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: ZA125G
Property number: TSB024

Author: PRP 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.
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Final Report

Project information

- **ZA reference number:** ZA125G
- **Location of property:** TSB024
- **Lead participant details:**

Lead participant details
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1. Project details and directory

Role	Organisation	Contact Details
Property Owner		
East Thames Group	East Thames Group	Address: 29-35 West Ham Lane, Stratford, London E15 4PH Tel: 020 8522 4050 Website: http://www.east-thames.co.uk
Design Team		
Architect	PRP Architects	Address:10 Lindsey Street London EC1A 9HP Tel: 020 7653 1200 / 0845 634 3614 Email: lon.prp@prparchitects.co.uk Website: http://www.prparchitects.co.uk/
Engineer	Colin Toms & Partners	
QS	PRP Architects	
CDM Coordinator	Bottone Associates	
Contractor		
Main contractor	Hill Partnerships	Address: The Power House, Gunpowder Mill, Powdermill Lane, Waltham Abbey, Essex, EN9 1BN Tel: 0208 527 1400
Sub-contractor	Multi-trade sub-contractor to Hill Partnerships (heating, electrics, kitchen etc.)	
PV installer	Viridian Solar	
Supplier - windows	Westport	

2. Introduction

At the outset, our aim was to analyse the technical feasibility and economic viability of reducing carbon dioxide emissions from Victorian solid wall houses, and particularly those with historic importance such as those in conservation areas, by 80%. Our objective was to undertake this analysis utilising the skills of the expert consultants and contractor in our team, whilst engaging with the dwelling tenant and suppliers of innovative construction materials and technologies to develop a whole house solution which is appropriate for this house type and ultimately economically replicable around the UK. Another important objective was to develop a solution which can be implemented whilst the residents are in occupation as we recognise the majority of homes will be occupied and circumstances will not typically allow residents to be relocated for the duration of the works.

We are highly aware that the application of whole house solutions to the UK's housing stock could damage the character and heritage of our towns and cities. With this in mind, we wished to preserve all original external architectural features on the house and where feasible ensure retention of the internal architectural features. Although this approach is technically challenging and may cost more to achieve, we feel it is the right approach and one that will allow future generations to enjoy the qualities of the housing stock from this era.

3. Occupants

Occupants were the same, before and after the retrofit. The single resident vacated the property during the retrofit works to avoid the disturbance. However, her son and daughter-in-law were in residence throughout the retrofit process.

During the retrofit, the resident stayed at her son’s house.

The tenant is elderly and likes the property to keep warm. The tenant is a smoker. The tenant has stated that she believes the window refurbishment to have had the most effect in increasing comfort. The measure (other than the windows) that the tenant is most impressed by is the A++ washing machine as it completes a wash cycle in 15 minutes.

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	No

4. Dates

Event	Date
Project start date (when was the first proposal discussed or agreed)	12.02.10 - first meeting with Contractor, Designer and property owner
Planning application submitted (if appropriate)	29.01.10
Planning permission granted (if appropriate)	29.03.10
Building Regulations application submitted (if appropriate)	19.03.10 Building Notice submitted
Building Regulations approval granted (if appropriate)	14.12.10
Contract for work let / signed	21.06.10
Occupants moved out (state if they remained or property was empty)	Resident vacated during works; however her son and daughter in-law were in occupation.
Start on site	13.07.10
Completion of retrofit	10.09.10
Occupants moved in	11.09.10
Monitoring system commissioned and operating properly	Monitoring company went into liquidation
Building defects corrected	10.09.10
Building services and controls operating correctly	10.09.10
Programmed start date (delayed by Spacetherm availability - see above)	14.06.10
Programmed completion date (delayed by Spacetherm availability and commissioning of Solar Thermal)	23.07.10

5. Pre-retrofit property

The house is a 3 bed terraced house situated in a Conservation Area in the London Borough of Tower Hamlets. It was built pre 1919 and is of solid brick wall construction. It is externally pointed and has some external decorative stone features around the windows and entrance door. The construction type, external appearance and layout of the house are typical of many dwellings of this age in England. The house has an L shaped plan with the main body of the house having a duo pitch roof and the rear portion a duo pitch roof shared with the adjoining dwelling. Space standards are good compared to modern standards but daylight levels in the second bedroom were poor.

The property was chosen by the landlord as the resident had approached them to assist in making the home more energy efficient as she was experiencing high heating bills. The property was also representative of several thousand other homes owned by the landlord and across the country. Testing measures in an occupied “hard to treat” home would be extremely challenging and beneficial in terms of lessons to be learnt for mass roll-out. This property provided an opportunity to identify simple, easy and sensible measures to apply in similar properties.

6. Design

The dwelling has been insulated internally to avoid loss of the external architectural character. The existing timber framed windows were to be retained in the front facade and the glass replaced with a new and innovative vacuum glazing system and the roof mounted renewable technologies located on the rear roof slopes and integral with the roof tiles and pitch. A light pipe has been installed through the roof to improve daylight levels. The upgrade strategy will improve the Energy Performance Rating to A. The strategy will provide substantial improvements to the thermal performance of the external fabric of the house, providing affordable warmth for the occupants. In addition, the costs associated with hot water production and for electricity will be reduced. The proposed strategy has been developed to be applicable to any house of this type in any location in the UK no matter whether it is in a Conservation Area. The solution offers the opportunity to retain the original external features of the house and consequently its character which provides the appeal for so many owners and residents who wish to live in period homes.

The following technologies and innovations were proposed to be used in conjunction with established approaches and technologies such as high performance double glazed windows and mineral fibre insulation to the roof space:

- Photovoltaics - 'Clearline PV' from Viridian Solar (A SME based in Bassingbourn, Cambridgeshire)
  Product is under development and not yet on the market and offers separation of roof and electrical trades, clarity of responsibility, ease of installation and low impact appearance.

- Greater than usual thickness of Spacetherm insulated drylining - from the Proctor Group

- Spacia vacuum glazing from Pilkington

- LED lighting - from PhotonStar LED Ltd (A SME based in Southampton)
  New product developed for social housing that uses 6.7w lamps and has a much extended life over incandescent or even compact fluoresecnt bulbs. It will be used

with a lighting control system to maximise efficiencies.

- Flue gas heat recovery - the Zenex Gas Saver, innovative use in combination with a solar thermal system

- Waste water heat recovery system - the Recoh-Vert (subject to detailed design)

- Low-energy decentralised whole house ventilation - Part F type 3

- Energy display system - from Microwatt

- Sun pipes from Monodraught will provide natural light to poorly lit areas

- Solar doorbell

If the proposals for the retrofit changed or, as in some cases, the property changed, please explain these changes and the background that led to the change.

Ventilation
The original phase 1 proposal for a passive ventilation system was substituted at phase 2 with Distributed Whole House MEV (always on low energy extract fans in kitchen and bathroom) as it is our experience that residents do not trust passive systems as they associate the lack of fans with the idea that there is inadequate ventilation, often installing additional fans. It is also very difficult to design a retrofit passive stack system

Zone control not installed
During the course of the project, it was discovered by the contractor that to install zone control would mean completely re-plumbing almost the entire central heating system. Additionally the property itself is relatively small and with large open plan areas to benefit fully from a full time and temperature zone control system. A simple room 'stat, programmer and TRV control system was retained. Although this will have had a slight detrimental effect on the CO_2 emission reductions, the targets should still be met.

Some white goods different
The original proposal included A++ 'white goods'. It was found that this specification is not commonly (or indeed at all) available for some product types. The highest energy specification products available within the budget were chosen; in some cases this was A or A+ rated only.

The tenant also wished to retain their tumble dryer for which no A rated alternative exists. Instead the tenants were given advice about how much energy a tumble dryer uses compared to line drying. The real-time energy display should confirm this.

Solar Doorbell
Omitted as no suitable product could be located.

Windows
Spacia glass has been omitted for two reasons:
1. Supply is prohibitively expensive for small orders as the product is shipped on order from Japan.
2. The existing window frames were considered too narrow to accommodate the extra thickness (9mm instead of 6mm) of glazing and retain structural integrity.

Floor Insulation
An area of the ground floor hallway was found to have had the original suspended timber

floor removed and a solid slab installed. This area at the base of the staircase meant that insulation could not be introduced here as originally proposed.

7. Construction

Organisation and management

Procurement – The project was negotiated with a framework partner of the landlord. Framework consultants and contractors were approached by the landlord's sustainability manager to express an interest in coming together to work on a retrofit project.

Contract type – Form of contract was an NEC 3 short contract.

Contract structure – Main contractor providing programme and on site management with a single multi-trade sub-contractor doing the majority of works on site with the exception of specialist installers eg: Solar PV, windows and monitoring equipment.

Sub-contractors – Single main multi-trade sub-contractor (carpentry, plumbing, electrics)

Specialist installers – Solar PV installers, specified by architect and engaged via main contractor

Specialist equipment suppliers – Photovoltaics - 'Clearline PV' from Viridian Solar. Spacetherm insulated drylining - from the Proctor Group. LED lighting - from PhotonStar LED Ltd. Flue gas heat recovery - the Zenex Gas Saver. Low-energy decentralised whole house ventilation. Energy display system - from Microwatt. Sun pipes from Monodraught. All products procured by main contractor.

Site supervision – Site agent of main contractor based on site for significant periods. Site manager of main multi-trade sub-contractor based permanently on site. No Clerk of Works engaged.

Role of architect/design team – Architect project manager visited site when opening up to discuss issues and provide design input and revised details to reflect on site conditions. Works signed off by architect and Building Control.

Lessons learned

Aerogel internal wall insulation
During the course of the project, the manufacturers of the Aerogel insulation significantly increased the price of the product as well as increasing lead-in time estimates. The project team had already secured an adequate supply (in anticipation of long-lead in times, and in the desire to complete the project as quickly as possible). Without this, considerable project delay could have occurred.

Due to the conservation area location, the insulation strategy for the walls necessitated the use of internal wall insulation on all walls except party walls. External wall insulation would be otherwise preferred.

As a result of solid wall construction of the building and the space constraints of the small room areas, a nanogel type product was used as a space saving measure.

It was difficult to install insulation on the staircase area due to the space limitations; on-site innovation took place to enable this issue to be addressed.

The thickness used on this project (60mm) was not the standard thickness produced by the manufacturer (10mm).

Windows
A number of window manufacturers needed to be investigated in order to be certain of supply of windows that fit the design criteria and landlord's requirements. There are very few manufacturers that can genuinely provide timber windows with the required whole opening U-value required for the project.

Due to the conservation area location, the planners required that the front facade windows be maintained and the rear windows be replaced with sash windows. The architect had initially suggested using triple glazing on the front windows (Pilkington Space Share vacuum glass), but this was not used due to the logistics of both initially shipping the product from Japan (minimum quantities were required) and any replacement glass needed in the future. The very thin modified frames that would be required would not allow any other local double glazing to be installed.

The final window installation used double glazing with similar performance and the sashes, rather than the frames were replaced. Completely new windows were installed in the back. External doors were changed to comply with target U-Value.

Residents
Although every effort was made to minimise disruption and keep the tenant happy, the retrofit strategy decisions were largely made independent of the specific tenant to enable applicability over a broader range. However, in some instances the specific circumstances of the elderly resident were considered, and therefore any complicated technologies that required user operation or effort (e.g. biomass) were not selected.

M&E Services
MVHR was not used since it was considered to be difficult in an existing building, where the installation of ducting is disruptive and expensive. It was also pointed out that tenants tend not to like MVHR due to perceptions and the learning required.
The use of the existing chimneys as flues for a potential passive ventilation system was assessed, but again the issue of the ducting involved and the impact on the building lead to this not being selected.

In general with disruptive measures such as the two previously mentioned, there is no guarantee that they will work. With a relatively non-airtight old building, increasing air tightness to the level required by MVHR is an unquantified risk, where the consequences on the fabric (interstitial condensation, etc.) of the building are not known. Rotten floors in Victorian houses often occur due to humidity when insulation is used. Frost damage is also an issue due to the cold bricks in solid walls.

The **heating system** installation involved using a very efficient gas condensing boiler and adopting measures to increase its efficiency further with the installation of flue gas heat recovery. The initial boiler manufacturer approached would not warranty the installation, but have since started doing so. The existing radiators were used as part of the eco-retrofit approach.

Waste water heat recovery was also investigated and included in the bid, but was not used since there was no space to fit it in.

The use of a **solar thermal hot water cylinder** could have been a problem if space was not

available. In this case, due to the single occupancy, the cylinder was installed in a third room. One possible option (for bigger families) could be to use some of the space above the staircase.

LED lighting which is more efficient but expensive to purchase was used. It is important to note that, after the project, the architects and contractor have adopted this technology in their own homes.

The ventilation strategy used continuously-on low energy fans installed in the toilet and kitchen. These were low cost and provided better ventilation than typical fan installations. The approach taken for the ventilation strategy was based on the Approved Document Part F.

Zoned controls were initially specified for the project; however, these are difficult to install in an existing building given the changes required in the service routes. These were replaced with a system similar to what was originally in place, with little impact on the overall CO_2 reduction target. ETRV (electronic TRV) zonal controls were considered to be an improvement on the current installation that could emulate zoned controls without the required service route changes.

Both **PVs and solar thermal panels** were installed, using up most of the roof area. No issues with council planners were reported since the panels were in line with the roof. **Monitoring Equipment.** The monitoring strategy was based on the use of a single company to carry out all work based on the EST specification. For this project, a Microwatt monitoring installation was used. However, they went into liquidation shortly after project completion.

Design information provided and installation stage

There was good communication between designers and site operatives, in which the site team had an important role to play. The dissemination of information was good and resulted in the smooth management of the work. “Tool box” talks were used to maintain communication and address issues.

Very detailed information (drawings) and a detailed scope of work (with an identifiable paper trail) were received by the contractor. The contractor’s extensive design-build experience also aided in programme delivery.

The programme involved one subcontractor (multi-trade) in addition to a highly skilled PV installer.

In general, minimal (unexpected) problems were encountered due to the high level of information provided by the initial survey carried out by the architect, which enabled adequate planning

The scope for future technical improvements in the process included:

A++ appliances, which were required by the competition programme, were very difficult to locate and source from the UK. The example of there being no “solar” door bells available in the UK highlights that there is a market for developing such products locally.

To improve the installation, individual heat recovery fans could have been added. These are, however, not adequately modelled in SAP.

The use of a single organisation for integrated system provision (e.g. heat distribution, heating system, and controls).

Issues with the monitoring company, such as failure to engage with contractor and architect to enable proper specification, were reported.

The 60 mm nanogel insulation material was deemed “not market ready”, was high cost and should therefore be used sparingly. The material was also difficult to work with and resulted in a lot of dust when cut (a health and safety issue). Since it was a relatively new product, the contractor did not have adequate experience using it and therefore learning took place on site in the field.

The SAP does not offer the facility to model the positive effects of many features that in reality have a great impact on CO_2 reduction targets, e.g. the sun pipe leading to less use of artificial lighting.

The TSB competition required certain elements be replaced (boiler) even though the installation had not come to the end of its lifecycle. Although opportunity to carry out the works in one go provided valuable lessons, future approaches should aim to implement a whole house approach over the lifecycle of the property rather retrofitting in one go. The life span of a property and the level of intervention, trigger points and pay back should be considered. This approach will also allow for planning for the future, the consideration of trigger points and co-ordination of works. This is especially relevant if the government decides to introduce retrofit as compulsory.

Additional effort is required to ensure that the tenant knows how to deal with the features of the building over time, for example, even though the contractor had hung up all pictures/curtain poles for the tenant, information should be provided to inform future tenants on how to fix items to the internal wall insulation.

Training of tenant/landlord liaison staff in the retrofit process, the systems installed and their efficient operation and maintenance.

Client Review

This project was the first the client was involved in. The project ran smoothly and minimal supervision was required. The quality of the finished product was very high.

Despite the constraints of the site (minimal storage), the implementation process was straightforward.

The programme was planned for 6 weeks; this was extended to 8 weeks. The process started later than planned due to product procurement issues especially with windows. The overall delivery time was still considered to be reasonable.

The tenant was engaged throughout the process and was happy with the outcome. In addition to the building works, the tenant was quite impressed with the 15 minute cycle of the newly installed washing machine.

8. Commissioning and occupancy

The resident was given a guided tour of the completed house with her son in attendance. They were shown each element of the works and given a demonstration of the relevant controls and what level of involvement would be required. An A4 ring binder with all relevant user manuals and warranty information was left with the resident. During the first few months after completion no defects were reported by the resident and no issues reported on how to use the heating systems etc. This was during the first Autumn and Winter season after completion.

Additional effort is required to ensure that the tenant knows how to deal with the features of the building over time, for example, even though the contractor had hung up all picture/curtain poles for the tenant, information should be provided to inform future tenants on how to fix items to the internal wall insulation.

More detailed information should be provided to the tenant to use solar thermal system and maintain efficient operation.

Tenant advice sessions / training.

Training of tenant/landlord liaison staff in the retrofit process, the systems installed and their efficient operation and maintenance.

9. Costs

The TSB budget, although quite large is not adequate when a lot of innovative solutions are installed over a short period of time. Total contract cost of works £122,217 inc. of VAT but exclusive of design and consultancy fees.

Even though some items, such as the windows, were very expensive, the project was completed on budget. However, some costs were absorbed by all parties. The contingency sum specified in the budget was sufficient to cover changes that occurred on-site.

For future retrofits, the scale of the project will determine the cost of the project as the amount of material, design costs will be reduced. Market changes and competition will bring also play a role in bringing costs down.

Item Stage>	Design stage		Post-construction		Comments
	Materials	Labour	Material	Labour	
Management and administration					
Design					
Construction overall					
- Prelims	22,560		19,200		
- Fabric measures	90,200		90,200		
- Building services (conventional)	inc		inc		
- Low /zero carbon technologies	inc		inc		
- Consequential costs					
Occupant temporary					No direct

housing					temporary housing costs incurred as resident moved to relatives. Temporary storage costs were involved to store furniture and belongings to give clear site access.
Monitoring equipment	4,000		4,000		Provided by Microwatt
Monitoring and reporting service					Provided by Microwatt
R&D costs (please detail)					
CDM Co-Ordinator	2,451		1,116		
Architects/Project Manager	16,920		12,790		
DVD production	3,200		4,000		
Environmental Consultants	9,561		15,691		
Structural Engineer	0		1,335		
Stat Fees (Planning/Building Control)	1,100		1,100		

10. Wash-up meeting

Wash-up meeting held 18 August 2011. Attendees: PRP, Hill Partnerships, East Thames Group, facilitated by UCL Energy Institute.

11. Doing it again

Definitely do again:

Subcontractor communication and co-ordination: The use of a well-informed single (multi-trade) subcontractor on the majority of the building work and good co-ordination with them was considered to be one of the most important factors in the success of the project.

Fabric first approach: The adoption of these measures lead to a quick turn-around of project and were considered to be both desirable and achievable on a mass-scale.

Use of passive measures: Passive measures that did not require too much tenant involvement resulted in uncomplicated operation and aided in ensuring that set targets were met.

Retrofit strategy: The proposals in the initial strategy by and large worked and lead to a

high quality end product.

Product procurement: Securing products and undertaking research into potential suppliers early on.

Whole house approach: The whole house energy measures plan developed by the architects for implementing retrofit over a 25-30 year programme could be widely used to incorporate measures when most cost effective with identified trigger points for intervention. This could potentially allow all properties to be retrofitted (over a long period of time) without having to decant any resident.

The collaborative work approach: This model was considered to be both desirable and achievable on a mass-scale.

Detailed survey: The highly detailed survey carried out by the architect prior to the work, presented a high level of detailed information that aided in ensuring that there were adequate measures put in place to deal with any problems encountered during the retrofit process.

Tenant engagement: Although the design was largely independent of the tenant, continuous tenant engagement ensured that they were well informed of the works throughout the process and were ultimately happy with the outcome.

Mechanism for decanting tenants: This would be adopted at times of intense retrofit activity alongside a programme of managing expectations to achieve the highest level possible of occupant satisfaction.

Definitely not do again

Triple glazed windows: Fitting vacuum glazed panels in existing windows was considered to be a difficult and expensive option given the current market in the UK. This option was therefore abandoned in favour of high performance double glazing.

High disruption but low carbon saving measures: Costs and targets should be balanced. Future retrofits are therefore not likely to involve such high reduction targets due to the high costs involved.

M & E: Difficult to achieve M&E routes should be avoided

Monitoring: More input was required on monitoring.

In-situ retrofit: Despite tenant enthusiasm, working with the tenant in situ throughout such a whole house retrofit project was considered to be very stressful for the tenant and contractors alike.

Reduction of costs

Restrict the use of Aerogel (or other premium insulation products such as Vacuum Insulated Panels) to areas where space is valuable

LED bulbs rather than whole fittings

Leasing or borrowing monitoring equipment

Improvement of the design process

Allowance for external calculation of savings outside SAP / PHPP - individual heat recovery ventilation, multiple appendix Q measures; time and temperature TRVs, more integration with construction team in terms of practicality of measures and explanation of scope of works.

Methodology to include tenant behaviour, especially the likelihood of taking up potential savings in increased comfort.

Use of 'greener' products where possible

Modelling to actual tenants to help manage expectations

A simple method for calculating thermal bridging, or rules of thumb for existing typical construction techniques, would improve this aspect of the design process. We chose to use the SAP default value both before and after improvement since it is difficult to calculate for the existing case and is likely to be poor and since, although we have included measures to counter thermal bridging, we have perhaps simply corrected for increased thermal bridging due to better surrounding u-values.

Improvement of the construction process

- Toolbox talks
- More during construction visits
- Restriction of sub-contractors (and / or closer management of sub-contractors by whole team (including design team))
- Keeping Decent Homes improvements more clearly separate from retrofit improvements financially
- Single organisation for integrated system provision (e.g. heat distribution, heating system, and controls)

Improvement of the commissioning and occupancy process

Tenant advice sessions / training similar to that undertaken by RELISH

Training of tenant / landlord liaison staff in the retrofit process, the systems installed and their efficient operation and maintenance

What efficiency gains would you expect from a larger programme of retrofits?

Efficiencies in all consultancy fees, e.g. architects and environmental designers (one design applicable for many houses). Efficiencies in procuring 50 homes as a single project in terms of contractor’s preliminaries, contract management, bulk discounts for materials purchase etc. More engagement from planners if whole street approach is adopted.

What, in your view, would be key to making replication at this scale successful?

A mechanism for decanting tenants at times of intense retrofit activity alongside a programme of managing expectations to achieve the greatest satisfaction for the occupants possible with the improvement works and the process.

Market and policy certainty so that contractors and supply chains can gear up to undertake the millions of necessary retrofits.

Term agreements for contractors with larger landlords in order to extend the usual range of

property services to include whole house retrofit.

Whole house plans for every property with identified trigger points for intervention, e.g. when roof works are necessary take the opportunity to install rooftop solar technology; when a property becomes empty take the opportunity to complete the whole house retrofit. Where a landlord has a typical 4% void rate, potentially all properties could be retrofitted over 25 years without having to decant any resident.

12. Additional Information

Boiler / FGHR combination
The original specification of flue gas heat recovery in combination with a system boiler (rather than the more usual combi boiler) proved problematic in terms of supplier, with our initial supplier choice having stated that whilst this was a viable combination of technologies , it could only be provided as an experimental product and therefore without warranty. Again, the team were able to locate a second supplier without causing delay to the project.

Aerogel insulation
During the course of the project the manufacturers of the Aerogel insulation significantly increased the price of the product as well as increasing lead-in time estimates. The project team had already secured an adequate supply (in anticipation of long-lead in times, and in the desire to complete the project as quickly as possible). Without this, considerable project delay could have occurred.

Windows
A number of window manufacturers needed to be investigated in order to be certain of supply of windows that fit the design criteria and landlord's requirements. There are very few manufacturers that can genuinely provide windows with the required whole opening U-value required for the project.

Additional costs of measures over traditional materials / technologies should be used for economic feasibility calculations rather than full costs. So the difference (in price and performance) between standard building regulations compliant double glazing and high performance triple glazing.

Materials choice for longevity.

Clearer communication between Tenant / Landlord and sub-contractors (such as monitoring equipment) to arrange access and manage expectations

Greater advantage of funding opportunities - In this project it would have been better to remove PV from the TSB funding to allow the FiT to be claimed. However there would still be a risk attached to this since it could still be refused on the grounds of having already received Government funding.

Other
Smart meter roll-out certainty

System 3 ventilation might include heat recovery

eTRVs

A whole house plan identified with trigger points for compatible potential improvements to be undertaken over a 25 year period with replacement items such as windows and boilers being made at natural cyclical replacement times.

Less reliance on maximum rooftop solar technologies at the outset, with provision to practical maximum (rather than amount to reach target) included in whole house lifetime plan.

Tenant reaction to the retrofit process is unpredictable and one outcome of this project is a greater understanding of tenant expectation management.

'Hidden' advantages of works such as faster wash times from A++ washing machines and better lighting quality from LED lights need to be identified and communicated to residents and landlords.

Clearer demarcation of responsibilities (i.e. subcontractors responsible for measuring roof area for suitability

Lack of product for solar doorbell a disappointment

A solid floor insulation product is needed

The issue of potentially claiming funding from the Feed-in Tariff (or in the future the Renewable Heat Incentive) needs to be considered. For new build, the Homes and Communities Agency have only recently made clear the boundary between their funding and the FiT. There is too much risk in this area to be able to guarantee funding for renewable energy by deciding early on to arrange funding in any particular way.

Monitoring organisations that can undertake utility, environmental, and renewable monitoring at a reasonable cost are few and far between

Informing neighbours of the nature of the works and the construction timetable

A mechanism for provision of energy efficient appliances to tenants. Social landlords do not typically provide tenants with appliances and the provision of these in this project unearthed a number of issues of responsibility.

A referable guide to energy efficient appliances. Procurement of the required A++ rated appliances was surprisingly difficult considering that the energy rating of appliances is a long established scheme.