FOLLOW-UP REPORT

FUTUREFIT

Installation phase in-depth findings

November 2011

energy saving trust

Affinity Sutton

Contents

1 Executive Summary

The Energy Saving Trust has worked with Camco to provide technical assistance to Affinity Sutton to evaluate the delivery of its FutureFit programme. This £1.2m internally funded project involved the low carbon retrofit of 102 Affinity Sutton owned properties across the country and aims to give the industry insight in to the most effective ways to deliver large scale low carbon retrofit schemes.

The properties have been retrofitted using a range of low, medium and high cost packages of measures. The retrofit programme was structured around 22 different archetypes – types of housing that are common to Affinity Sutton's portfolio and to the social housing sector as a whole.

The range of measures installed included wall, floor and roof insulation, whole house mechanical ventilation systems with heat recovery (MVHR), single room heat recovery ventilation (HRV), boiler upgrades, heating controls, low energy lighting, voltage optimisation equipment, low flow restrictors and photovoltaic panels. However the precise package of measures for low, medium and high intervention scenarios varied from one archetype to another. Airtightness testing has been included pre and post retrofit to assess the level of improvement made to the thermal performance of the properties.

There are two phases to the project - the installation phase and the 'energy monitoring and evaluation' phase. This study focuses on monitoring the installation phase by investigating the practical challenges in ensuring energy efficiency standards are achieved within budget and with least disruption to tenants. This has provided useful insights in relation to the design of retrofit packages, installation issues, resident response to proposed works and cost of delivering the work packages, all of which are summarised below. These issues have profound implications for future roll-out of retrofit packages within Affinity Sutton stock and more widely on the viability of Green Deal investment in existing homes in the UK.

- **Package Design** - Each property is unique and although classifying properties into archetypes is a useful starting point, work packages would require re-designing to respond to property specific attributes and resident needs. To ensure that work packages meet the 'golden rule' under Green Deal, an iterative tool will be required for assessors that allows both the energy saving potential and financial returns to be calculated as work packages are changed to suit each property.

- **Installation Issues** - The most problematic measures to install were internal wall insulation (with installation issues in nearly 50% of the properties that had this measure proposed), floor insulation (in around 15% of the properties), HRV (in approximately 25% of the properties), and weather compensators (in about 75%of the properties). For all of these, the installation issues were not technically insurmountable. However the knock on impact on the cost of implementing the measures in properties where there were problems and the level of disruption to tenants, would make them unfeasible in some instances.

  In terms of the overall impact of the measure on dwelling energy use, internal wall insulation, and floor insulation are the most critical. Particularly problematic for internal wall insulation were smaller properties, those that had kitchens and bathroom fixtures on or abutting external walls, and those with door openings abutting external walls (and therefore requiring structural changes).

  For overlay floor insulation, problematic properties were those that had different floor types (such as a combination of suspended timber and solid floors) and those with appliances installed under worktops (therefore requiring the worktops, wall units, and tiling to be re-positioned).

Some of these issues can potentially be mitigated by aligning the retrofit programme with other trigger points, such as kitchen and bathroom upgrades[1]. This would bring down the marginal cost of installing the work packages.

Again, in case of cavity fill for blocks of flats, this is best carried out in one go as compared with a property by property approach, both for practical reasons and to reduce fixed costs (e.g. surveys, access etc.). The same approach is preferable for external wall insulation due to both cost reasons and planning issues. Having said that, more flexibility is required within the planning process to accommodate some householders opting out of the process or delaying green deal packages to align such measures more closely with trigger points on individual properties (e.g. external re-decoration, double glazing etc).

- **Post-installation results** - Results from post-works airtightness tests indicate that there is a huge variation both in terms of percentage improvement and absolute values across the archetypes. Currently, there appears to be no clear trend by property age (possibly due to a previous history of works to the properties) or by type of wall construction in terms of performance levels achieved or percentage improvement.

  Airtightness test results pre-works range from 2 – 23$m^3/m^2/h$ @50Pa while post-works the range narrowed down to 2 –15$m^3/m^2/h$ @50Pa. The average percentage improvement on individual archetypes ranged anywhere from zero to plus 72%. For some of the properties the airtightness marginally worsened post-works. This suggests that airtightness considerations need to be better integrated with specifications for other upgrade measures being installed in the property such as installation of wall and floor installation, MVHR/ HRV systems, etc. There also needs to be more detailed consideration given to the cost-benefit of carrying out airtightness packages in specific property types, such as post 1983 blocks of flats.

- **Cost of measures** - There is very limited published information on the actual cost of energy efficiency measures for housing retrofit. Therefore one of the objectives of this monitoring exercise was to understand the hidden costs involved in delivering these work packages that might not necessarily be factored in when developing a retrofit strategy. Comparisons have been made to the cost data in the Energy Saving Trust Housing Energy Model (March 2010)[2].

  The cost of measures incurred on the FutureFit properties are significantly higher especially where overheads, prelims, profits and VAT are taken into account. While in some instances better specifications may account for some of the difference, e.g. in the case of floor insulation, in other instances the cost of even mature and widely adopted measures, such as cavity and loft insulation, is higher by a factor of two or three compared to the predicted costs.

  Measures such as floor insulation and internal wall insulation show a significant amount of fixed costs for associated works such as moving resident belongings, removing and re-fitting kitchen and bathroom fixtures, skirtings, windows beading, boards and architraves, etc. As mentioned above, aligning a retrofit programme to trigger points will help mitigate the costs for some of these associated works.

[1] *To view the first in a series of Energy Saving Trust trigger point guides for trade, see 'Fitting a new kitchen' here: www.building-request.eu/sites/www.building-request.eu/files/Trade%20Trigger%20Guide%20Kitchen%20(Compressed)_0.pdf*

[2] *The EST Housing Energy Model is an analytic tool that explores how different energy efficiency measures and renewable energy technologies affect the performance of homes in Great Britain. Looking at the period 2007 to 2050, the model predicts how much energy and CO_2 could be saved by applying different measures to homes, in different combinations and with different uptake rates. It identifies the cost of installing and running these measures over time and performs cost/benefit analysis. The cost data in the Housing Model was put together based on discussions with trade associations, manufacturers and installers, and excludes any grants or hassle costs. See: www.energysavingtrust.org.uk/uk/Publications2/Local-authorities/Strategy-development/The-Energy-Saving-Trust-Housing-Energy-Model-assumptions*

Within the FutureFit costs, certain measures have a wider range than others. For instance, internal wall insulation and PV installations have the widest cost range, with the cost difference between the lowest and the highest value anywhere from 2.5 to 3.75 times. The marginal per unit costs for both these measures are highly sensitive to the total area/system size that is installed. Other measures such as HRVs and TRVs show little variation from one archetype or contractor to another.

- **Resident issues** - From the resident's perspective, the disruption from internal wall and floor insulation was considered significant enough for residents to refuse these measures in roughly a quarter of properties where these were originally proposed. Other measures that proved unpopular with residents were blocking-up fireplaces (in a third of the properties) removing gas fires and zoned heating controls (in about a quarter of the properties) and to a lesser extent heat recovery ventilation (in around 12% of the properties).

- **Resident Satisfaction surveys** - As part of the study, residents were asked to rate their perceptions regarding level of disruption and whether the work packages were fit for purpose on a scale of 1 to 4, with 1 being low and 4 high. Around 65% of the residents that had low packages installed rated the level of disruption at the lowest end of the scale. It was encouraging to see that around 50% of the residents with medium packages also rated the disruption as minimal (rating of 1) with around 75% rating it as minimal or one level higher (rating of 2 on a scale of 1-4).

  The saving in energy bills and improved comfort were cited most commonly by tenants as the perceived benefits from the works being carried out in the properties. The majority of residents agreed that the measures installed aligned with their needs and were fit for purpose. The response was comparatively more positive for properties with medium packages than those with low packages, with around 85% of the residents rating the measures as nearly or totally aligned to their needs in case of medium packages compared to ~75% for low packages.

The key implications for Affinity Sutton when planning future programmes of works for their existing housing portfolio are:

- Work packages need to be tailored for each property to take into account the property attributes, condition and resident needs. Savings in energy bills and thermal comfort generally appear to be a much bigger driver than CO_2 savings from the resident's perspective.

- Although none of the technical issues are insurmountable, consideration needs to be given to aligning the work programme to trigger points to keep both costs and disruption to a minimum. Certain property types are intrinsically less suited to specific measures and in this case due consideration should be given to the cost-benefit of alternative options/specifications (e.g. external insulation for properties not suited to internal insulation).

- The potential to bring retrofit costs down needs to be assessed by engaging with the supply chain and integrating work packages more closely with the maintenance regime and overall asset management programme

2 Introduction

FutureFit is a £1.2m internally funded retrofit project involving low carbon retrofit of 102 Affinity Sutton owned properties across the country. The properties have been retrofitted using a range of low, medium and high cost packages of measures. The project was structured around 22 different archetypes – types of housing that are common to Affinity Sutton's stock and to the social housing sector as a whole.

The contractor organisations delivering this initiative on ground were Apollo, Rydon and Keepmoat.

There are two phases to the project - the installation phase and the monitoring and evaluation phase. This study focuses on the installation phase with a view to capture the practical learning on site and to draw out the successes of the project, both of which will inform an effective strategy for future refurbishment projects across the remainder of Affinity Sutton's stock. To achieve this objective, the following activities were undertaken

- **Monitoring of installation process** to widen our existing understanding of the factors affecting the carbon saving potential of retrofit measures. This includes assessment of relevant issues at technology level (such as ease of installation, space issues etc.) as well as supply chain and resident issues.
- **Comparison of predicted costs and actual costs** incurred for retrofit measures with a view to identify hidden costs as well as to identify opportunities for cost reduction where scaling out to the rest of Affinity Sutton's housing stock.
- **Technical modelling of varying occupancy levels and user behaviour** to identify potential impact on energy and cost savings

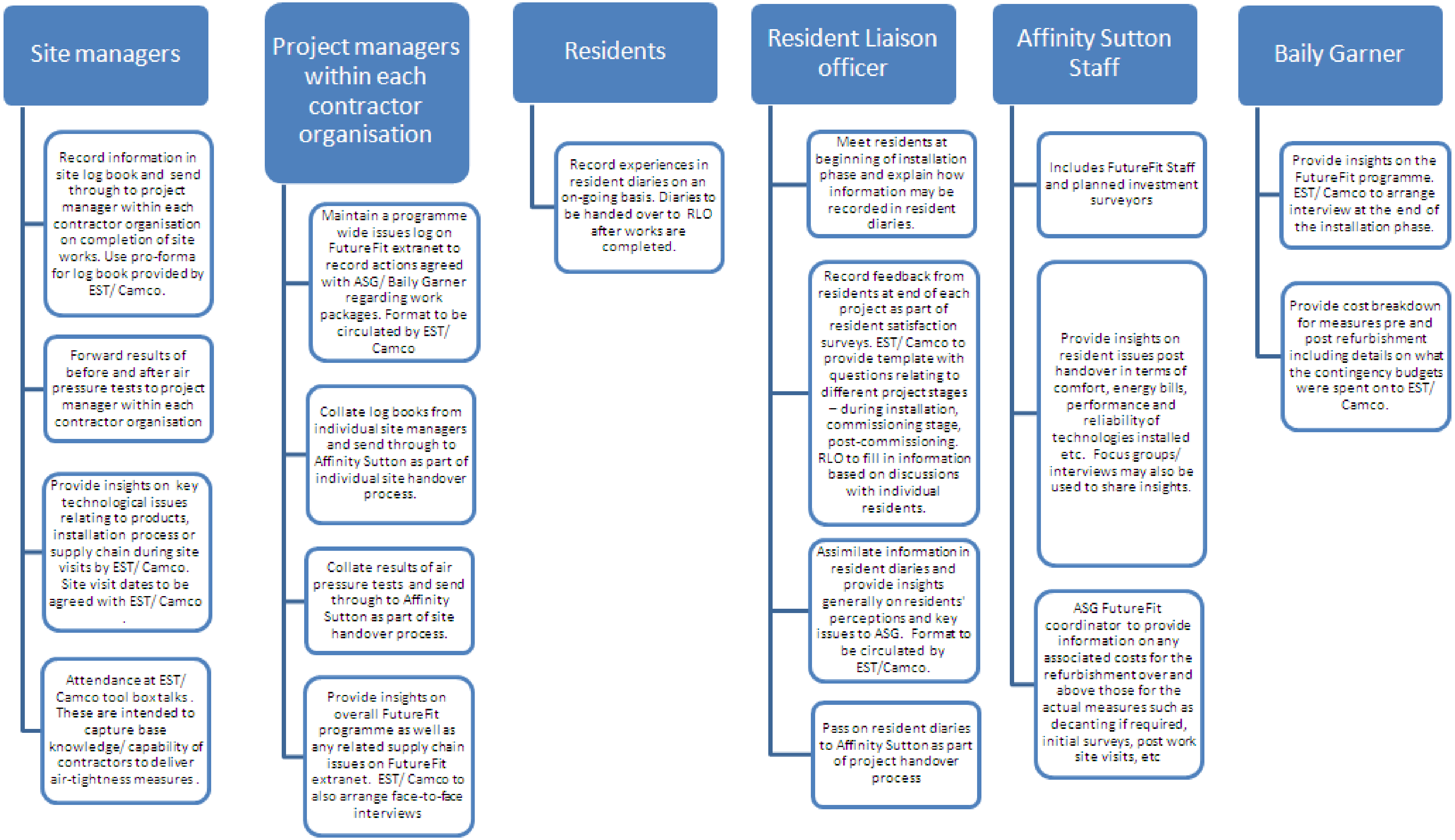
3 Our Approach

This study uses a range of information sources to enable a comprehensive view of the issues involved - from the perspective of Affinity Sutton, contractor organisations and the tenants. These are summarised in the process map in Figure 1 below. The process map was backed up by data collation templates that included

- Site log books for use by site managers
- Issues log for use by project managers within each contractor organisation
- Resident diaries
- Resident Satisfaction Surveys for use by RLOs (Resident Liaison Officers)
- FutureFit programme insights for use by RLOs
- Issues log for use by ASG staff (planned investment surveyors)
- FutureFit programme insights for use by ASG staff who visited properties post handover

A copy of the data collation templates is included in the Appendix

Figure 1: Data collation process map



4 Monitoring of installation process – summary of findings

4.1 Overview of installation, supply chain and resident issues

This section provides an overview of the key issues for each of the measures and property types. It draws on the feedback received from site managers, project managers, tenants and Affinity Sutton staff. The graph below provides a quantitative assessment of the installation and resident issues by measure, while Table 1 and Table 2 provide a more qualitative assessment both by measure and by archetype.

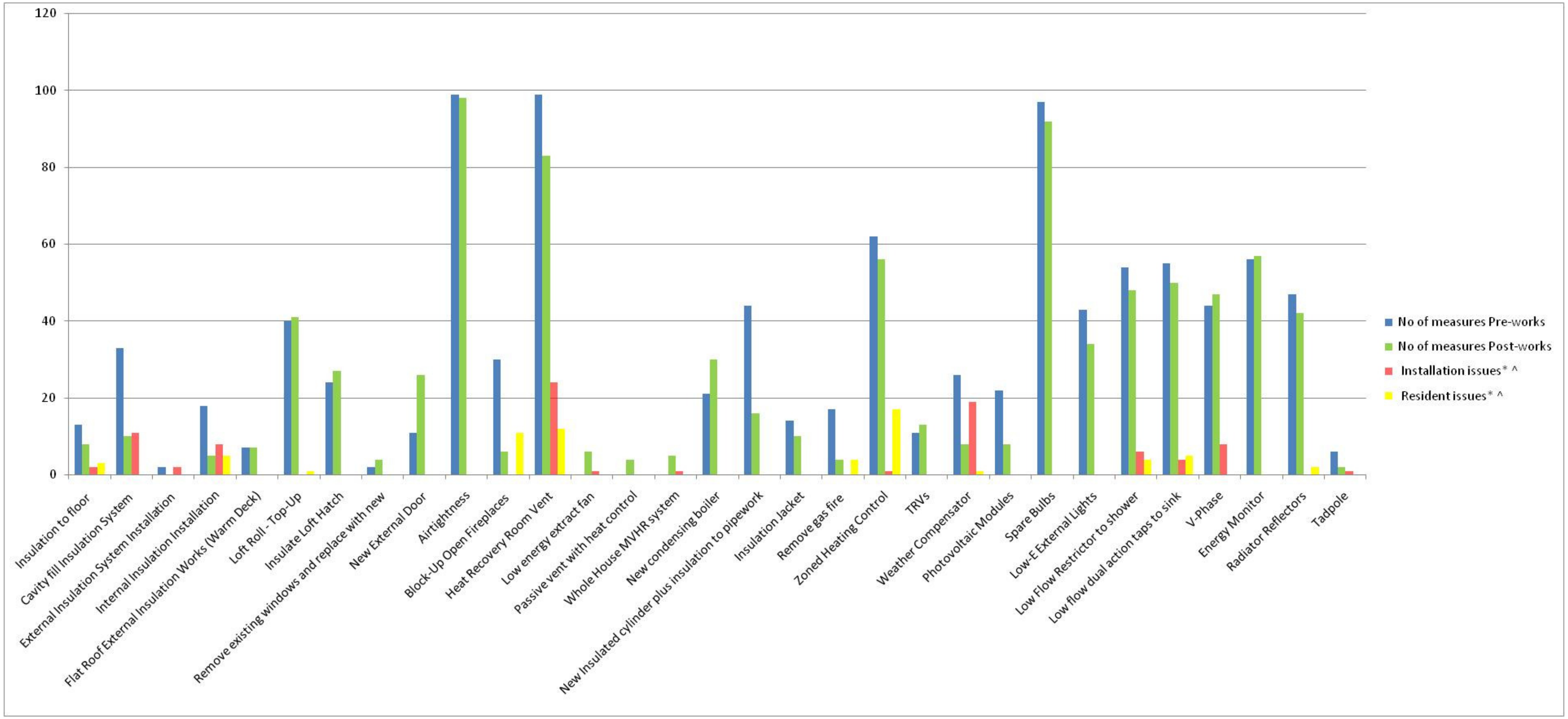


Figure 2: Installation and resident issues by measure

Notes for figure 2:
*Please note that where properties had both installation issues and residents objecting to the works, these have been included in both.

^ Also note that measures may have been added or excluded due to reasons other than installation or resident issues, such as property characteristics being different than suggested by initial surveys or to ensure that the overall cost of packages doesn't significantly differ than planned. These are not included in the figures above.

For HRVs, the number include properties where there was an issue with even one of the HRV units

Figures for zoned heating relate to hardwired units that required modifications to pipework and installation of motorised valves. In some properties, zoned heating specification was changed to wireless units or in other instances to programmable TRVs, both of which were relatively less disruptive than the original specification.

Figures for V-phase related to properties that required a new customer unit to be installed

The difference in proposed and installed figures for PVs relates to instances where the system sizes were considered too small to be cost effective.

The most problematic measures to install were internal wall insulation (with installation issues in nearly 50% of the properties that had this measure proposed), floor insulation (in around 15% of the properties), HRV (in approximately 25% of the properties), and weather compensators (in about 75%of the properties). For all of these, the installation issues were not technically insurmountable. However the knock on impact on the cost of implementing the measures in properties where there were problems and the level of disruption to tenants, would make them unfeasible in some instances

From the resident's perspective, the disruption from internal wall and floor insulation was considered significant enough for residents to refuse these measures in roughly a quarter of properties where these were originally proposed. Other measures that proved unpopular with residents were blocking-up fireplaces (in a third of the properties) removing gas fires and zoned heating controls (in about a quarter of the properties) and to a lesser extent heat recovery ventilation (in around 12% of the properties).

Please refer to Table 1 below for more details of installation and resident issues specific to each measure.

Interestingly, the majority of the installation issues are not specific to an archetype and can be attributed mostly to the property, either due to its size or internal layout, or to the measure itself (e.g. sourcing and installation issues outlined in Table 1). Please refer to Table 2 for more details.

Table 1: Summary of installation, supply chain and resident issues by measure

Measure	Archetypes	Installation issues	Supply chain issues	Resident issues
Internal Wall Insulation	**2, 5, 12, 16**	Associated works required that needed to be allowed for in the works programme and budgeting are - removing and reinstalling wall fittings including skirting boards and cornice details, radiators, etc - adjusting floor finishes to altered room dimensions, - extending electrical/ aerial/ telephone sockets and switches to bring them forward to the face of the new wall surface, - extending pipework and reinstalling radiators - In some instances, boiler is required to be moved (where installed on external walls) - removing and re-installing kitchen and bathroom/WC fittings and tiling where these are on the external wall One of the main issues in such instances was that internal fittings may not fit back in to the same space once IWI is installed,(e.g. disabled shower) or may require significant modifications (e.g. kitchen units) - removing and re-installing window beading and door frame architraves, plus provision of new window boards - for properties with suspended timber ground floor, injecting cavity insulation to the underside of the timber floor at the section adjoining the external wall to prevent the cold bridging - where internal doors abut the external wall, structural changes are required to move door openings As expected, there were space issues in case of smaller dwellings (e.g. Arch 5);	Delivery time lag of 1 week for British Gypsum Thermaline Super insulation board	Disruption cited as the main reason for refusing internal wall insulation; High incidence (roughly quarter of the properties). ***Action:*** *Potential to integrate wall insulation with other trigger points to be assessed within the asset management strategy.*

Measure	Archetypes	Installation issues	Supply chain issues	Resident issues
Cavity Wall Insulation	**3, 5, 7, 18, 19, 20**	Access was a problem in instances where property is part of a larger block of flats (scaffolding or cherry picker required). Provision of scaffolding was expensive to treat one property, plus there were issues around cavity fill flowing into adjacent properties as the fill process cannot be controlled. Re-filling the cavity where existing cavity fill of poor quality also proved problematic.	n/a	n/a
Floor insulation	**4,5,13,15, 16**	**Suspended timber floors:** Insulation to suspended timber floors (where exposed with no floor coverings) was the most straightforward and least expensive option. **Overlay insulation:** A number of associated/ remedial works were required in instances where the insulation was overlaid on existing floors including removing and refitting kitchen and bathroom fittings, skirting boards and floor coverings, as well as adjustments to doors, door frames, thresholds, kitchen plinths etc. In 5 out of 6 instances new floor covering was installed instead of replacing with old (e.g. where PVC floors or carpets are glued down). The latter added substantially to the per m^2 cost in most instances (typically £25m^2 over and above the cost of the measure). In instances where there was level threshold (rather than a door sill), internal and external door would require adapting to the new floor levels. This is problematic in case of composite or steel doors. An alternative solution adopted in this case was to excavate next to the door and lay the insulation lower down to create a mat well. Refitting of kitchen units to suit new floor levels also proved problematic in instances where appliances are installed below worktops. This required wall units and other fittings, such as extractor hood and wall tiling, to be repositioned to suit new floor levels (as against cutting down the kick plinths and keeping the fittings in the same position). In one of the properties central heating pipework was fitted to the skirtings and will have required rerouting at significant additional expense.	Insulation products such as Spacetherm and Kingspan Kooltherm K7 have a delivery time lag of 7 days.	Disruption was cited as the main reason for refusing floor insulation works; High incidence (roughly quarter of the properties). ***Action:*** *Potential to integrate floor insulation with other trigger points to be assessed within the asset management strategy.*

Measure	Archetypes	Installation issues	Supply chain issues	Resident issues
		Properties with combination of floor types: Where a property has different types of floors (e.g. solid and timber suspended) this causes problems with floor levels. The approach is this case was to install overlay insulation throughout the property. However, where insulation is overlaid on suspended floors, consideration also needs to be given to ensuring access to pipework etc. for future maintenance.		
Loft insulation	**1,3,5,7,8, 10, 12, 13, 14, 16, 20,22**	n/a	n/a	Minimal (only one refusal); In instances where the loft top-up fully covered the floor joists, residents were concerned about not being able to use their lofts for storage.
Double glazed windows	**2,3,6**	n/a Original specification set a minimum performance level of 1.6W/m2K. The feedback from the contractors has been that a window unit with a U-value of 1.4 can be sourced at little extra cost.	n/a	n/a
Insulated doors	**2,7,8,10,12, 13, 17, 22**	n/a	n/a	n/a
Airtightness measures	**All**	There is a huge variation in terms of the performance level achieved post-works across the properties, both in absolute and percentage terms; no significant installation issues have been flagged up. Where properties were carpeted, mastic sealant to skirtings and floor/ skirting joint was omitted.	n/a	Residents in at least a third of the properties that were proposed to have fireplaces blocked as part of the work packages refused to have this measure installed. ***Action:*** *Consider using dampers to reduce draughts when not in use. Installing wood-burning stoves may be an option as they are more efficient than open fires.*

Measure	Archetypes	Installation issues	Supply chain issues	Resident issues
Room Heat Recovery Ventilation (HRV)	**All**	The main issue was where properties had internal bathrooms and kitchens. Although some models have the option to duct them to the outside, this significantly adds to the fan power and compromises the energy/ CO_2 savings from the measure. There were space issues in some archetypes that resulted in one or more of the HRV units being omitted. In few of the properties the vent was close to the external boiler flue and therefore a heat recovery unit was not recommended. One of the models used initially in the properties required a 6" hole for installation, which meant drilling a new hole in every case (Vent-Axia HR25 Solo, or the Kair K-HRV150/12RH). A newer model (Lo-Carbon Tempera) was used in some properties that could be fitted into an existing 4" hole making the installation process easier and quicker. In both instances, the fan could be fitted in wet areas without the need for additional low voltage transformers.		Resident in around 12% of the properties that had HRV unit proposed refused to have the measure installed citing damage to finishes, disruption or noise as potential issues.
Mechanical Ventilation with Heat Recovery (MVHR)	**1,8,9,16**	This measure was installed on only a small number of properties (total of five). There were problems with installing ductwork due to space issues on one out of the five properties.	1 to 2 weeks to source from main dealer for Vent-Axia Lo-Carbon Kinetic E	No issues raised. However, as the sample size is quite small the feedback may not be totally reflective of resident perceptions.
Condensing gas boiler	**2,3,5,7,11,13,17,20, 21, 22**	n/a	n/a	n/a
New cylinder	**4,7,10,14,17**	n/a	n/a	n/a
TRVs	**5,7, also no. of other properties as required**	n/a	n/a	n/a
Zoned heating controls	**All except 1,5 and 18**	The original specifications for zoned heating controls have proved problematic to install due the modifications required to the pipework and in instances this required the floorboards to be removed to install the motorised valves. This significantly added to the disruption and associated costs of installing the systems. To get around the issue, wireless 2 zone systems manufactured by Honeywell, were chosen to be installed by one of the contractor organisations. The wireless systems were overall much less disruptive to install. Any existing room thermostat were removed and the main control box hard wired. The radiator controllers were easy to	n/a	Disruption; high incidence (around a quarter of the properties). In case of the wireless systems, a number of residents found the controls difficult to understand and operate. In at least 3-4 instances, the residents asked for the system to be removed

Measure	Archetypes	Installation issues	Supply chain issues	Resident issues
		install where radiators had TRV bodies. In a number of properties this was not the case, and the contractors on an average changed around two radiators per property which involved draining the system. Due to the different trades required on site, the installation worked more costly. Overall the wireless systems were a more expensive option (~975 total cost of kit incl. installation compared to initial budget of £450). Yet another specification used by one of the contractors was programmable TRVs. These were the least disruptive and cheapest of all options, although these are not currently recognised in the SAP methodology.		and TRVs to be re-installed. ***Action:*** *Cost-benefit analysis of wireless zoned heating systems to be carried out during the monitoring phase plus their ease of use to be assessed through resident surveys at the end of the monitoring phase.*
Weather compensator	**2,3,4,9,12,13, 19,20,21**	The main issue was sourcing products that were compatible with the existing boiler installed in the property. In some cases this was down to difficulty in identifying the model number. While there are specific products available in the market that are compatible with most boilers (such as Heating Save) they are relatively expensive at (~£500 for HeatingSave, ~£220 for Energy Master from Total Energy Controls). On a number of properties where zoned heating controls were also specified, both measures could not be installed together due to the existing system configuration, and therefore zoned heating controls were installed instead.	n/a	No issues apart from one instance where the resident has been unwilling to have it installed.
Photovoltaic panels	**1,2,10, 13, 15, 18, 19, 20, 21, 22**	Smaller systems (< 0.5kWp) were deemed not to be cost-effective to install in most cases due to the fixed BoS (Balance of System) costs. In case of flats located on the ground or intermediate floors, the cabling needed to be routed through communal areas or externally. There were also spaces issues with locating the inverter in some instances. External inverters, although more appropriate in these instances, were comparatively expensive.	There have been issues with sourcing MCS accredited inverters to match the system size of 0.2 - 0.5kWp that were originally specified for some of the properties.	n/a
Air Source Heat Pumps	**16**	Measure not installed in any of the properties. Requires installation of a wet system in properties with electrical storage heaters, which significantly adds to the total cost (around £5k) and disruption.	Measure not installed in any of the properties	Measure not installed in any of the properties
Low energy lights/ bulbs	**All**	The main issue is that not all existing light fittings accept low energy lamps. Low energy lamps are also not compatible where dimmer switch have been installed.	n/a	Refused by a minority (~1%) of the residents as it was felt that the replacement lamps were not bright enough.

Measure	Archetypes	Installation issues	Supply chain issues	Resident issues
Radiator reflectors	**3, 4, 5, 6, 8, 9, 10, 12, 14, 15, 17, 19, 20, 22**	n/a	n/a	Refused by a very small minority (<1%) of residents due to its appearance.
Low flow restrictors for taps and showers	**All except 2, 4 and 20**	Restrictors not compatible with existing fixtures in around 10% of the properties.	n/a	Residents in around 10% of the properties refused the measure, citing low water pressure in some cases.
Voltage Optimisation (V phase)	**1, 3, 4, 5, 6, 10, 11, 12, 13, 14, 16, 17, 19, 20**	The unit is easy to install. However, for around a third of properties that had V-phase installed, a new consumer unit was required. For electric heated properties, the board requires additional breakers to separate circuits.	Delivery time lag of 2 weeks	n/a
Tadpole device	**8,14**	Space issue in one of the properties out of a total of 6 properties that had a tadpole device specified.	n/a	n/a
Energy Monitor	**All except 2, 11, 13, 14, 17, 20,21**	n/a	Watson Energy Monitor delivered from USA and has a delivery time lag of 2 weeks; replaced with an Owl monitor in some properties	n/a

Table 2: Summary of installation, supply chain and resident issues by archetype

< Black text> *Issues that are specific to the archetype*

< Blue text> *Issues that are specific to the property (e.g. due to its size or internal layout) or to the measure more generally, rather than all properties of that archetype*

H *Please note that only two of the properties with high packages were occupied (Arch 16 and Arch 13) and the remaining five were void properties (out of which four properties were stakeholder led design)*

Archetype	Description	Package	Installation issues	Resident issues	Observations
1	Flat, 1983-1990, cavity construction	L,M	Single room heat recovery units (HRV) not suited due to the need for ducting; For low package, these were replaced with low energy fans (plus passive vents in bedrooms in case of properties with significant condensation problems) and for medium package with whole house mechanical ventilation system.	n/a	Extremely good fabric air tightness pre-works suggests little benefit of carrying out draughtproofing and airtightness measures. However, all properties are from the same block of flats and therefore results may be specific to these properties rather than the archetype. Smaller PV systems (~0.5kWp or lesser) not considered cost effective.
2	Flat, 1900-1929, cavity construction	L,H	Asbestos in property, which may be typical of properties in this age band. Requires allocation of contingency sum to cover this. Single room heat recovery units not suited due to space issues in kitchen.	n/a	Average air tightness below current Building Regulations pre-works and ~8% improvement post-works on an average suggests only marginal benefit of draughtproofing and air tightness measures. Requires a larger sample size to determine whether this holds true for most properties of this archetype, plus additional analysis to draw co-relation with property condition/ history of works carried out on the property.

Archetype	Description	Package	Installation issues	Resident issues	Observations
3	House, mid-terrace, 1900-1929, cavity construction	L,M	New consumer unit required for installation of V-Phase.	Floor insulation and wired zoned heating controls considered too disruptive. In properties where no existing extract fans installed, residents not keen on installing HRV units resulting in delays to work programme. In a number of instances, residents have been unwilling to block-up existing fireplaces.	On an average, fabric airtightness pre-works is close to minimum Building Regulations performance standard with ~11% improvement post-works.
4	House, end-terrace, 1900-1929, solid wall construction	L,M	New consumer unit required for installation of V-Phase.	Instances where residents have been unwilling to block-up existing fireplaces.	~70% improvement in airtightness on an average post-works improving to an average of $5m^3/m^2/h$ @50Pa. This makes the measure cost effective both in terms of energy use and thermal comfort.
5	Flat, 1930-1949, cavity construction	L,M	In some properties, cavity fill has been problematic due to poor quality of existing fill material. Internal wall insulation has been problematic due to the need for structural changes (moving door openings that abut external walls) as well as space issues in smaller properties. Planning permission refused for insulating some of these properties externally. Insulation between timber floor joists replaced with overlay insulation to floor - as a mix of floor types (timber and solid concrete) would have resulted in level changes. Space issues with installing HRV units in kitchen. *Please note properties have a mix of solid and cavity walls	Low water pressure citied as an issue for retrofitting low flow fixtures.	Huge variation in airtightness of fabric pre-works (ranging from 3.6 – $22m^3/m^2/h$ @50Pa and improvement of ~22% on average post-works.

Archetype	Description	Package	Installation issues	Resident issues	Observations
6	Flat, 1991-1995, cavity construction	L,M	New consumer unit required for installation of V-Phase.	n/a	Extremely good airtightness levels of ~3m^3/m^2/h @50Pa pre and post works. However, only two properties in the archetype and from the same scheme. So difficult to extrapolate the air tightness results for the archetype.
7	House, end-terrace, 1930-1949, cavity construction	L,M	n/a	n/a	A significant number of the properties had airtightness close to minimum Building Regulations performance standard pre-works (10m^3/m^2/h @50Pa). About 45% improvement in airtightness performance post-works to around 6m^3/m^2/h @50Pa. Residents observed a difference in terms of reduced draughts post-works.
8	House, end-terrace, 1930-1949, solid wall construction	L,M	n/a	n/a	MVHR installed in one of the properties that had an existing mechanical extract system as this was considered a cheaper option than installing HRV units. Huge variation in airtightness pre-works (by a factor of two) for the two retrofitted properties of this archetype with both properties ending up with post-works figure marginally higher than current Building Regulations performance standard.
9	Flat, 1996-2002, cavity construction	L,M	Space issues with installing HRV units in one of the two properties. Installing MVHR in the other property also proved problematic due to space issues for installation of ducting. In both cases low energy extract fans were installed instead. Weather compensator could not be installed along with zoned heating.	n/a	Extremely good airtightness levels of <3m^3/m^2/h @50Pa pre works for both properties.

Archetype	Description	Package	Installation issues	Resident issues	Observations
10	House, end-terrace, 1930-1949, system built	L,M	On one of the six properties, HRV could not be installed in the kitchen as the external vent was too close to the boiler flue. In one of the property, flow restrictors were not compatible with existing fittings.	5 out of 6 residents considered the disruption for installing wired zoned heating far outweighed the potential benefits. 4 out of the 6 residents were unwilling to block-up existing fireplaces.	40% increase in fabric airtightness to $8.3m^3/m^2/h$ @50Pa on average.
11	Flat, 1950-1966, cavity construction	L,M	On one of the four properties, sourcing a zoned heating system compatible with the existing boiler was an issue. All units required a new consumer unit for installation of V-Phase. For 3 out of the 4 properties, the electric showers did not have flow restrictors fitted as both the contractor and resident felt that this may cause problems. ***Action:*** *Any potential issues to be verified with suppliers of electric showers*	n/a	Average airtightness pre-works of $<5m^3/m^2/h$ @50Pa reducing to $\sim 3.3m^3/m^2/h$ @50Pa post-works.
12	Flat, 1950-1966, solid wall construction	L,M	Weather compensator could not be installed along with zoned heating.	Internal wall insulation refused by the resident in one of the two properties.	Extremely good airtightness levels of $<3m^3/m^2/h$ @50Pa pre works from both properties. Marginal improvement (~2%) post-works.
13	House, end-terrace, 1950-1966, cavity construction	L,M, H	n/a	Internal floor insulation refused by resident as part of a medium package of works on one of the properties. Loft-roll top up refused by in one property out of a total of the 6 occupied properties. HRV, zoned heating controls and blocking up of fireplace was refused by 3 out of the 6.	About 20% improvement in airtightness performance post-works to around $6m^3/m^2/h$ @50Pa on average.

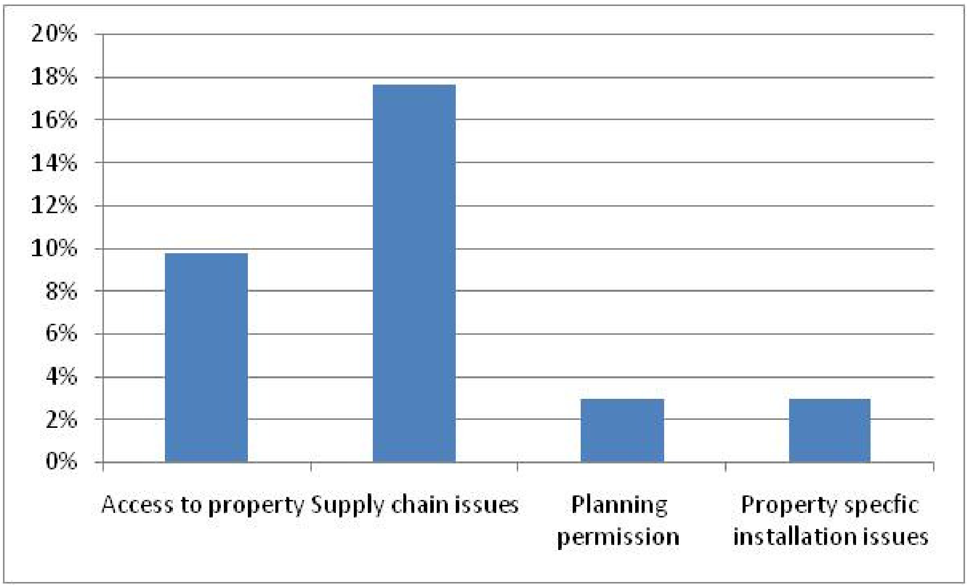
Archetype	Description	Package	Installation issues	Resident issues	Observations
14	House, end-terrace, 1983-1990, cavity construction	L, M	n/a	Residents for both properties were reluctant to have zoned heating controls installed. In one of the properties, this was requested to be removed after installation.	About 50% improvement in airtightness performance post-works to around 5.6m^3/m^2/h @50Pa on average.
15	Flat, 1967-1975, cavity construction	L, M	Cavity fill proved problematic due to need for cherry picker/ scaffolding. On one out of the eight properties, HRV could not be installed in the kitchen as the external vent was too close to the boiler flue.	On one (out of the 8 properties retrofitted for this archetype), resident not willing to have zoned heating controls installed.	Average airtightness dropped from 3.9 pre-works to 2.7m^3/m^2/h @50Pa post-works. Smaller PV systems (~0.5kWp or lesser) not considered cost effective.
16	House, mid-terrace, 1967-1975, cavity construction	L,M, H	All of the properties had issues with HRV in bathrooms due the need for them to be ducted. Weather compensator could not be installed along with zoned heating.	One of the residents unhappy with low flow restrictors and requested them to be removed.	Marginal improvement (~2%) in airtightness performance post-works to around 10.5m^3/m^2/h @50Pa on average.
17	House, mid-terrace, 1976-1982, timber frame	L,M	n/a	The residents raised draughts and cold as the main issues for 3 out the 5 properties retrofitted. One of the residents refused flow restrictors and radiator reflectors to be installed.	Pre and post-works test results not available.
18	Maisonette, 1967-1975, cavity construction	L,M	Cavity fill proved problematic due to need for cherry picker/ scaffolding.	n/a	Marginal improvement (~8%) in airtightness performance post-works to around 5.5m^3/m^2/h @50Pa on average. Smaller PV systems (~0.5kWp or lesser) not considered cost effective.
19	Flat, 1976-1982, cavity construction	L,M	Cavity fill proved problematic due to need for cherry picker/ scaffolding. Insufficient space to install HRV in all three properties and low energy extract fans installed instead.	n/a	Marginal drop (-1%) in airtightness performance post-works to around 4.6m^3/m^2/h @50Pa on average. Smaller PV systems (~0.5kWp or lesser) not considered cost effective.

Archetype	Description	Package	Installation issues	Resident issues	Observations
			Weather compensator could not be installed along with zoned heating.		
20	House, mid-terrace, 1976-1982, cavity construction	L, M	Zoned heating not installed due to the need of cutting/ re- plumbing pipework and the level of disruption this would cause. Please note that some contractors opted to install a 2-zone wireless model produced by Honeywell or programmable TRVs. New consumer unit required in all properties for installation of V-Phase	At least two of the 5 residents raised issue of condensation and cold in the properties pre-works. Residents in two (out of the 5 properties retrofitted) reluctant to have HRVs installed.	Marginal improvement (~7%) in airtightness performance post-works to around 8.7m^3/m^2/h on average.
21	House, end-terrace, 1991-1995, cavity construction	L,M	HRVs not installed in one out of the three properties due to space issues.	Two out of the three residents felt that properties were cold and draughty pre-works. For one out of the three properties retrofitted of this archetype, the resident was reluctant to have HRVs installed. Same in case of zoned heating controls.	Marginal improvement (~2%) in airtightness performance post-works to around 7m^3/m^2/h @50Pa on average. PV installation increased to 0.6kWp to make it more cost effective.
22	House, end-terrace, 1996-2002, cavity construction	L	n/a	n/a	12% improvement in airtightness post-works to 6.9m^3/m^2/h @50Pa

4.2 Impact of supply chain and access issues on project programme

Feedback from site managers suggest that overall there were delays to work programme on a third of the properties, with around 18% attributed to supply chain issues and 10% due to resident issues (such as access to the property, agreeing measures to be installed, etc). However, the actual number of days by which the work programme got extended cannot be quantified as in most instances the site managers have entered the revised handover date agreed with ASG in the site log books. Property specific installation issues include removal of asbestos in one of the void properties, repairs to floors in one of the property and PVs fixing issues in another.

Figure 3: Percentage of properties with delays to work programme



4.3 Airtightness test results

Before and after airtightness tests were carried out for all properties being retrofitted. For each property, the airtightness package included works to walls, floors, services, windows and doors. Pre-works, the results vary significantly across the archetype and within archetypes in some instances. Post- works, again there is a huge variation both in terms of percentage improvement and absolute values across the archetypes.

Figure 4 and Figure 5 below show the range of pre and post-works test results for each archetype. Figure 6 shows the pre and post works average value for each archetype and Figure 7 shows the improvement for each property plus the average improvement by archetype.

Archetype 4 (1900-1929 solid brick house) and archetype 10 (1930-1949 system build end terrace house) has some of the worst performing properties and also show the biggest improvement post-works. In contrast, archetypes 2, 6, 12, 15, 16, 18, and 20 show only a marginal improvement. There appears to be no clear trend by property age, possibly due to as previous history of works to the properties, or by type of wall construction. For example, archetype 2 is the same age band as archetype 4 and the same wall construction as archetype 5, albeit older, yet properties of archetype 2 have on an average a much higher airtightness pre-works than archetype 4 and marginally better than archetype 5. Post-works, archetype 4 performs significantly better than archetype 2 and archetype 5 performs marginally better.

Interestingly, archetypes 1 (1983-1990 cavity flat), 6 (1991- 1995 cavity flat), 9 (1996-2002 cavity flat) and 12 (1950-1966 solid brick flat) had pre-works airtightness figures of ~3$m^3/m^2/h$ @50Pa, which in some instances marginally worsened post-works.

Figure 4: Airtightness test results for properties pre-works

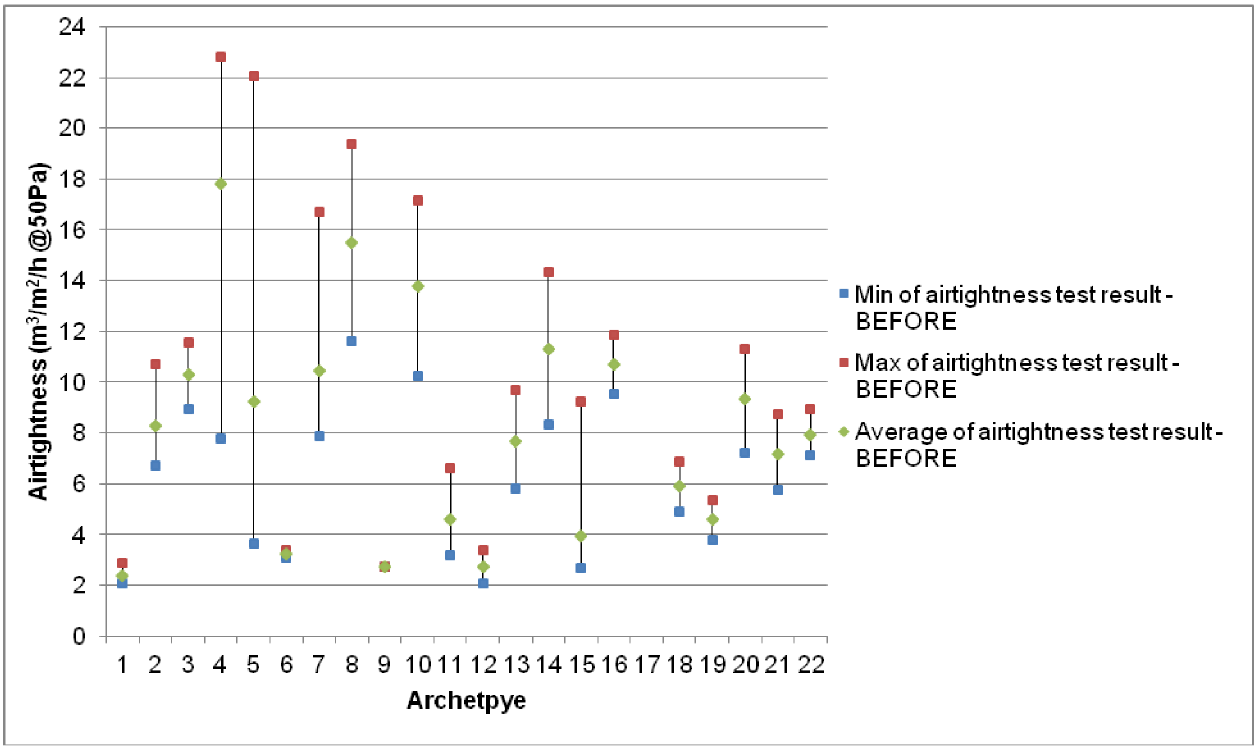


Figure 5: Airtightness test results for properties post-works

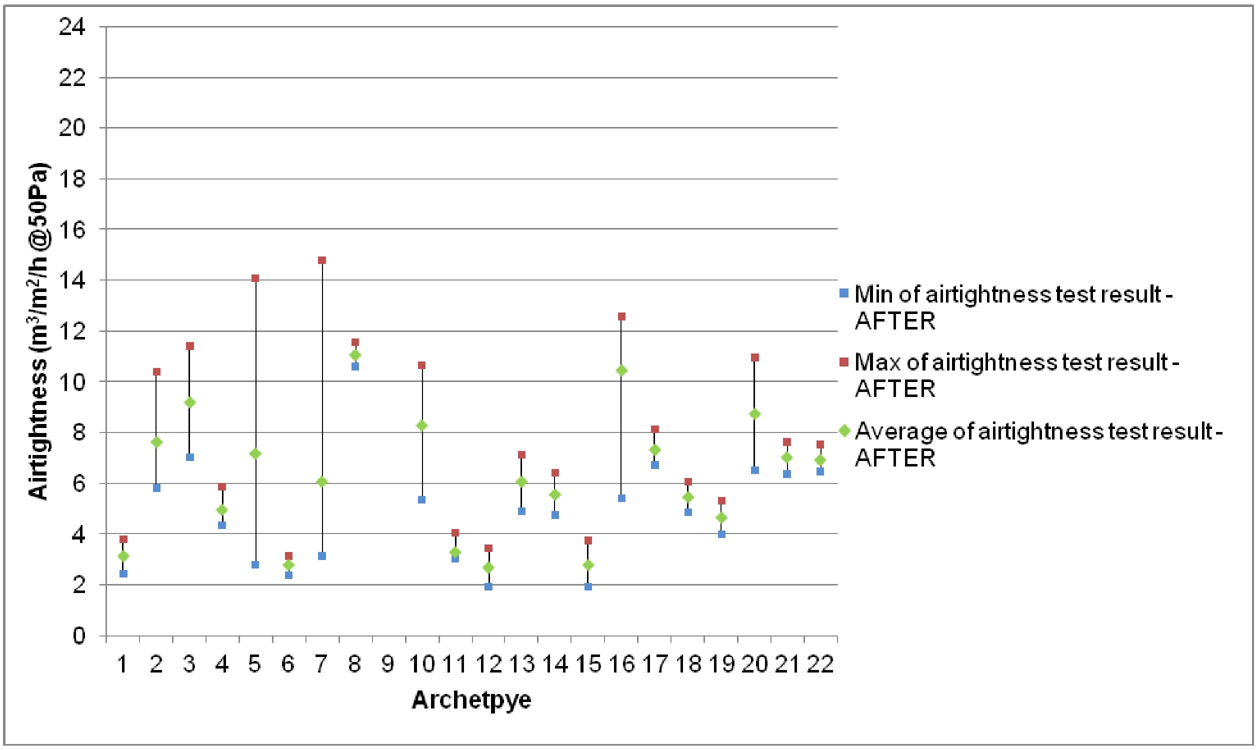


Figure 6: Average fabric airtightness pre and post works

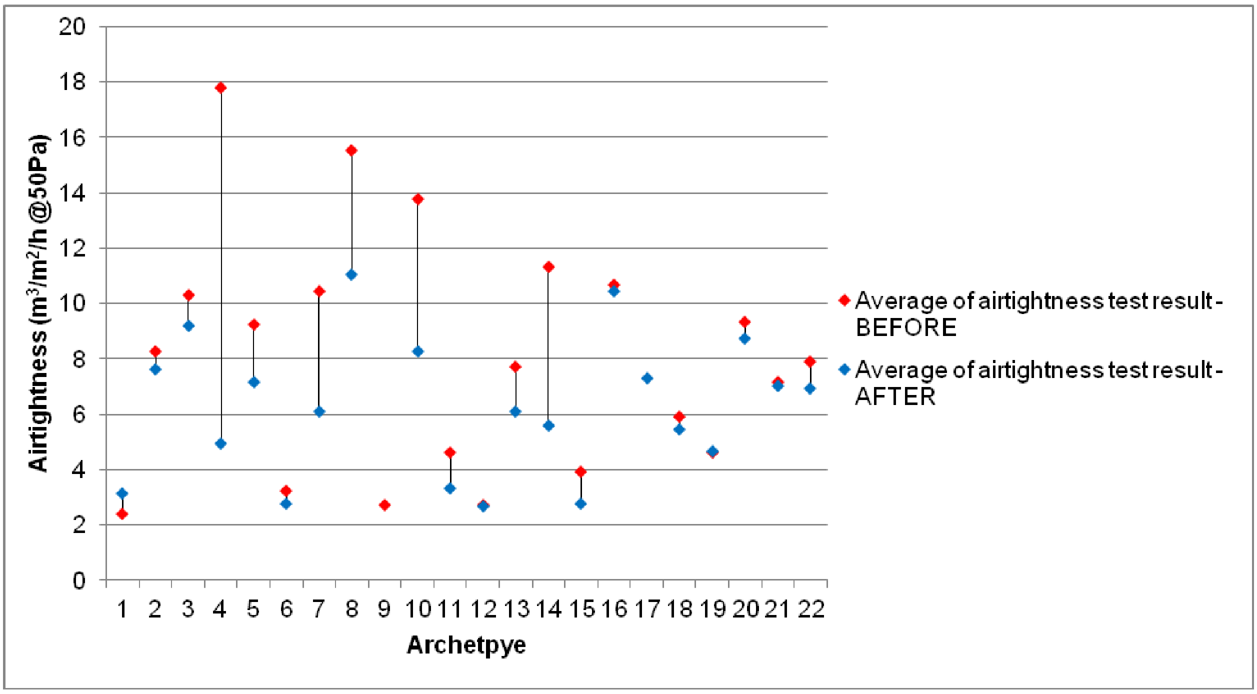
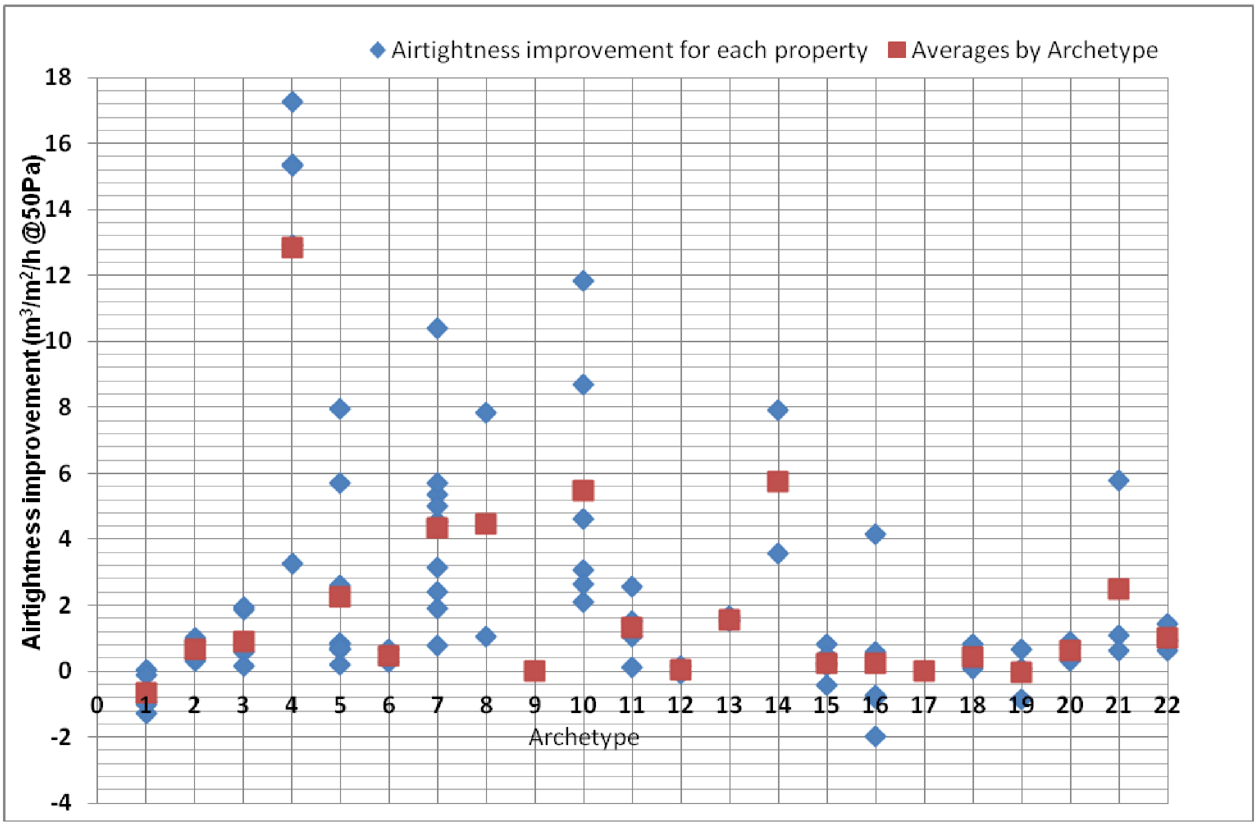


Figure 7: Airtightness improvement by property and average improvement by archetype



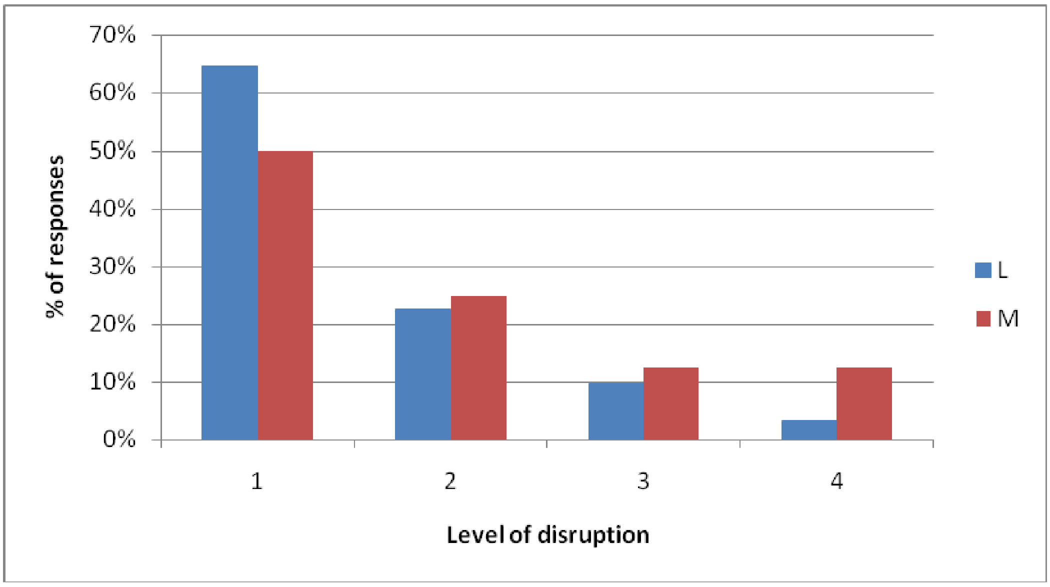
4.4 Resident satisfaction surveys

The section summarises the findings of the satisfaction surveys carried out after completion of work packages. As part of this survey, residents were asked to rate their perceptions regarding level of disruption, whether the work packages were fit for purpose, quality of the handover documentation/ training provided, and their understanding of the systems/technologies installed on a scale of 1 to 4, 1 with 1 being low and 4 high. In each instance, the results have been plotted by package type, that is, low and medium.

Please note that only two of the properties with high packages were occupied and the remaining five were void properties. Due to the small sample size, the high package has been excluded from the results presented below.

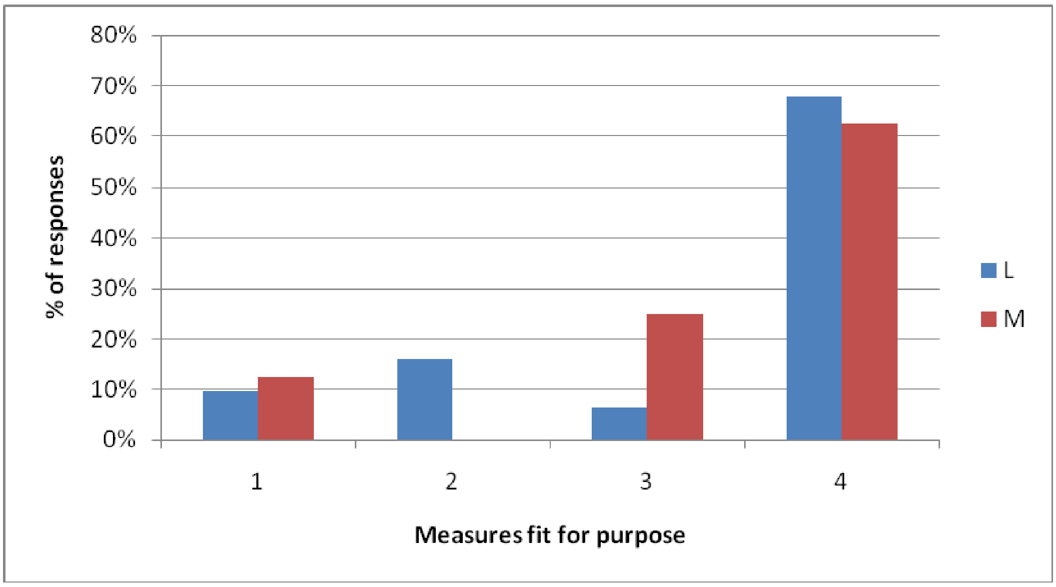
Rating the level of disruption: Around 65% of the residents that had low packages installed rated the level of disruption at the lowest end of the scale. What is encouraging is that 50% of the residents with medium packages also rated the disruption as minimal (rating of 1). About 75% of the residents with medium packages rated the disruption as minimal or one level higher (rating of 2) on a scale of 1-4.

Figure 8: Level of disruption - 1 minimal, 4 very disruptive



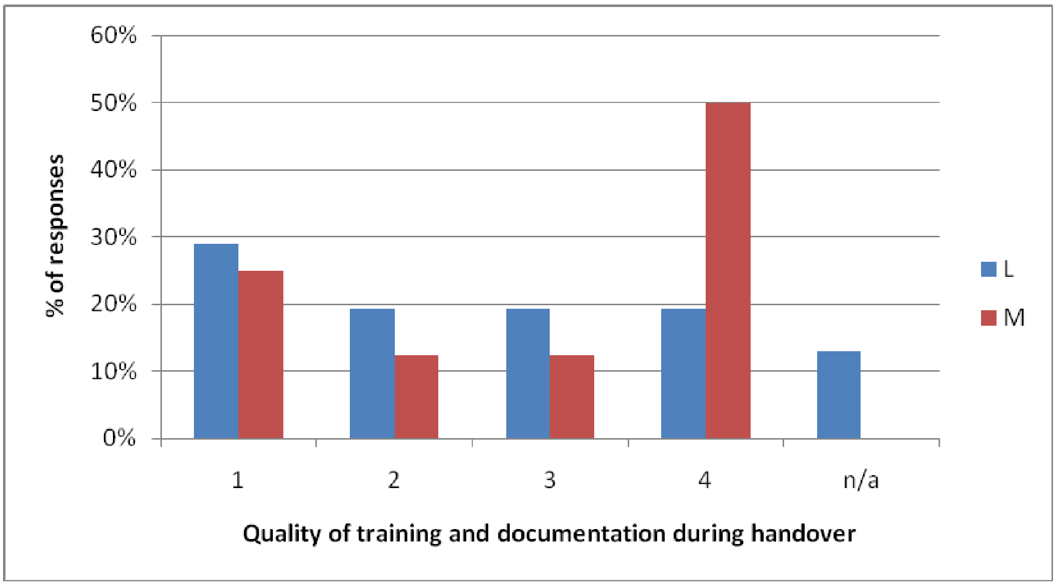
Are measures fit for purpose: The saving in energy bills and improved comfort were cited most commonly by tenants as the perceived benefits from the works being carried out in the properties. The majority of residents agreed that the measures installed aligned with their needs and were fit for purpose. The response was comparatively more positive for properties with medium packages than those with low packages, with around 85% of the residents rating the measures as nearly or totally aligned to their needs in case of medium packages compared to ~75% for low packages.

Figure 9: Measures fit for purpose - 1 not relevant, 4 totally aligned



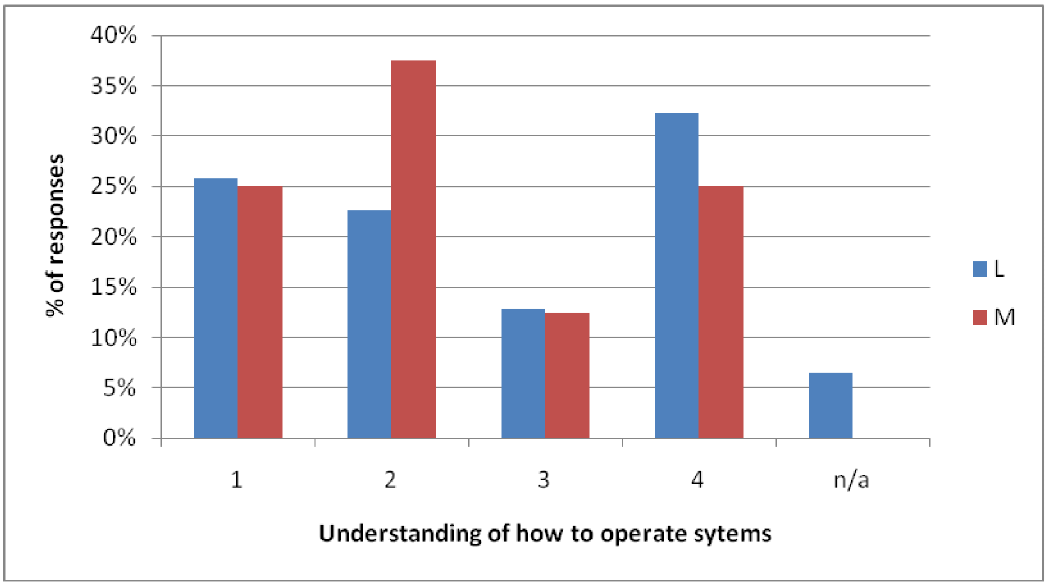
Rating the training and documentation provided at handover stage: For the low packages the response was spread more or less evenly, though the majority rated the quality of handover documentation as basic. For the medium packages, around 50% of the residents rated it as excellent, another 25% rating it as basic and the remainder 25% rating it as somewhere in between.

Figure 10: Quality of training and documentation during handover - 1 basic, 4 excellent



Understanding of the systems installed: Despite a majority of the residents with medium packages rating the handover documentation as excellent, over 60% rated their understanding of the systems as basic or one level higher. This suggests that there may still be need to improve their understanding in follow on visits by ASG staff to ensure that the systems are used as efficiently as possible.

Figure 11: Understanding of how to operate systems - 1 basic, 4 excellent



5 Cost of retrofit measures

5.1 Estimated versus actual costs

Table 3 below provides the average cost of installing energy efficiency measures and renewable technologies on the FutureFit properties. Where applicable, these are broken down by marginal costs and fixed costs. The marginal costs relate to per unit cost of installing the measure. The fixed costs are independent of the installed area/ capacity and would include for instance costs for relocating resident's belongings to install floor insulation or cost for scaffolding to install cavity wall insulation in flats.
Costs are presented both before and after preliminaries, overheads and VAT are added. These typically increase the base-cost of the measure by as much as 1.5 times based a rate of 15% for Prelims, 6.5% for overheads and 20% VAT. Please note that a VAT of 5% has been applied to insulation measures (and associated works), heating controls and renewable technologies. These measures are highlighted in red in the table below.

In each instance, a comparison is also provided with the cost of the measure assumed in EST Housing Model 2010. The EST Model is an analytic tool that explores how different energy efficiency measures and renewable energy technologies affect the performance of homes in Great Britain. Looking at the period 2007 to 2050, the model predicts how much energy and CO_2 could be saved by applying different measures to homes, in different combinations and with different uptake rates. It identifies the cost of installing and running these measures over time and performs cost/benefit analysis. The cost data in the Housing Model was put together based on discussions with trade associations, manufacturers and installers, and excludes any grants or hassle costs[3].

[3] EST Housing Energy Model assumptions: www.energysavingtrust.org.uk/uk/Publications2/Local-authorities/Strategy-development/The-Energy-Saving-Trust-Housing-Energy-Model-assumptions

Table 3: Average cost of energy efficiency measures before and after works

	EST Housing Model			Pre-works estimated costs (excl. prelims, overheads and VAT)				Average incurred costs across all archetypes (excl. prelims, overheads and VAT)			Total cost incl. prelims, overheads and VAT	
Measure	Cost			Cost				Cost			Cost	
	Fixed	Marginal	Unit	Fixed	Marginal	Unit	Notes	Fixed	Marginal	Notes	Fixed	Marginal
Cavity Wall insulation		£4.75	£/m²		£12 - £18	£/m²	Costs dependant on no. of storeys		£11.75	Measure not installed in block of flats where cost expected to be higher due to access issues		£15.1
Loft insulation	£240	£0.018	£/mm. m²	£50	£7.0	£/m²	400mm Rockwool insulation					
Loft insulation (Top-up)	£240	£0.018	£/mm. m²	£50	£5.5	£/m²	200mm Rockwool insulation	£50	£5.20	Cost range £4 - £9.8	£64	£6.7
Internal Wall Insulation		£70	£/m²	£1,420	£64	£/m²	Fixed costs relate to - relocating resident's belonging - removing and refitting kitchen and bathroom fittings - removing existing tiling in kitchen/ bathroom - Removing and re-fixing window beading and door architraves, plus supply of new window boards.	£1,832	£57	Marginal cost range £45 - £106. Higher end of the range for one specific property due to the small area to be treated. This value has been excluded when calculating the average marginal cost for the measure.	£2,356	£72.8
External insulation	£1,500	£85	£m²	£310	£156	£/m²	Marginal costs include costs for excavation to ensure that external insulation is taken down to the top of the foundation footing detail.			Measure not installed due to planning issues		

	EST Housing Model			Pre-works estimated costs (excl. prelims, overheads and VAT)				Average incurred costs across all archetypes (excl. prelims, overheads and VAT)			Total cost incl. prelims, overheads and VAT	
Measure	Cost			Cost				Cost			Cost	
	Fixed	Marginal	Unit	Fixed	Marginal	Unit	Notes	Fixed	Marginal	Notes	Fixed	Marginal
							Fixed costs relate to - adapting below ground drainage connections - planning permission					
Floor Insulation		£42.52	£/m²	£2050-£1640	£45	£/m²	**Insulation to floor – Overlay** Marginal costs relate to aerogel insulation bonded to chipboard. Fixed costs relate to - Removing and re-fixing kitchen fittings - Removing and re-fixing bathroom fittings - Removing and re-fixing floor coverings - Removing and re-fixing skirting boards - Storage of residents belongings Range dependant on whether resident belongings stored within property or off-site container	£2,188	£60.10	Marginal cost range £38 - £73 across the three contractors. This cost does not include floor covering replacement at an additional cost of £26.5/m2 (5 of the 6 properties that had floor insulation installed had floor covering replaced). Instead the avg. cost for removing and re-fixing floor coverings has been added to the fixed costs. Storage containers provided to avoid the need for decanting at an additional cost of £350 per property.	£2,814	£77.3

	EST Housing Model			Pre-works estimated costs (excl. prelims, overheads and VAT)				Average incurred costs across all archetypes (excl. prelims, overheads and VAT)			Total cost incl. prelims, overheads and VAT	
Measure	Cost			Cost				Cost			Cost	
	Fixed	Marginal	Unit	Fixed	Marginal	Unit	Notes	Fixed	Marginal	Notes	Fixed	Marginal
				£2050-£1640	£56	£/m²	**Insulation to Suspended Timber floor - Existing covering provided over boards** Fixed costs as above	£2,188	£48	Marginal cost does not include floor covering replacement at an additional cost of £26.5/m^2. Instead the avg. cost for removing and re-fixing floor coverings has been added to the fixed costs.	£2,814	£61.2
				£1250-£840	£52	£/m²	**Insulation to Suspended Timber floor - Existing exposed boards** Fixed costs relate to - Removing and re-fixing skirting boards - Storage of residents belongings Range dependant on whether resident belongings stored within property or off-site container	£648	£46		£833	£59.2
Insulated doors		£500	£/door		£900-£1200	£/door	External door/ Front entrance door		£800-£832	Average of external door/ front entrance door		£1,175 - £1,223
Foam insulated DHW cylinder		£400	item		£850	item	Includes cost of new 50mm factory insulated cylinder; includes insulating all existing primary pipework		£706	Cost range £500 -£775		£1,038

	EST Housing Model			Pre-works estimated costs (excl. prelims, overheads and VAT)				Average incurred costs across all archetypes (excl. prelims, overheads and VAT)			Total cost incl. prelims, overheads and VAT	
	Cost			Cost				Cost			Cost	
Measure	**Fixed**	**Marginal**	**Unit**	**Fixed**	**Marginal**	**Unit**	**Notes**	**Fixed**	**Marginal**	**Notes**	**Fixed**	**Marginal**
Primary Pipework insulation		£101	item									
Insulation jacket					£40	item			£31			£39.5
Double glazing		£200	£/m²		£478	per window	Plus associated works to reveals; U-value of 1.6W/m2K (compared to 1.8W/m2K for the EST spec)		£398	Cost range £245 - £448		£585
Reduced infiltration A - to 5m³/m².h		£240	item		£630	item	For airtightness Pkg 1 - 'complete air tightness improvement works' to Archetype 3; Predicted costs vary with archetype (from £440 - £1040) depending on property size, number of windows and doors, etc. Costs shown for Archetype 3.		£656	This package was carried out for Archetype 3 only with improvement in airtightness from average of 10.3 m³/m²/h @50Pa pre-works to 9.2 post-works		£964
Reduced infiltration B - to 1m³/m².h (incl. Heat Recovery)	£3,500		item		£3,580	item	No comparable specification. Cost for airtightness package 1 above and whole house mechanical ventilation.		£2,315	No comparable specification. Cost for airtightness package 1 above and whole house mechanical ventilation.		£3,402
Draught proofing	£101		item	£70	£45	per window	Fixed cost of £70 is cost of draughtproofing door	£65	–	No data available for windows. Data for doors relates to one property only.		–
Heat Recovery	£3,500		item	£2,950			MVHR System	£2950		Cost range £740 - £2950. Lower end relates to specific	£4,336	

	EST Housing Model			Pre-works estimated costs (excl. prelims, overheads and VAT)				Average incurred costs across all archetypes (excl. prelims, overheads and VAT)			Total cost incl. prelims, overheads and VAT	
Measure	**Cost**			**Cost**				**Cost**			**Cost**	
	Fixed	**Marginal**	**Unit**	**Fixed**	**Marginal**	**Unit**	**Notes**	**Fixed**	**Marginal**	**Notes**	**Fixed**	**Marginal**
										properties which already had mechanical extract systems installed and therefore required no new ducting.		
Low energy light bulbs		£2.50	£/bulb		£3	£/bulb			£2.8			£4.2
Heating controls	£398.4		per dwlg.		£28	per TRV			£32			£41
					£450	zoned heating control	3-zone systems with motorised values		£608	Average costs for three different specifications used on site – original specification (~£630), Honeywell 2-zone wireless systems (~£975) and programmable TRVs with time and temperature control (£415).		£782
					£130	weather compen sator			£134			£173
					£100	boiler interlock			_	Not installed		_

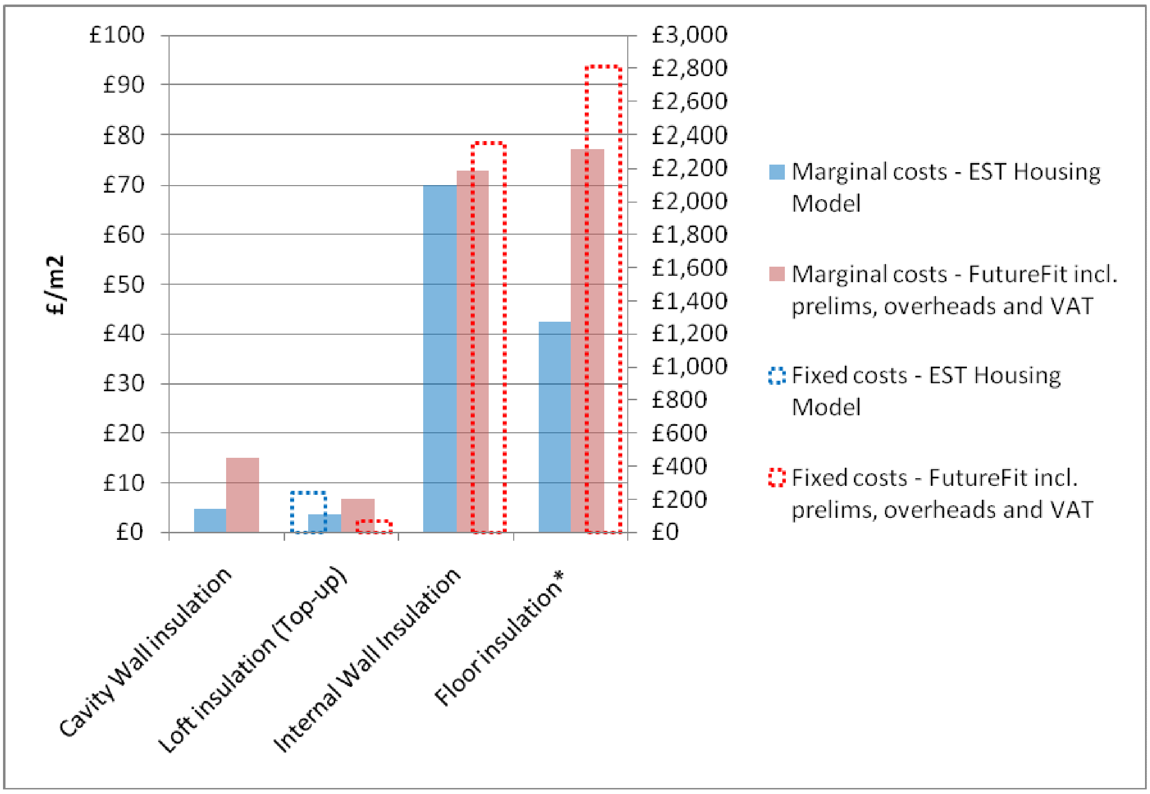
	EST Housing Model			Pre-works estimated costs (excl. prelims, overheads and VAT)				Average incurred costs across all archetypes (excl. prelims, overheads and VAT)			Total cost incl. prelims, overheads and VAT	
	Cost			Cost				Cost			Cost	
Measure	**Fixed**	**Marginal**	**Unit**	**Fixed**	**Marginal**	**Unit**	**Notes**	**Fixed**	**Marginal**	**Notes**	**Fixed**	**Marginal**
Condensing boiler replacement (gas)		£2,500	item		£1,037		Excludes cost for new insulated cylinder		£1,398	Cost range £1,298 - £1455		£2,055
Low flow water fittings		£25	per tap		£40	per tap			£40			£59
		£55	per shower		£55	per shower			£51			£74
Photovoltaic panels	£2,000	£4,300	£/kWp	£300	£4,500	£/kWp	Fixed costs relate to BWIC	£351	£6,200	Cost range £3,160 - £10,111 depending on installed system size.		£9,112

Figure 12 below shows a comparison of the fixed and marginal costs for insulation measures on an average across FutureFit properties compared to those in the EST Housing Model. The FutureFit costs shown are total incurred costs inclusive of prelims, overheads and VAT. This indicates that on an average costs incurred for the FutureFit properties are relatively higher. While in some instances better specifications may account for some of the difference (e.g. aerogel insulation specified in case of floor insulation), in other instances the cost of even mature and widely adopted measures, such as cavity and loft insulation, is higher by a factor of two or three. This trend is seen across most other measures as shown in Figure 13 and Figure 14 below.

Measures such as floor insulation and internal wall insulation show a significant amount of fixed costs for associated works such as moving resident belongings, removing and re-fitting kitchen and bathroom fixtures, skirtings, windows beading, boards and architraves, etc. Aligning retrofit programme to trigger points will help mitigate the costs for some of these associated works.

Some of the measures also show a wider cost range across properties than others and this is discussed in more detail in the next section.

Figure 12: Comparison of costs for insulation measures



* FutureFit costs relate to aerogel overlay insulation

Figure 13: Comparison of costs for airtightness and ventilation, heating systems and controls

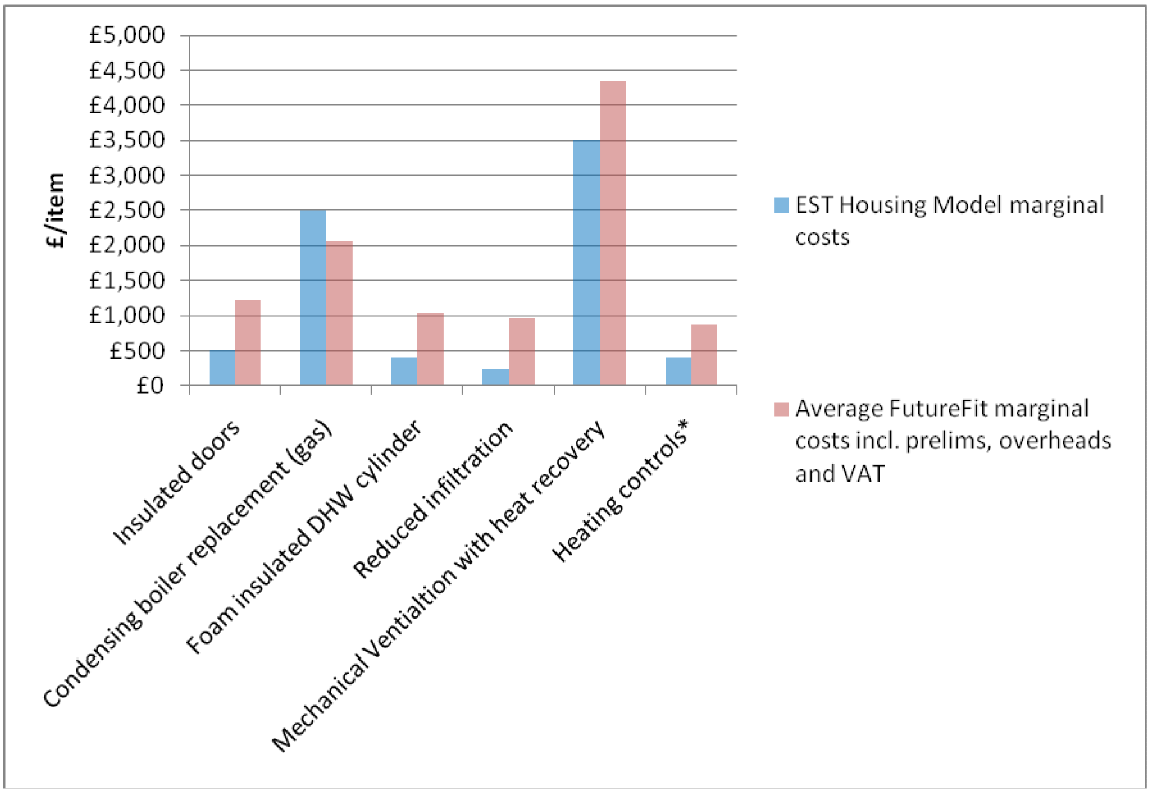
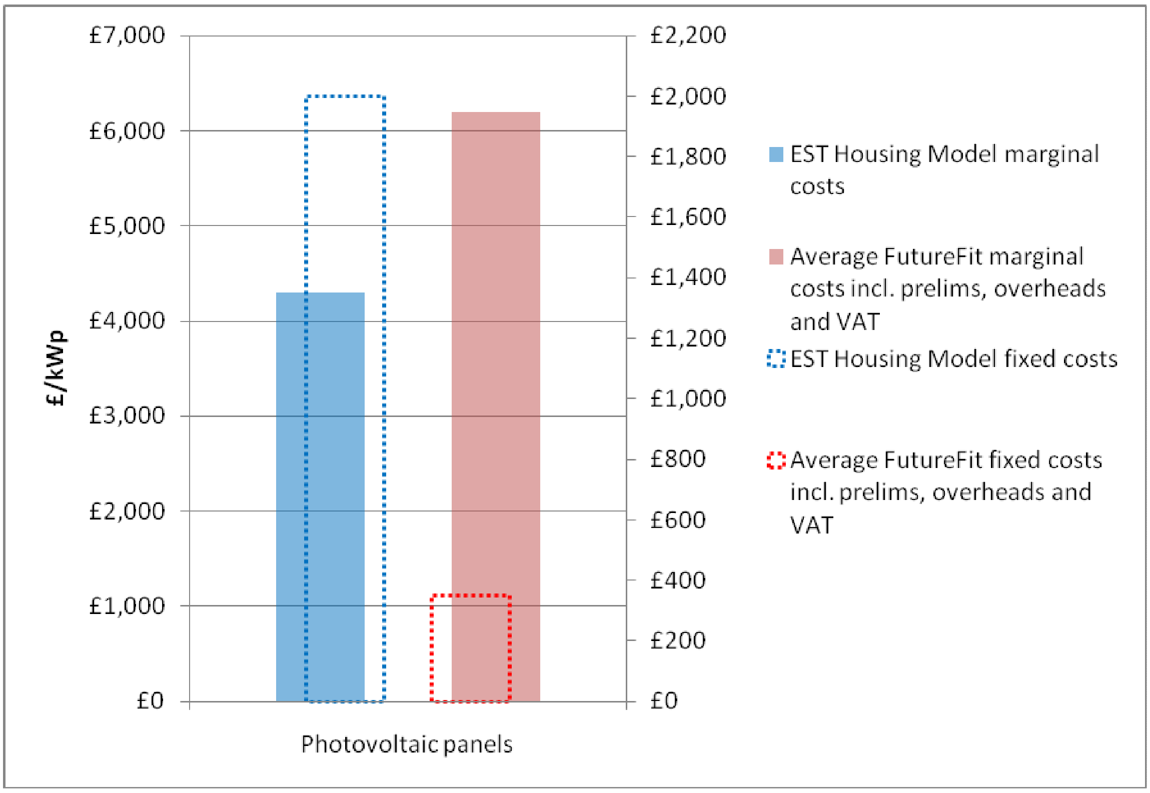


Figure 14: Comparison of costs for photovoltaic panels



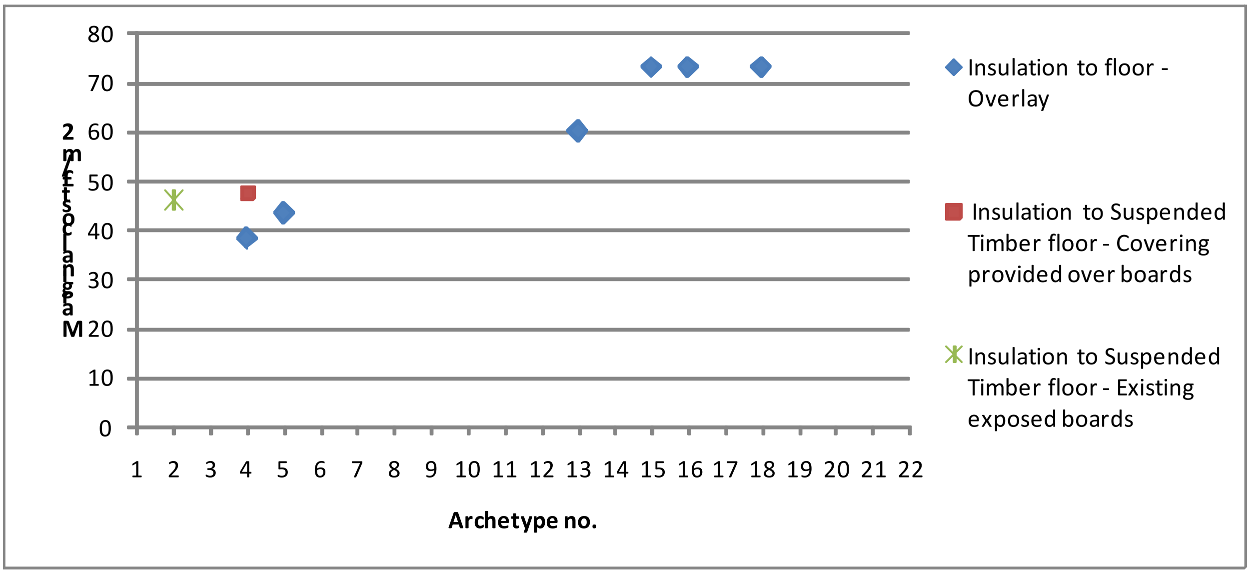
5.2 Variation in costs of energy efficiency measures by archetype

The figures below show the range of costs for installed measures by archetype. As is evident, certain measures have a wider range than others. For instance, floor insulation, MVHR systems and PV installations have the widest cost range, while other measures such as HRVs and TRVs show little variation from one archetype or contractor to another.

Separate discussions were held with each of the contactor organisations to understand the reasons for the differences in costs across the property types as summarised below.

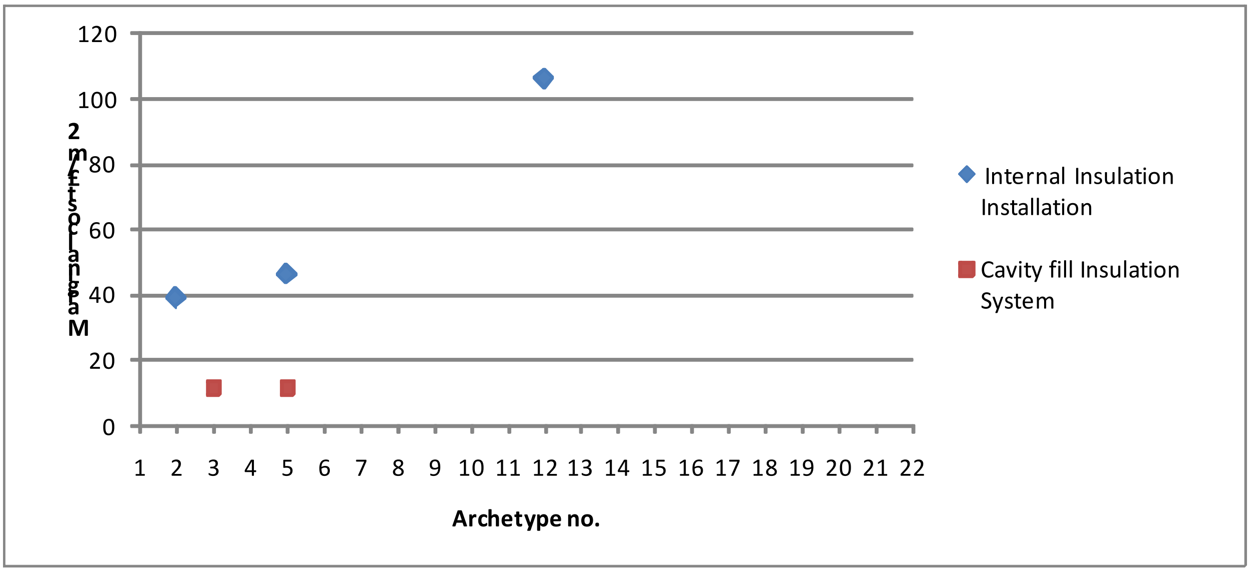
Floor insulation - Figure 15 shows the variation in marginal costs for floor insulation measures excluding cost of renewing floors coverings. The difference in costs in case of overlay insulation was down to two factors – how the measure was procured (with a supply and fit contract working out the cheapest) and the other being how the insulation was supplied on site, that is, un-bonded or pre-bonded to the laminate. The pre-bonded version had a supply time lag of 8 weeks, while the un-bonded version was readily available but required the insulation to be bonded to the laminate on site that significantly added to the installation costs of the measure

Figure 15: marginal cost range for floor insulation measures (excl. floor coverings)



Internal wall insulation –
Figure 16 shows that there is a significant cost differential across the small sample of properties that had internal wall measures installed. Discussions with the contractor organisations have indicated that the higher marginal cost for Archetype 12 was attributed to the much smaller wall area to be treated (~15m^2). However, due to the small sample size, it is difficult to establish any meaningful correlation between wall areas and marginal installation costs.

Figure 16: Marginal cost range for wall insulation measures



Airtightness measures – As is evident in Figure 17 below, the cost of the measure varies significantly by archetype, which is attributed to the size of the property and its condition. It is pertinent to mention that the retrofit packages in all of the properties were intended to achieve the same performance levels. The level of intervention (air tightness packages 1- 4) was defined based on whether part of the air tightness works would be covered within another measure being installed in the property e.g. internal wall insulation or floor insulation in which case the air tightness package would be limited to partially intrusive or non-intrusive.

Figure 18 below shows the improvement in airtightness by installation costs. While there appears to be a marginally positive correlation with greater improvement in airtightness achieved with increasing costs, the results are skewed by small number of properties that have out-performed.

Figure 17: Cost range for airtightness package

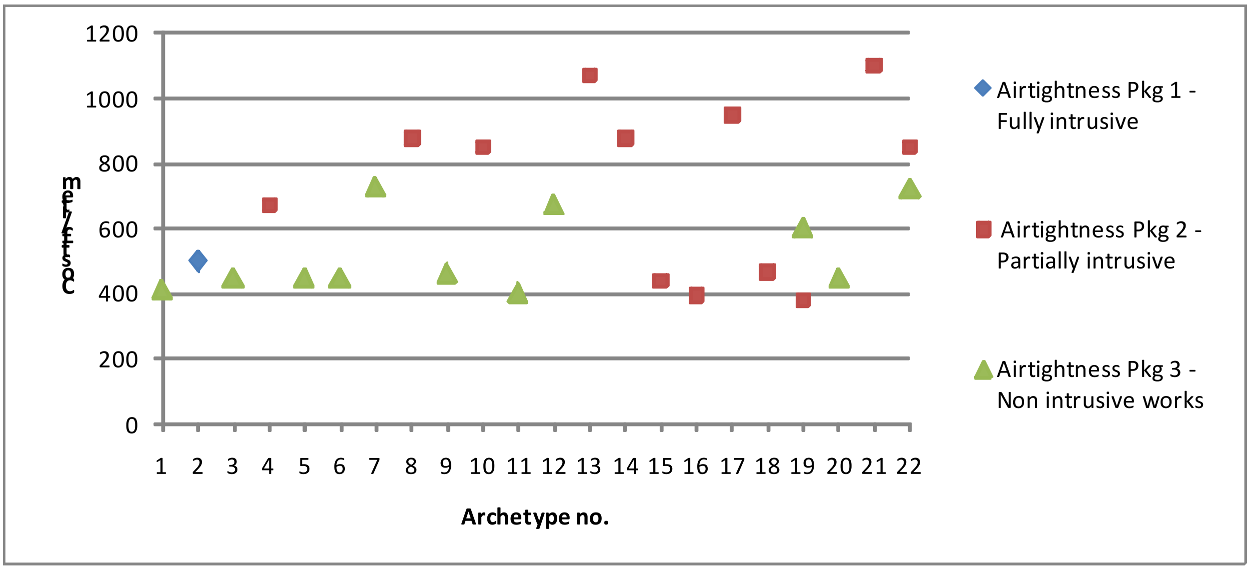
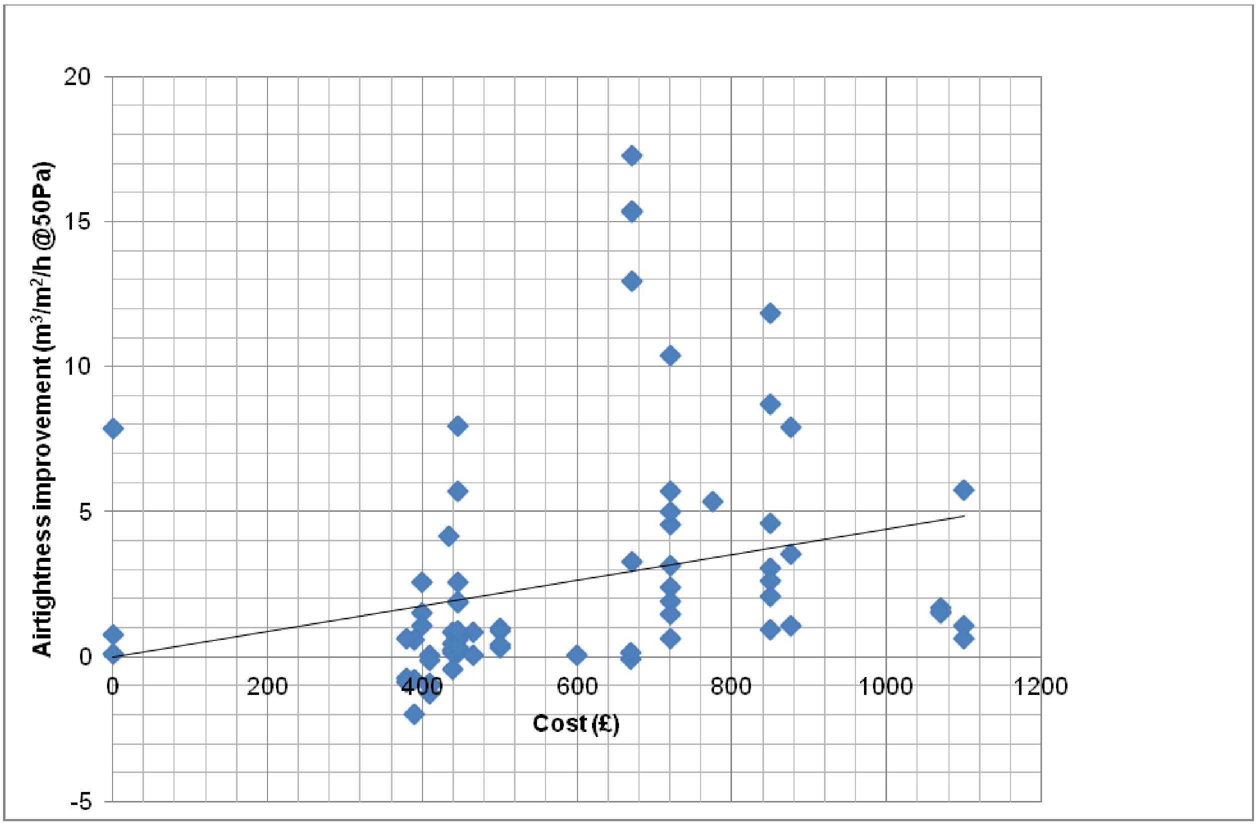


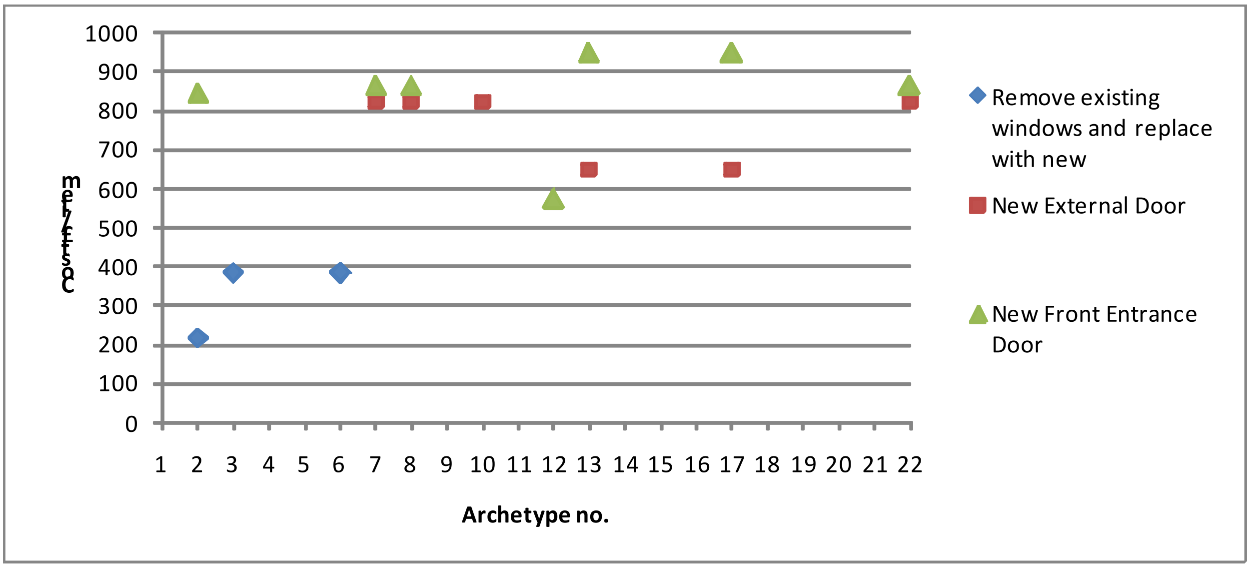
Figure 18: Improvement in airtightness by installation cost



Doors and windows – The cost of new front door in case of Archetype 12 is substantially lower than other archetypes, which is attributed to the difference in specifications. The specifications were varied in this instance to match the existing doors.

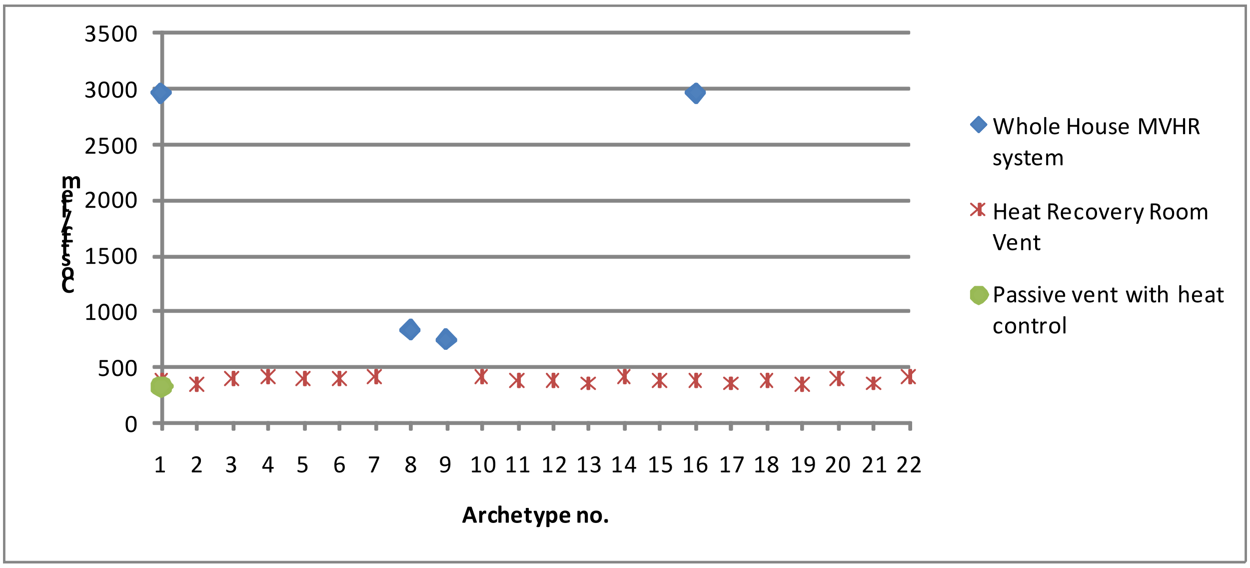
The cost of window is largely determined by the type of window unit (e.g. opened, sealed, sash windows etc.) which accounts for the difference in costs across properties.

Figure 19: Cost range for new doors and windows



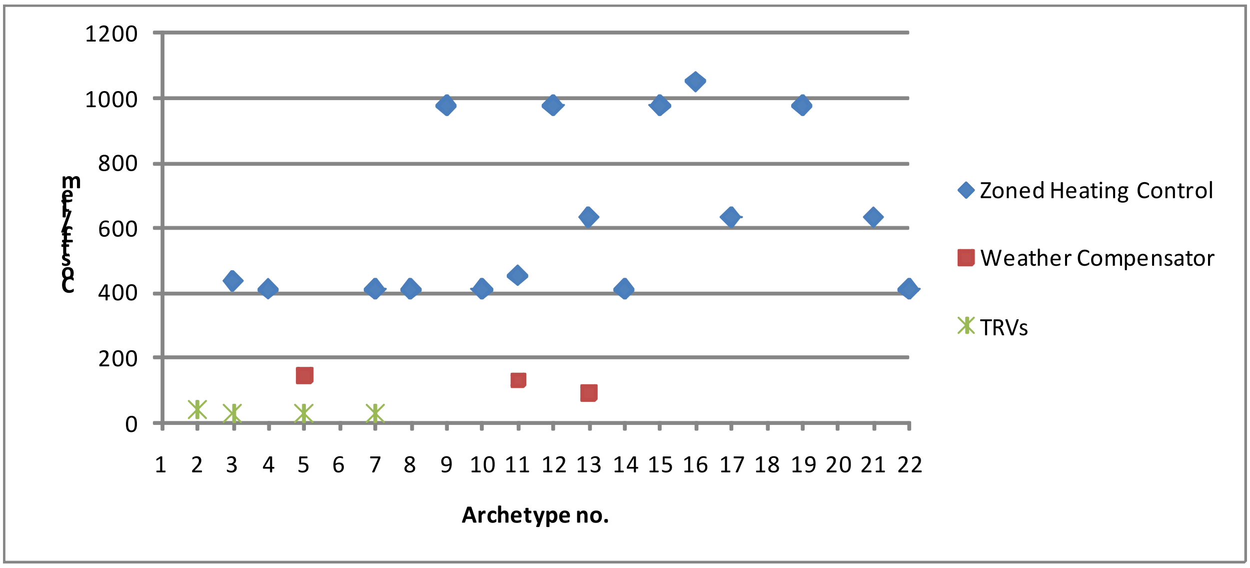
Ventilation systems –There is little variation in costs of heat recovery room ventilation systems across archetypes. In case of mechanical ventilation systems, archetype 8 and 9 already had mechanical extract systems in the properties being refurbished (and therefore did not require any ducting to be installed), which resulted in the abnormally low cost for upgrading to MVHR.

Figure 20: Cost range for ventilation systems



Heating controls - The cost range for zoned heating controls reflects three different specifications – the top range is for a 2-zone wireless system with a controller installed in the living room and radiator controllers in individual rooms; the mid-range costs relate to the original FutureFit specification with 3 programmable zones controlled by motorised valves, and the lower end of the cost range relates to programmable TRVs that allow for both time and temperature control in individual rooms.

Figure 21: Cost range for heating controls



Photovoltaics – The experience from FutureFit suggests that the marginal cost of PVs is highly sensitive to the system size installed with the higher end of costs in Figure 22 below relating to system sizes of around 0.5 kWp and the lower end to around 1.3kWp. Figure 23 below shows the co-relation between installed size and system costs.

Figure 22: Cost range for PV installation (excl. BWIC)

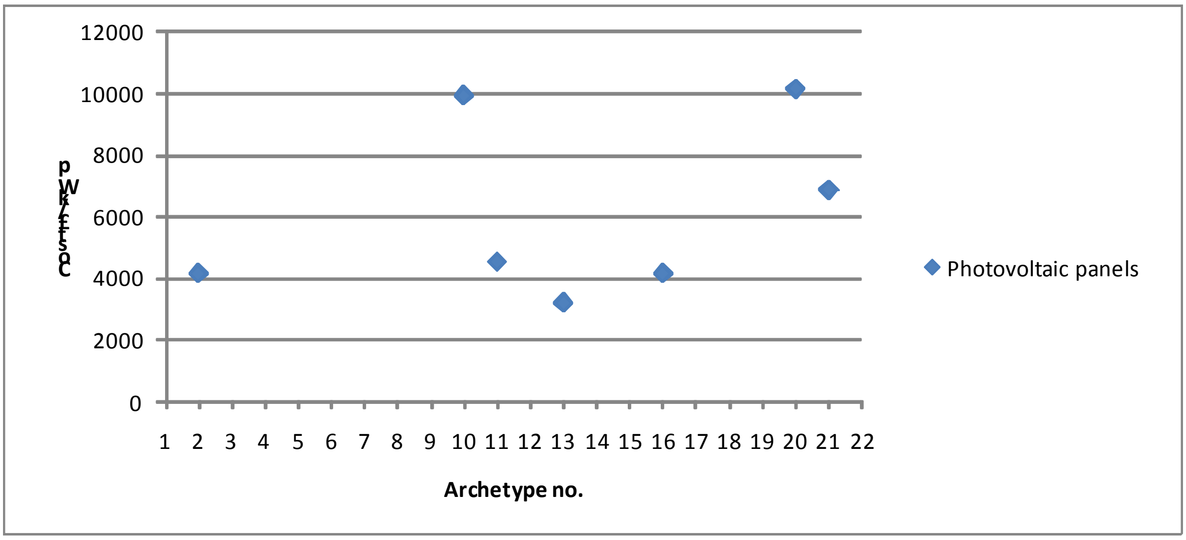
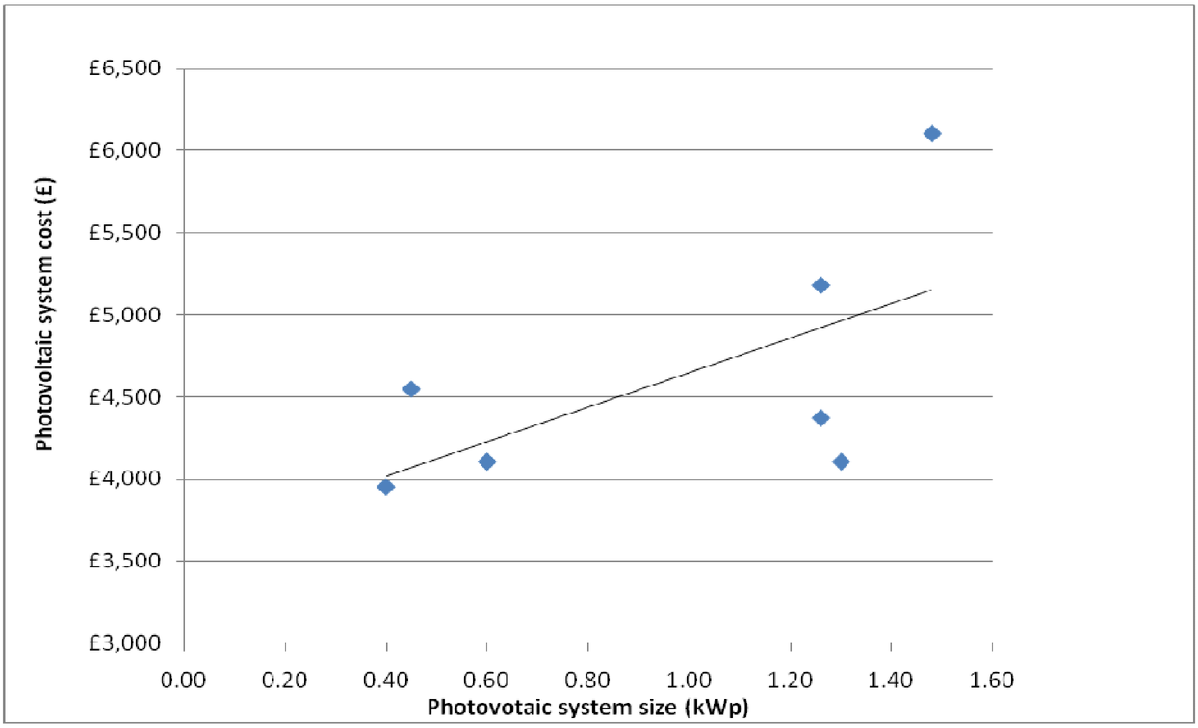


Figure 23: System sizes versus installed costs for PVs



6 Impact of user behaviour on energy and cost savings

The energy usage in the FutureFit properties is currently being monitored on site with a view to assess the improvement post-works. This section presents the likely impact of occupancy patterns and user behaviour on CO_2 emissions and energy costs, with a view to highlight the potential reasons for variation in predicted energy costs compared to monitored costs. The analysis has been carried out using Archetype 5 (1930-1949, flat, cavity construction) and low package as an example.

The base case scenario pre-works and the post-works for the low package has been modelled using the standard assumptions in SAP regarding occupancy, heating patterns and appliance use. A range of scenarios were then modelled varying the occupancy, heating hours, temperature to which the property is heated, and the appliance usage. These results are presented in Figure 24 and Figure 25 below.

The analysis suggest that where the residents use the heating for extended hours, heat the dwelling 2 degrees higher than standard case and have above average appliance use, this erodes all the savings compared to a standard base-scenario. This highlights the importance of taking user behaviour into account when predicting the energy/ CO_2 savings and the likely payback of upgrade packages.

Figure 24: Impact of user behaviour on CO_2 savings

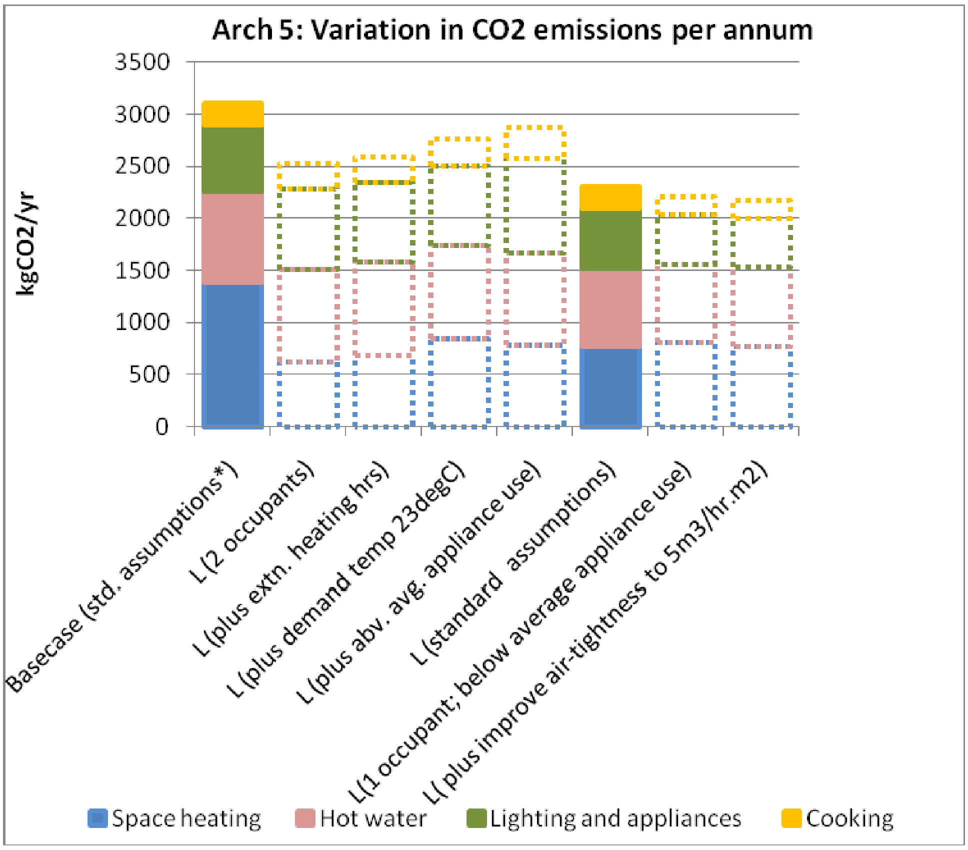
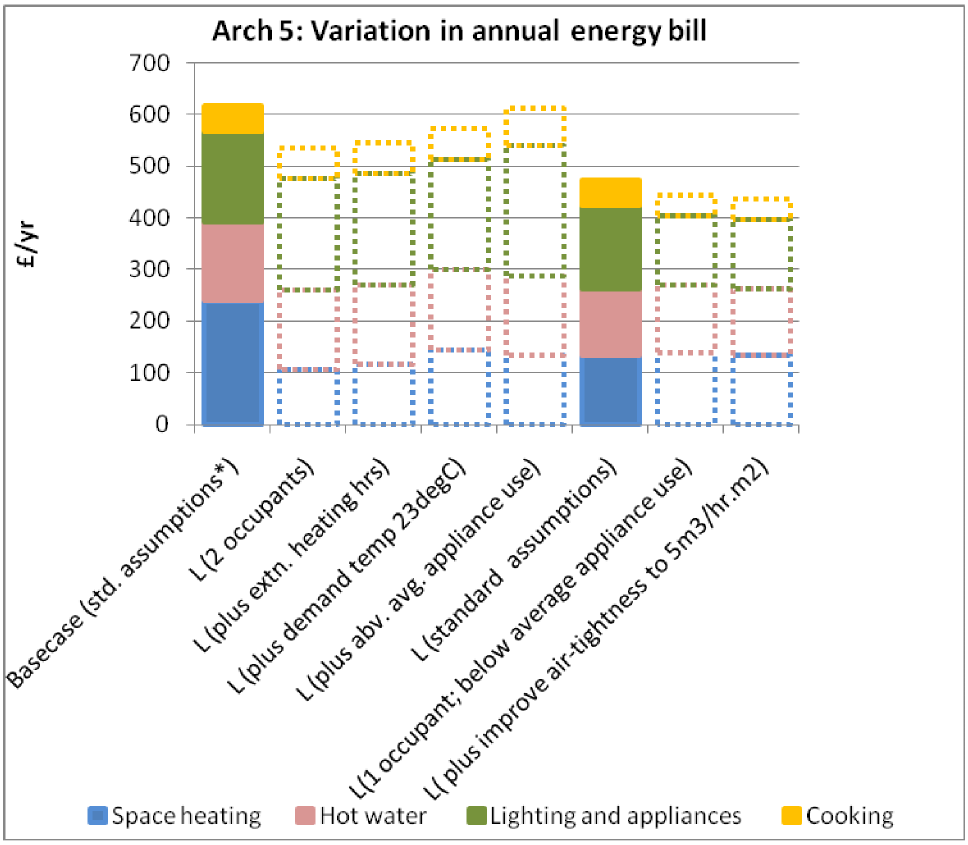


Figure 25: Impact of user behaviour on energy costs



7 Conclusions

Considerations for future work packages and product specifications

These have been informed by the installation and resident issues raised in the preceding sections and draw on the discussions with Affinity Sutton, Baily Garner and the contractors.

Wall insulation – To avoid access issues and associated fixed costs, cavity wall insulation should be installed in one go for block of flats as against a property by property approach. Given the planning constraints, the same approach should be taken for external wall insulation, specifically in case of block of flats and terrace/ street of houses. This reinforces the idea of an area based approach to retrofitting.

This approach may however prove challenging in case of mixed tenures. Therefore more flexibility is required within the planning process to accommodate householders opting out of the process or, for instance, in case of mixed tenures delaying green deal packages to align closely with trigger points on individual properties.

Ventilation – More clarity is required in terms of the relative performance and cost effectiveness of HRV's versus other alternative ventilation strategies, such as MVHR, passive vents with heat control and low energy extract fans, to help inform future work packages. Consideration also needs to be given to the airtightness levels that can be achieved cost effectively, and the ventilation strategy that will work most optimally at the levels of airtightness achieved.

With regard to HRVs, newer products with lower fan power are now becoming available in the market and therefore the specifications should continually be updated to reflect this. Noise should also be a key consideration in deciding on the specification. Those with slow start and switch-off may feel less noisy and therefore may be more acceptable to residents. Also models that can fit a standard 4" hole typically required for extract fans will be easier, quicker and less disruptive to install.

Heating controls – Consideration should be given to wireless zoned heating controls to avoid need for adapting existing plumbing and associated disruption for residents. However at around £1000/dwelling, zoned heating controls may not be the most cost effective measure for smaller properties. Feedback from residents also suggests that maximising the benefits of such systems may require a more intensive training and handover process. Time and temperature control radiator valves or 'programmable radiator controls' may be an alternative consideration at about 40% of the cost for wireless zoned heating controls. Comparative performance should be assessed where possible during monitoring phase taking into account ease of operation and user behaviour.

Airtightness measures – The performance standard achieved varies both significantly across and within archetypes. Pre-works airtightness test results should be used as a trigger to determine the cost-benefit of carrying out a full airtightness package. It is recommended that smoke tests be carried out to determine the typical air leakage paths in properties of different construction types which in turn would feed into a detailed inventory of air tightness works for each typology. This will help ensure consistency across contractors in terms of the works carried out and greater confidence on the performance standards that can be achieved.

Photovoltaic panels – Experience from FutureFit properties suggests that systems smaller than ~1.2kWp may not be cost effective due to high fixed costs associated with access, wiring, inverter, system design and commissioning. In block of flats where roof area may be limited, it may beneficial to install a larger array to serve the communal areas as against a number of smaller arrays for each flat.

Guidelines for maintenance staff – The specifications for work packages should be supplemented by guidelines for maintenance staff. For instance, once airtightness measures have been installed, maintenance staff needs to be made aware of these when working in these properties and should understand what would need to be done to rectify things (for instance, removing bath panels when they have been sealed previously).

Performance related issues that should be addressed during the next phase of monitoring

Apart from the energy and CO_2 savings realised from work packages overall, the performance of individual technologies should be assessed where feasible through a combination of monitoring data and resident surveys, in particular

- In a number of instances, residents have described the properties as draughty and cold pre-works. Post-works monitoring to establish both energy savings and improvement in thermal comfort to assess the benefit of work package.
- There appears to a re-occurring issue of condensation and damp in properties with very low airtightness levels. The performance of the ventilation systems installed in improving this should be monitored along with the energy performance of these systems as in due course this will impact on the maintenance costs of these properties for Affinity Sutton as well residents health. It is also important that residents understand how HRV/ MVHR systems work so that this problem is not created in properties that now have much lower airtightness levels, for instance, where the systems are switched off due to noise issues.

- The potential benefits of continuous HRVs in properties with varying air tightness levels should be assessed compared to other ventilation strategies, e.g. low wattage intermittent extract fans in case of properties with airtightness greater than 5.
- As mentioned above, the relative performance of zoned heating systems and programmable radiator controls should be assessed, where possible, during the monitoring phase.
- Specific technologies that are not currently included under SAP may require a more rigorous evidence base with regard to their energy saving potential to justify their inclusion in a future retrofit strategy. This includes V-phase, radiator reflectors and tadpole device.

Appendix 1 – Data collation templates

Site log book - For use by site managers

Site/ dwelling address	
Date works commenced on site	
Scheduled handover date	

Airtightness tests

1	Pre-works airtightness test result	
2	Airtightness test result after completion of works	
3	Please advice on any additional airtightness works carried out other than those outlined in specification documents issued by Baily Garner	
4	Please list any airtightness works omitted from the specification documents issued by Baily Garner.	

Amendments to package of works installed

5	**All measures installed as per agreed order sheet? (Y/N)**			
6	If the answer is No above, please indicate the measure/s that have not been installed.	1. External wall insulation	2. PVs	3. etc.

7 When was the decision to exclude these measures taken?	• Post site survey • During works	• Post site survey • During works	• Post site survey • During works
8 Please indicate the reason why the measure was not installed (Please tick)	• Not suited to this property type • Product not available due to supply chain issues • Installation issues (e.g. lack of space) • Unwilling resident • Other	• Not suited to this property type • Product not available due to supply chain issues • Installation issues (e.g. lack of space) • Unwilling resident • Other	• Not suited to this property type • Product not available due to supply chain issues • Installation issues (e.g. lack of space) • Unwilling resident • Other
9 Please elaborate on the reasons.			

10 If the answer to Q5 above is no, please list any additional measures (not originally included in the order sheet for this dwelling) that have been installed.	1. External wall insulation	2. PVs	3. etc.
11 When was the decision to install these additional measures taken?	• Post site survey • During works	• Post site survey • During works	• Post site survey • During works
12 Please indicate the reasons for including these measures	• Chosen as an alternative to a measure that was omitted • Resident request • Other	• Chosen as an alternative to a measure that was omitted • Resident request • Other	• Chosen as an alternative to a measure that was omitted • Resident request • Other
13 Please elaborate on the reasons for inclusion.			

14 Please provide product specifications.			
15 Please indicate product cost plus cost of installation.			

Amendments to work specifications or system sizes

16 For the package of measures proposed for this site, were there any agreed changes to work specifications. If so, please list the measures for which specifications were amended.	1. Replacement windows	2. MVHR system	3. PVs etc .
17 When was the decision to amend the work specifications taken?	• Post site survey • During works	• Post site survey • During works	• Post site survey • During works
18 Date amendments agreed			
19 Please indicate the reasons for changes to specifications	• Product supply chain • Resident issues •Installation issues / site logistics •Insufficient space •Other	• Product supply chain • Resident issues •Installation issues / site logistics •Insufficient space •Other	• Product supply chain • Resident issues •Installation issues / site logistics •Insufficient space •Other
20 Please elaborate on the reasons for the changes.			
21 Would these changes to specifications impact on cost of the measure and by how much?			

22	Would changes to work specifications impact on the warranties for this or other measures installed on site?			
	Variation in cost of measures installed			
23	Please indicate measures for which incurred costs are different from those budgeted.	1.	2.	3.
24	Date recorded			
25	What is the likely variation in costs? Please indicate as percentage or absolute values.			
26	What are the reasons for this variation in costs?	• Product costs • Resident issues such as access to property etc. • Installation issues • Issues during installation and commissioning • Changes to specifications • Other	• Product costs • Resident issues such as access to property etc. • Installation issues • Issues during installation and commissioning • Changes to specifications • Other	• Product costs • Resident issues such as access to property etc. • Installation issues • Issues during installation and commissioning • Changes to specifications • Other
27	Please elaborate			
28	Are there any site specific issues that will result in increased cost of maintenance for the measures installed (or would invalidate the warranties)?			

Competency of the workforce/ Training needs

29	Did the workforce or any of the staff members require specialist training for the measures installed? (Y/N)	
30	Please provide details of the training.	

Delays to project programme

31	Have there been delays to project programme? (Y/N)	
32	Please indicate reasons for the delay.	• Product supply chain issues • Resident issues such as access to property etc. • Installation issues • Issues during installation and commissioning • Changes to specifications • Other
33	Please elaborate on the reasons for the delay? E.g. where supply chain was an issue, please indicate which product and lead in time for procuring it.	
34	Final handover date	

Commissioning and handover

35	What is the qualification of contractor staff commissioning building services and associated controls?	

36	Which building systems and products were included (e.g. boilers, heat recovery ventilation, renewable technologies, and controls)?	
37	What were the target operating conditions for commissioning heating systems?	
38	Were the system operation and controls explained to the residents as part of the handover process?	
39	How long did the process take?	
40	Have residents been provided with any documentation as part of the handover process such as instruction manuals for products installed, user guides, etc.	
41	Was there a specific request for additional information from the residents?	

Issues log - For use by project managers within each contractor organisation

Item	Date	From	Position	Description	Response	Outcome
1	Date issue raised	Record name of person raising the issue	Info/ clarification requested from	Provide details	Red = Pending	Describe what was agreed and action to be taken.
2					Green = resolved Date resolved	
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						

Site diary - For use by residents

Site/ dwelling address	
Date works commenced on site	
Scheduled handover date	
Final handover date	

Residents are encouraged to record any information that they consider relevant to the works being carried out including taking their own photos. Please use the following prompts to record your experiences on an on-going basis.

Record your comments on any works that you found particularly intrusive.

Could the sequencing of works be altered to minimise disruption?

Where new heating systems or technologies have been installed, are you happy with the information provided on how to operate and control them effectively?

How well have the benefits of the upgrade works been communicated?

Your best and worst experience each day

Date	Comment	Issue raised with	Action taken by contractor (where relevant)	Photo (Y/N)

Questions to be included in Resident Satisfaction Surveys - For use by RLOs

	Site/ dwelling address	
	Site handover date	
	Date survey conducted	
	No. of residents	
1	Issues and problems with the property before the works are undertaken (please record only issues related to energy consumption and/or thermal comfort e.g. drafts, too hot, too cold, condensation, damp etc.)	
2	Perceived benefits on refurbishment measures	• Improved comfort • Savings in energy bills • Reduced CO_2 emissions/ avoiding climate change • • • None
3	How would you rate the packages of works in terms of the level of disruption/ inconvenience?	• 1 (minimal; not a key concern) • 2 • 3 • 4 (very disruptive; overweighs the likely benefits)

4	Do you feel the measures implemented were fit for purpose and would meet your current and future needs? Rate on a scale of 1-4.	• 1 (not relevant at all) • 2 • 3 • 4 (Totally align with our needs)
5	Were you provided training on how to operate the systems as part of the handover process?	Y/N
6	How would you rate the quality of training and documentation provided as part of the handover process?	• 1 (basic) • 2 • 3 • 4 (excellent)
7	How would you rate your understanding of how best to operate the new technologies (e.g. heat recovery ventilation, heating controls, PVs, etc?)	• 1 (basic) • 2 • 3 • 4 (excellent)

FutureFit programme insights - For use by RLOs

Please record you insights under the following categories:

General perceptions on benefits of retrofit packages What are the general perceptions on the likely benefits of investing in energy upgrades? Do the perceptions differ for fabric energy efficiency measures (such as insulation, increased airtightness) and renewable technologies (solar hot water, PVs)?

Level of intervention Did the residents find the package of works more intrusive than anticipated? Was there a marked difference in opinion between residents for low and medium packages of work? What were the key concerns that might affect future up-take of such package of works for other residents e.g. length of works, phasing of works (by taking a room by room approach for instance), type of measures, etc.?

Relevance of measures
Did the residents feel the measures implemented were fit for purpose and would meet their current and future needs? Did they address issues and problems with the property before the works were undertaken, e.g. drafts, too hot, too cold, condensation, damp etc.

Commissioning and handover
Were the system operation and controls explained to the residents as part of the handover process? Were the residents happy with the type and content of information provided as part of the handover documentation? Did they feel confident in terms of adjusting controls for new systems (such as boilers, heat pumps or heat recovery ventilation units, and the like)?

Post-commissioning visits Please record any insights from post-commissioning site visits. These could relate for instance to system performance and reliability, thermal comfort issues, condensation issues, quality of workmanship etc.

Issues log - For use by ASG staff

Please use this log to record insights on resident issues post handover in terms of comfort, energy bills, performance and reliability of technologies installed etc.

Item	Date	Name	Dwelling address	Description	Action	Outcome
1	Date recorded	Record name of person recording the issue	Site address to which the issue relates to	Provide details	Blank = No action required	Describe what was agreed and action to be taken.
2					Green = resolved Date resolved	
3					Red = Pending	
4						
5						
6						
7						
8						
9						
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FutureFit programme insights - For use by ASG staff

Please record you insights under the following categories:

Resident comfort Do residents feel a marked improvement in thermal comfort post installation? If so, what do they attribute it to most (e.g. reduced drafts, a better heating system, improved controls for the heating system such as room thermostats, increased affordability to heat house to a higher temperature, etc.)? Is condensation an issue post works due to increased airtightness?

System performance and reliability Are the residents generally comfortable with operating the new heating systems and/or other technologies installed as part of the package (e.g. heat recovery ventilation) Have these new technologies been reliable to operate? If not, what were the problematic areas? Elaborate on specific problems for new condensing boilers, heat pumps, solar hot water, solar PVs, heat recovery room ventilation, etc. These could include, for instance, sound from heat pump, problems with supply temperatures, etc.

Energy bills

Have the residents seen any impact on their fuel bills? If yes, what is the range of savings each month? If not, what are the likely reasons (e.g. heating the house to a higher temperature/ longer than before, have a direct debit so not sure if there are any savings, don't think the installed technologies work properly, etc.)?

Quality of workmanship

Are there any concerns regarding the quality of workmanship and/or the durability of some of the measures installed?

Benefits of refurbishment packages

Do the residents feel that the upgrade packages actually delivered against their perceived benefits?

Appendix 2 – Archetype parameters

Archetype	Age	Type	Built form	Wall type
1	1983-1990	Flat		Cavity
2	1900-1929	Flat		Cavity
3	1900-1929	House	Mid-terrace	Cavity
4	1900-1929	House	End-terrace	Solid Brick
5	1930-1949	Flat		Cavity
6	1991-1995	Flat		Cavity
7	1930-1949	House	End-terrace	Cavity
8	1930-1949	House	End-terrace	Solid Brick
9	1996-2002	Flat		Cavity
10	1930-1949	House	End-terrace	System Built
11	1950-1966	Flat		Cavity
12	1950-1966	Flat		Solid Brick
13	1950-1966	House	End-terrace	Cavity
14	1983-1990	House	End-terrace	Cavity
15	1967-1975	Flat		Cavity
16	1967-1975	House	Mid-terrace	Cavity
17	1976-1982	House	Mid-terrace	Timber Frame
18	1967-1975	Maisonette		Cavity
19	1976-1982	Flat		Cavity
20	1976-1982	House	Mid-terrace	Cavity
21	1991-1995	House	End-terrace	Cavity
22	1996-2002	House	End-terrace	Cavity

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