HJALTLAND H.A. DEEP RETROFIT PILOT PROJECT

Technical Report - PUBLIC

November 2024

CHANGEWORKS.

This report is a redacted version of the full Monitoring and Evaluation Report provided to Hjaltland Housing Association in June 2024. To protect tenants' privacy, all tenant feedback has been removed.

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1. Overview

Hjaltland Housing Association [the Association] is developing a strategy for their capital programme and a timetable of upgrades to work towards upgrading all stock to go beyond the statutory requirements and provide truly low carbon, warm, comfortable homes for tenants. As part of this, a pilot project, trialling a range of measures across five properties in Virkie, Shetland Islands, has been undertaken with grant support from the Energy Industry Voluntary Redress Scheme.

Changeworks have conducted an independent analysis of data from technical monitors installed by the Association. Tenants were interviewed about their experiences and data was collected on energy consumption. This report provides an outline of the measures installed and the impact on the properties and their tenants, in line with the key aims and objectives (see section 2).

All properties in the pilot are timber kit construction (100mm) bungalows with external blockwork and dry dash render, built circa 1976. This typology prevents quick and affordable solutions such as cavity or external wall insulation being adopted.

Table 1: Overview of properties

Property ID	Property Type	Floor area
Property 1 (Fabric first)	2 bedroom	$73m^2$
Property 2 (Fabric first)	2 bedroom	$73m^2$
Property 3 (Fabric first)	3 bedroom	$89m^2$
Property 4 (PV)	2 bedroom	$73m^2$
Property 5 (ASHP)	2 bedroom	$73m^2$

Occupancy ranged from one to four people. Four of the five houses were under-occupied.

Table 2: Overview of existing heating systems, retrofit measures installed and cost

Property	Heating and hot water system (post-install)	Main Retrofit Measures[1]	Total Cost[2]
Property 1 (Fabric first)	Quantum HHR Storage heaters, panel heaters in bedrooms and towel rail. Dimplex 210ltr unvented cylinder with off-peak and boost immersions. 8.5kW electric shower, supplied via 24hr off-peak.	Wall insulation, new door, and Mechanical Ventilation with Heat Recovery (MVHR)	£33,199
Property 2 (Fabric first)	Quantum HHR Storage heaters, panel heaters in bedrooms and towel rail. Dimplex 210ltr unvented cylinder with off peak and boost immersions. Mixer shower from HWC.	Wall insulation, floor insulation, new door, and MVHR	£35,518
Property 3 (Fabric first)	Quantum HHR Storage heaters, panel heaters in bedrooms and towel rail. Dimplex 210ltr unvented cylinder with off-peak and boost immersions. Mixer shower from HWC.	Wall insulation, floor insulation, new door, and MVHR	£38,489
PV	Quantum HHR Storage heaters, panel heaters in bedrooms and towel rail. Dimplex 210ltr unvented cylinder with off-peak and boost immersions. Mixer shower from HWC.	6 ground mounted PV panels only	£10,010
ASHP	Mitsubishi Air Source 5kW Heat Pump (ASHP. Existing Dimplex 210ltr unvented cylinder with off-peak and boost immersions. Bath only in property.	ASHP only (20L buffer tank)[3]	£13,806

[1] For full details of the works undertaken see section 4.1.4.
[2] Cost of works only – zero VAT rated (excludes monitoring equipment, compliance testing and consultant fees).
[3] The Association has been installing heat pumps in its new build properties since 2009 and currently has 281 properties with heat pumps installed. This property is the first to have a heat pump installed as a retrofit without any insulation upgrade, in order to measure performance in a 'poorly performing' building. The design is slightly different to the new build properties because it includes a 20ltr buffer tank, fan assisted radiators and has been designed with a flow temperature greater than 45°C. The system has been designed and installed by a Microgeneration Certification Scheme (MCS) approved contractor with the necessary insurance backed warranty and certification.

1.2. Summary of key findings

- **All properties showed a reduction in energy demand** (and associated carbon emissions). This included a reduction in off-peak energy used primarily for heating and hot water. Despite this reduction in demand, and a drop in average external temperatures at two of three properties post-installation, temperatures in all properties were well within expected comfortable levels following the installation of measures. **Less energy was required to maintain tenant comfort.**

- All fabric first properties achieved a greater than 25% reduction in energy demand as per the main objectives of the pilot. Actual **energy demand reductions for fabric first properties ranged from 28 - 40% (average energy demand reduction was 33%)**.

- Indoor **air quality** (humidity and CO_2 levels) **improved in the fabric first properties** despite improved air tightness. This is due to the MVHR systems which were installed alongside the fabric upgrades.

- The **ASHP property** also **saw a significant energy demand reduction** (35% - above the average of the fabric first properties) and coupled with fabric measures could have a much greater impact. However, the additional cost of the heat pump plus ongoing maintenance and depreciation penalty for replacement of existing storage heaters make it unfeasible for a wider retrofit programme for the Association.

- The **PV panels generated an average of approximately 7kW per day across the year for the PV property (a total of approximately 15% of energy demand)**. However, only 2-3kW were generated during the winter when electricity demand for heating was higher. This accounted was easily consumed within the property without need for storage. The additional cost and maintenance of a battery to adjoin the system, makes them non-viable for wider roll-out in Association properties.

- **The measures installed have helped to reduce the role of energy bills as a driver of fuel poverty**. The greatest financial savings were from the Property 1 and the ASHP Property. However, global energy unit price increases will have impacted on the savings that householders would have hoped to see.

- Significant **investment in tenant support and engagement was required to facilitate this pilot**. Tenants who were in-situ during the works did suffer some disruption, but this was minimised by working on properties during period of tenant absence (e.g. holidays).

- Despite the clear energy efficiency improvements in most properties, none of the retrofit works enabled the properties to meet EPC Band B (as per EESSH2). However, it is anticipated that, **with the exception of the PV property, all properties would meet the requirements of the new SHNZS**.

2. Aims and objectives

The overall aim of the pilot project was to improve the Association's stock to meet the EESSH2 standard (EPC Band B by 2032). However, the Association aims to go beyond the statutory targets and provide truly low carbon, warm, comfortable homes for their tenants.

This section of the report outlines the findings of the pilot evaluation under the key objectives of:

- reduce energy demand (by a quarter for fabric first properties)[4]
- lower carbon emissions (lifetime savings)
- reduce air infiltration
- show impact on air quality / temperature / relative humidity
- improve EPC banding
- understand experience / householder satisfaction with installation process
- reduce fuel poverty

2.1. Reduction in energy demand

Typical electricity usage

All properties saw a reduction in electricity consumption from the grid following the retrofit works (see Figure 1). The greatest energy reduction was Property 1 (40% reduction) which had fabric measures installed. All fabric first properties saw a decrease greater than the 25% energy demand reduction target.

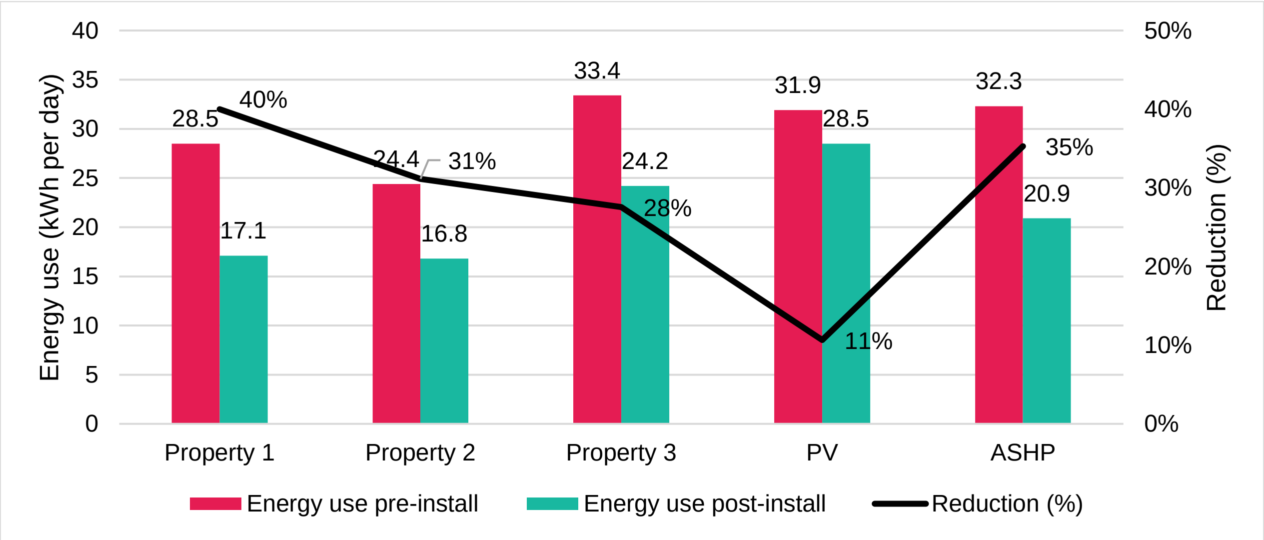

Figure 1: Grid energy use pre- and post-install across all properties, plus percentage reduction[5]

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[4] Target energy reduction to bring retrofit properties in line with new build properties with enhanced insulation.
[5] The PV property has an old style 'disc' meter which turned backwards when power (from the solar panels) was being exported to the grid. The usage is therefore difficult to determine accurately using this as a measure. The usage figures

Table 3 shows the change in energy use during peak and off-peak periods. Heating, hot water and 24hr circuits are charged at off-peak rates (see Table 4 for more information on the metering set-up). All properties saw a reduction in off-peak energy use: from 34% in the Property 3 to 55% in Property 1; all above the 25% target in demand reduction. Heating and hot water are the predominant end-uses for off-peak energy, so the measures have reduced energy use for these purposes. The ASHP property had an Air Source Heat Pump (ASHP) installed to replace High Heat Retention (HHR) storage heaters, and this also used off-peak rate energy. The potential energy savings when combining an ASHP with fabric measures are likely to be much greater than that achieved by fabric measures, or an ASHP alone. However, the additional installation, maintenance and replacement costs do not present the best long-term solution for the Association and make this option financially unviable. There is also a depreciation penalty associated with removing systems before the end of their expected life (see section 3.1).

Table 3: Energy use in different properties during peak and off-peak times, pre- and post-install, sorted by largest off-peak saving

	Peak[6] time energy use (kWh per day)			Off-Peak[7] time energy use (kWh per day)		
Property	Pre-install	Post-install	Saving (%)	Pre-install	Post-install	Saving (%)
Property 1	4.9	6.5	-33%*	23.6[8]	10.6	55%
Property 2	5.3	3.8	29%	19.1[9]	13.0	47%
ASHP	10.1	8.7	15%	22.2	12.3	45%
Property 3[10]	5.2	5.5	-5%*	28.2	18.7	34%
PV[11]	9.4	-	-	22.4	-	-

stated here are calculated using pre-installation consumption, minus the use of energy from the PV panels, see section 2.1.1.
The energy supplier (Ovo) was unable to supply a compatible meter during the trial and the property remained on a THTC tariff with the domestic meter turning backwards when a surplus of energy was produced..
The ASHP property pre-installation energy figures are based on meter readings taken during previous tenancies.
[6] 'Domestic'
There were various tenancy changes in Property 1 prior to the current tenancy beginning, therefore pre-installation energy use is based on a similar occupancy level (but different occupants).
[7] Heating, hot water and 24hr
[8] Includes 2.46kWh per day on the 24hr supply (boost immersion, panel heaters, towel rail and shower).
[9] Heating uses an average of 6kWh/day, hot water 4.49kWh/day and 24hr (boost immersion, panel heater, towel rail and shower 1.98kWh/day.
[10] These figures are based on meter readings, as the OWL monitor had a fault which meant that a break-down of consumption by circuit was not possible.
[11] As the post-installation meter reading cannot be relied on (see 5 above) we cannot assume a reduction in overall consumption. Energy consumption from the grid has reduced (see section 2.1.1), but there is no way of determining the reduction for peak / off peak.
* The negative here indicates an increase

Table 4: THTC meter set-up

Property	Peak Rate Standard	Off-peak Rate radioteleswitch[12]	Off-peak 24hr
Property 1	Lights, sockets, appliances	Storage heaters, hot water immersion	Panel heaters, boost immersion, towel rail, electric shower
Property 2	Lights, sockets, appliances	Storage heaters, hot water immersion	Panel heaters, boost immersion, towel rail, electric shower
Property 3	Lights, sockets, appliances	Storage heaters, hot water (immersion cylinder)	Panel heaters, boost immersion, towel rail
PV[13]	Lights, sockets, appliances	Heating, hot water (cylinder)	Boost immersion, electric towel rail
ASHP	Lights, sockets, appliances	Existing hot water cylinder immersion	ASHP, boost immersion, towel rail

2.1.1. Impact of PV panels

The PV property was the only property which had solar PV panels installed. Six ground mounted solar panels were fitted on a wooden frame within the garden of the property in March 2023. All the panels are South facing and connected to the power supply through the Eddi diverter. This diverter prioritises usage in the property before charging the hot water, before exporting to the grid. **No battery was provided for this trial.**

*Table 5: Energy use from the grid figures pre- and post-install the PV property **- PV***

	Pre-installation	Post-installation
Total Energy Use	31.86 kWh per day	28.46 kWh per day[14]
CO_2e per day	21.35 kg	19.07 kg
CO_2e per year	7,793 kg	6,960 kg

The solar PV array has generated 1,709 kWh over the 242 days it has been installed, which is an average of approximately 7 kWh per day. The amount exported back to the grid is 883 kWh over the same period, which equates to 4 kWh per day. The property has therefore benefited directly from receiving 825 kWh from the solar PV over the last 242 days, which is an average of 3.4 kWh

[12] The radioteleswitch gives between 5 and 12 hours of charge each night
[13] Solar PV is connected to the hot water cylinder and will provide a charge if there is no demand elsewhere in the property
[14] The post-installation figure is calculated using pre-installation consumption, minus the average daily energy use from the PV panels of 3.4 kWh.

per day.[15] This shows the PV could generate approximately 15% of the energy use for the PV property, if excess generation could be stored in a battery for use later.

However, in practice only up to around 11% of the generated electricity could be feasibly used in the property, without battery storage. Average 'peak' domestic power usage in the PV property was around 9 kWh per day and during the summer months the storage heating is generally switched off. The average hot water demand is 5 kWh per day and so through the summer months the total energy use would be in the region of 14-15 kWh per day. Average generation through the summer was 10 kWh per day (highest level of PV generation was 12 kWh in June), therefore this array could in theory provide nearly all the required energy use for a limited number of months, if battery storage was utilised. However, when the energy need is greatest (i.e. in the winter) the PV is only supplying an average of 2-3 kWh per day which can easily be consumed within the property without the need for battery storage. The additional outlay and ongoing maintenance costs for battery storage are therefore hard to justify.

2.2. Lowered carbon emissions

Based on electricity reductions (outlined in section 2.1), the associated carbon emission reductions have been calculated using the carbon intensity of the Shetland Grid[16] and are shown in Table 6 and Table 7. The Shetland Grid has a significantly higher carbon intensity than standard UK grid electricity (0.670 kgCO_2e/kWh compared to 0.207 kgCO_2e/kWh[17]) so the carbon savings are around three times higher than would be seen on mainland UK.

However, a project to connect Shetland's electricity grid to the UK mainland electricity grid is expected to be completed in 2024. At this point, the carbon intensity of the Shetland grid will likely decrease; however, it is possible that the UK grid intensity will also change. The impact of this new connection is not yet known.

*Table 6: CO_2 emissions associated with energy use **per year** pre- and post-install, sorted by greatest saving*

Property	Pre-installation CO_2e (tonnes)	Post-installation CO_2e (tonnes)	Savings CO_2e (tonnes, %)
Property 1	7.0	4.2	2.8, 40%
ASHP	7.9	5.1	2.8, 35%
Property 2	6.0	4.1	1.9, 32%
Property 3	8.2	5.9	2.3, 28%
PV	7.8	7.0	0.8, 10%

[15] The MCS certificate estimates an annual generation of 1732kWh which is approximately 5kWh per day; this correlates with the monitored data, given that the monitoring period doesn't include December - March.
[16] Using Shetland Grid carbon intensity: 0.670 kgCO_2e/kWh (2023 figures, 0.618 (supply) + 0.052 (T&D loss).
[17] UK Department for Energy Security and Net Zero (2023) Available at: Greenhouse gas reporting: conversion factors 2023 - GOV.UK (www.gov.uk)

*Table 7: CO_2 emissions associated with energy use **lifetime savings**[18], sorted by largest saving*

Property	Lifespan of system	Savings (tonnes CO_2e)
Property 1	30 years	84
ASHP	30 years	84
Property 3	30 years	69
Property 2	30 years	57
PV	25 years	45

2.3. Reduced air infiltration

Air Tightness testing

Air Tightness testing was conducted on Property 1, Property 2, and Property 3[19] prior to fabric measures. This allowed for a comparison post-installation and also informed the ventilation strategy. Further details on how the testing was conducted can be found in section 4.1.3. Air permeability results can be found in Table 8 and the air change rates can be found in Table 9 below.

A reduction in air permeability and air change rates was found in all three properties due to the fabric improvements. This will have a positive impact on heat retention and tenant comfort. Lower air permeability will improve the energy performance of a building, however, air infiltration rates of less than $5m^3/hr/m^2$ @ 50 Pascals can cause problems with internal air quality and condensation unless addressed through "an appropriate ventilation strategy which will commonly involve continuous mechanical extract ventilation"[20] planned ventilation. All three properties here are now below this threshold but were fitted with MVHR systems. The maximum air permeability figure in Scotland Building Regulations is $7m^3/hr/m^2$.

Table 8: Air permeability pre- and post-installation, sorted by greatest reduction

Property	Pre-install air permeability (m^3)	Post-install air permeability (m^3)	Reduction (%)
Property 2	4.2	3.0	30%
Property 1[21]	3.8	2.8	26%
Property 3	3.7	2.9	21%

[18] These figures are estimated and do not include embodied carbon, carbon emissions associated with the installation process or additional carbon associated with replacement parts etc. during the overall system lifespan. They also do not account for the connection of Shetland to the UK grid.
[19] The PV property is a direct comparison to Property 2; the pre-install air permeability results can be considered to be similar to that in the PV property pre- and post-install
[20] Quote from technical handbook (see Building standards technical handbook February 2023: domestic buildings - gov.scot (www.gov.scot))
[21] Property 1 had underfloor insulation installed prior to the deep retrofit works commencing. The pre-installation air permeability and air changes would be more in line with Property 2 before the underfloor insulation was installed.

Table 9: Air change rate pre- and post-installation, sorted by greatest reduction

Property	Pre-install air change rate (l/hr)	Post-install air change rate (l/hr)	Reduction (%)
Property 2	5.7	4.0	30%
Property 1	5.2	3.8	26%
Property 3	4.8	3.8	21%

2.4. Impact on internal environment

Temperature, relative humidity, and CO_2 levels were monitored in all properties to determine the impact of measures on the internal environment.

Temperature: In terms of comfort levels, the Energy Saving Trust recommends maintaining internal temperatures of between 18 to 21°C. The World Health Organisation (WHO) suggests 18°C is the ideal temperature for healthy and well-dressed people. Both organisations suggest that this is also the ideal temperature for sleeping.

Relative Humidity: Healthy relatively humidity (between 40% and 60%) provides a more pleasant internal environment for occupants. Relative humidity above 60% may allow condensation to occur and above 70% is associated with mould growth.

CO_2: Typically, occupied indoor spaces should maintain a CO_2 concentration of less than 1,000 parts per million (ppm) with suitable ventilation. Regularly exceeding 1,000ppm can affect occupants, especially over long periods of time. Ventilation and regular air changes can improve poor air quality with high concentrations of CO_2. The Association's aim was for their retrofitted properties to be well ventilated, healthy homes.

Tenant feedback (where available) on comfort levels was collected by Changeworks and provided to Hjaltland Housing Association to provide context to the technical data.

Key findings

- Post-installation temperatures in all properties were well within expected comfortable levels. Section 2.1 shows a reduction in energy demand, whilst achieving these temperatures.
- No pre-installation data was collected on the non-fabric upgrade properties (The PV property and the ASHP property). The pre-installation temperatures in Property 1 were slightly lower than the others as this property was void. Without pre-installation data on all properties, it is difficult to make a judgement on the impact of fabric first vs non-fabric upgrade properties.
- Indoor air quality (humidity and CO_2 levels) improved in Property 1, Property 2, and Property 3, despite the fabric improvements and improved air tightness (see 2.3). This is due to the MVHR systems which were installed alongside the fabric upgrades.
- Some tenants initially reported concerns about the operation of MVHR systems, but all were found to be working efficiently and humidity and CO_2 levels were well within healthy limits. Tenants were supported with the operation of the systems where required.
- The two properties which did not receive fabric improvements (or ventilation upgrades) saw greater CO_2 levels than the other properties, though this could be attributed to other behavioural factors.

Property 1

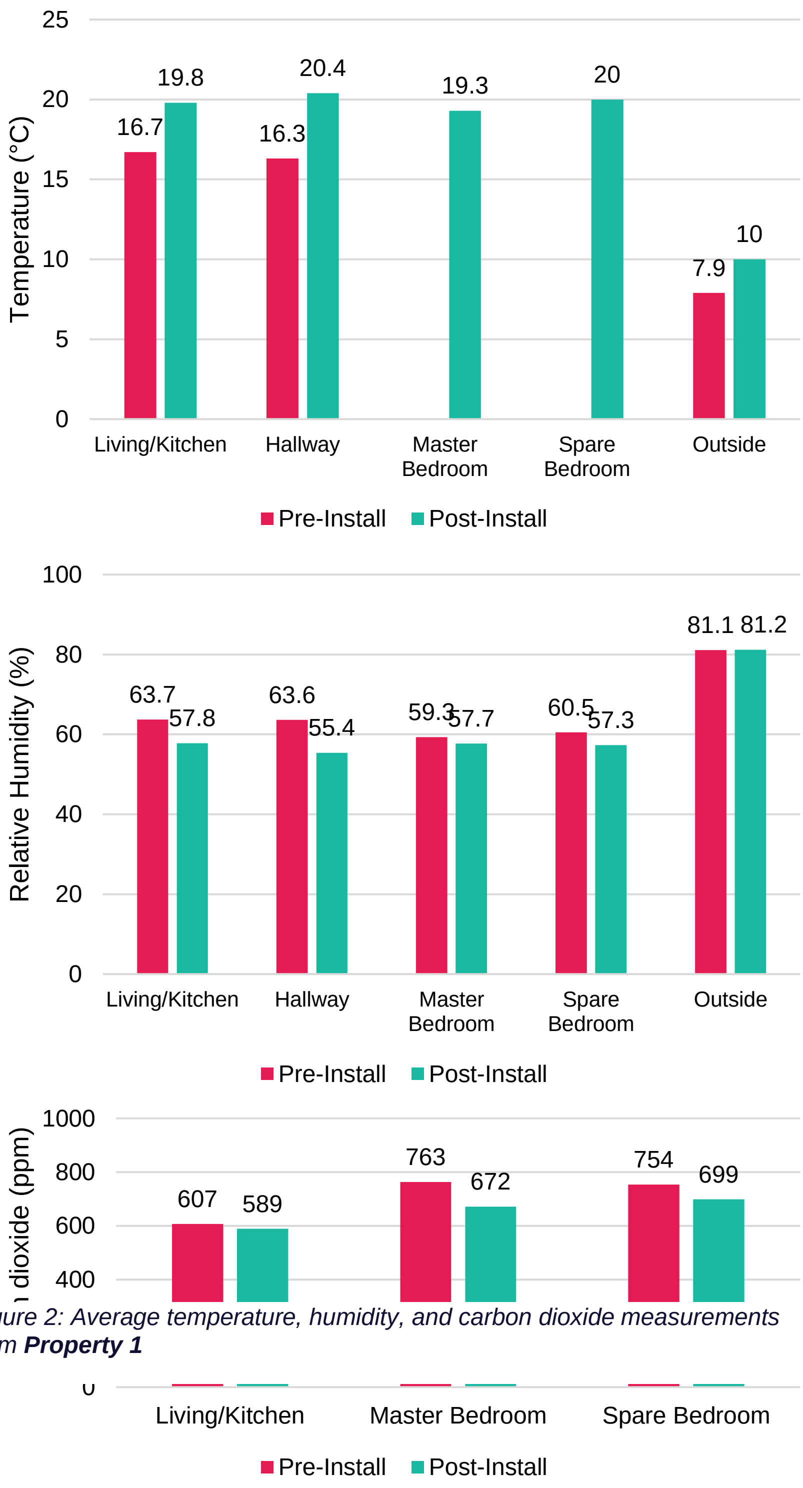


*Figure 2: Average temperature, humidity, and carbon dioxide measurements from **Property 1***

The average **temperatures** within each of the rooms increased to around the 20°C range following the upgrade, see Figure 2[22].

Average **humidity** levels within the property reduced by around 8% across all rooms despite the property being more airtight following a reduction in the passive air changes. This is due to the installation of the MVHR system which is providing the necessary air changes. All average readings following the retrofit are well below the 60% level where condensation might occur and significantly below the 70% level associated with mould growth.

CO_2 levels have seen a reduction in the region of 8% across the three rooms and are well below the 1,000 ppm thresholds. This reduction has been achieved despite the fact the property is more airtight and is a result of the MVHR system introducing fresh air into the property.

[22] Sensors were in place for 119 days pre-install. After-install the sensors remained in place for 491 days. Temperature and humidity were recorded in all habitable rooms, while CO_2 was measured in the open plan living room / kitchen and the bedrooms. During the pre-installation period, the property was void, and readings were not taken in the bedrooms.

Property 2

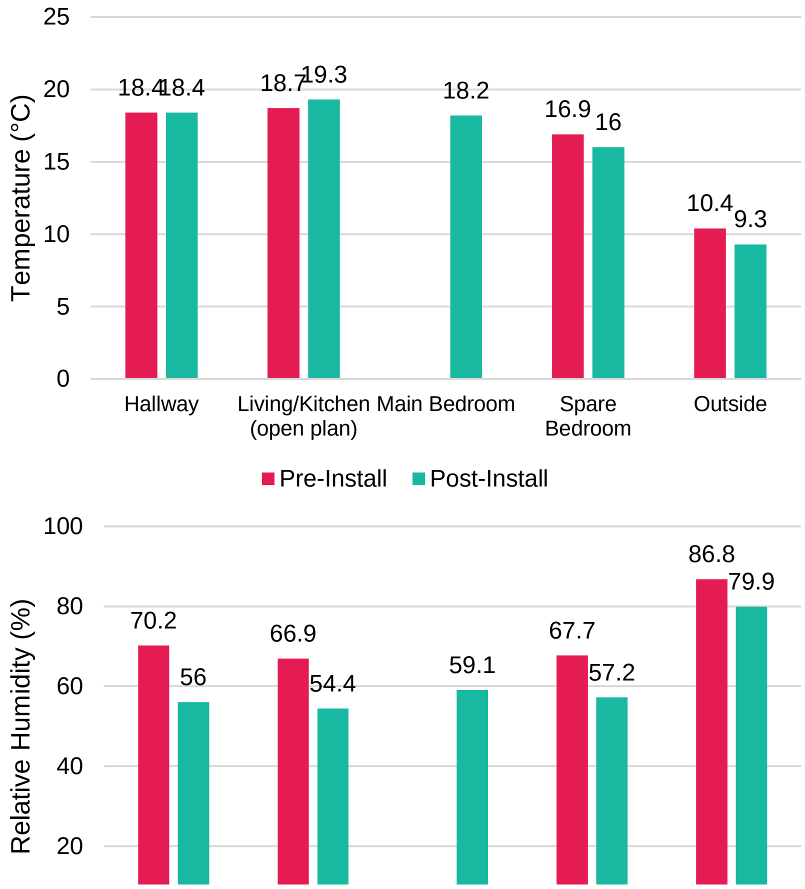
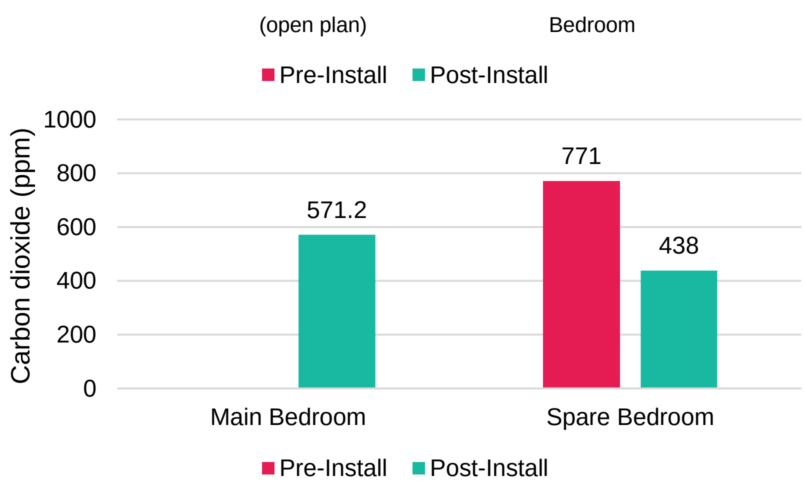


*Figure 3: Average temperature, humidity, and carbon dioxide measurements from **Property 2***



As shown in Figure 3, the average **temperatures** within each of the rooms remained around the 18°C range throughout the 395 days following the upgrade[23].

The bathroom towel rail is always left on (only occasionally switched off in the summer).

An average reduction in **humidity** levels of 18% across all monitored rooms was noted despite the fact the property is more airtight following a reduction in the passive air changes. This is due to the installation of the MVHR system which is providing the necessary air changes. All averages following the retrofit are below the 60% level where condensation might occur and significantly below the 70% level associated with mould growth. A potential damp and mould risk was flagged by the AICO monitor in the unheated spare room, however the MVHR was found to be running correctly and no condensation was reported in the property.

[23] Sensors were in place for 63 days pre-install from May to Jul of 2022. After-install the sensors remained in place for 395 days from Oct 22 through to Oct 23.
An AICO Ei1020 monitor was fitted in the living room which only monitors temperature and humidity. It has been recommended to fit the alternative AICO Ei1025 sensor in all living rooms in future as these also monitor carbon dioxide.
The sensor in the main bedroom was faulty for a period of time prior to the works being completed and therefore no records were available for this room.

CO_2 levels have seen a reduction of 43% in the spare bedroom with both bedrooms well below the 1,000 ppm thresholds. This reduction has been achieved despite the fact the property is more airtight and is a result of the MVHR system introducing fresh air into the property.

The AICO sensors had highlighted dust mite allergens during humid conditions. The MVHR was checked and additional support was provided on when and how to use the 'boost' function..

Draughts were also picked up by the AICO monitors but this was found to be directly due to occupant behaviour.

Property 3

The average **temperatures**[24] within each of the rooms remained around 20°C throughout the heating season (October - April), as shown in Figure 4. It should be noted the average temperature prior to the upgrade was measured during the summer months, with a 4°C higher outside temperature, which may explain the drop in average temperatures from pre-installation to post-installation; however, the post-install temperatures are still within a comfortable range.

[24] Sensors were in place for 58 days pre-install from June to August of 2022. Post-install, the sensors remained in place for 321 days from December 2022 through to October 2023. CO_2 was only measured in the living room, main bedroom, and gym (bedroom 2).

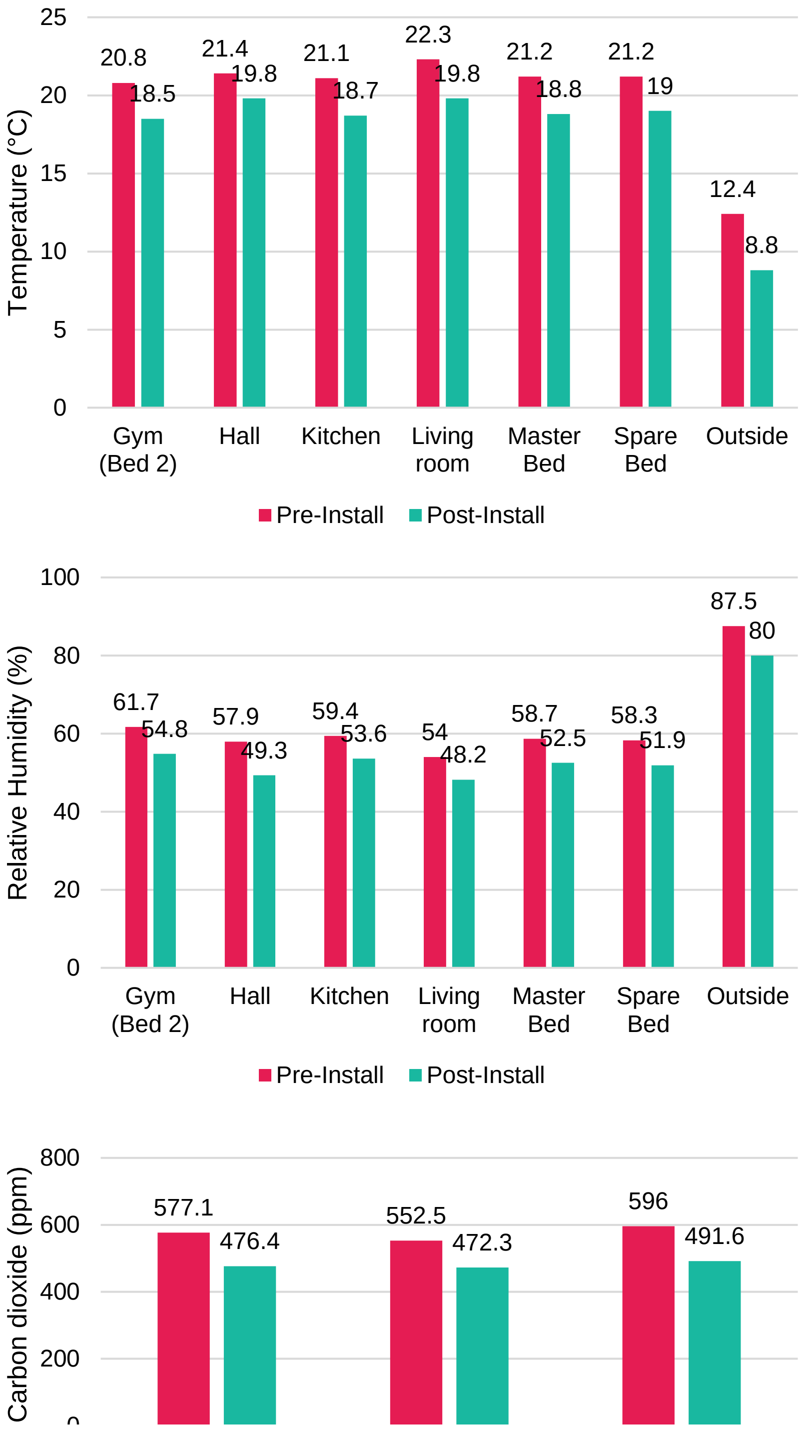


Figure 4: Average temperature, humidity, and CO_2 measurements from ***Property 3****, pre- and post-install*

An average reduction in **relative humidity** of around 11% across all rooms was noted despite the fact the property is more airtight following a reduction in the passive air changes. This is due to the installation of the MVHR system which is providing the necessary air changes. All averages following the retrofit are well below the 60% level where condensation might occur and significantly below the 70% level associated with mould growth.

CO_2 levels have seen a reduction in the region of 17% across the three measured rooms and are well below the 1000 parts per million (ppm) thresholds. This reduction has been achieved despite the fact the property is more airtight and is a result of the MVHR system introducing fresh air into the property.

PV Property

There was no data collected prior to the installation of the solar panels, however, there were no fabric or heating measures installed in this property (PV panels only). Therefore, there is no anticipated change to the internal environment as a result of the retrofit works. Post-installation internal conditions are shown in Table 10.

Table 10: Average temperature, humidity, CO_2 after PV installation at the ***PV*** *property*[25]

	Temperature (°C)	Humidity (%)	CO_2 (ppm)
Livingroom	21.9	54%	1482
Bedroom 1	18.3	63%	1169
Bedroom 2 [26]	18.0	62%	856

The above average **temperatures** are in line with the expected comfort levels for the main living space and bedrooms.

Ventilation is delivered through localised extract fans in the kitchen and bathroom along with trickle vents on all windows. The living room has an annual average **humidity** of 55% which is well within the 60% threshold. Both bedrooms have an annual average of more than 60%, with the spare bedroom breaching 70% through November. The fact the spare bedroom is not heated to the same level as the rest of the house will have an impact on the humidity.

High levels of $\mathbf{CO_2}$ are noted with all rooms exceeding the 1,000ppm recommended level for periods of time. This was most likely due to the reported use of a supplementary gas heater. Advice was provided to modify these behaviours.

[25] Based on monitoring across an 8-month period (Apr-Nov)
[26] Room is rarely used.

ASHP property

*Table 11: Breakdown of average temperature, humidity, and CO_2 levels after installation at the **ASHP** property*[27]

	Temperature (°C)	Humidity (%)	Carbon Dioxide (ppm)
Hall	19.8	51.5	N/A
Main Bed	19.2	56.6	754
Bed 2	18.5	68.4	1725
Kitchen	18.8	59.6	N/A
External	9.2	80.1	N/A

Average **temperatures** within each of the rooms (post-installation) were between the 18 - 20°C range following the installation (see Table 11). Despite the variation in external temperature between 0 and 15°C, the internal temperatures were typically maintained in line with expected comfort levels (see section 4.4).

There are no records of **humidity** levels in this property prior to the installation of the heat pump other than assumed high levels due to mould growth in the bedroom cupboards that was treated at the end of the previous tenancy. It should be noted the ventilation is delivered through localised extract fans in the kitchen and bathroom along with trickle vents on all windows. The living room and bedrooms spent an average of 205 days (71%) of the trial period with humidity levels above 60%, while the second bedroom recorded over 70% relative humidity for more than half of the data collection period. The bedrooms and kitchen had peak relative humidity readings of over 80% (see section 4.4 for further details).

High **CO_2** levels were noted in both bedrooms at the ASHP property, especially bedroom 2. This was attributed to occupancy factors.

[27] Averages for all rooms are over 332 days, excluding Bed 2 which is over 235 days. CO_2 levels were only recorded in the bedrooms. There is no pre-installation data for this property.

2.5. Change in EPC banding

Pre- and post-installation EPCs were conducted on all five properties to determine the impact of measures on Energy Efficiency (EE) ratings and EPC Bands. As shown in Table 12, all but one property saw an increase in EE rating, though all increases were small. The two properties who received heating or renewable measures saw the largest increases and both moved from Band D to Band C.

Both the pre- and post-installation EPCs for Property 1 were conducted by the same assessor. Assumptions on both EPCs appear correct so it is unclear why the EE rating and EPC Band reduced.

All three fabric first properties had MVHR installed to ensure necessary air quality was provided. It is acknowledged that the current RdSAP software used to produce EPCs cannot model the impact of MVHR accurately and this is the main reason these properties have remained in Band D. Modelled performance without MVHR showed all three properties achieving an EPC Band C (75). Based on these upgrades, none of the properties would meet the Band B requirements of EESSH2[28].

Table 12: Energy Efficiency Rating and EPC Bands (pre- and post-install), sorted by greatest increase

Property	Energy Efficiency Rating			EPC Band	
	Pre-installation	Post-installation	Increase	Pre-installation	Post-installation
ASHP	65	71	6	D	C
PV[29]	66	80	4	D	C
Property 3	65	66	1	D	D
Property 2	65	66	1	D	D
Property 1	71[30]	68	-3	C	D

Scottish Government has recently consulted on a new ‘Social Housing Net Zero Standard’ (SHNZS)[31] to replace EESSH2, which proposes to move away from using EPC bands to measure performance. The proposal is to have a ‘Fabric Efficiency Rating’ measure and confirmation of net zero ‘Clean Heating’ systems. All five properties in this project have net zero clean heating systems installed, however, some tenants also use gas heaters and while the consultation doesn’t

[28] Energy Efficiency Standard for Social Housing – see Energy efficiency in social housing - Home energy and fuel poverty - gov.scot (www.gov.scot)
[29] Based on draft EPCs
[30] An earlier EPC (conducted in 2015) showed Band D (66). This property received underfloor insulation prior to this trial, which accounts for the higher score and Band C EPC.
[31] Social housing net zero standard: consultation - gov.scot (www.gov.scot)

specify details about secondary means of heating, it is very clear in its goal to remove or replace polluting heating systems. Improved fabric efficiency should reduce the need for supplementary heating, therefore the new 'Fabric Efficiency' standard is key. It proposes the following targets (based on modelled data):

A. Proposed range for maximum space heating and hot water demand of 112 - 162 kWh/m2/yr[32], or

B. Proposed range for maximum space heating demand only of 71 - 120 kWh/m2/yr.

Table 13 shows the (modelled and actual) space heating demand of the five properties and shows that post-installation, all but the PV property meet the proposed upper range, but all fail the lower limit when modelled. Only Property 1, Property 2 and the ASHP property would meet the lower limit with actual figures. The PV property does not meet limits proposed and additionally may not meet the proposed ventilation strategy without further alterations.

Table 13: Space heating and hot water demand and compliance with proposed SHNZS, sorted by lowest post-installation modelled demand

Property	Pre-installation space heating demand (kWh/m²/yr)		Post-installation space heating demand (kWh/m²/yr)		Post-install meets SHNZS?
	Modelled[33]	Actual[34]	Modelled[35]	Actual[36]	
Property 1	103	118	90	53	Yes
Property 3	122	116	92	76	Yes
Property 2	128	95	104	65	Yes
ASHP	129	111	116[37]	103[38]	Yes
PV	127	112	127	112[39]	No

[32] i.e. while this is the proposed range, it is not proposed that the demand falls within this given range; an upper limit from within this range will be determined following the consultation.
[33] Figures here are from EPCs.
[34] Actual figures include heating and hot water from off-peak meter readings.
[35] Modelled results as for pre-installation; these figures do not include MVHR.
[36] Actual figures include heating and hot water, based on off-peak consumption, from meter readings, except for PV property.
[37] The modelled post-install figure is lower than the pre-installation despite no fabric measures being installed. This is due to assumed losses in the SAP software.
[38] The actual post-installation space heating demand for the ASHP property is calculated based on an assumed 8.25kWh of electricity demand for heating (total off-peak energy use minus 4kWh for hot water (see Les Shurrock, 2008 STP09-DHW01 Analysis of the EST DHW data.doc (bregroup.com)) and a Coefficient of Performance of 2.5 (an agreed figure for ASHPs in Scotland).
[39] This actual figure is based on the pre-installation off-peak consumption which is assumed to have changed very little as a result of PV installation.

2.5.1. Modelled vs Actual

Table 13 also highlights the comparison between modelled data (from RdSAP) and the actual delivered energy. In all the post-installation cases, the modelled figure is greater than the actual; for the fabric first properties, the post-installation difference is particularly great. Conversely, or the pre-installation figures, only the actual demand for Property 1 is greater than the modelled figure.

It also shows the impact of the householders, as Property 2, the ASHP and PV properties all have similar pre-installation modelled figures but different actuals.

The post-installation actual figures include the MVHR which is excluded from the modelled figures; therefore, the modelled post-installation results for Property 1, Property 2 and Property 3 are an even grosser over-estimate than initially appears.

2.6. Impact on fuel poverty

All tenants saw a reduction in energy consumption. The associated energy savings (based on costs as of December 2023[40]) are shown in Figure 5. The greatest financial savings were from the ASHP property and Property 1. However, the savings outlined here are not the actual savings that tenants will have felt in ‘real’ terms; rather they indicate the difference the measures have had on the bills tenants would have had to pay otherwise. The retrofit works were done during a period of increasing energy prices and subsequently fuel poverty. Global energy unit price increases will have impacted on the savings that householders would have hoped to see. The measures installed have helped to reduce the role of energy bills as a driver of fuel poverty.

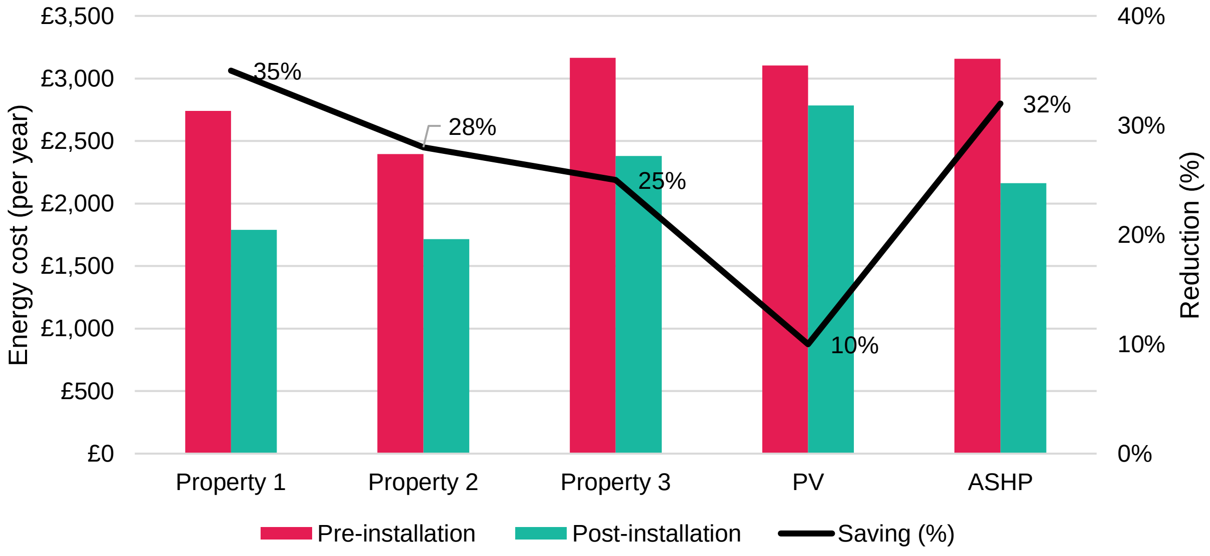


Figure 5: Impact of measures on energy bills (including standing charge), sorted by greatest saving[41]

[40] OVO THTC tariff rates: Anytime energy use – 28.37p (peak); Heating energy use – 23.53p (heating); Standing charge 56.26p per day

[41] The PV savings are based on the pre-installation energy bills and on an assumption that around 11% of the energy use in the property was met by the PV generation.

Changeworks has provided the Association with individual tenant feedback regarding bills and fuel poverty.

2.7. Tenant experience

The tenants in three properties were in-situ before, during and after the retrofit works. The tenants in the ASHP property and Property 1 moved in after the works were completed and therefore could not provide feedback on the installation process, nor provide a comparison to how they experienced the property pre-install. However, where applicable, tenants were asked to provide feedback on their experience during the installation, and the impact the measures have had on them and their homes. This has been recorded and reported to the Association but is excluded from this public report to protect tenants' privacy.

The tenants were heavily supported by the Association during the works. This included home consultation visits to fully explain the scope and scale of the retrofit, plus engagement throughout the delivery phase and during the post-installation period. As this was a pilot project, the staff resource required to support tenants was extensive. A full outline of the tenant engagement process can be found in section 4.5.

2.7.1. Fabric Improvements

[SECTION REDACTED]

2.7.2. PV installations

[SECTION REDACTED]

2.8. Lessons learned

Monitoring equipment

- Two different sensor systems were used; one was found to be better quality than the other; the energy monitor clamps from one supplier were found to fall off the cables more often.

- Monitoring equipment need to be checked regularly to check they are operational; data from some monitors needs to be downloaded at least every three months.

Tenant Liaison

- Pre-installation, tenants should receive full details of the proposed works, including a copy in writing / with photographs.

- Disruption for tenants was reduced by scheduling works whilst they were not at home. Bathroom refits were easier in properties with a second toilet.

- When tenants remain in-situ during works, belongings and furniture should be well protected and storage provided to reduce the number of items that need to be regularly moved around the property. Contractors will also need to allow time to tidy site at the end of each day.

- Post-installation tenants need a full explanation of works and a full handover process, especially if they are new to the property. This should include technical and practical instruction on new systems, e.g. MVHR.

- Tenants may require support with replacing furniture / fixings post-installation.

Retrofit Process

- Sequencing and scheduling of works and co-ordination of contractors needs to be accurate to ensure high priority items are delivered and completed on time and to prevent duplication of works. Some elements (e.g. external doors) have long lead in times and should be ordered well in advance.

- More sealant around penetrations, or specialist sealant products are required to improve air tightness. Additionally, air flow is required between rooms and doors may need planed to facilitate.

- Some materials could not / should not have been re-used as a quality finish could not be achieved.

Electricity Meters

- Total Heat Total Control (THTC) dial meters are not compatible with PV installations. The inaccurate readings made it difficult to determine the impact and caused concern for tenants. This has been flagged with the utility company however, there seems to be a lack of both suitable meters and qualified local installers. The Association has advised that there are currently no meter installers in Shetland, and it is very difficult for residents to have their meter changed when required. This issue has been raised with the local MSP and MP.

3. Further analysis

3.1. Cost benefit analysis

Table 14 shows the breakdown of costs associated with the retrofit works, including monitoring equipment, compliance testing, and consultant fees.

Table 14: Breakdown of associated costs (£)

	Costs				
Property	Works (Zero Vat)	Monitoring Equipment (Inc Vat)	Compliance testing (Inc Vat)	Consultant fees (Inc Vat)	Total
Property 1	£33,199	£1,026	£660	£4,073	£38,957
Property 2	£35,518	£984	£484	£4,385	£41,371
Property 3	£38,489	£1,169	£484	£4,385	£44,527
PV	£10,010	£1,310	N/A	£1,894.80	£13,325
ASHP	£13,806	£967	N/A	£594	£15,367

Life cycle costs (see Table 15) have been calculated to establish the total cost to the Association, including maintenance costs. Costs are not adjusted for inflation. Maintenance and other running costs are important to consider, alongside initial capital costs as the Association aims to avoid rent increases as a result of retrofit works.

Property 1, Property 2, and Property 3 which received fabric improvements also required a suitable ventilation system to ensure good air quality. The life cycle costs are based on the maintenance of this system. The impact of the energy improvement works on the Associations Asset Management strategy has been assessed and it is accepted that upgrading to external wall and floor insulation and focusing on the detailing required to remove thermal bridges and increase airtightness is an investment in the structure of the property with no ongoing maintenance costs.

Table 15: Lifecycle costs of energy improvement works

Property	Model	Notional Lifespan Unit	Unit Replace Cost	Notional Lifespan Components	Comp. Replace Costs	Servicing Cost per year	Maint. per year	Total Lifecycle cost over 30 years[42]	Additional cost per year[43]
Property 1[44]	Nuaire MRXBOX	15 yrs	£1,676	30 yrs (Ducting)	£2,453 (Ducts)	£38	£30	£7,845	£260
Property 2[45]	Nuaire MRXBOX	15 yrs	£1,676	30 yrs (Ducting)	£2,453 (Ducts)	£38	£30	£7,845	£260
Property 3[46]	Nuaire MRXBOX	15 yrs	£1,676	30 yrs (Ducting)	£2,453 (Ducts)	£38	£30	£7,845	£260
PV[47]	Solar panel[48]	25 yrs	£9,170	12 yrs	£1,680[49]	£10	£50	£12,350	£495
ASHP[50]	Mitsubishi Ecodan 5kW ASHP	15 yrs	£5,760	20 yrs (radiators)	£1,251 (radiators)	£112	£150	£20,647[51]	£700

Running costs savings versus the additional maintenance costs for each property are shown in Table 16. These show that the fabric measures had a much greater overall saving over the lifetime (30 years, except PV which has a 25-year lifespan) than the ASHP or PV.

The early replacement of the heating system in the ASHP property will also have an impact on the component accounting for this property with an additional £3,250 to 'write off' this year for depreciation (not included in Table 16). This ‘depreciation penalty’ is a significant issue for the

[42] PV lifecycle 25 years instead of 30 years
[43] This is an additional ongoing cost to the Association over a lifecycle (stated) excluding inflation.
[44] Costs as of 24/11/2023.
[45] Costs as of 24/11/2023.
[46] Costs as of 24/11/2023
[47] Costs as of 05/12/2023. As the panels are not building mounted no structural impact costs have been included.
[48] Costs would be higher if battery storage was also provided.
[49] Allows for two replacements over lifespan of system. Components include inverter, diverter, meter, and CT clamps.
[50] Costs as of 05/12/2023. Hot water continued to be supplied by the existing cylinder, therefore only the new heating system is included in the lifecycle costs.
[51] Costs based on a like for like replacement of the ASHP, plus radiator replacement only (not pipework) and an anticipation of servicing costs based on experience of ASHPs in other Association owned properties.

Association as it may impact the retrofit work that can be undertaken in some properties if the depreciation cost has also to be accounted for in lifecycle costing.

Table 16: Running costs savings due to improvements installed, sorted by greatest difference between savings and cost

Property	Additional costs over 30 years	Running cost savings over 30 years	Difference	Difference / year
Property 1	£7,800	£28,525	£20,725	£691
Property 3	£7,800	£23,545	£15,745	£525
Property 2	£7,800	£20,377	£12,577	£419
ASHP	£21,000	£29,857	£8,857	£295
PV[52]	£12,375	£7,967	£4,408	£176

3.2. PAS 2035

The Association appointed a Retrofit Coordinator as part of the retrofit pilot to oversee the whole process. As part of the PAS 2035 elements of the pilot programme, a basic monitoring report was produced by Changeworks, reviewed by the Retrofit Coordinator, and shared with the Association. Changeworks understands that the Retrofit Coordinator has not yet been able to register the project onto the national database through Elmhurst. The automatic system won't recognise the funding route for the works (Energy Redress scheme) and as yet there has been no resolution.

3.3. Monitoring and evaluation framework for future programmes

Following the evaluation of the deep retrofit, some recommendations on the monitoring and evaluation framework can be made:

- Ensure a way of collecting pre- and post-installation energy consumption, without relying on meter readings, especially where PV is being installed that may negatively impact existing meters.
- Collect CO_2 readings from at least the living rooms in all monitored properties (as well as temperature and humidity).
- Ensure all monitoring equipment is suitably robust.

[52] Over 25 years

4. Appendix

4.1. Methodology

4.1.1. Tenant experience

Comprehensive pre-installation, post-installation and follow-up interviews were conducted with tenants (where relevant) to understand their experiences of living in the property. The final interview was timed to allow sufficient time for changes in comfort, costs etc. to be noted and measured. This interview evaluated the overall impacts of the retrofit on the property and the tenant. The pre-install and follow-up interviews looked at the following:

- Experiences of comfort/ discomfort
- Confidence and ability at managing home energy systems
- Satisfaction with the property
- Issues with the property (e.g. draughts, mould etc.)
- Perceptions of affordability and approximate heating fuel expenditure.

The post-installation interview gathered feedback on the installation and handover processes.

4.1.2. Internal environment and electricity consumption

Monitoring equipment was used to gather data on temperature, humidity, carbon dioxide and electricity consumption. Meter readings were also used in some cases to determine or corroborate electricity use. Electricity consumption was then used to determine associated costs (using tenants THTC tariff rates) and carbon emissions (using Shetland Grid carbon factors).

Monitoring Equipment – PV property

Temperature, Humidity, and Carbon Dioxide in the property was monitored using iOPT environmental monitors. The energy use was also monitored using iOPT energy clamps along with assessing peak and off-peak meter readings. The Solar PV installation was monitored using the eddi diverter unit that was connected to the 'myenergi APP' accessed via staff phones.

The property has four main electric suppliers; iOPT clamps were connected to each one to measure usage as per Table 17.

Table 17: iOPT circuits for the PV property - PV

Circuit	Name	Purpose
1	Domestic (Mains)	Supply for 'domestic' usage – sockets, lights etc.
2	Storage	Supply to storage heaters (timed by radioteleswitch)
3	24hr	Supply to panel heaters and boost immersion
4	Hot Water	Supply to hot water immersion (timed by radioteleswitch)
5	PV	Measures solar PV generation[53]

Monitoring Equipment – Property 1, Property 2, Property 3, and ASHP property

An OWL energy monitor was used to monitor energy consumption on the storage heating, hot water, and 24hr peak supplies in these properties. Unfortunately, there was a fault on the monitor clamps, insufficient data was collected on the split between the three supplies at Property 3. AICO environmental monitors (AICO - Ei1025 Temperature & Humidity Sensor and AICO - Ei1025 Temperature, Humidity, and Carbon Dioxide Sensor) were used to collect data on temperature, humidity, and CO_2 levels in all three properties.

4.1.3. Air tightness testing

Table 18: Air Tightness Testing Methods and Contractors (Property 1, Property 2, Property 3 only – all fabric first)

Property	Pre-installation		Post-installation	
	Method	**Contractor**	**Method**	**Contractor**
Property 1	Blower Door	Shetland Heatwise	Blower Door	Shetland Heatwise
Property 2	Blower Door	SSD Group	Blower Door	SSD Group
Property 3	Blower Door	SSD Group	Lowe Pressure Pulse	Hjaltland Trading

4.1.4. SAP scores

Energy Efficiency ratings are taken from pre- and post-installation EPCs to determine the impact of measures on EPC Bands.

[53] This clamp did not work correctly.

4.2. Retrofit works

Property 1

- **Walls –** The work comprised of stripping out the existing 100mm glass wool insulation from all the external walls and sealing the kit sections prior to installing 100mm Xtratherm Safe R SR/FB in between the studs with all joints sealed and taped. There was then a layer of 50mm Xtratherm Safe R SR/FB applied to the inner face of the kit, to remove thermal bridging, which also had all joints sealed and taped to provide a vapour barrier. The Tyvek Dupont Air-Guard membrane was then installed as an air tightness layer before the service void was formed using 25mm timber strapping with plasterboard facing. Warmup thin insulation boards were used to form new ingoes around windows.
- **Floor** – The floor in this property had previously been upgraded with 75mm Xtratherm rigid insulation fitted and sealed between the joists during a tenancy change. The floor was therefore not included in the retrofit upgrade.
- **Door –** A new door was installed between the hallway and the porch as part of the upgrade to the external envelope. The door had a U value of 1.3W/m^{2}k with Argon gas filled triple glazing and insulated panel.
- **Ventilation –** The property was served by localised bathroom and kitchen through wall extractor fans which were removed prior to installing a Nuaire MRXBOXAB-ECO2B Mechanical Ventilation with Heat Recovery (MVHR) unit. The system extracts damp moist air from the kitchen and bathrooms and uses the heat to warm the fresh incoming air supplied to the bedrooms and living room.
- **General –** The kitchen units and bathroom suite had to be removed, set aside, and replaced following the upgrade. The kitchen units had to altered due to the layout of the kitchen and the loss of 75mm on external walls with the new insulation build up. Electrical outlets on external walls had to be repositioned. All internal partitions abutting an external wall had to be cut back to allow the new insulation to pass through to ensure continuity of new wall build up.

*Table 19: Thermal transmittance through surfaces in **Property 1** (post-install)*

Surface	U-Value (W/m^{2}k)	Condition
Walls	0.15	100% completed
Floor	0.25	Existing (Upgraded previously)
Door	1.3	Complete
Windows	3.10	Existing (Pre 2003 double glazed units)
Loft	0.14	Existing (300mm glass wool)

Property 2

- **Walls** – The work comprised of stripping out the existing 100mm glass wool insulation from all the external walls and sealing the kit sections prior to installing 100mm Xtratherm Safe R SR/FB in between the studs with all joints sealed and taped. There was then a layer of 50mm Xtratherm Safe R SR/FB applied to the inner face of the kit, to remove thermal bridging, which also had all joints sealed and taped to provide a vapour barrier. The Tyvek Dupont Air-Guard membrane was then installed as an air tightness layer before the service void was formed using 25mm timber strapping with plasterboard facing. Warmup thin insulation boards were used to form new ingoes around windows.
- **Floor** – Where possible the existing 50mm glass wool insulation was removed from under the floorboards and 120mm Xtratherm XT/UF was installed with all joints sealed.
- **Door** – A new door was installed between the hallway and the porch as part of the upgrade to the external envelope. The door had a U value of 1.3W/m^{2}k with Argon gas filled triple glazing and insulated panel.
- **Ventilation** – The property was served by localised bathroom and kitchen through wall extractor fans which were removed prior to installing a Nuaire MRXBOXAB-ECO2B Mechanical Ventilation with Heat Recovery (MVHR) unit. The system extracts damp moist air from the kitchen and bathrooms and uses the heat to warm the fresh incoming air supplied to the bedrooms and living room.
- **General** – The kitchen units and bathroom suite had to be removed, set aside, and replaced following the upgrade. The kitchen units had to altered due to the layout of the kitchen and the loss of 75mm on external walls with the new insulation build up. Electrical outlets on external walls had to be repositioned. All internal partitions abutting an external wall had to be cut back to allow the new insulation to pass through to ensure continuity of new wall build up.

*Table 20:Thermal transmittance through surfaces in **Property 2** (post-install)*

Surface	U-Value (W/m^{2}k)	Condition
Walls	0.15	100% completed
Floor	0.18	52% completed (kitchen and bedrooms only)
Door	1.3	Complete
Windows	3.10[54]	Existing (Pre 2003 double glazed units)
Loft	0.14	Existing (300mm glass wool)

[54] This is an assumed U-value using RdSAP.

Property 3

- **Walls** – Existing 100mm glass wool insulation was stripped from all the external walls and kit sections sealed prior to installing 100mm Xtratherm Safe R SR/FB in between the studs with all joints sealed and taped. There was then a layer of 50mm Xtratherm Safe R SR/FB applied to the inner face of the kit, to remove thermal bridging, which also had all joints sealed and taped to provide a vapour barrier. The Tyvek Dupont Air-Guard membrane was then installed as an air tightness layer before the service void was formed using 25mm timber strapping with plasterboard facing. Warmup thin insulation boards were used to form new ingoes around windows.
- **Floor** – Where possible the existing 50mm glass wool insulation was removed from under the floorboards and 120mm Xtratherm XT/UF was installed with all joints sealed. An assumed 45% of the floor insulation was removed and replaced (40.17m^2 total across living room, bedroom 2 and bedroom 3).
- **Door** – A new door was installed between the hallway and the porch as part of the upgrade to the external envelope. The door had a U value of 1.3W/m^{2}k with Argon gas filled triple glazing and insulated panel.
- **Ventilation** – The property was served by localised bathroom and kitchen through wall extractor fans which were removed prior to installing a Nuaire MRXBOXAB-ECO2B Mechanical Ventilation with Heat Recovery (MVHR) unit. The system extracts damp moist air from the kitchen and bathrooms and uses the heat to warm the fresh incoming air supplied to the bedrooms and living room.
- **General** – The kitchen units and bathroom suite had to be removed, set aside, and replaced following the upgrade. The kitchen units had to altered due to the layout of the kitchen and the loss of 75mm on external walls with the new insulation build up. Electrical outlets on external walls had to be repositioned. All internal partitions abutting an external wall had to be cut back to allow the new insulation to pass through to ensure continuity of new wall build up.

*Table 21: Thermal transmittance through surfaces in **Property 3** (post-install)*

Surface	U-Value (W/m^{2}k)	Condition
Walls	0.15	100% completed
Floor	0.18	45% completed (Bedrooms and Living room only)
Door	1.3	Complete
Windows	3.1	Existing (Pre-2003 double glazed units)
Loft	0.14	Existing (300mm glass wool)

PV Property

The work involved the installation of a string of six ground mounted Solar Panels on a wooden frame within the garden of the property. The panels are all South facing and are connected to the power supply in the property via the Eddi diverter. The diverter prioritises usage in the property before charging the hot water before exporting to the grid. There is no battery provided for this trial.

Table 22: Thermal transmittance through surfaces in the PV property ***- PV*** *(existing)*

Surface	U-Value (W/m^{2}k)	Condition
Walls	0.39	Existing
Floor	0.37	Existing
Door	Half glazed	Existing (Double Glazing)
Windows	3.10	Existing (Pre 2003 double glazed units)
Loft	0.14	Existing (300mm glass wool)

ASHP property

The works in this property comprised of the replacement of High Heat Retention Quantum Storage Heaters with an air to water heat pump. A 5kW Mitsubishi Ecodan (R32) was installed for heating only with a mixture of oversized and fan assisted radiators. A 20ltr buffer tank was also installed to promote efficiency levels. The heat distribution system was controlled with Thermostatic Radiator Valve's (TRV's), LCD controller on the fan assisted radiators and a Mitsubishi Flow Temp Controller (FTC) for programming. No fabric upgrades were made to the property.

Table 23:Thermal transmittance through surfaces in the ASHP property ***- ASHP*** *(existing)*

Surface	U-Value (W/m2k)	Condition
Walls	0.39	Existing
Floor	0.37	Existing
Door	Half glazed	Existing (Double Glazing)[55]
Windows	3.10	Existing (Pre 2003 double glazed units)
Loft	0.14	Existing (300mm glass wool)

[55] There is a cat flap on the front door.

4.3. PV property solar PV electricity tables

Table 24: Solar PV onsite electricity generation in kWh (£ are calculated at peak rate)

	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
kWh per month	298	277	362	168	253	198	108	45
£ per month	£97.84	£90.95	£118.64	£55.14	£83.02	£64.81	£35.39	£14.63
kWh per day	10	9	12	5	8	7	3	2
£ per day	£3.26	£2.93	£3.95	£1.78	£2.68	£2.16	£1.14	£0.52
							Total	1709 kWh £560.42

Table 25: Total electricity used in the property in kWh (£ are calculated at peak rate)

	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
kWh per month	180	108	104	37	147	118	89	41
£ per month	£59.11	£35.49	£34.21	£12.10	£48.22	£38.70	£29.32	£13.35
kWh per day	6	3	3	1.2	5	4	3	1
£ per day	£1.97	£1.14	£1.14	£0.39	£1.56	£1.29	£0.95	£0.48
							Total	825 kWh £270.50

Table 26: Electricity used for hot water in kWh

	Apr	May[56]	Jun	Jul	Aug	Sep	Oct	Nov
kWh per month	**66**	**0**	**0**	**0**	**63**	**57**	**41**	**18**
kWh per day	**2**	**0**	**0**	**0**	**2**	**2**	**1**	**1**
							Total	245 kWh

[56] The supply from the Solar PV to the hot water cylinder had inadvertently been switched off for 104 days between May and July.

Table 27: Electricity used on domestic supply (sockets, lights, etc.) in kWh

	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
kWh per month	114	108	104	37	84	61	49	23
kWh per day	4	3	3	1	3	2	2	1
							Total	580 kWh

4.4. ASHP property internal conditions

Temperature

Table 28: Highest and lowest temperatures (°C) recorded[57]

	Highest	Lowest
Hall	26.7	16.4
Main Bed	23.9	15.3
Bed 2	22.8	13.6
Kitchen	23.0	15.7
External	14.7	-0.1

Table 29: Average room temperature (°C) at different external temperature thresholds

	External Temp <5°C (32 days)	External temp between 5 & 10 °C (169 days)	External Temp >10°C (131 days)
Hall	20.3	20.3	19.1
Main Bed	20.0	19.5	18.5
Bed 2	18.8	18.1	18.9
Kitchen	18.7	18.9	18.8
External	3.7	7.7	12.5

[57] Data in all rooms recorded over 332 days after installation, except Bed 2 (235 days).

Humidity

Table 30: Time in different rooms where the humidity was in excess of 60% and 70%

	Days above 60% Humidity	Time[58] above 60% Humidity	Days above 70% Humidity	Time above 70% Humidity
Hall	101	30%	14	4.2%
Main Bed	125	38%	66	19.9%
Bed 2	174	74%	124	52.8%
Kitchen	148	45	71	21.4%
External	316	95	275	83%

Table 31: Highest and lowest humidity (%) recorded in different rooms

	Highest	Lowest
Hall	74.1%	27.8%
Main Bed	81.4%	27.8%
Bed 2	85.9%	29.6%
Kitchen	82.2%	36.9%
External	98.0%	49.8%

Carbon dioxide

Table 32: Minimum, average, and maximum CO_2 (ppm) measurements in the Main Bed and Bed 2

Room	Days Measured	Minimum CO_2 (ppm)	Average CO_2 (ppm)	Maximum CO_2 (ppm)	Days over 1000[59]	% over 1000
Main Bed	333	443	754	2,898	43	12.9%
Bed 2	235	401	1,725	5,499	160	68.1%

4.5. Tenant engagement process

Background

The Association received tenant questionnaire feedback (September 2021) from 60 respondents on a variety of issues including energy consumption. This snapshot indicated around 55% were in fuel poverty with 18% of these in extreme poverty. The pilot location was prioritised for energy improvement works because high need had been identified including two registered complaints about the energy costs and condition.

Seven of the 15 households had received energy support intervention in the last year either through receipt of energy fuel vouchers or offered technical support to manage energy consumption.

[58] Time above column indicates what % of time that rooms were above those thresholds.
[59] Number of days and % of time where CO_2 is in excess of 1000 PM is also included.

Initial Intervention

The Association began to address this by providing under floor insulation in three properties at change of tenancy by lifting floorboards and installing 120 mm rigid underfloor insulation, with encouraging results showing a reduction in energy use.

Consultation

The Association wrote to the tenants in the pilot area in December 2022 to let them know they were trialling works to install internal wall insulation in an empty property.

The Chief Executive then wrote to tenants in February 2022 to invite expressions of interest in becoming involved in an extended trial, having successfully received Energy Redress Funding. The extended trial included a further three properties as well as the initial empty property allowing upgrades to the insulation in three properties and fit photovoltaic panels to a fourth.

Expression of Interest Process

The Expression of Interest process involved asking tenants to return questionnaires to indicate if they wanted to be involved in the full internal insulation retrofit and/or the photovoltaic panels pilot and gave tenants the option to apply to transfer to the first property once it has been upgraded.

Tenants were advised the works would involve significant disruption including;

- Installing monitoring equipment 2-3 months before works started measuring humidity, temperature, and energy use.
- Internal walls throughout the property being stripped back and re-insulated by a local contractor, involving two rooms at a time. Underfloor insulation possibly involving the uplifting of carpets and flooring.
- Temporary removal of the kitchen and bathroom – same kitchen and bathroom to be reinstated.
- Installation of a new MVHR unit and external door.
- Daily visits from the Association and the Retrofit Co-ordinator.
- Photographs regularly being taken before, during and after works.
- Monitoring for one year after the installation works are completed.

Returned Expression of Interest Forms

The Association received expressions of interest from eight of the 14 tenants and short-listed three properties by picking addresses out a hat. The short-listed tenants were then visited to provide more information about the pilot scheme.

Home Consultation Visits

The engagement process with the remaining trial properties involved the following:

- A detailed explanation of the project including providing photographs of the initial pilot retrofit.

- The levels of disruption were explained as tenants were being asked to remain in the properties whilst the contractors would be working on two rooms at a time.
- Completed a tenant risk assessment to identify specific risks to the tenant and their family that needed to be taken into account by the client and the contractor. This included information about health and mobility conditions and pets living in the property. Also discussed the household calendar to see when tenants might be away from the property or have additional guests staying.
- Tenants were left an information pack which contained information about the process, example photos, details about different roles in the project, Changeworks independent monitoring and the monitoring equipment, and sensors which would be supplied.
- Tenants were given time to consider if they were still willing to participate in this trial project.

Sign Up Properties

Following the in-depth consultation one tenant decided to transfer to another property instead of being involved in the insulation retrofit.

A second tenant decided not to pursue Solar PV as they felt it was unsuitable for locating in their garden due to risk of damage from young children.

Three tenants committed to becoming trial property partners and signed data / monitoring agreements so that data information could be shared with Changeworks.

Pre-Start Engagement

The contractor, Retrofit Co-ordinator and Association staff jointly visited the tenants to ensure that the risk assessment and household needs were fully understood. Details such as types of flooring, fixtures and fittings on walls were noted. Sequence of works and timescales were discussed and start dates agreed which enabled tenants sufficient time to pack and be ready for works starting.

Changeworks independently carried out a pre-start interview.

Monitoring sensors were installed to remotely provide humidity, temperature, carbon dioxide and energy readings.

On-site Construction Works

The Association staff regularly visited each property during the works to check on contractor progress, carry out Clerk of Works role and to check on the tenants. This was time-consuming for the staff involved who were often visiting daily during the trial project. Tenants also had direct phone numbers to get in touch with staff if there were issues. For example, temporary toilet facilities had to be supplied for one property at short notice.

Technical inductions were carried out with tenants, so they had a full understanding of new components in their properties e.g. Mechanical Ventilation Heat Recovery or Solar PV.

Changeworks carried out an interview during or just after the construction works.

Post Construction Works

The Association staff have continued to obtain regular monitoring information from tenants for the year since the retrofits were completed. This includes obtaining meter readings, monitoring sensor data, and making adjustments to properties where required such as altering the ventilation flow rates and carrying out further technical inductions on solar PV and MVHRs.

Changeworks carried out a post works interview to obtain feedback from tenants.

Final feedback interviews were carried out by Hjaltland staff to reflect on lessons learned and the success of the project.

4.6. Learning log

Fabric properties

- Initial trial in a void property was invaluable for enabling the sequencing of works going forward in occupied properties and for future planning for kitchen removal and temporary storage, temporary toilet facilities, and room sequencing.
- External door needs 6 - 8 weeks lead in time for delivery and fitting.
- New tenants needed a full explanation of works that have been carried out, including photos of the works to understand what works had taken place and to enable them to engage in the monitoring process.
- The technical induction on the MVHR unit ensured the tenants knew how the property is now ventilated.
- New tenants are able to enjoy the benefits of the retrofit works without having gone through the disruption of the works.
- The Retrofit Co-ordinator has recommended that air flow is required between rooms. Air flow under doors can be the easiest way to introduce this but tenants have had thick carpets fitted which means the living room and bathroom doors need planned to create air gaps. Vents between rooms could have been added to address air flow instead.
- Pre-works communication - tenant recommends additional information is given in writing as well as verbally and through photographs and information pack to assist digest the level of works that will be involved.
- Floor and furniture protective covers needs to be improved.
- Adjustments need to be made on site if there are changes to the tenant's health during the construction works
- A tenant risk assessment is prepared with each the tenant prior to work commencing, and sub-contractors need to be made aware of tenant’s medical needs when appropriate.
- A storage facility is needed for furniture and belongings that are not regularly used when works are taking place. This avoids constantly shifting furniture and boxes.
- Underfloor insulation needs to be done prior to kitchen units being reinstated. Sequence of works was not well enough planned and led to duplication of works.
- Contractors need to tidy and clean up at the end of each day. This adds time to the day.
- Some flooring needed replaced (kitchen) and one carpet required professional refitting.

- Tenant needed assistance with refitting mirrors, blinds, shelves, TVs etc.
- There was an advantage in getting the kitchen done while the tenant was away from home for a period of time.
- Second toilet made it easier getting bathroom done because tenant still had a toilet facility.
- In some instances the under floor level for kitchen could not be checked until kitchen units were removed as it would have damaged flooring. Unfortunately, there was insufficient room to insulate under the floor.
- Wet wall was re-used but on hindsight did not provide the tight finish that was required around pipework.
- Co-ordination of sub-contractors needed improvement as they did not understand the high priority to get works finished such as the MVHR fitted.
- A greater understanding and more coherent approach to air permeability needed[60]. In this instance, more sealant was needed around holes and cable penetrations after in-house air tightness test which showed air permeability of 2.88.
- The data monitoring equipment needs to be checked more regularly and information downloaded at certain dates (max 3 months available for OWL daily usage stats)
- In future clamps should be additionally cable tied to prevent them coming loose happening.

PV Property

- The design of the solar PV is essential to maximise solar gain for the occupants. In this instance the 6 PV panels (producing up to 2.4 kWh per hour) generate electricity which is consumed on the high-rate domestic board or diverted to the hot water cylinder when no domestic power is required before surplus energy is returned to the grid.
- During a technical visit to PV property the hot water cylinder Eddi switch found to be switched off by mistake by a furniture item lying against the switch.
- Dial meter is not compatible with Solar PV - Meter is turning backwards. This has been reported to the utility company but has not been rectified.
- The solar PV was installed on the ground instead of on the roof. Astroturf was installed under the structure because the tenant had difficulty cutting the grass underneath.
- The iOPT sensor clamps for energy use were commissioned for 100Kv supply rather than 50Kv.

ASHP property

The Association has been installing heat pumps in its new build properties since 2009 and currently has 281 properties with heat pumps installed. This property is the first to have a heat pump installed as a retrofit without any insulation upgrade, in order to measure performance in a 'poorly performing' building.

[60] Passivhaus recommend the use of an airtightness champion (see guidance: 74924 Passivhaus Airtightness.indd (passivhaustrust.org.uk))

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Get in touch with the team to discuss how we can help you.

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