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: ZA586R
Property number: TSB041

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:** ZA586R
- **Location of property:** Crawley, RH10
- **Lead participant details:** ECD Architects, Studio 3, Blue Lion Place, 237 Long Lane, SE1 4PU, www.ecda.co.uk
- **Date report issued:** October 2012

## Contents

1. Project details and directory ..... 4
2. Introduction ..... 5
3. Occupants ..... 6
4. Dates ..... 7
5. Pre-retrofit property ..... 7
6. Design ..... 7
7. Construction ..... 9
8. Commissioning and occupancy ..... 10
9. Costs ..... 13
10. Wash-up meeting ..... 14
11. Doing it again ..... 16
12. Business benefits ..... 17

## 1. Project details and directory

| Role | Name & Position | Organisation | Contact Details |
|---|---|---|---|
| Property Owner | | | |
| Crawley Homes | | Crawley Homes | Town Hall The Boulevard Crawley West Sussex RH10 1UZ<br>01293 511803<br>www.crawley.gov.uk |
| Design Team | | | |
| Architect | | Energy Conscious Design | Studio 3, Blue Lion Place, 237 Long Lane, SE14PU<br>020 79397500<br>www.ecda.co.uk |
| Engineer | | Carter Clack | 49 Romney Street, Westminster<br>London, SW1P 3RF<br>0207 233 0303<br>mail@carterclack.co.uk |
| QS | | Keegans | Studio 2, 193-197 Long Lane, London, SE1 4PD<br>0207 199 0900<br><br>www.thekeegansgroup.com |
| Contractor | | | |
| Main contractor | | Wates Living Space | Town Hall The Boulevard Crawley West Sussex RH10 1UZ<br>01293 438317<br>www.wates.co.uk |
| Sub-contractor – electric | | Woodlands PH | 2 Buckwins Square, Burnt Mills, Basildon, Essex. SS13 1BJ<br>01268724300<br>www.woodlandsph.co.uk |
| Sub-contractor - heating | | British Gas | PO Box 4805, Worthing, BN11 9QW<br>www.britishgas.co.uk |
| PV installer | | Solar Technologies/ British Gas | Unit 29, Romsey Industrial Estate, Greatbridge Road, Romsey, Hampshire, SO51 0HR<br>01794 830154<br>www.solartechnologies.co.uk |

| | | |
|---|---|---|
| Supplier - windows | Green Building Store | Heath House Mill, Heath House Lane, Golcar, Huddersfield, HD7 4JW<br>01484 461705<br><br>www.greenbuildingstore.co.uk |
| Supplier - internal Insulation | A Proctor Group | A Proctor Group Ltd, The Haugh, Blairgowrie, Perthshire<br>PH10 7ER, Scotland<br>01 250 872 261<br>www.proctorgroup.com |
| Supplier – external Insulation | Rockwool | 26-28 Hammersmith Grove, London, W6 7HA,<br>0845 241 2586<br>www.rockwool.co.uk |
| Micro CHP supplier | Baxi | Brooks House, Coventry Road, Warwick, CV34 4LL<br>0844 871 1525<br>www.baxigroup.com |
| Heat Recovery Ventilation | EnviroVent | EnviroVent House, Hornbeam Business Park, Harrogate, HG2 8PA<br>01423810810<br>www.envirovent.com |
| Intelligent Heating Controls and monitoring equipment | Wattbox Ltd | The Techno centre, Coventry University, Technology Park, Puma Way, Coventry, CV1 2TT<br>07974936215<br>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 1950s and 1960s, 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 Cornish 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 – a family of five - occupied the property before and after the retrofit. During the work they were decanted into a void property owned by Crawley Homes nearby.

## 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 storey-height prefabricated or pre-cast concrete panel system for the ground level external envelope, comprising grooved pre-cast columns and a cavity construction where each leaf is comprised of 3 inch thick, 3 foot long planks. The top floor is contained within a timber mansard roof structure and all other internal partitions are of lightweight timber construction. There is a single storey flat roofed rear extension of cavity wall construction. The layout internally contains a kitchen and 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.

Approximately 30,000 Cornish Unit houses were built across the UK over a 20 year period from the late 1950s to the early 1970s. A high proportion of these property types still remain to this day. Built as part of the Crawley New Town development, Crawley Homes has 60 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. TSB041 is a typical property of this type 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 Rockshield external insulation and render system, aerogel backed plasterboard internal insulation at first floor, 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.

ROCKSHIELD/ROCKPRIME INSULATION. External wall insulation comprising 200mm of vapour permeable stone wool insulation finished with a silicone render coating will allow any moisture within the existing structure to migrate freely through the overcladding whilst improving the thermal fabric to give a U-value of 0.15 W/m²K. At ceiling level, Rockprime blown stonewool insulation will be installed to a depth of 420mm to achieve a homogenous insulation layer that achieves a U-value of 0.1 W/m²K.

AEROGEL INSULATION. Spacetherm thermal laminates provide unrivalled performance for thickness, with a thermal conductivity of 0.013 W/m²K. This performance is achieved through the combination of Aerogel super-insulation with the flexibility and robustness of a fibrous blanket. The product is suited to internal dry-lining situations where space is critical achieving U-values of around 0.15 W/m²K for solid-walled properties with a 110mm build-up.

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.

Some changes to the proposal were made as the project design progressed:

1. The rear extension was originally to be insulated externally with Rockwool; however, this proved to be technically difficult at an internal corner junction with a window on the main house. The size of the window would have had to be reduced in order to allow application of the external insulation; this wouldin turn have reduced daylight levels in this part of the house. For this reason, and to help reduce the cost overspend on the project, the single storey rear extension was insulated internally with Celotex and a battened service void. This resulted in a small drop in performance of the building fabric in this area.

2. The amount of photovoltaic panels on the rear south-facing roof had to be slightly reduced as the original proposal for 8 panels did not physically fit on the roof.

3. When the orignal shower was removed from the rear extension a manhole was found underneath. As we needed to cover this with floor insualtion and a new shower tray we needed to devise a solution that would satisfy building control. In the end we constructed a steel plate to cover the manhole junction at low level and prevent any backup in the event of a blockage. We then ensured there was a rodding point on each branch that connected to the manhole.

## 7. Construction

- Procurement – The project was negotiated with Wates - under their existing Decent Homes framework
- Sub-contractors – Single M&E subcontractor with a number of other minor trades
- Specialist installers – All installers were procured via the main contractor
- Specialist equipment suppliers – All specialist equipment was procured via named sub-contractors

The majority of the issues revolved around the airtightness strategy and the requirement for constant and well-enforced site supervision. All the Crawley Homes projects suffered from poor airtightness results and this would need to be rectified on future projects.

The works were undertaken via the existing TPC 2005 (amended 2008) Contract, under which Wates was 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 organised 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 their execution whilst the homes remained occupied.

The structure of Wates' delivery approach was generally successful and the utilisation of the Decent Homes contract enabled quick and effective mobilisation. However, coordination of the contractor's works interfaces was a key area of the operation which could have been managed better. 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

Installation and commissioning challenges have been noted as follows:

**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.

The only minor disadvantages this installation brings is the difficulty in fixing to thin coat

render over a non-solid backing and its sensitivity to impact.

**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 panelled 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 programme 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.

The project team feels that there has been a lack of post-sales support from Baxi.

**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 changed reduced the number of panels fitted on site when they discovered the roof was not big enough to accommodate the desktop array design. However, they failed to match the inverter to this new design and did not commission the system. When commissioning was eventually attempted, they had to change the inverter.

**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 badly 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 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.

During final commissioning, Envirovent agreed that the designed fan unit was inadequate in duty for the house volume and they exchanged it for a bigger unit.

**LED Lighting**

LED lighting is fitted across the ground floor.

Tenants initially perceived levels to be too dim but have become accustomed to them 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**

There have been some teething problems with this equipment along with a lack 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 home's 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 problems. Signal strength varies between locations and is unreliable. Batteries frequently run flat and, until they are replaced, the sensors do not function, with 'error' messages flagged on the home display.

Residents have learned the controls available to them and are very satisfied with the system.

## 9. Costs

| 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 | 92,048.40 | 113,745.73 | |
| - Prelims | 9,470.00 | 10,000.00 | |
| - Fabric measures | 23,871.81 | 23,871.81 | |
| - Building services (conventional) | 3,013.94 | 3,013.94 | |
| - Low /zero carbon technologies | 21,202.32 | 21,202.32 | |
| - 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 | |

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 - £92, 048.40 + 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 | £23,871.81 |
| - Replacement fenestration, Green Bldg Store | £12,292.66 |
| - MicroCHP/HRV/Photovoltaic array, British Gas/Baxi/EnviroVent | £21,202.32 |
| - Ceiling works | £4,820.00 |
| - LED lighting supply, GreenLED | £3,013.94 |
| - Supply of appliances, various | £3,559.20 |
| - EST monitoring | £7,000.00 |
| SUB-TOTAL | £75,759.93 |

+ 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 4no. properties carried out by Wates on behalf of Crawley Homes.

- All aspects were discussed (both positive and negative) covering the following areas:

- Boilers - Baxi Ecogen
- Wattbox
- LED Lighting
- Doors and Windows
- Airtighness tape
- MVHR

- Loft Hatches
- Flooring Insulation
- PV
- Practicalities
- Void Properties
- General Items
- Contract
- Programme

This washup 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 4 properties 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 door was specified by a number of the Retrofit for the Future projects and this seemed to exacerbate the 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.

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 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. The Retrofit for the Future 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 resulted 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.