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: ZA538P
Property number: TSB076

Author:

Keniston Housing Association

The work reported here has been funded by the Technology Strategy Board under the Small Business Research Initiative (SBRI) under the Retrofit for the Future programme. This project is one of nearly 90 projects funded under the programme. Further information on the programme can be found at: www.innovateuk.org/retrofit

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Driving Innovation

SBRI Government challenges. Ideas from business. Innovative solutions.

Final Report

Project information

- **ZA reference number:** ZA538P
- **Location of property:** BR6, Kent
- **Lead participant details:** Keniston Housing Association
  13 Artington Close
  Orpington
  BR6 7UL
- **Date report issued:** 5th May 2011

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Appendix A: Graph showing monitoring of room temperatures before and after the heat pump was installed.

1. Project details and directory

Role	Organisation	Contact Details
Keniston Housing Association	Keniston Housing Association	13 Artington Close Orpington BR6 7UL www.kenistonha.co.uk
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Architect:	Broadway Malyan	Riverside House Southwark Bridge Road London SE1 9HA www.BroadwayMalyan.com
Environmental Engineer	JWA Associates	Head Office Suite 3a, The Courtyard Shaftesbury Dorset SP7 8BP www.jwabuildingperformance.com
Main contractor	Total Concept Solutions	TCS Group 2nd Floor, 141 - 142 Fenchurch St London EC3M 6BL www.tcsgroup.eu.com
Sub-contractor – M&E	Icel Group Ltd	Icel Group Ltd, Ashmill Business Park, Ashford Road, Lenham, Kent ME17 2GQ www.icel-group.co.uk
PV installer	Naturalwatt Ltd	Naturalwatt Ltd. Queensgate House 48 Queen Street Exeter Devon EX4 3SR United Kingdom www.naturalwatt.com
Supplier – windows and doors	Piper Windows	Piper Windows 140 Newington Road Ramsgate Kent CT12 6PP www.piperwindows.co.uk
Supplier – heat pump	Aermec UK Ltd	288 Bishopsgate London EC2M 4QP www.aermec.co.uk

Role	Organisation	Contact Details
Supplier – green sockets	Vixen Controls Limited	Newport Road Aldershot Hampshire www.vixencontrols.com
Supplier – monitoring and controls		The Technocentre Coventry University Technology Park Puma Way Coventry CV1 2TT www.wattbox.com

2. Introduction

The project initially came about as a result of a connection between Broadway Malyan Architects, who were seeking to test the low carbon retrofit market and Keniston Housing Association, who look after 700 homes in London and the South East and were interested in investigating whether there could be common approaches to the sustainable retrofit of existing housing stock. We were also keen to explore whether solutions which reduce energy consumption result in perceived and actual reduced energy bills for low income families.

The aim was to review whether there could be a replicable solution applicable to both void and tenanted homes that may or may not be at Decent Homes standards and makes most benefit from shared external spaces between houses. The project was an attempt to really reduce disruption to tenants by carrying out mostly external works (the digging of a borehole on communal land, with the wider potential of bringing a district or shared energy network to the estate.

3. Occupants

The occupants of the property were the same, before and after the retrofit and occupied the property during the retrofit.
It would be worth understanding that the occupants had and will have a particularly large impact on the measured energy and environmental performance of the property. Before the retrofit the occupants used a greater-than-average amount of heating and electricity, and tend to occupy the property almost continuously.

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

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	2	2
	Before retrofit	After retrofit
Married couple / partners	Yes	Yes
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)	September 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	April 2010
Occupants moved out (state if they remained or property was empty)	N/A
Start on site	April 2010
Completion of retrofit	March 2011
Occupants moved in	N/A
Monitoring system commissioned and operating properly	January 2011
Building defects corrected	March 2011
Building services and controls operating correctly	January 2011

5. Pre-retrofit property

The property is a 95sqm two-bedroom two-storey end of terrace house built in 1982 and was renovated to meet Decent Homes standards in 2004. It is located in BR6, Kent in a residential estate. The property is one of a line of eight almost identical houses in a terrace. The house faces a pedestrian-only pavement within a local density of approximately 26 dwellings per hectare. There is a small garden to the front with a 10 metre long garden to the rear, which faces on to the shared external green alongside vehicular access. There is a large wood and fields nearby and farmland to the south. This estate is within a pocket of housing where there are no known exceptional statutory planning issues in this location.
The house is a cavity wall construction, with aluminium double glazed windows. Originally the rear upper level featured timber cladding, but new cavity walls were tied to existing brickwork piers in a renovation in 2004, when all cavity walls were injected with mineral fibre insulation. The property was supplied with mains gas and electricity, with a wall mounted gas boiler.
In terms of original property selection, the housing officer identified 5 properties where local knowledge indicated that the tenants would be positive about the proposed works. After consultation with the architect and engineer, the proximity to communal grassed areas suitable for the ground source heat pump borehole was the deciding factor.

The property has fuel bills prior to the retrofit for gas and electricity. According to the bills, in the two years between August 2006 and August 2008, the two tenants used on average 8,000kWh of electricity and 9,300kWh of gas. SAP calculations estimated the following usages:

- Electric use 4361 kWh per year
- Natural Gas use 13603 kWh per year
- CO2 Emissions 58 kg CO2/m² and yr
- Primary Energy Requirement 292 kWh/m² and yr

Mid-way through the retrofit the property was being monitored using the Wattbox, which was installed before other works had been completed. It allowed us to monitor the room temperatures and external temperatures and the use of electricity before and after the heat pump was installed. A graph to show the difference in room temperature profile is in Appendix A.

6. Design

The key measures of the proposed retrofit were based on an incremental approach to carbon saving, starting with reducing operational energy demand, delivering energy efficiently and generating energy using renewable technology. During Phase 1 we undertook both thermo-imaging and air permeability tests to investigate the performance of the fabric in relation to user habits and demands on the existing central heating. The main result of this on the design was to slightly increase the airtightness of the envelope whilst maintaining a natural ventilation strategy, increase the levels of loft insulation and replace the windows and doors with high-performance units. We then decided upon low energy lights triggered by smart controls and low energy electric appliances. The heating and hot water system would be replaced by an all-electric system comprised of a vertical borehole ground source heat pump (GSHP) system to provide central heating, year round hot water and possible cooling in summer and 3.7 kWp roof-mounted photovoltaic panels.

All of the work would be undertaken with the tenants in occupation, which drove most of the decision making. The key aim was to carry out as much work outside of the property as possible using communal space for drilling the borehole for example and to reduce disruption we tended towards limiting internal works to the absolute minimum necessary, such as replacing radiators and electric shower to be compatible with the heat pump. From a purely energy-minded standpoint it would have been preferable to increase levels of wall and floor insulation but on weighing up the benefits of the ability for the occupants to remain in their home and the predominant aesthetic of the estate we decided that the approach would be predominantly technological in terms of changing the energy delivery systems.

On the whole, the key proposals for the retrofit did not change much in the course of the construction process and the project was delivered very much as designed.
There were two main design elements that changed during the construction period. The first was to relocate the heat pump unit to a more accessible location, which was the external brick bin store attached to the front of the house. This fully-enclosed storage space contained the electricity meter and gas meter, which needed relocating to the outside in its own small cupboard for the heat pump. This was a choice based on wanting to maintain continuous heating and hot water during the switchover of the systems. This caused some delay to the project, as the meter move was dependant on the utility companies.
The second was the decision to install a secondary hot water source – a gas-fired combination boiler as a back-up to the heat pump, which had teething problems after commissioning during the cold period in November and December, when the heat pump kept cutting out. We did not want to allow the possibility of the tenants being without fixed heating and running hot water during the Christmas period, and although we had removed all of the gas system to install the heat pump (including water cylinder, pipework etc.) we still had adequate space in the kitchen to leave a combi boiler, which to date has not been used, since the heat pump has been working as planned.

7. Construction

Key facts:

Procurement - The project was negotiated with a framework partner, who was the contractor of the heat pump system.

Contract type – standard JCT Minor Works 2005 (rev 2009) with Contractors Design

Contract structure – a main contract with direct labour covering the borehole for the heat pump, with other trades sub-contracted

Sub-contractors – There were two sub-contractors in the construction phase:

- Mechanical – who also covered some of the builder's works
- Electrical

Specialist installers – There were four sub-contracted specialist installations in the construction phase:

- Window and door installation - engaged via the main contractor
- Solar photovoltaic system installation - engaged via the main contractor
- Green button installation - engaged via the main contractor
- Controls and monitoring installation - engaged via the client and architect

Specialist equipment suppliers – in addition to the above, the only specialist equipment was the heat pump, which was supplied by Aermec and procured directly by the main contractor.

Site supervision – the main contractor had a site agent who should have been permanently on site but after numerous prolonged delays made visiting inspections

Role of architect – retained to oversee construction, Sign off works and provide valuations as Contract Administrator. After issues with the main contractor's performance, the architect organised much of the specialist installation work and handled defects directly with sub-contractors.

One of the most valuable outputs from the project was undoubtedly the lessons learned on site about what worked well and what went wrong, and how these were identified and managed.
The key decision taken during phase 1 was to assess whether the heat pump installer (the major system in the house) could manage the role of main contractor. On assessment it appeared that this should not be a problem, given that the heat pump and its supplementary work elements, e.g. borehole drilling installation of radiators, controls, pipe work etc. comprised the bulk of the retrofit works, and the heat installer has had a long-standing track record with these installations. We felt that it should have been straightforward enough to expand that role to include managing other concurrent installations without having to connect with them in any complex way, i.e. the upgrading of loft insulation, the installation of triple-glazing windows and doors, the installation of photovoltaic panels and the installation of green sockets. This did not turn out to be as successful as planned, with the heat pump installer, who took on the role of main contractor struggling to manage two crucial areas:

1. Contractual relationships with the supply chain
2. Engagement with the occupants

The problems the contractor had in managing their own finances and the effect of this on the SME supply chain (in what has been a very difficult economic period) cost the project several months of delay, which had big impacts on the wellbeing of the tenants who were advised that the project should have been completed within two months. Recovering from this miss-management of the tenants' expectations has been particularly challenging. However there will be many unforeseen challenges with new technology and new processes and it made us consider whether retrofit work with particular tenants in situ is suitable when testing somewhat new ideas - it takes a huge level of tolerance to be surrounded by unfinished building works and not be in direct control of it.

Notwithstanding the problems the most successful aspect of the project has been the continuous environmental testing of the house and continuing to monitor it. By undertaking air permeability tests and carefully reviewing the data so far we have been able to respond, optimise or improve on different items of the house which has been useful for the whole project team. Understanding performance and occupant behaviour has been very useful, and it has been valuable to support anecdotal feedback with numeric data.

8. Commissioning and occupancy

Commissioning was carried out on the solar photovoltaic installation, the green button and controls and the heat pump system. The problems discovered related to the heat pump system, which took several visits from a technical standpoint. The heat pump kept cutting out after commissioning in the particularly cold weather and we were unsure whether the problems were occurring because of inadequate design, because of a poor installation issue or due to the extra connection to the smart controls.
When the cold weather arrived in November, the heat pump tripped out and the integrated alarm sounded, alerting the tenants to a problem with the heat pump. On the first occasion the tenants managed to call the team and were able to reset the pump after simple instructions on the telephone. This resetting of the unit seemed to work and the heat pump continued running for a further two days before tripping out again on a Saturday morning. This time the reset function did not work and the contractor who installed the heat pump was not responding to phone calls. As responsible landlords it was necessary to supply the tenants with temporary fan heaters as an emergency measure that could be used in the rooms the tenants were occupying, but this did not obviously deal with the issue of a lack of hot water, and it became a potential safety risk for the tenant to be carrying kettles of water up and down the stairs for washing purposes. For that reason a gas combi boiler was put back into the position of the gas boiler which was removed (along with the associated water tank etc.).
When the contractor was able to re-attend the site a whole day was put aside for trying to diagnose the problem with the heat pump. After consultation with the manufacturer there was a lot of debate questioning the design of the system and the size of the pump within the unit. After further physical investigation it turned out that there were two issues – firstly that the glycol ratio in the circulating fluid was too great and secondly that there were some air pockets in the pipework between the pump and the borehole. Both of these issues caused the refrigerant not to circulate as designed and hence the tripping out of the unit. The glycol mix was emptied and refilled and excess air was bled from the system. The system has worked without problems since.

The performance of the retrofitted property has been heavily dependent upon the actions and activities of the occupants. They have been present during each retrofit process and for all of the installations that have taken place and it has taken some time for them to adjust to the difference in the heating that comes from a heat pump compared to a gas-fired system (e.g. more steady air temperatures and not burning hot to-the-touch radiators). On the whole the tenants have been receptive the changes the retrofit has had on their home (which they have lived in for 27 years).
A Home User Guide has been compiled which explains all of the retrofit measures as well as further items such as local amenities, transport, sustainable DIY etc.. The controls systems were demonstrated to the tenants and the landlords but we are still awaiting a full demonstration from the contractor to the landlord’s maintenance team of the heat pump operation and maintenance.

9. Costs

All costs shown below exclude VAT and have been rounded to the nearest whole pound.

Item Stage>	Design stage		Post-construction		Comments
	Materials	Labour	Material	Labour	
Management and administration				£9,021	Contractor's fee to manage sub-contractor's works
Design				£10,340	Architects fees spread out over the whole of phase 2 – detailed design and construction
Construction overall			£71,384		The Contract Sum
Further Detail:					
Site Set Up / Health and Safety / CDM / Contractor's Design	£11,700				Essentially preliminaries + Contractor's Design
Drilling bore hole			£21,600.00		
Spoil Away			£1,500.00		
Windows- supply and Installation			£3,400.00		
Plumbing and electrical works to heat pump			£2,400.00		
Gas meter move and disconnection			£1,000.00		
Groundsource Pipework			£4,200.00		
Heat pump			£5,012		
Supply, deliver and install new radiators			£2,894		Includes removal of existing radiators
Supply and install new distribution box and cable replacements and electrical extension box			£1,361		
Re instatement works of external landscaping			£1,465		Including extra cleaning bill post-drilling
Supply and installation of Vixen equipment			£5,765		Green sockets, light switches and button

Supply and install secondary connection box for controls			£840	
Power wiring and towel rail			£840	
Loft Insulation			£1227	
A++ fridge-freezer, washing machine and Dish washer			£1039	Bought directly from supplier
External doors			£1310	Includes new bin store door
Testing and commissioning			£3000	Primarily heat pump
Wattbox			£10,000	NOT included in contract sum
Photovoltaic cell supply and installation, remote monitoring			£19,588	Not included in contract sum

10. Wash-up meeting

Due to the contractor's lack of response, a wash-up meeting has not been held. However, input into the report has been made remotely by client and architect.

11. Doing it again

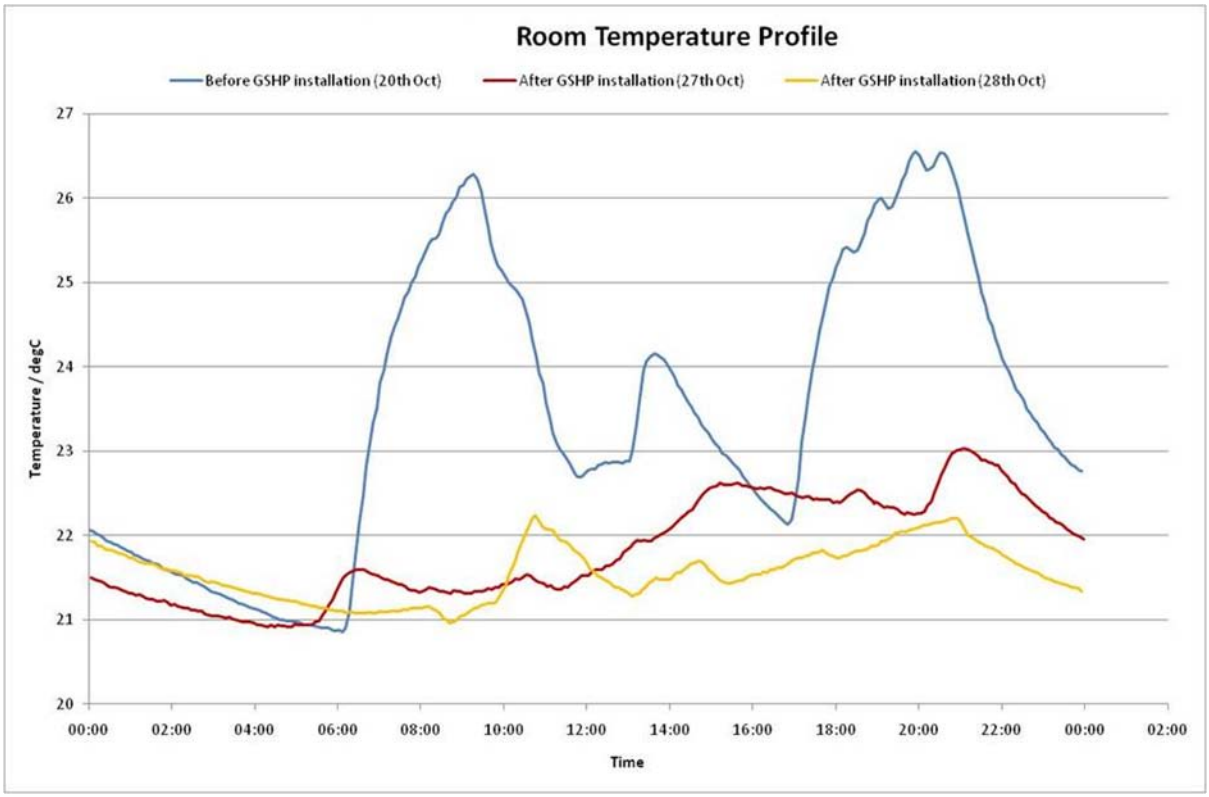
Many lessons have been learnt during the retrofit process. Key points are set out below:

1. **Definitely do again**
   Simple controls and detailed data acquisition – this has been particularly useful PRE as well as post-retrofit as it has allowed better comparative analysis of the results.
2. **Definitely not do again**
   Using the main installer to manage other elements of the works turned out to be very bad experience for all involved, as the programme was heavily delayed and the tenants incurred a period of no heating and hot water, which was exactly the opposite of what we aimed to do, albeit for a period of a few days. Overall, we could have given more attention to the communication from the contractor to the tenant, and where possible taken responsibility for it. The tenant had a lot of questions for the contractors/operatives and sometimes answers from different people confused the situation. As a complete team we should have taken more care to ensure that all involved better understood the concept of the technology and have a higher level of technical understanding, which in hindsight would have helped. A small one off scheme is difficult to justify the high level of resources needed but, with so much that was new and unfamiliar, it would have been a good investment of time.
3. **Reduction of costs (what we might leave out and how we would make things cheaper)**
   The borehole process would have been far more cost-effective it several boreholes were drilled and many properties were connected in one phase or future phases.
4. **Improvement of the design process**
   Much better communication and planning with regard to the energy utility companies, who were very slow to attend the site and move the energy meters.
5. **Improvement of the construction process**
   A bit more mobilisation time and a more realistic programme that could have been adhered to would have made the entire project far more successful with more trust from all parties. Surprisingly, the collaborative nature of the project team members did not help situations when the contractor underperformed.
6. **Improvement of the commissioning and occupancy process**
   The commissioning required the attendance of several trades and specialist installers, which resulted in further delays to the process.
7. **Efficiency gains we would expect from a larger programme of retrofits, eg: 50 homes of similar age and design in a similar neighbourhood**
   As mentioned above, the borehole drilling would be far more cost-effective if done on mass as would the purchase of specialist items, such as the green sockets, which are cost-prohibitive in this context. The installation of solar technology (requiring scaffolding) could be undertaken with great efficiency on a street-by-street basis.
8. **In our view, key to making replication at this scale successful**
   Sufficient trust in the installers of technology, particularly with regards to heating and hot water.

12. Business benefits

Several lessons have been learned that will benefit the participants' organisations in terms of innovation, efficiency and increased opportunities.
From the design and installation teams, this project will obviously contribute to their portfolio of work, and the experience can be applied to future projects. It has given the different organisations greater certainty of what may and may not work, and what safety measures could be put into place when undertaken projects with a level of innovation. At present the project has not created further business leads or opportunities, however, the design team are currently engaging in discussions with several social landlords who are considering a "mass retrofit" of their existing stock.
It is difficult to estimate the future value of retrofit business as a result of the project particularly as the most cost-effective measures are still the basic energy efficiency measures and there is still hesitation over whether new legislation or incentivisation (such as the Green Deal for example) will have the necessary impact to carry out this kind of work on the scale that it is needed.

13. Appendices

Appendix A:

Mid-way through the retrofit the property was being monitored using the Wattbox, which was installed before other works had been completed. It allowed us to monitor the room temperatures before and after the heat pump was installed. Graph below: