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: ZA592C
Property number: TSB042

Author: ECD Architects

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:** ZA592C
- **Location of property:** RH10, Crawley
- **Lead participant details:** ECD Architects, studio 3, Blue Lion Place, 237 Long Lane, SE1 4PU
- **Date report issued:** October 2012

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1. Project details and directory

Role	Organisation	Contact Details
Architect	Energy Conscious Design	Studio 3, Blue Lion Place, 237 Long Lane, SE14PU 020 79397500 www.ecda.co.uk
Crawley Homes	Crawley Homes	Town Hall The Boulevard Crawley West Sussex RH10 1UZ 01293 511803 www.crawley.gov.uk
Engineer	Carter Clack	49 Romney Street, Westminster London, SW1P 3RF 0207 233 0303
QS	Keegans	Studio 2, 193-197 Long Lane, London, SE1 4PD 0207 199 0900 www.thekeegansgroup.com
Main contractor	Wates Living Space	Town Hall The Boulevard Crawley West Sussex RH10 1UZ 01293 438317 www.wates.co.uk
Sub-contractor – electric	Woodlands PH	2 Buckwins Square, Burnt Mills, Basildon, Essex. SS13 1BJ 01268724300 www.woodlandsph.co.uk
Sub-contractor - heating	British Gas	PO Box 4805, Worthing, BN11 9QW www.britishgas.co.uk
PV installer	Solar Technologies/ British Gas	Unit 29, Romsey Industrial Estate, Greatbridge Road, Romsey, Hampshire, SO51 0HR www.solartechnologies.co.uk
Supplier - windows	Green Building Store	Heath House Mill, Heath House Lane, Golcar, Huddersfield, HD7 4JW 01484 461705 www.greenbuildingstore.co.uk
Supplier - internal Insulation	A Proctor Group	A Proctor Group Ltd, The Haugh, Blairgowrie, Perthshire PH10 7ER, Scotland 01 250 872 261 www.proctorgroup.com
Supplier – external Insulation	Rockwool	26-28 Hammersmith Grove, London, W6 7HA, 0845 241 2586 www.rockwool.co.uk
Micro CHP supplier	Baxi	Brooks House, Coventry Road,

		Warwick, CV34 4LL 0844 871 1525 www.baxigroup.com
Heat Recovery Ventilation	EnviroVent	EnviroVent House, Hornbeam Business Park, Harrogate, HG2 8PA 01423810810 www.envirovent.com
Intelligent Heating Controls and monitoring equipment	Wattbox Ltd	The Techno centre, Coventry University, Technology Park, Puma Way, Coventry, CV1 2TT 07974936215 www.wattbox.com

2. Introduction

Crawley was one of the original eight new towns around London aimed at getting people to move from the over-crowded capital into the countryside. To get such massive housing expansion off the ground, the Government-appointed development corporations often looked to exploit the programme benefits of non-traditional forms of construction such as timber frame and pre-cast or in-situ concrete. Crawley saw a number of sites developed using these systems in the 1950's and 1960's, which still exist today and are now managed by Crawley Homes, on behalf of the Borough Council. This project focused on one such housing archetype – the Selleck Nicholls Williams unit - and established a complementary and replicable set of measures which significantly reduce energy use and CO2 emissions associated with this particular form of dwelling. It is intended that the findings will inform the remainder of Crawley Homes' similar properties and will also be widely applicable to other social landlords or building owners with similar stock.

Our approach to energy saving and CO2 reduction was to follow a lean-clean-green hierarchy: seeking to minimise heat losses from the property's thermal fabric and ventilation method; to supply residual space and water heating using replicable, low carbon technology; to minimise lighting and appliance energy loads; and finally to consider micro-generation using proven renewable energy systems.

3. Occupants

The same tenants occupied the property before and after the retrofit. During the work they were decanted into a void property owned by Crawley Homes nearby.

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	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		
Any disabled persons		

4. Dates

Event	Date
Project start date (when was the first proposal discussed or agreed)	01/05/2009
Planning application submitted (if appropriate)	n/a
Planning permission granted (if appropriate)	n/a
Building Regulations application submitted (if appropriate)	09/08/2010
Building Regulations approval granted (if appropriate)	22/09/2010
Contract for work let / signed	
Occupants moved out (state if they remained or property was empty)	
Start on site	
Completion of retrofit	18/08/2011
Occupants moved in	18/07/2011
Monitoring system commissioned and operating properly	August 2011
Building defects corrected	August 2011
Building services and controls operating correctly	August 2011
Other key dates? (please add more lines as necessary)	End of DLP - October 2012

5. Pre-retrofit property

This non-traditional or system built housing was based on a double storey-height, pre-cast concrete loadbearing cross wall panel system for the party walls and elevation flanks. Infill panels between precast flanks are of timber-framed construction possibly lined with asbestos panelling. The roof comprises a timber trussed roof structure and all other internal partitions are of lightweight timber construction. The layout internally contians a kitchen and wc/ utility room at ground floor along with a bathroom and open plan living dining area. At first floor there are 3 bedrooms and a bathroom.

Selleck Nicholls Williams were a subsidiary of china clay giant ECC Ltd, producing prefabricated homes comprising factory-made exposed aggregate cross walls, timber infill panels and roof trusses. In the late 1960's Crawley has clustered estates built using the design and formed of semi-detached and 3-4 unit terraces and 3-storey blocks of flats. These property types still remain to this day. Built as part of the Crawley New Town development, modern day Crawley Homes has 200 such units, out of a total management stock of over 9,500 properties in the town, including over 8,100 rented homes and over 1,450 leasehold properties. TSB042 is a typical 3-bedroom property of this type built in 1968, and is applicable to many other social housing stock throughout the UK.

6. Design

Our approach to energy saving and CO2 reduction is to follow a lean-clean-green hierarchy: seeking to minimise heat losses from the property's thermal fabric and ventilation method; to supply residual space and water heating using replicable, low carbon technology; to minimise lighting and appliance energy loads; and finally to consider micro-generation using proven, renewable energy systems.

The package of measures proposed to achieve these targets included vacuum insulated panels and render system, Rockprime blown stonewool loft insulation, aerogel-backed laminate flooring, PassivHaus-standard, triple-glazed timber windows, doors with integral insulation, humidity-responsive heat recovery ventilation with a retrofit airtightness strategy, a Baxi Ecogen micro-CHP boiler, Wattbox intelligent controls and user interface, LED lighting throughout, A+ (or better) rated appliances and roof-mounted photovoltaics. This package clearly encompasses a comprehensive 'whole-house' approach to the retrofit competition.

VACUUM INSULATION PANELS: Nanopore ultra thermal insulation is a nanoporous solid with a low density and small pores. Gas molecules within the insulation experience the 'Knudsen effect ', virtually eliminating gas energy exchange. Solid state conduction is low due to the low density, and Nanopore's proprietary infra-red opacifier greatly reduces radiation. This filler is encapsulated in a metallised film and evacuated to provide unrivalled thermal properties. The thermal conductivity of Nanopore VIPs at ambient temperature is 0.00036 W/mK - this is approximately 10 times lower than expanded polystyrene.

AEROGEL FLOOR INSULATION: Spacetherm thermal laminates provide unrivalled performance for thickness, with a thermal conductivity of 0.013 W/m²K. Spacetherm C allows floor insulation values to be substantially increased, quickly and simply, with minimal loss of space.

HIGH PERFORMANCE WINDOWS: The Green Building Store Ecopassiv range combines an ultra low U value with 100% FSC Pure timber. They offer extremely low U values, with a whole window Uw value of 0.75 W/m²K and glazing Ug value of 0.60 W/m²K.

MECHANICAL VENTILATION with HEAT RECOVERY: The EnergiVent Q brings new levels of energy efficiency and innovation to the concept of heat recovery ventilation. The system offers a number of innovations: vapour tracking controls and inlet valves; intelligent, energy saving zone controls; DC motors; wireless remote user interface; 5 year filters; and a modular design allowing greater ease of installation. The system is SAP Q approved.

MICRO-CHP SYSTEM: In harder-to-treat properties, it may not be possible to achieve advanced practice levels of fabric heat loss reduction, therefore the need for an easily replicable efficient form of heating remains. The Baxi Ecogen unit uses a free-piston Stirling engine to provide around 6kW of thermal output for space heating and hot water while generating up to 1kW of electricity per hour that can be used in the home. Field trials and laboratory testing have indicated savings of 1 tonne of CO2/yr with this technology.

INTELLIGENT CONTROLS: The Wattbox controller is a newly developed control system which monitors and learns residents' occupancy. The innovative step is in monitoring house electrical consumption to learn occupancy from which, the controller anticipates and times space heating. Similarly, it monitors, learns, controls and optimises hot water heating so excess is avoided. It replaces the timeclock and thermostat with simple 'more/less' heat buttons.

LED LIGHTING: LED lamps offer significant advantages over compact fluorescent lamps: they are 90% efficient; offer significant energy savings; last nearly four times as long; do not contain mercury and phosphor in dangerous quantities, and can be recycled at the end of their life. We anticipate entire dwelling lighting loads of less than 150W with a predicted lifespan of around 20 years with this technology.

7. Construction

The works were undertaken via the existing TPC 2005 (amended 2008) contract, under which Wates were delivering the Crawley Decent Homes programme. This was convenient and obviated the need to set up a special contract for the TSB Retrofit for the Future projects.

Wates appointed a dedicated site manager to the projects who supervised all site activities, ensuring that the works were carried out safely in accordance with activity-specific risk assessments and method statements.

Scope was organized into subcontract delivery packages and orders placed with a general purpose building contractor (GPBC) and specialists. The GPBC used direct labour and subcontractors to carry out stripping out and demolition, groundworks, roofing, alterations to building fabric, installation of airtight membranes and tapes, floor insulation, dry lining, internal doors, sanitaryware, fittings and decoration.

Specialist contractors were employed by Wates to install:

- External Wall Insulation (EWI)
- Loft insulation
- External doors and windows
- Micro-CHP, central heating and plumbing
- Photovoltaic panel micro energy generation (PV)
- Loft access hatches
- Mechanical Ventilation with Heat Recovery
- Intelligent building monitoring and control system

Materials and products were procured by Wates from manufacturers and suppliers nominated by the architect.

Tenants were temporarily re-accommodated as the extensive internal works were too disruptive to permit there execution whilst the homes remained occupied.

The structure of Wates delivery approach was generally successful and the utilization of the Decent Homes contract enabled quick and effective mobilization. However, coordination of the contractors' works interfaces was a key area of the operation which could have been managed better by Wates. With hindsight, it would have been beneficial to take time at the start of the job to call all of the contractors together in workshops to gain clear and mutual understanding of the objectives of the project and the limits and interfaces of each other's activities. This is the contractor's major lesson learnt.

8. Commissioning and occupancy

External wall insulation (EWI)

Proprietary external wall insulation with thin coat render finish was applied to walls. This is a highly effective method of insulating walls with minimal disturbance to residents and none to internal finishes.

As doors and windows were being replaced, the normal EWI retrofit difficulties of extending cills and compromising reveals were not an issue. Similarly, eaves overhangs were sufficient to accommodate the extra wall thickness, obviating any alterations to the roof. Rainwater pipes were altered to new positions.

Due to the vacuum property of the system, the disadvantages this installation brings is the taboo in fixing anything to the thin coat render and its sensitivity to impact. This will be an important message to be understood for its future lifetime.

Loft insulation

400mm of Rockwool insulation was blown into the loft. This was an easy and very effective installation.

Floor insulation

Existing concrete floors were insulated by over-boarding with plywood backed with aerogel high performance insulation. This is a very effective means of insulating the floors with minimal impact on building fabric. However, it was a significantly disruptive exercise and required the residents to vacate during installation.

Retained existing doors had to be undercut to accommodate the additional floor build-up. This lowered door heads and altered proportions of paneled doors.

Doors and Windows

Triple glazed, high performance doors and windows were supplied and installed by Green Building Store, a small specialist supplier which struggled to maintain program during and after the job.

The doors and windows are very heavy and require complicated safe handling methods which are not always available on small, single sites.

Whilst they function very well, they are not suited to cheaper forms of construction as a retrofit installation. The required structural opening modifications in the panellised walls were very difficult to achieve.

There have been many maintenance issues, including seals dislodging and misalignments. Adjustment is complicated but with the instructions provided in the manuals, normal maintenance crews should be able to manage. The misalignments may have been a matter of settlement and may never re-occur. However, they should be monitored.

Baxi Ecogen Boilers

This cutting edge micro-CHP unit is largely prototypical and as a first generation has had its teething problems.

These boilers are extremely heavy, requiring a specialised rig to handle them. They are designed as a wall-mounted unit needing very solid supporting structure.

As they are micro-CHP machines, generating electricity with their Stirling engines, installers require MCS accreditation in addition to GasSafe and IEE qualifications and special training from Baxi. At the time of these installations, there were very few fully qualified Ecogen installers and British Gas, the installer, struggled to provide the appropriate personnel.

A generation meter registers the amount of energy generated by the system.

Despite its thick, acoustically insulated casing, the Ecogen is a noisy boiler; when the engine is working, its noise can be heard throughout these small homes.

The onboard controller, which appears to be very sophisticated, is currently over-ridden by the Wattbox intelligent building monitoring and control system. Consequently, tenants have no experience of using it.

Baxi have been lacking in post-sales support.

PV

British Gas Solar Technologies (BGST) designed and installed the PV array with little disturbance to the roof.

This generates free electricity for use in the home during the day. A generation meter registers the amount of energy generated by the system.

BGST were very good at the initial and installation stages but post-installation support was poor.

Airtightness membranes and tapes

It is essential before installation that all details have been thoroughly developed and that operatives are trained and briefed on the importance of perfect seals and junctions to components and fabric.

This is the part of the installation which would have benefited most from the contractors' workshop mentioned in section 7.

Loft access hatches

These are made by Welhoeffer in Germany and supplied by Green Building Store. They are allegedly airtight but failed under test.

Support from both companies was poor and requests to inspect installations on site were rejected. A video of the installations was sent to them and eventually, they supplied replacement latches when excessive play in the original ones was noted. This had little effect on performance. The problem appears to be the build quality and tolerance generated by chipboard construction with too small seals.

Mechanical Ventilation with Heat Recovery

The systems were supplied and installed by EnviroVent, a small company which struggled to provide support service.

The ductwork installation of this kind is very difficult to ‘thread’ through structure in a retrofit application and this was the greatest challenge for this installation. Final balancing and commissioning of systems took a long time and the convolution of ductwork complicated this exercise.

LED lighting

LED lighting is fitted across the ground floor.

Tenants initially perceived levels to be too dim but appear to have accustomed themselves to this now.

There is an issue of compatibility with piercing airtight membranes during installation but this can be overcome with careful detailing and special enclosure to the fittings.

Wattbox intelligent building monitoring and control system

Again, there have been many teething problems with this equipment which seems to be fairly prototypical. It was designed by a small group of ex-Rolls Royce controls engineers and there does not seem to be enough of them to provide adequate support.

The system comprises a remotely monitored central computer with outstation sensors located at various positions around the home and on equipment to read room and equipment temperatures. Its objective is to learn the habitual energy usage patterns of the occupants and optimise control of the homes’ energy systems to provide the most economical run times.

Wattbox communicates to the central monitoring station via a SIM card and the sensors are powered by batteries. This presents two fundamental problems. Signal strength varies between locations and is unreliable. Batteries frequently run flat and until they are replaced, the sensors do not function and ‘error’ messages are flagged on the home display.

Signal strength in this house is sporadic, and the Wattbox communication system is believed not to work. After suffering much frustration over lack of hot water and heating when required, the tenant has configured the Baxi Ecogen boiler controls to override the Wattbox system.

9. Costs

This project was procured as a composite group of 4 projects within the Crawley Homes ownership. The costs identified for this project are illustrated as accurately as possible, and whilst this project was under budget the composite group were on budget. This was achievable by economies of scale across the schemes.

The 4 projects batched together were:
ZA586R – TSB041
ZA592C – TSB042
ZA630V – TSB046
ZA631J – TSB047

Item Stage>	Design stage Materials and labour	Post-construction Material and labour	Comments
Management and administration	15,000.00	15,000.00	
Design			
Construction overall	107,284.50	82,242.73	
- Prelims	11,037.50	11,250.00	
- Fabric measures	39,404.10	39,404.10	
- Building services (conventional)	3,176.92	3,176.92	
- Low /zero carbon technologies	21,142.33	21,142.33	
- Other (add more rows and break down costs further if you wish)	N/A	N/A	
- Consequential costs	N/A	N/A	
Occupant temporary housing	N/A	N/A	Accommodated in a Council owned void property
Monitoring equipment	7,000.00	7,600.00	
Monitoring and reporting service	Incl.	Incl.	
R&D costs (please detail)	N/A	N/A	
(add more rows if there are other items)	N/A	N/A	

Below are the design/ feasibility stage estimated costs:

CONSULTANT SERVICES - £15,000 + VAT: We have considered the breakdown of the consultant team involvement in the next stage, and envisage the following services to come from ECD and their sister companies, Keegans and PPCR:

- Liaison with Planning Officer and achievement of detailed planning consent

- Prepare Schedule of Works/Outline specification and detail drawings
- Confirmation of Contract Sum, to be carried out by Keegans QS
- Project Manager, to be carried out by Keegans PM
- Site visits and inspections plus diary/blog of progress
- QS site services, incl valuations, certification, final account negotiations etc to be carried out by Keegans QS
- Final production of SAP/PHPP analysis plus EPC certificate and production of Home User Guide
- M&E co-ordination role (lighting, ventilation, heating, monitoring and PV system layouts) and Str Eng input
- Tenant consultation/interviews/report over 24 month monitoring period (in conjunction with PPCR)

CONTRACTED WORKS - £107,284.50 + VAT: These figures summarise a summary breakdown of the subcontract packages plus the main contractor's preliminaries, overheads and client contingency.

- Fabric insulation measures, Rockwool/Walltec	£39,404.10
- Replacement fenestration, Green Bldg Store	£10,939.67
- MicroCHP/HRV/Photovoltaic array, British Gas/Baxi/EnviroVent	£21,142.33
- Ceiling works	£2,767.10.
- LED lighting supply, GreenLED	£3,176.92
- Supply of appliances, various	£3,869.80
- EST monitoring	£7,000.00
SUB-TOTAL	£86,638.92

+ 12.5% preliminaries/overheads + 8% contingency + 17.5% VAT

DECENT HOMES FIT-OUT WORKS - Funded by Crawley Homes and undertaken by Contractor, these are separate to the TSB funded works.

10. Wash-up meeting

A wash-up Meeting was held on the 17th August 2011 and was relevant to the four projects carried out by Wates on behalf of Crawley Homes.

All aspects were discussed (both positive and negative), and discussions centred on the following areas:

- Boilers - Baxi Ecogen
- Wattbox
- LED Lighting
- Doors and Windows
- Airtightness tape
- MVHR
- Loft Hatches
- Flooring Insulation
- PV
- Practicalities
- Void Properties
- General Items
- Contract
- Programme

This wash-up meeting was attended by:

Crawley Homes
Wates
Keegans
ECD Architects

11. Doing it again

The key learning points from the retrofit are considered as follows:

- **Contractor skills** – although generally not an issue on this retrofit project (as mentioned before, there were issues with the airtightness results on the four projects in which Wates were involved), the project did flag up the need for more investment and training in skills related to retrofitting techniques, to enable retrofits to become more commonplace. The retrofitting of insulation and air-tightness in particular were areas where specialist knowledge/skills are required. Although Wates have been involved in retrofit projects before, the team involved in the Crawley projects were new to the principles and were working as an adjunct to the Decent Homes programme. However, the project reflected their own environmental ethos and they valued it as an opportunity to be involved and to up-skill their staff.

- **Supply of materials** – long lead-in times required for ordering and delays in delivery for some products caused significant knock-on delays to the completion of the retrofit. For example, the Green Building Store door was specified by a number of the Retrofit for the Future projects and this seemed to exacerbate the long delays that were experienced with this product. This highlights the need for a more efficient supply chain if large-scale retrofits are to be undertaken. There has also been a delay in rectification of certain items as the specified suppliers are generally of a smaller scale, with specific interest in the retrofit market.

- **Resident engagement** – resident involvement from the outset was key to the successful realisation of the project, and for the resident to buy-in to the retrofitted property. The tenants were key members of the project team from the start of the project and were consulted on every aspect of the design and construction.

- **'Simple' technology** – however simple the technology is to use, steps must be taken to ensure that the resident is comfortable on how to use it. The Wattbox is the only high-tech equipment that the residents have to use as a result of the retrofit, to control the temperature of the house. It is simple and intuitive to use, however there have been various occasions when an error message has been displayed and the tenants have been unsure of what to do. This is an item that the client is unhappy about and would prefer not to use this technology in future.

ECD have been involved in the design and management of thirteen R4tF projects and have employed a wide variety of technologies across a number of house types, with nine client bodies and seven different contractors, and using a number of different procurement routes. Our learning from this process includes the following:

- In order to ensure best value all projects should be tendered. We note that R4tF the process encouraged contractor partnering however this proved to be of limited value as most of the specialist knowledge and support provided at design stage was sourced from specialist manufacturers and sub-contractors.

- Provide as much detailed information at tender as possible. We provided a standard specification and suite of details across all of our projects which were adapted to suit the technologies installed.
- Obtain as much relevant site/ building information as possible from the client before construction (including asbestos surveys).
- Liaise closely with the site agent as he/ she will be critical in ensuring site quality is maintained. If possible allow input from a fully trained clerk of works on a weekly basis to ensure that site agents are following drawings and maintaining quality.
- Deal with vacant properties first so that the lessons can be learnt on each property type before tenants are exposed to potential delays.
- Ensure that where named/ nominated sub-contractors are included their performance is monitored. For example the installation of Micro-CHP units by British Gas has generally been poor resulting in delays to the main contract.
- Supply of specialist materials: this needs to be carefully managed and understood at the outset of the job to avoid potential delays.

ECD are involved in a number of ongoing retrofit projects and are employing the lessons learned from the R4tF programme.

12. Business benefits

This project has used a number of innovative technologies which the project team hope to use on more mainstream projects over the next few years.

Networking with specialist suppliers has also increased the team's skills and understanding of the technologies involved and potential opportunities. This has led to new work within the retrofit market and hopefully further opportunities in the future for low-carbon retrofit and refurbishment.

An increasing awareness of the need for retrofitting existing housing stock has illustrated that an increasing percentage of works within the retrofit sector will be necessary over the next 5 years.