolic around the edges of the downstairs rooms, we thought it would reduce the risk of punctures to the VIPs further when future tenants nail down replacement carpets. Overall, it was thought this was a much more practical and cost effective solution.

- Roof insulation: The risks associated with cutting and installing rigid insulation between the rafters were a concern, e.g. a sudden downpour whilst these works were carried out, before the new roof felt was fitted. To reduce the risk the works were carried out within a day.

- Flat roof within bathroom: The insulation had to be installed to the interior of the roof area. The existing plasterboard ceiling was removed, insulation fitted, new plasterboard ceiling installed, dry line finished and decorated. This was disruptive to the resident as there is only a single WC.

External works:

The external insulation works and windows works were relatively easy to manage and, whilst unsightly during the process, only caused inconvenience rather than disruption to the resident.

Windows and doors:

High specification products were used. For the doors in particular this limited the available products and suppliers that could be used, which led to higher prices than a slightly lower specification but more readily available product. The additional carbon saving for the high specification door is marginal and a better total value may have been achieved by looking at the wider market and being less stringent with targets.

Underfloor heating:

This was very disruptive for the resident. The works schedule had to be organised so that there was always an available room for the resident.

8. Commissioning and occupancy

The heating system was commissioned within an afternoon. The air source heat pump was simple and straightforward to understand when commissioning; we felt however that the user interface could be simplified.

The resident continued to live in the property as the work took place, so she could see the works taking place and measures installed. She was also provided with a simplified list of the works at the beginning and a number of discussions were held to ensure she understood the process.

Handover involved a run-through of the heating system controls and a very simple 2-page crib sheet on how to use the system effectively (see Appendix).

The main thermostat controller was limited to prevent the resident trying to set the temperature above 24°C whilst leaving the windows and doors open (which she has a tendency to do) and therefore waste heat. Furthermore, we attempted to explain to her that the heat pump technology, which operates most efficiently when coupled with the low temperature distribution underfloor heating, takes longer to heat the house and therefore she should minimise the amount of time she leaves her windows and doors open to prevent that loss of heat.

9. Costs

Item Stage>	Design stage		Post-construction		Comments
	Materials	Labour	Material	Labour	
Management and administration	£4,424.00	£6,582.00	£4,424.00	£6,582.00	All parties realised they were required to remain within the agreed contract sum. Therefore, there was little change from the design stage sum. The couple of small omissions (i.e. no labour for the installation of insulation to the sloping ceilings were absorbed in the additional contingency that was required due to consequential costs such as redecoration (as strongly requested by the tenant), replacement extract fans, damp proof works etc.
Design		£16,975		£16,975	
Construction overall	£96,314.04			£96,314.04	
- Prelims					
- Fabric measures	£20,324.00	£26,210.41	£20,324.00	£26,210.41	
- Building services (conventional)	Included in Low /zero carbon technologies			Included in Low /zero carbon technologies	
- Low /zero carbon technologies	£13,725.88	£5,268.00	£13,725.88	£5,268.00	
- Other (add more rows and break down costs further if you wish)	£1,540.00	£2,894.25	£1,540.00	£2,894.25	
- Consequential costs	£0	£0	£0	£6,342.51	
Occupant temporary housing	£0	£0	£0	£0	
Monitoring equipment	£1,165.05	£1,200	£1,165.05	£1,200	
Monitoring and reporting service	£0	£19,475	£0	£19,475	
R&D costs (please detail)	£0	£0	£0	£0	

10. Wash up meeting

Discussion on the success of the project, lessons learnt and the challenges took place when the main contractor, M&E contractors and project team were on site to undertake the snagging and in subsequent conversations.

All the outputs from these discussions have been covered in the other sections of this report.

11. Doing it again

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

1. Definitely do again: Install the phenolic external wall insulation, triple glazing and underfloor heating.
    - ⇨ At phase I the external wall insulation appeared to be the best in terms of cost per tonnes of CO_2 saved. In addition, the installation of the above measures seemed to make the greatest difference in the way the house felt internally – instead of being cold and damp it felt warm and cosy.
    - ⇨ The installation of the phenolic external wall insulation was a smooth process. The entire design team were astonished at the effect the external wall insulation had on the warmth and comfort levels to the property.
    - ⇨ Uponor Unipipe system 12 underfloor heating system was ideal for this particular project. The installation was well planned, with particular zones being installed over a 5 day period. The essential element of this installation was the floor laying by a competent carpenter immediately after the pipework had been laid and tested. The user interface offered by Uponor is outstandingly simple to control.

2. Definitely not do again: Install the solar gain heat pump
    - ⇨ The solar gain heat pump has been removed from the property due to concerns over its operation.

3. Reduction of costs:
    - ⇨ We would omit the solar gain heat pump and replace it with a lower cost, more tried and tested heat pump.
    - ⇨ We could have potentially omitted the replacement porch from our design. In addition, although the triple glazing made a positive effect to the feel of the property, it was an expensive measure to install.

4. Improvement of the design process
    - ⇨ The design process went as well as it could have, so we probably wouldn't have changed much.

5. Improvement of the construction process (reduce timescale, smooth operation, etc.)
    - ⇨ The construction process was generally very efficient.
    - ⇨ However there could have been times where more labour could have been on site to complete works, such as redecorating, in order to

speed up the process and reduce the length of disruption to the resident.

- ⇨ We would recommend works to take place in the summer months when the effect of leaving windows and doors ajar is negligible and the potential for mud being trampled into the house is minimised.
- ⇨ Having the resident in-situ slowed the work programme, e.g. there could only be a limited number of people on site at a time, appliances and plumbing had to be left working, rooms made available for use and the site had to be tidy at end of each working day. Overall there was a high level of liaison required with the tenant throughout the process.

6. Improvement of the commissioning and occupancy process
   - ⇨ Commissioning of the solar gain heat pump was not done in the worst case conditions (i.e. mid-winter when temperatures fall below zero) and therefore, despite having an official commissioning document, the system did not work sufficiently.
   - ⇨ We attempted to engage the resident as much as feasibly possible to ensure her cooperation throughout the process. However, as an elderly resident not used to lots of disruption, the process was quite stressful for her. We decided it best to give her a break at one stage, but this had to be balanced with the fact that we didn't want to prolong the overall process. We found it very important to respect her wishes by ensuring shoes were always taken off on entering the house etc.

We would expect efficiency gains in almost all aspects of the retrofit works in a larger programme of retrofits, e.g. 50 homes of similar age and design in a similar neighbourhood. This would result in specialist installers being able to complete their works on a number of properties in a single day, therefore reducing travel costs and having the potential for overall cost reductions due to economies of scale. Furthermore, delivery cost to site would be reduced per dwelling as products for a number of properties could be delivered at once. This is particularly relevant to the VIPs, which were imported from Germany. An increase in the demand for these products in the UK would also encourage the suppliers to expand fully into the UK market, therefore making these products more readily available in this country.

In my view, the key to making replication at this scale successful would be to have a comprehensive plan of works and reliable suppliers who will conform to delivering in a timely fashion, so that the works could be rolled out down a street in an efficient and cost effective manner.

12. Business benefits

All project partners are positive about their experiences on this project, the lessons learnt and the opportunities it presented.

Climate Consulting has extensive experience in providing consultancy for the design of low carbon solutions for both refurbishments and new build. This project has enabled the organisation to gain detailed, hands-on experience throughout the works programme, and to gain an understanding of the practicalities of (for example) using insulation materials that would often be deemed too expensive, innovative or difficult to source for a standard works programme. This knowledge and other lessons learnt will assist us in the advice that we give to clients. Monitoring the property prior and post works is also giving us valuable information on actual benefits and usage patterns rather than from modelling data alone. Climate Consulting is continuing to build its retrofit consultancy, and anticipates approximately £500,000 worth of consultancy in this sector over the next 5 years.

Jenner Contractors have gained the opportunity to speak with authority when talking to potential clients about the Green Deal, and potential retrofit schemes. Whilst it is difficult to put a value on this, Jenner Contractors recognise that it is going to be a developing and expanding market and this project has given us the opportunity to be seen as an attractive partner for such works.

Bryant and Reina Limited have benefitted greatly from the opportunity to participate in this project. It was our first retrofit project and was a satisfying and valuable learning experience, both in terms of the technology and the practical issues involved in designing and implementing a project of this type. Since ZA606E we have undertaken one other retrofit project. With the experience now gained we have a highly credible offering in the market place for retrofits. It is difficult to quantify how big this market will be in the future, but we believe it will be a growing opportunity and we are extremely well placed to take advantage of it.

13. Appendix - Heating and Hot Water Controls

Programmer in Airing Cupboard in Main Bedroom

Iflo Two Channel Programmer
Hot water - denotes programme settings for your hot water
Heating - denotes programme settings for your heating

OFF – Will not run the heating first floor/hot water
TIMED – Turns the heating first floor/hot water on and off at set times programmed e.g. 6.00-8.00 and 16.00-21.00
ONCE – Runs the heating first floor/hot water from the first time it is set to come on to the last time it is set to go off e.g. **6.00**-8.00 and 16.00-**21.00**. It will use the times highlighted in red from programmed times.
ON – Will run the heating first floor/hot water 24hrs a day
ADVANCE – Overrides times till the next off time set e.g. Programmer set on auto 6.00-8.00 and 16.00-21.00. Pressing the MAN button at 14.00 will bring on the heating first floor/hot water till 21.00 then will carry on with normal operation

Room Thermostat
Regulates temperature of heating on the first floor. Recommended between 18 and 22

Underfloor Heating – Ground Floor

UFH Room Thermostat

Regulates room temperature for the underfloor heating in each room.

Set temperature using the + an – buttons. Recommended temp is 21 degrees this will ensure maximum efficiency

This is the only control required