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WHOLE HOUSE RETROFIT INNOVATION COMPETITION

Project summary

Contents

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Executive Summary

The Whole House Retrofit project in Sutton was funded by the Department for Energy Security and Net Zero between 2019 and 2023. It set out to complete whole house retrofits on 100 properties across a range of archetypes to meet the Energiesprong performance specification of 40kWh heat demand per square metre per year.

Over four phases, the project aimed to achieve a cost reduction of 5%-20% through scale, repetition, and trialling innovative products and processes. Most importantly, it aimed to improve the health and wellbeing of residents as well as share knowledge and lessons learned to help catalyse the retrofit market.

The project faced a number of challenges, coinciding with the start of the global COVID-19 pandemic which caused delays, cost inflation, tenant dropouts and supply chain issues such as labour shortages and businesses going into liquidation.

Despite this, 23 homes were retrofitted as part of the project with many achieving or exceeding the performance targets, resulting in more comfortable, affordable and sustainable homes for residents.

Homes were fitted with new roof and windows, traditional External Wall Insulation (EWI), Air Source Heat Pump, Mechanical Ventilation with Heat Recovery, and solar PV, with later phases trialling innovative offsite manufactured products and enhanced cavity wall insulation.

Performance monitoring systems were installed into all homes with data from the first phases of the project indicating a step change in energy performance. Internal conditions in the homes are demonstrating year-round comfort with average energy savings of 80%.

The project showed how an archetype-based approach to assessment of measures can lead to better decision making for retrofit, which in future could help manage cost and risk. Solutions developed during this project can now be scaled, enabling supply chain to build long-term relationships and achieve efficiencies in delivery.

Some other key lessons learned from the project are:

- planning applications should be permitted on a neighbourhood level to increase efficiencies
- it is possible to streamline pre-works surveys by ensuring it is the party responsible for design or manufacture who undertakes them, reducing duplication
- quality and availability of stock condition data can have a major impact on project cost, timelines and ability to scale up, especially when unexpected remedial works are required
- the landlord needs a full understanding of the legislative requirements of resident consultation, allowing sufficient time and preparing conceptual information on retrofit that facilitates a meaningful conversation with residents.

Although the project was delivered during a challenging time and consequently didn’t retrofit as many homes as originally hoped, it did achieve many of its aims. Whole house retrofits were carried out to four different archetypes by three contractors, activating the supply chain to grow their knowledge and experience in the retrofit industry. Two new energy modules were commissioned to be trialled as part of the project, helping new entrants to develop their ideas and make them market ready. Even though challenges were faced around planning for the modules, these offsite manufactured solutions could be a practical solution to many current barriers such as space and aesthetics. The key now is for more programme-based approaches to be developed so that the scale and cost reductions can be realised.

Finally, post-retrofit surveys have shown that residents are happy with their upgraded homes and are enjoying the health and wellbeing benefits.

1. Project summary

1.1. Project summary

The Whole House Retrofit (WHR) project was led by a consortium consisting of: London Borough of Sutton; Energiesprong UK; Turner and Townsend, and Sutton Housing Partnership. The project submitted a bid into the Department for Energy Security and Net Zero's (formerly Department for Business, Energy and Industrial Strategy) Whole House Retrofit competition in May 2019 and the project was awarded up to £3,105,578.00 grant funding in February 2020. The purpose of this report is to summarise the activities undertaken to deliver the outcome and aims of the project while providing insight on the lessons learned. Further background information on the programme can be found in the Whole House Retrofit and Social Housing Decarbonisation Fund Demonstrator: joint outcome and economic evaluation report [1]

The Whole House Retrofit (WHR) project was delivered to houses in the London Borough of Sutton (LBS). The project committed to using the Energiesprong approach to whole house retrofit, resulting in warm, affordable and performance guaranteed net zero homes.

The 'Energiesprong' (Energy Leap) approach to retrofitting was developed in the Netherlands (NL). By the time of the bid in 2019 it had been delivered to thousands of homes in NL where they were achieving significant cost reduction and demonstrating supply chain innovation which resulted in homes being made net zero in a matter of days. The approach had also been trialled in Nottingham and in Essex (for Moat Housing Association), but on pilots of relatively small numbers of homes (10 homes, 17 homes, 5 homes).

The Energiesprong approach aims to use offsite manufactured wall and roof panels and energy modules which can all be installed rapidly onsite to reduce disruption to residents. It also uses a performance outcome specification rather than a detailed specification, which enables innovative approaches to be deployed.

Performance targets are high, ensuring the homes are net zero through a significant reduction in heating use (40 kWh/m^2) and efficient heating typically through heat pumps, along with sufficient renewable energy generation to provide the household with almost all their annual energy requirements. The performance must be guaranteed and monitored and this, along with significant reduction of residual energy costs, enables residents to be charged a flat rate 'comfort fee.' This creates additional revenue for the landlord to pay back their investment, while ensuring residents pay the same or less than before the works.

Initially the project was led by Energiesprong UK (ESUK) with Turner & Townsend, Sutton Housing Partnership (SHP) and London Borough of Sutton (LBS) as partners.[2] However, after the bid process, LBS

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[1] The independent evaluation of the outcomes and delivery of the Whole House Retrofit and Social Housing Decarbonisation funding programmes can be found here: https://www.gov.uk/government/publications/whole-house-retrofit-and-social-housing-decarbonisation-fund-demonstrator-joint-process-evaluation

[2] London Borough of Sutton (LBS) is referred to throughout (as the formal Energiesprong partner), being the owner of the properties. Please note that Sutton Housing Partnership (established by LBS in 2006) manages the council housing stock on a day-to-day basis.

took over as lead partner due to their financial size, with ESUK as a key partner rather than the 'lead' as originally planned.

LBS had already secured funding from the Greater London Authority (GLA) to deliver 10 homes as part of their Energy Leap project. The Department for Energy Security and Net Zero WHR project grant funding was intended to enable greater market development and demonstration across 100 homes managed by SHP on behalf of LBS. The retrofits were to be carried out across two LBS estates, Coulsdon and St Helier. The larger number of homes was expected to enable several key outcomes:

1.1.1 Cost reduction

The project was intended to deliver 26% cost reduction per home, from the small number in a pilot project to a greater volume of circa 100 homes in a later phase. This was expected to be realised through improved retrofit solutions resulting from the 'lessons learned' exercise, delivery process efficiencies (e.g. reductions in cost through improved processes for offsite wall panels and offsite roof panels and new energy modules), and reduction in project development time.

1.1.2 Innovation

The team was working with UK offsite wall manufacturer, Mauer, who had delivered a previous Energiesprong project under Engie (now Equans). Mauer was also being used on an Energiesprong project in Devon. Although there were no UK manufactured energy modules available at the time of the bid, a UK based manufacturer developing a new innovative energy module was identified. The project was intended to demonstrate both innovations as solutions and to show how improvements could be realised during the project lifetime, leading to cost reduction.

1.1.3 Number of homes and resident impact

The project set an initial target of retrofitting 100 homes using a whole house retrofit methodology to achieve a space heating performance target of 40 kWh/m^2. Monitoring the in-situ performance of retrofitted properties, alongside improving resident health and wellbeing were also key project priorities.

The homes in Coulsdon were non-traditional build with inherently poor energy performance. The Unity Construction archetype homes were first built in the UK in the late 1940s, redesigned and built across the UK, totalling 19,000 units. The non-traditional construction is based on concrete columns braced together with light steelwork. Between the vertical columns, horizontal concrete panels are 'dropped in' to form the outer leaf, with a clinker blockwork inner leaf. Copper straps were used to tie the concrete panels to the columns. The ground floor slab is solid concrete, while the intermediate floors are part of the light steelwork structure. The original roofs were covered in asbestos sheeting (long since replaced by the landlord). The homes were constructed on site from standardised components made in the Unity Structures Ltd factory in the Midlands.

Typical problems now found in Unity Homes include corrosion of the copper ties, vertical cracking in the concrete columns and rusting of the steels, although this was not a problem at Coulsdon. The Unity is just one non-traditional archetype, various other similar factory-built precast concrete non-traditional archetypes exist, to which the repeatable solutions and learnings could be applied.

1.1.4 Project approach

Phase 1a - Coulsdon

The project was originally designed to realise cost reduction through adopting a staged approach to delivering whole house retrofit at scale. Engie (now Equans) were procured to deliver an initial pilot of ten homes, with the opportunity post-pilot to price for a further 40 homes. Engie priced the first ten homes at £92k and the next 40 at £76k per home (exc. VAT). The bid was based on delivering these homes with the built-in cost reduction and then a further 5% over two additional phases to realise to original 100 property target.

The COVID-19 pandemic arose shortly after LBS awarded Engie the delivery contract. Several occupants withdrew or deferred from the original ten pilot homes. Retrofits commenced on six homes, however, one of these also withdrew and ultimately only five properties were retrofitted in the initial pilot.

During delivery of the first phase, the construction industry and supply chain were seriously impacted by the COVID-19 pandemic. It was necessary to redesign and deliver the retrofits using traditional External Wall Insulation (EWI) measures due to Mauer going into liquidation. The works were still a high-performance full retrofit, including roof, walls, windows, and energy services. The designed performance modelled in the Passive House Planning Package (PHPP) by the Engie design team was 48 $kWh/m^2/year$ heat demand. This performance was accepted due to the design changes it was necessary to make after Mauer supplied measures were no longer possible to include.

The actual monitored performance achieved for the first phase was 40 $kWh/m^2/year$. This shows how, although a PHPP model matches quite accurately for heating demand, it still includes assumptions on the thermal characteristics and building performance as well as occupancy numbers and behaviour. The actual 12 month monitored performance typically compares positively on Energiesprong projects if the build quality has been installed with careful attention to detail – such as airtightness.

On this first phase, all building services were installed in the traditional manner within the existing properties. Energy services modules were introduced on the later project phases. Figure 1 includes examples of properties retrofitted on each phase of the project.

Phase 1a: Coulsdon

Before

After

Archetype	Unity semi-detached
Number of homes	5
Features	Post war typology. Made of stack-bonded pre-cast concrete panels with cavity, within a precast reinforced concrete columns and horizontal and diagonal metal braces.
Original design energy target	50 kWh/m^2/year heat demand
Measures delivered	• Solar PV • Onsite traditional wall insulation • Triple glazed windows • ASHP • MVHR • Solar diverter (DHW) • Removal of gas connection • Monitoring

Phase 1b: Browning Avenue

Before

After

Archetype	Solid brick semi-detached
Number of homes	2
Features	Single skin brick wall
Original design energy target	40 kWh/m^2/year heat demand
Measures delivered	• Solar PV • Onsite traditional wall insulation • Triple glazed widows • ASHP with cylinder in new porch • MVHR • Monitoring • Removal of gas connection

Phase 2: St Helier (Bow Tie Construction)

Before

After

Archetype	Traditional cavity wall semi-detached
Number of homes	6
Features	Traditional cavity wall with previously insulated cavities.
Original design energy target	60 kWh/m^2/year heat demand
Measures delivered	• Solar PV • Zip-Up cavity wall insulation • Triple glazed windows • ASHP in 'porch pod' • MVHR • Battery storage • Removal of gas connection

Phase 4: St Helier (Osborne Property Services)

Before

After

Archetype	Traditional cavity wall terraced
Number of homes	10
Features	Traditional cavity wall with existing insulation which had failed. Also asbestos found in cavities from previous soffit / window replacements.
Original design energy target	40 kWh/m^2/year heat demand
Measures delivered	• Monodraught HomeZERO energy module housing heat pump, Sunamp thermal store and MVHR. • External Wall Insulation • Triple glazed windows, new doors • Solar PV • Removal of gas connection

FIGURE 1 EXAMPLES OF PROPERTIES RETROFITTED ON EACH PROJECT PHASE

Costs increased on the five pilot homes to £116k per property and Engie were not able to maintain their £76k per property price target for the subsequent phases of the project. LBS were not prepared to pay the higher price which was proposed because of the overspend on the initial pilot homes. Therefore, the contract was terminated.

Phase 1b - Browning Avenue

SHP then procured Bow Tie Construction to enable further properties within scope of the project to be retrofitted. Phase 1b comprised retrofit of two homes at Browning Avenue in Worcester Park (which were originally included in the Engie Coulsdon contract). These were delivered using traditional EWI (non-offsite) and a Bow Tie 'Porch Pod' which incorporated a Viessman heat pump.

Phase 2 - St Helier

This phase was also delivered in St Helier estate by Bow Tie Construction. It included six homes part-funded under the Energy Company Obligation (ECO) scheme. These homes were a different archetype (masonry with thin cavity walls) to the previous phases. The innovative retrofit measures proposed included a higher performance cavity wall insulation, with particular attention paid to airtightness, and a 'Porch Pod', incorporating a new UK-manufactured energy module.

Phase 3 - Coulsdon

Phase 3 was included in the original project scope. This was intended to include the remaining homes in Coulsdon that had not yet been retrofitted (please see Phase 1a above). However, LBS decided not to proceed with this phase as originally planned when the initial cost target of £76k per property was not achieved.

Phase 4 - St Helier

The final phase of work (Phase 4) included 10 properties delivered by Osborne Property Services. This phase was designed as 'prototype' phase of works for the Mayor of London's Retrofit Accelerator – Homes Innovation Partnership (RA-HIP)[3].

ESUK and Turner & Townsend progressed this "Innovation Partnership" procurement approach in parallel with delivery of the Whole House Retrofit project. This approach was developed in response to procurement challenges frequently encountered across all Energiesprong projects in the UK. Contractors were found to have often not bid for works due to the requirement for them to take on risks associated with performance guarantees and innovative solutions. Therefore, a new approach was developed to provide significant volume and generate sufficient interest to mitigate the perceived risks. Please see Table 1 for a summary of the number of properties retrofitted in each phase of the project.

[3] The Retrofit Accelerator - Homes programme is funded on a 50:50 basis by the Mayor of London and the European Regional Development Fund (ERDF). The delivery partners, led by global professional services company Turner & Townsend, include Energiesprong UK and the Carbon Trust.

Phase / Location	No. properties (Original Scope)	No. properties (Retrofitted)	Additional Information
Phase 1a - Coulsdon	6	5	- Contractor: Engie (now Equans) - Pilot reduced from 10 to 5 properties due to tenant withdrawals
Phase 1b - Worcester Park	-	2	- Contractor: Bow Tie Construction - Properties transferred from original Phase 1a
Phase 2 - St. Helier	27	6	- Contractor: Bow Tie Construction - Part-ECO scheme funded
Phase 3 – Coulsdon	40	0	- Did not proceed due to cost target not being met in Phase 1a
Phase 4 – St Helier	27	10	- Contractor: Osborne Property Services - Prototype RA-HIP properties
Total	**100**	**23**	

TABLE 1 - SUMMARY OF PROPERTIES RETROFITTED ON EACH PHASE OF THE PROJECT

1.1.5 Key achievements

The project was delivered during a challenging time, with COVID-19 in the first two years followed by significant construction cost inflation. Both factors, combined with stress in the contractor supply chain, impacted outcomes negatively when compared to the strategic objectives developed in 2019 and early 2020. However, despite the challenges, the WHR 104 project did realise several notable achievements:

Activation of the supply chain

Whole house retrofits to four different archetypes, with three contractors including two large companies (Osborne and Equans) and one small company (Bow Tie), activating the supply chain at contractor level. Alongside the three main contractors which grew their knowledge and experience in this 'early stage' retrofit industry, each also inducted their subcontractors and supply chain along with significant numbers of tradespeople who would not have been familiar with low-energy buildings and retrofit prior to this programme.

Innovation

The first homes had the energy services installed inside the properties, which used valuable space and took more time to install. Subsequent phases used energy modules to tackle these challenges. Like all innovative processes, we can expect there to be some teething problems and even an occasional failure – but only by trialling new ideas can we demonstrate their potential to provide new solutions to old problems.

Two different energy modules were ultimately commissioned from new entrants in the marketplace. The initial module trialled was found to be not yet market ready. This module is now being redesigned by the manufacturer and all parties have learned lessons.

The Monodraught energy module solution (please see Figure 2) generally worked well. Data outputs are not fully available at time of writing, but Energiesprong is working with Monodraught to resolve this. Scaling up/economies of scale are sought via repeatability, but all homes are different and therefore require an element of flexibility to refine the final detailed design. Like all manufacturers, Monodraught need landlords to provide a visible pipeline before they will invest in production facilities, factory space, designs, approvals etc. to scale up successful innovations. Once efficiencies are available through scaling-up, only then can we bring costs down.[4]

FIGURE 2 MONODRAUGHT 'HOMEZERO' ENERGY MODULES (WORKS STILL IN PROGRESS)

Airex automated humidity control was used for underfloor ventilation. This underfloor ventilation system has been trialled and is being monitored to understand its effectiveness, which could address a hard-to-treat area in UK homes.

Post-retrofit data monitoring is evidencing performance of 40-60 kWh/m^2/year heat demand being delivered. Contractual guarantees sit behind this, creating a different dynamic between the Solution Provider and the design process, although this does add to the whole house costs and is being reviewed by ESUK to consider other approaches to ensure quality without adding cost.

Scalable solutions

The Mayor of London's Retrofit Accelerator - Homes Innovation Partnership (RA-HIP) was used for the delivery of Phase 4 of the WHR works. This innovative procurement approach allows landlords and Solution Providers to work through four phases (design, prototype, pilot and scale-up) with each phase of delivery targeting higher numbers of homes and lower costs. This reduces risk and ensures learning remains within the team so it can be implemented on subsequent phases. The partnership was also set up

[4] Benefits of Monodraught HomeZERO (and other energy modules) include: Factory assembled i.e. not onsite, components by established manufacturers (e.g. Samsung), plug and play in one day with minimal disruption to residents and appealing aesthetics.

with collaboration at its heart, including a collaboration hub managed by ESUK. Providing the four phases of the Innovation Partnership are concluded, this will launch a £10bn framework for whole house retrofit available to any housing provider or local authority in the UK. This provides an opportunity for LBS and SHP to move forward within an existing procurement route, with a collaborative contractor, if they can secure further budget.

Archetype designs and prototypes were demonstrated for four different housing typologies including both terraces and semi-detached layout. The project phases discussed above provide enough 'lessons learned' to significantly reduce design and project planning time for later phases on any of these archetypes. Equally important, the real-world experience from early projects helps to reduce the risk exposure and areas of potential uncertainty on future similar projects.

Cost reduction trajectory

The cost reduction target was not achieved during this project due to the smaller numbers of homes retrofitted, rising inflation and the lack of continuity in approach.

Evidence that cost reduction follows volume exists at London Borough of Enfield. In 2023 Osborne completed a pilot of 10 homes through the Innovation Partnership, as part of the Mayor of London's Retrofit Accelerator programme (as detailed above). Following the pilot, Osborne has demonstrated that a further 100 homes could be retrofitted for London Borough of Enfield at circa 25% less than the cost per home in the pilot. The savings are the result of savings in preliminaries and overhead costs, alongside knowledge and learning resulting from the pilot.

Health and wellbeing of residents

Post-retrofit surveys have recently been completed, indicating that residents are happy with their significantly improved homes and are enjoying health and wellbeing impacts.

One resident said he'd tell other people that they'd be "absolutely nuts not to have this done," with another stating that: "[yes] it's disruptive… but look at the end result – you'll have lower energy bills, cleaner, fresher air, beautiful looking properties… a house at a comfortable temperature."

Watch the full interviews: https://vimeo.com/792574578

FIGURE 3 JOHN BUTLER, SUTTON HOUSING PARTNERSHIP (PHASE 1B) RESIDENT (PHOTO CREDIT: JACK GRAHAM/THOMSON REUTERS FOUNDATION)

Phase 2 did experience some problems following the initial 'ECO 6' (Energy Company Obligation) whole house retrofit scheme. Initially residents were not content due to the high cost of operating the heat pump which was installed within the innovative 'Porch Pod' energy module (please see Figure 3 for an example of a Phase 2 property). Following analysis of the data, and discussions with residents, the heat pumps within the porch pods were replaced by the contractor with another manufacturer's equipment and residents are now satisfied. They have already seen the impact during this winter period, evidenced through post-retrofit surveys undertaken by Energiesprong UK.

Performance monitoring

Monitoring data is being collected across all retrofitted properties. For the first two phases, which data is available for, properties are performing at least in-line with their design targets and, in the case of the first phase, showing better than modelled performance (please see Figure 4).

The first three phases are being monitored (in full) by Carnego under contract from the Solution Provider. Phase 4 is being monitored by Monodraught who have onboard monitoring systems in the HomeZERO module and by Osborne Property Services which is collecting the remainder of performance data via the solar PV system.

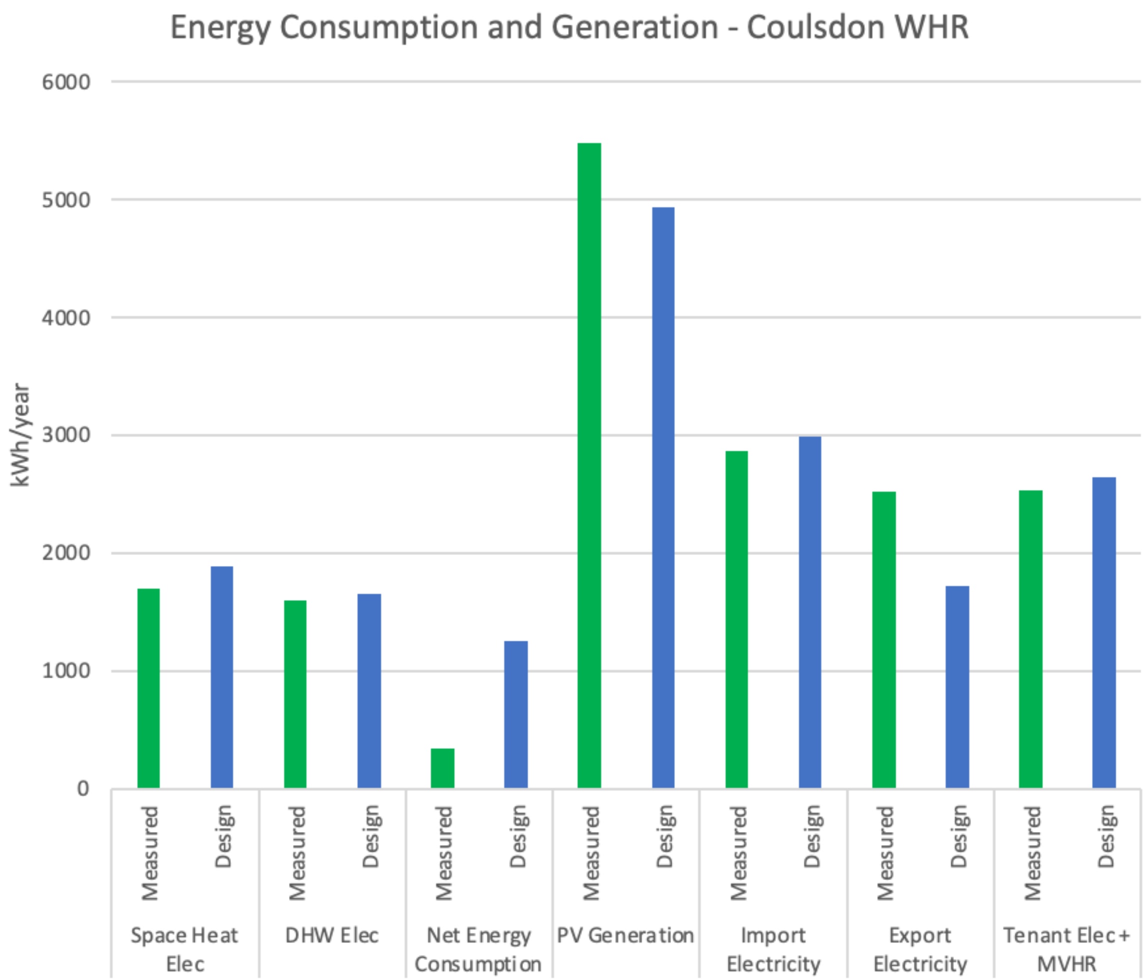

FIGURE 4 ENERGY CONSUMPTION AND GENERATION – PHASE 1A COULSDON WHOLE HOUSE RETROFIT

Retrofit performance monitoring data collection was designed to include measurement of internal conditions, energy consumption/generation and fabric performance (please see Table 2 for further details). There were slight variations between schemes depending on the specific equipment installed.

Measurement	**Variable**	**Notes**
Internal Conditions	Temperature and Relative Humidity	Main Bedroom and Living Room
Energy Consumption and Generation	Import and Export Electricity	i.e. Mains Meter Usage
	PV Generation	Self-Consumption by Calculation
	Energy Services Consumption	i.e. Heat Pump, Immersion, Ventilation etc.

		Tenant consumption by deduction (or metered separately)
	Hot Water Consumption	In Litres or kWh
Fabric Performance	Whole House Heat Transfer Coefficient (HTC)	Calculated from Energy Consumption and Internal Temps using SmartHTC
	Mould Risk	Calculated from Internal Conditions Data using Build Test Solutions Mould Risk Algorithm

TABLE 2 RETROFIT PERFORMANCE MONITORING MEASUREMENT PARAMETERS

2. Property selection, retrofit measures, and energy demand reduction

2.1 Resident engagement and refusal

The project engaged a total of 210 tenants across the Coulsdon and St Helier estates. A total of 72 of those engaged chose not to participate in the project. A further 5 were excluded due to technical reasons. 91 of those engaged were interested initially. A further 42 only received early engagement. The graph in Figure 5 shows the total number of residents engaged in each location.

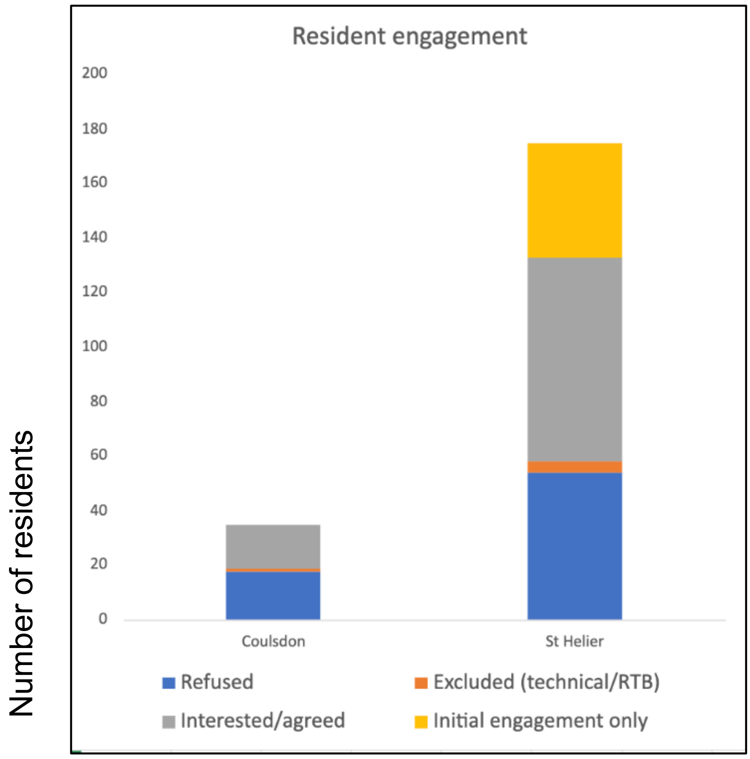

FIGURE 5 RESIDENT ENGAGEMENT LEVELS ACROSS COULSDON AND ST HELIER ESTATES

Tenant refusals are a challenge frequently encountered on whole house retrofit schemes. Examples of tenant refusals which occurred on this project included three tenants who refused works because they were vulnerable and shielding during COVID-19 pandemic. Ten tenants also refused works because they were put off by the expected disruption (please see Figure 6 for further details of reasons for tenant refusals where known). Furthermore, some properties with bathroom pods (added after original construction) were too expensive or complex to address within the project budget available.

Residents who received energy efficiency measures fed back that some of their neighbours who initially declined to participate in the project subsequently regretted they had done so once they saw the completed works.

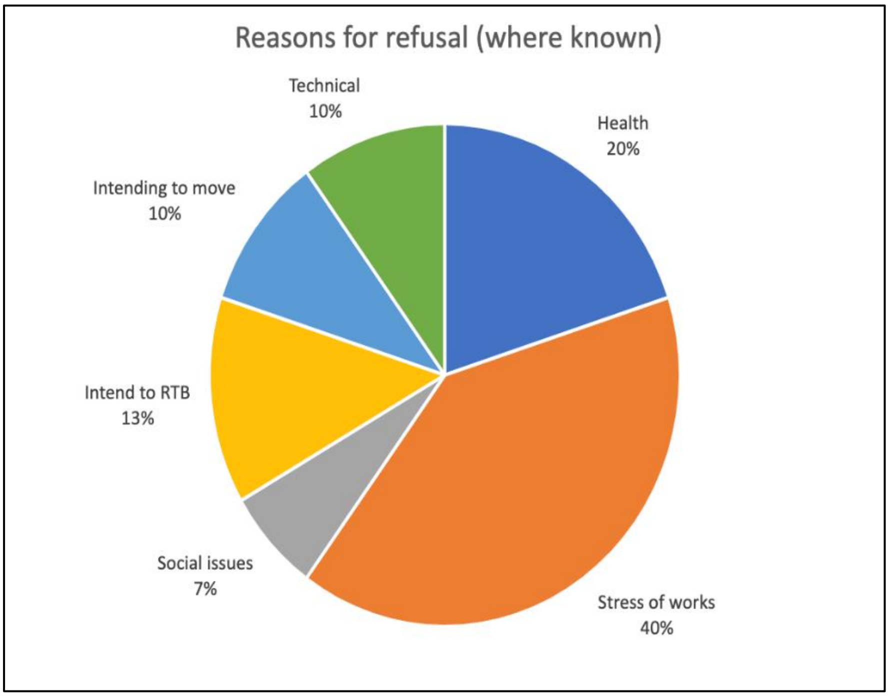

Figure 6 Reasons for tenant refusal (where known) based on 210 total

2.2 How measures installed differed from original plans

All homes in the project included high levels of fabric energy efficiency alongside energy generation and heat pumps - designed as a whole house retrofit to meet the Energiesprong performance outcome specification.

At bid stage the fabric solution proposed included offsite manufactured wall panels. However, after Mauer (the manufacturer) went bankrupt, the approach to external insulation became less innovative. Three of the phases included external wall insulation, while Phase 2 included cavity wall insulation using a new Bow Tie 'Zip-Up' innovation[5].

All homes included heat pumps, mechanical ventilation with heat recovery, and solar panels. In the first phase all this equipment was located within the property[6], causing some tenant dissatisfaction. In the later three phases, energy modules or porch pods were included which meant that the equipment could

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[5] Bow Tie Construction's "Zip-UP" continuous insulation system provides an in-situ 'wrap'. Walltite cavity pour foam is installed from the outside, an airtightness barrier and additional insulation is installed in the loft. The floor void is actively ventilated via a mechanical ventilation with heat recovery system. Cavities are cleaned from exterior by removing sections of brick to minimise thermal bridging and achieve the thermal performance required.

[6] Equipment fitted in properties utility rooms in Phase 1a included a mechanical ventilation with heat recovery unit and associated ducting, hot water cylinder and associated pipework to/from an air source heat pump unit, PV panel controls and inverter.

be housed outside of the property and did not take up valuable space inside. Some homes included residential lithium-ion batteries which enabled the solar energy to be stored and used during peak hours. The batteries used were different sizes ranging from 2.8kw to 5.4kw, and different manufacturers which will enable post completion evaluation of whether larger batteries are useful with smaller solar panel arrays. Batteries were situated in the lofts, which caused additional complications in terms of ensuring fire safety, and weight considerations. In future there should be more consideration around where batteries could be located.

We now recommend batteries in all retrofit projects. They provide greater energy independence, while also saving money for the resident – allowing them to run their home on solar day and night, and thereby need to buy less power from the electricity supplier. There is less dependence on the grid while also supporting the transition to all-electric homes.

2.3 Changes to energy use targets set

The energy use target was 40 kWh/m^2 for the first phase. Design indicated an expected 48 kWh/m^2/yr performance. Actual performance of 40 kWh/m^2 has been evidenced from subsequent monitoring.

The second phase of works (Phase 1b) included 40 kWh/m^2 as a target.

The third phase (Phase 2) targeted 60 kWh/m^2/yr because the innovation approach being demonstrated was focusing on cavity wall insulation and airtightness, rather than solid wall insulation.
The final phase (Phase 4) was part of the Mayor of London's Retrofit Accelerator - Homes Innovation Partnership. This scheme had built in some flexibility on thermal performance to reflect the learning from earlier phases around different archetypes requiring different solutions and how different archetypes achieved different performance even with the same measures. The target was 50kWh/m2/yr and most properties have been modelled to achieve less than 40kWh/m2 with some as low as 34 kWh/m2/yr.

2.4 Methodologies and barriers for measuring (pre- and post-retrofit) the performance of retrofitted properties and barriers

2.4.1 Pre-retrofit

Where possible, Heat Transfer Co-efficient (HTC) measurements (using 'SmartHTC') were taken prior to any retrofit works. This provides a baseline measurement of the performance of the individual home which is useful to optimise potential design solutions and to validate post-retrofit improvements achieved. SmartHTC measurement requires three weeks of monitoring in occupied homes during the winter and involves simple meter readings and multiple (~five) standalone temperature (and relative humidity) loggers. It is not always possible to co-ordinate these measurements with residents; hence it was only conducted on a sample of homes.

Energy consumption data is collected from residents (where available) and analysed to understand overall pre-retrofit performance. Typically, this requires submission of previous energy bills by the resident. Where there is a smart meter present, it is theoretically possible to access 13 months of historical half-hourly data. This however is often not possible due to complications with accessing data from suppliers. Postcode level energy consumption data is generally available (and useful) to ascertain likely performance (essentially) street-by-street, but it does not characterise individual properties.

Where residents were willing, an occupant satisfaction survey (designed in accordance with BS40101: Building Performance Evaluation and PAS2035: Retrofit Coordination) was also implemented to measure the performance of the home from the perspective of the resident.

2.4.2 Post-retrofit

The properties had monitoring systems installed as part of the retrofit works, which are logging detailed data on:

- Internal air quality: temperature, humidity, and CO2 (in some instances);
- Energy consumption including:
  - Total electricity import and export;
  - PV generation (self-consumption can be inferred);
  - Space heating energy output from the heat pump (for kWh/m2/yr);
  - Energy systems energy consumption (i.e. heat pump and ventilation). Note that the Seasonal Coefficient of Performance (SCOP) of the heat pump can be calculated from this data;
  - Hot water consumption;
  - Tenant electricity consumption is inferred from the above data.

This monitoring data is then compared to the design calculations (on a monthly and annual basis) to validate the performance of individual properties. High consumption (or under-performance) can be identified and investigated where necessary. This monitoring continues for the duration of the performance guarantee[7] and protects the resident against any underperforming elements.

The HTC of the properties is calculated from the monitoring data and compared to design calculations to validate the desired fabric performance has been achieved. Where possible, this is supplemented with post-completion airtightness testing results to provide further detail.

Where projects have had less than 12 months of post-retrofit operation, it is not possible to conclude whether performance targets have been met in full. ESUK has worked with suppliers to attempt to break down performance expectations into monthly values so that more frequent performance validation can take place. However, this is not standard practice and ESUK are working on standardised proformas for creating this data.

There have been occasional teething problems with monitoring systems, in particular on Phase 1b, where a comms fault with the electrical consumption data has meant that it has not yet been possible to report the annual performance. Internal condition data is in line with expectations, and resident feedback has also been positive, but updates are awaited to finalise the monitoring results.

Occupant satisfaction surveys are distributed after 12 months post-retrofit (where there is agreement of the client and residents) These results can be compared to pre-retrofit surveys (where they are available) to demonstrate performance improvements (and unintended consequences if there are any). At the time

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[7] One of the innovations that underpins the Energiesprong model is that the contractor (Solution Provider) signs a performance guarantee, ensuring that the in-use energy use and generation are in line with the approved design. The only way to provide this guarantee is to closely monitor the energy consumption and other metrics after the project is complete. By guaranteeing performance, the model unlocks new revenue streams to fund the investment, while dramatically reducing heating costs and making homes more comfortable and affordable to live in. Find out more: https://bit.ly/EnergiesprongPerformance

of reporting, it has not been possible to apply the occupant survey to any of the completed properties (either due to completion dates or agreements) but these will be carried out wherever possible during 2024 (being earlier than the 12 months for some phases).

3. Cost of delivery

3.1 Breakdown of the baseline per property cost of whole house retrofit works

Costs are shown below for each phase in the following table.

Contractor	**Engie**	**Bow Tie**	**Bow Tie**	**Osborne**	**Osborne**
No properties	**5**	**6**	**2**	**6**	**4**
Works Element	**Phase 1a - Coulsdon**	**Phase 2 - St Helier**	**Phase 1b - Browning Ave**	**Phase 4 - St Helier (rear extension)**	**Phase 4 - St Helier (no extension)**
Roof	£7,577		£12,234	£3,480	£705
Loft insulation		£423		£2,933	£3,408
Wall remedials	£6,160	£1,685	£630	£13,088	£13,088
Cavity Wall Insulation		£5,550		£500	£500
External Wall Insulation	£20,002		£16,291	£14,467	£10,863
Heat Pump and Mechanical & Electrical services	£15,555	£13,649	£16,461	£29,206	£29,207
PV	£3,367	£5,812	£6,800	£4,155	£4,155
Windows	£6,099	£8,415	£11,452	£8,987	£8,406
Doors		£4,442	£9,104	£3,061	£3,061
Floor				£413	£413
Gas disconnection				£2,175	£2,175
Other (Prelims)	£8,383	£6,396	£15,200	£9,511	£9,511
Other 2 (OHP)	£8,986	£5,912	£13,037	£14,040	£11,704
Other 3 (Design)	£11,193	£4,138	£4,538	£4,088	£4,088
Other 3a (Stage One Design)				£3,000	£3,000
Other 4 (Scaffolding)	£2,696	£417	£2,696	£2,480	£2,480
Other 5 (Monitoring & Evaluation)	£11,005	£4,624	£3,593	£1,975	£1,975
Other 6 (Retrofit Variations)	£15,003	£27,070	£15,258	£1,930	£1,930
Ave. cost per property	**£116,026**	**£87,478**	**£127,294**	**£119,489**	**£110,669**

TABLE 3 – COSTS BROKEN DOWN BY ELEMENT AND PHASE

The table below gives the project timelines by project phase. Phase 2 practical completion (PC) was significantly delayed due to the need to replace the original heat pumps. The PC date is the date when the replacement was completed, and the PC certificate was issued. This has significantly increased the project period. Active works were not being undertaken during the majority of this period, and the actual replacement works and installation of batteries where relevant took two weeks per home so the time taken per home reflects this, rather than the total project duration.

Project timelines	**Phase 1a - Coulsdon**	**Phase 2 – St Helier**	**Phase 1b - Browning**	**Phase 4 - St Helier**
	Engie	Bow Tie	Bow Tie	Osborne
Start date	18/08/2020	05/07/2021	15/02/2022	09/01/2023
Original intended completion date	26/03/2021	28/03/2022	05/08/2022	11/04/2023
Project works completed		05/05/2022		
Practical completion (inc. rectification)	22/09/2021	08/12/2023	05/08/2022	29/11/2023
Original time per home (days)	44	44	86	9
Actual time per home (pre remediation)		51		
Actual time per home (days)	80	61	86	32

TABLE 4 – RETROFIT DELIVERY TIMELINES ACROSS EACH PHASE OF THE PROJECT

General notes on costs for all phases:

- No breakdown of heat pump and Mechanical Ventilation with Heat Recovery (MVHR) costs (assumed).
- Does not include third party consultants' costs.
- Does not include VAT.
- No costs for other works deemed not related to retrofit e.g. kitchens and bathrooms, asbestos, retrofit variations not an exact science e.g. remedials - how much to apportion to retrofit works.

Specific notes on costs per phase:

Coulsdon

- External wall insulation (EWI) includes costs for enabling works such as removing wiring in existing cavities and having to pin external skin to internal skin in order to hold weight of insulation materials. This is complicated because originally another ‘offsite’ panelised system was to be used, but the manufacturer failed prior to commencement.
- Wall remedials were disputed by the contractor as a client risk, but really the surveys, structural investigations and retrofit designer could have flagged the issues to client earlier, avoiding contractor risk premium.

- Retrofit variations not an exact science e.g. electrical remedials. The client's QS apportioned the costs to remedial or retrofit headings fairly. Any disputes over extensions of time/prolongation costs not fully accounted for in the sums to address the COVID-19 delays.

Energy Company Obligation (ECO)6

- Significant additional cost from contract prolongation due to specification challenges resulting from innovation.
- Any disputes over extensions of time/prolongation costs not accounted for in the sums.

Browning Avenue

- Any disputes over extensions of time/prolongation costs not accounted for in the sums.

St Helier

- Construction inflation uplift applied at end financial year 2023 due to cost increases across construction industry.
- Heat pump and ventilation combined unit.
- Asbestos and structural issues delayed completion.
- Some delays in receiving monitoring data from energy services modules.
- Some window/door costs supply/labour costs combined in costings.
- Middleton Road and Green Wrythe Lane room in roof and associated remedials.
- Note significant non-retrofit remedial variations.

Full costs including those not necessarily classed as retrofit are given in Table 5 below.

Phases	Final Account	No of Homes	Total Ave. Cost / home	Variation from baseline cost estimate	Ave cost / home of additional works (inc in total cost)
1a - Engie - Coulsdon	£823,846.37	5	**£164,769.27**	**+£72,996.00**	**£48,743**
2 - ECO6 - St Helier	£524,871.93	6	**£87,478.66**	**+£7,478.66**	**-**
1b – Bow Tie - Browning Ave	£299,240.17	2	**£149,620.09**	**+£6,620.09**	**£22,326**
3 - Coulsdon - Design	£30,000.00	33	**did not proceed**		
4 - St Helier	£1,231,914.59	10	**£123,191.46**	**+£31,563.06**	**£8,191**
Total	**£2,909,873.06**	**56**			

TABLE 5 – FINAL ACCOUNT BY PHASE

3.2 Steps taken to achieve cost reductions

The project experienced significant challenges with costs. The timing of the beginning of the project, with the pandemic impacting supply chain and delivery approaches, meant there were extra costs for materials, delayed sequencing of works, restricted access to homes and extra time costs. Also, longer lead-in periods caused delays. These were disputed between the Client (London Borough of Sutton) and the Contractor in some cases.

The Zip-Up method on 'Phase 2' was aiming to develop a lower-cost approach to delivering whole house retrofit. Although costs increased from original estimates, as shown in Table 5, the result was still between £30k and £40k per home less than the properties retrofitted in other phases using external wall insulation.

One of the significant findings is the level of cost related to remedial works that were required. These would not usually form part of the energy efficiency works and instead would fall under repairs and maintenance. Some of the properties were in a worse condition than expected. For example, residents had made changes to properties without any approval. These included removing roof trusses to convert the attic into a 'room-in-the roof'. ESUK has found across all projects that landlord maintenance and property records can be very varied. This means that the poor condition of some of the properties is unexpected to the whole project team, including the landlord.

There are costs which have not been shown in Table 3 above which were incurred, arguably due to the retrofit, including asbestos removal, rewiring and kitchen replacement. In Table 5 these have been included but with the cost of other works shown in the final column so it is clear how much additional work was required on average per phase.

It is a challenge to extract which costs would or could have been incurred without the retrofit, but as a guide these remedial or consequential improvement costs varied and in some cases were as high as £48k per property – so quite extensive in places. Many of the works associated with remedying issues caused by historic damp (please see Figure 7 for an example of damp and mould found pre-retrofit in a property) and preventing further damage, such as repairing broken drains, should have been carried out regardless of the retrofit, but it appears to be the case that these issues only come to light once the retrofit surveys have started. In one case, a drain had been leaking, causing black mould in the house, and this had been attended to many times by the landlord without being fully resolved. Only when the contractor was onsite could this be rectified properly. Other similar instances where repairs were required regardless of the retrofit included structural issues and missing lintels.

FIGURE 7 EXAMPLE OF DAMP AND MOULD PRE-RETROFIT IN HOUSE ON BROWNING AVENUE

3.3 Achieved cost reduction for whole house retrofits per property within the project lifetime

Costs for the Zip-Up approach which is intended to achieve 60kWh/m2/year heat demand were £30-40k cheaper than the other phases which used external wall insulation. This is therefore a reduction of 24% - 30%. The original bid set out a plan to deliver cost reduction of 24%. However, this was from a starting point of £96k, so costs rose by £20k – £30k. If measured against £96k, the % reduction is only 8% when looking at the lowest cost phase. It is also worth noting of course that the cavity wall solution can only be applied to relevant typologies.

Selecting the right solution for the right typology is an area where we felt there is opportunity for further cost reduction. Creating a methodology to link tested and evidenced solutions with homes which require retrofit based on a range of property attributes could save significant time and design work. If these were linked to a procurement route, this could provide a simple way to scale solutions which work, therefore reducing much of the up-front preliminaries cost.

3.4 Suggested cost reduction beyond lifetime of the project

- **Scale** – small projects with no follow-on will always be more expensive per property than larger projects and those with a clear pipeline for suppliers.
- Site-related costs – spread preliminaries over larger number of properties;
- Resident engagement – more effective when delivered at scale (people's availability, reuse of materials etc.).
- **Pipeline** – suppliers require visibility and security of the pipeline to invest in training, facilities, and R&D that will reduce cost;
- **Archetype-based design** rather than bespoke one-off projects – replicability of design spreads the cost over more properties;

- **Offsite solutions** – while currently more expensive due to early-stage market and prototype products, there is greater potential for cost reduction with scale than with onsite solutions such as traditional EWI which is largely labour-based costs. Cost reduction for offsite solutions is likely to come with significant scale later in programmes rather than earlier due to the high investment needed for new manufacturing facilities (and the certainty of a pipeline required to attract that investment);
- **Retaining and upskilling staff** – effective delivery requires knowledgeable and experienced staff within all parties. Solution Providers have spoken of the inability to attract or retain staff due to the uncertainty of contract length. When staff leave, much of the knowledge and relationships with local people is also lost;
- **Policy changes** – implementing policy changes such as planning officers presuming in favour of approval or developing a catalogue of permitted development solutions could accelerate the progress and reduce upfront costs significantly.

4. Lessons learned

4.1 Lessons learned throughout the whole house retrofit process

4.1.1 Planning and property selection

Planning

- Local Authorities should align their operational teams (including planning) behind their carbon neutral goals.
- Where planning applications are required for retrofit, these should be based on neighbourhoods rather than individual properties. This creates efficiency for delivery, and it enables street-by-street cross-tenure or community projects to be realised.
- Planning approval for heat pumps caused delays on this project due to concerns around potential for increased noise.
- Changes of planning officers throughout the life of the project, each interpreting the guidance in different ways, and then their managers interpreting the guidance in another way all caused delays.
- Permitted Development Rights can lead to some innovation passing through the system to approval quicker than others. Knowledge from a planning perspective can help in certain circumstances – resulting in changes to design.

Property selection

- The intended housing lists were changed multiple times as the result of objections by residents or assets team. The development of the final list of homes needs to be agreed before the pre-planning application process and the subsequent planning processes.
- Pepper-potting has also been a concern for some planning teams and should be considered early in the process. This also links into party wall issues.
- The disparity of funding available between social and neighbouring private homes is stark. We need to consider broader approaches that address mixed tenure schemes.
- Sometimes a final property list cannot be confirmed until later in design, but before that point there needs to have been engagement with the resident – even if they are subsequently informed that their home is not on the final list.
- Finalising the design can be challenging without the full property list. Pre-retrofit surveys can also lead to ‘last minute’ changes to the list.
- Landlords need to fully understand their stock before engaging in any discussions. The assets team should be working closely with the retrofit team.
- Greater use of digital tools and protocols to help residents on the proposed property list fully understand the proposal would be helpful.

4.1.2 Property surveying and suitability assessments (including built form, party walls, etc.)

- Pre-works surveys should ultimately be undertaken by the party responsible for design (i.e. contractor in design and build). It is wasteful if the landlord undertakes surveys and then passes over responsibility to the contractor as they will need to do them again.
- The parties undertaking surveys need to be aware of PAS 2035 requirements for pre-works surveys.
- A landlord requires cost certainty pre-tender and they could therefore complete a sample of surveys solely for tendering/procurement process. These can then be handed to the contractor to avoid the landlord paying twice.

- As ESUK builds up their library of archetype and house-type understanding and solutions, the surveying and suitability process is becoming easier, faster, and more effective.
- The quality and availability of stock condition data can have a major impact on project cost, timelines and ability to scale up, e.g. when unexpected remedial works are required. Landlords should consider sample surveys (e.g. for asbestos), if they do not already have the information.

4.1.3 Design and sequencing of works

- The 'chicken and egg' scenario of design progression and property lists is described above. Which comes first? This is to some extent an issue around the first stage of an archetype-based programme.
- Design meetings need to involve all stakeholders and be held on a weekly basis until the design is 'frozen'.
- PAS 2035 presents several challenges around specific materials, particularly with regards to supplier PAS 2030 accreditation and insurance-backed guarantees required by Trustmark. This can be resolved by choosing different measures or suppliers. However, when using new innovative suppliers (like Monodraught) some flexibility is needed.
- Retrofit co-ordinator concerns over historic misapplications of polyurethane (PU) foam for cavity wall insulation resulted in 'robust' discussions regarding the lower cost of using a 'fossil fuel' material vs a more expensive and potentially less effective alternative.
- ESUK is working with design teams and retrofit co-ordinators to try to balance PAS 2035 compliance and necessary caution with the need to innovate and design solutions with the potential for cost reduction and high real-world performance.
- The additional requirements of PAS 2035 may lead to an increase in caution from insurers/retrofit co-ordinators. While this is the intent of PAS 2035, the industry also needs to be able to innovate.

4.1.4 Understanding the design brief

- The ESUK team working alongside proven contractors who understand whole house retrofit and architects who are in this specialist field, leads to significant project advantage and risk reduction (when compared to the opposite situation).
- New Solution Provider teams and their staff need a period of 'deep training' to help them understand what the project objectives are, and how to achieve them. Contractors are not always retrofit experts.
- At all times, the client organisation/landlord needs to employ competent, suitably skilled managers (or appoint consultants at an early stage). There is often a lack of consistency, with changing personnel; some of whom understood the design brief better than others.

4.1.5 Procurement process and supply chain capacity and capability

- ESUK experienced project delays resulting from failed procurement processes on these and other projects. The traditional client attitude of passing all risk to the supply chain is not appropriate for deep retrofit, which is complex and risky. Early-stage collaboration between client and contractor is (in ESUK's opinion) the only way to ensure project success. Many client landlords treat retrofit projects in the same 'traditional' way that they treat new build, where the risk is passed down to the contractor through the supply chain. Retrofit projects are not the same, with a different risk profile because everything is focussed on existing properties and the contractor and supply chain does not expect to take the responsibility for these. Furthermore, the homes remain occupied during the works with all the 'human factors' that are involved. Where a building contract allows for uncertainty that means 'risk' to the supply chain and they adjust their prices upwards to accommodate that uncertainty. Each form of contract (e.g. JCT, NEC, CM etc.) has pros and cons which need to be understood fully.

- Very few manufacturing companies are delivering offsite manufactured solutions for retrofit, but more are showing interest – if the right market conditions prevail. Housing Providers and Solution Providers have no appetite to place orders prior to receiving notice to proceed at the end of the design stage.
- Some clients and some contractors are still taking a "business as usual" specification / procurement approach, rather than working together to design new concepts. More policy direction targeting retrofit offsite manufacture is required, although ESUK is leading on this in the UK and finding workable solutions which can be transferred from one project to the next. This programme has benefitted from this as regards to building services modules.
- On this programme ESUK invested in identifying and engaging with potential offsite suppliers. ESUK talked to manufacturers to learn about the sector, current product offerings and routes to market. This takes time, resource and technical knowledge which clients do not (understandably) generally possess.

4.1.6 Remedial/enabling works

- ESUK has found that most cost movement from the original cost plan is due to the need for remedials to the existing building, not from changes in the retrofit measures. The increased costs result from not carrying out planned maintenance over decades, the historic use of asbestos in construction materials, and structural issues. Once identified, it is better to undertake remedial measures at the same time, but these need to be costed independently.
- A holistic approach is required by landlords - they should incorporate retrofit into asset data management and therefore be able to plan their investment programme more effectively.
- A holistic approach reduces disruption to occupants/tenants. For example, if the landlord has a Kitchen and Bathrooms (K&B) Framework contractor in place, how can these be undertaken by a Retrofit Contractor? Or can the K&B contractor work alongside the Retrofit Contractor?
- Combining these works can also make the offer more attractive to residents as they often value improved amenities or aesthetics over more abstract energy bill savings or sustainability.

4.1.7 Execution of retrofit works

- As stated above, remedials (i.e. not energy efficiency/retrofit measures) need to be considered as part of separate capital works budgets. However, they should be integrated into the contract workstream concurrent with energy works. Co-ordination between all parties is the key.
- Pilot projects like these are a difficult journey for everyone. ESUK are developing experience and solutions to build on lessons to reduce time and costs by scaling up retrofit programmes from here on.
- ESUK prefer to look at properties on a 'block by block'/'street by street' basis, not 'property by property'.

4.1.8 Tenant engagement

- The communication process from the point of project conception is important. Training resident staff on the proposed activities and disruption, but also the lifetime-long benefits need to be given more thought.
- Information for residents about the activities within whole house retrofit and how people's lives will be improved is critical. Some landlords allow residents to change their minds and 'pull out' when already a long way into the process. It is so important to ensure that landlord staff are pre-trained and able to provide a detailed summary of works and disruption to be expected, and to answer any questions. Some residents are willing to sign up with minimal information, others require a lot more, such as detailed design drawings and specification.
- Landlord policy should ensure that their staff are able to explain the energy bill savings, how the process will work, what vulnerabilities exist and how to work with them. Mental health and other

personal circumstances should not be ignored when used as a reason for not progressing energy efficiency works, but quite the opposite, reasons for ensuring these improvements go forward.

- Solution Providers and Housing Providers should work collaboratively on the engagement plan, recognising it will be a proactive and iterative process and that all parties are on a learning curve to improve early-stage consultation and engagement.
- A typical challenge in tenant engagement is tenant refusal. They decline the works due to concern about disruption to lifestyle, lack of understanding about the benefits of the retrofit measures, vulnerabilities or issues which make residents hard to reach, and concern about the impact of the project, including nervousness about operating new systems.
- There are seven areas of focus in the 'tenant journey': resident engagement strategy; communications strategy; resident liaison officers; disruption to residents; works information strategy; contractor journey; and handover process.
- Some of the target property lists have been changed multiple times, this is a root-cause of many challenges (as discussed above).
- The landlord needs a full understanding of the legislative requirements of resident consultation, allowing sufficient time and preparing conceptual information on retrofit that facilitates a meaningful conversation with residents.
- Finding ways to incentivise residents is important. ESUK recommend finding out what issues they have with their home and ensure these are incorporated into the specification for works. This could be a home issue or a neighbourhood issue, particularly when delivering large projects.
- Having simple resident booklets which use photos to explain works is better than long written text. Also asking the contractor to walk the tenants around the home explaining any changes and pipe runs is a good idea to ensure residents understand the impact and can ask questions and make suggestions, before the installation is onsite, when changes will cost more money.

ESUK believe that a project team that has worked with a landlord previously makes the potential for success on future projects far better. Project teams that have worked together and have the expertise result in significant 'value gain' when compared to teams that have not worked together before or have worked together but not well. The right team in place prevents delays and disruption on a project, which also supports the case for early engagement between landlord and contractor.

4.2 Adapting project's approach in response to lessons learned

4.2.1 Supply chain and innovation

- The supply chain is interested and willing, but inexperienced. This is an immature market.
- Contractors and supply chain are unable to 'follow through' with their initial interest in a project when such a small number of properties are confirmed (i.e. a pilot of up to 10 homes).
- Initial assessment of and upfront evaluation of properties for the final property list changed on multiple occasions. Should damp and structural concerns mean that willing residents are eliminated from the property list early on?
- Once 'agreement in principle' has been received from the planning authority to the proposed designs, these should not be changed - or the process may need to start again. Clear, decisive decision making from all stakeholders is required.
- Secure agreement from residents, and then tie them in. It is unhelpful if they are permitted to keep changing their minds.
- Landlord clients need to demonstrate leadership. They need continuity of management staff. Constant changes lead to delays, frustration, wasted money and confusion.
- Piloting the approach on 10 homes initially is beneficial. Each time a new solution or archetype is included, there is a need to learn lessons on smaller pilots before expanding to larger numbers. However, without the chance to expand to the next phase the lessons learned are not able to be implemented to realise cost savings. The project was expected to demonstrate the 6 + 40 homes staged approach. However, the first phase was more expensive due to several factors, both within and outside the control of the delivery team.
- This resulted in new contracts and new approaches, and therefore this did not achieve the scale intended. However, the Mayor of London's Retrofit Accelerator Homes - Innovation Partnership approach, which was used for the last phase, was structured to enable volume to be realised through a staged approach. Sutton, having only just finished the first 10 homes through this contract with Osborne, still need to decide whether to proceed. However, a whole house retrofit project elsewhere (Enfield), is at the time of writing going through the process of developing their next project stage so learnings can be shared from that project.
- Supply chain development efforts have shown that long-term certainty of pipeline volume is crucial for offsite construction. Mauer was unable to remain solvent. Ultrapanel, though not participating in the Sutton project, also needs a visible pipeline before investing. It requires a volume commitment three years in advance of investing capital in factory and production lines, recruiting staff and software. Having a gradually increasing number of homes is counterproductive, as it diverts efforts into doing more pilots, rather than focussing on production efficiency.
- Similarly, volume has been identified by Monodraught as essential for investment in the HomeZERO module as detailed below.
- The Mayor of London's Retrofit Accelerator – Homes Innovation Partnership created significant interest in the market - but ESUK's reflection is that in order to achieve cost reduction, it is not sufficient for the contracts to have the opportunity for the landlord to drop out without penalty. However, landlords do need to be able to manage the performance of the contractor, and the costs. While the contracting structure cannot now be changed, there could be an opportunity to create stronger tie-in through a finance offer for landlords, which assumes payback over a long period. This could create the longer-term certainty required for Solution Providers and their supply chain to invest in cost reduction.

4.2.2 Building services

The supply chain and innovation are both discussed above.

In terms of innovation, there are two main aspects to retrofitting at scale. The first is the scalability of the technological solution. The second is the cost of adoption. Over the duration of this programme, undertaken in four phases across the London Borough of Sutton area, we can state that ESUK has moved from a traditional 'in situ' installation of all the components of a building services installation inside the home, to the design, development and trialling of external installation (please see Figure 8 for examples of energy pod evolution across the project).

In the first phase, heat pump, tank, MVHR, pipework, ductwork and associated wiring were all squeezed into a utility room in the homes. These rooms were fortunately part of the original archetype design, but not a space usually available.

The second phase comprised a 'Porch Pod' manufactured 'offsite' and dropped into place to connect with wiring, pipework and ducting from the house into the porch. The third phase installed all the building services equipment into an 'onsite' porch built in-situ.

By the fourth phase, the designs developed in the first phases had 'iterated' into an offsite manufactured building services 'module', built in a factory in the UK, transported to site and installed directly off the lorry into place for connections from the house.

FIGURE 8 THE EVOLUTION OF ENERGY MODULES ON THE PROJECT - FROM INTERNAL ENERGY SERVICES TO INNOVATIVE PORCH PODS

The project has enabled the introduction of new processes, products and technologies which directly address a number of practical challenges with retrofitting of heat pumps and new energy solutions: space, landlord maintenance, time on site and overall cost. The additional important benefit is reduced disruption to the occupants, both in terms of eliminating potentially intrusive installation around the home and a quick 'switchover' from the gas boiler to the new services installation. This is an exemplary display of design development, and ESUK hope to further build on the approach piloted in this project for future installations.

4.3 Process innovations applied within the project (technology, process or project delivery)

The key innovations on this project were the Monodraught HomeZERO 'building services module', and the 'Porch Pod' by Bow Tie Construction. These are innovative, robust, custom designed outdoor energy services solutions for refurbishment/retrofit net zero energy homes. They are manufactured offsite and delivered as shown below in Figures 9 and 10. Although some of the components are manufactured outside the UK, the assembly and product development are UK based.

FIGURE 9 MONODRAUGHT MODULE BEING DELIVERED TO A HOME IN SUTTON

FIGURE 10 MONODRAUGHT MODULE INSTALLED ON FINISHED HOME IN SUTTON

The equipment inside the module (please see Figure 11) comprises the Samsung Eco Heating System (heat pump with tank), a Sunamp heat battery, Zehnder MVHR and controls.

The significant advantages of these modules include:

- Desirability – not taking up space in the house;
- Serviceability – 24hr landlord access/maintenance to high tech installation;
- Aesthetics - appealing design combined with porches, bin stores, lighting, post box etc.
- Quality - offsite factory assembled and tested;
- Speed of delivery and install – built in factory while works onsite proceed concurrently;
- Multiple ‘routes to market’ - i.e. supply and install by manufacturer, or supply-only to any competent mechanical and electrical services contractor.

During the development of HomeZERO, Monodraught trialled most manufacturers of heat pumps and MVHR before settling on Samsung and Zender respectively, both of which integrate with Sunamp and Monodraught open protocol digital controls. Monodraught intends to retain these two manufacturers as their partners.

In summary, the product has completed the conceptual and design phases, been tested on one new-build and one retrofit project and can be described as ‘market ready’.

What next? ESUK now need to see a clear market demand, leading to a consistent visible pipeline. This will give Monodraught the confidence to ‘tool up’ and invest in the financing, recruitment and production necessary.

FIGURE 11 INSIDE MONODRAUGHT'S HOMEZERO MODULE

4.4 Resident engagement throughout the retrofit process

SHP employed two resident liaison officers (RLOs) to work across the two locations, although only one was still employed by the end of the project. These RLOs undertook most of the early engagement with residents, with support from the SHP programme manager and ESUK.

The main activities up to the end of the design stage were:

- Register interest in a generic retrofit scheme (limited details were released due to caution around overpromising);
- Secure a representative sample of properties for winter monitoring and surveys.

Once contractors were on site, they also provided their own RLOs.

Engagement suffered due to a lack of resourcing and uncertainties around whether the project could proceed or not. Housing Providers are usually unwilling to even begin engagement before the project is certain to proceed, with procurement, contracting, grant funding and design all complete. This comes from a position of not wanting to overpromise to residents (who often have a poor opinion of their landlord), and to avoid spending on staff while the project is still not confirmed. However, this approach means that once the project officially starts there is either a long lead-in time to get to site due to lack of resource, or engagement is rushed because of funding deadlines. As with other issues, this is largely a problem with doing pilot projects rather than ongoing programmes.

5. Road map to mass deployment

5.1 Barriers to mass deployment identified during the project, (including political, economic, social, technical, legal, or environmental barriers)

Political will and policy drivers – All landlords in theory need to achieve the '2050' Net Zero standard which is some way from where most are now, with many homes yet to be addressed. Social landlords are currently seeking to ensure that their properties have an EPC rating of at least band C - many of their homes are below 'C' and their strategy is to address 'worst first'. This focusses on the groups of residents in fuel poverty or other vulnerabilities. The Social Housing Decarbonisation Fund (SHDF) programme is helping to achieve this, but neither the EPC C target, nor the current social housing focused funding are particularly aimed at decarbonising heat. Therefore, the improvements which are being made now are not going far enough to achieve net zero targets, and other public and private financing methods will be required to address all the existing barriers. The public finances and UK political environment cannot resolve all the problems we face.

Competing pressures for budget - Landlords have many competing pressures, which include fire and safety compliance, damp and mould, new quality standards, increasing levels of homelessness, investing in new-build housing, and rents that are capped or restricted – all in a highly regulated environment. This feedback is based on our engagement with landlords over the last few years. More recently borrowing costs have increased registered providers are feeding back that they are facing challenges in meeting their EPITDA (earnings before tax, depreciation and amortisation) requirements, which can cause them to break lender covenants. This is a measure of how well they are performing financially, which shows the very real financial pressure on social landlords, and hance for each landlord they must decide where their investment priorities lie. Maintaining and improving their existing homes while bringing them up to highly efficient thermal and living standards is just one important priority. Some landlords are beginning to work together to share knowledge, learning and procurement efficiencies, which ESUK believes is a strategy that we can enthusiastically support through sharing our scaling-up strategies and efficiencies. Examples of this include SHP bidding as part of a group of housing providers for SHDF Wave 2, and other larger consortiums starting to form for wave 3.

Lack of coherent funding options – given the level of under-investment which is evidenced from this project, and others we have been involved in, and fuel poverty, it is unlikely that a fully “self-funding” model can be developed in social housing. Through our links with Dutch retrofit experts, we understand the Dutch Energiesprong approach is closer to self-funding, through the combination of net metering (net zero energy = zero bills = higher revenue income for net zero homes) and greater investment in maintaining housing assets. These are two enabling elements that are absent from the UK context. Therefore, unless both of these elements are changed through increasing landlord ability to invest, and changing energy tariff structures, retrofit will likely always require some level of grant funding. This needs to be easy to access at a time of the landlord’s choosing, rather than from sporadic, competitive funding which drives stop-start activity. The current approach of competing in short time frames for grants (with these rarely met) creates an inefficient programming approach, and often results in the wrong decisions being made. Anecdotally from many of the landlords and suppliers we are speaking to, the current structure of SHDF is causing immense upwards pressure on costs, due to landlords effectively competing against one another. However, one benefit is that it does create a ‘rush’ to get works done and therefore creates a level of political will at the local level, which may not be there if there was an open-ended opportunity to secure funding. We saw this with another project with Sutton Housing Partnership where EU funding was available, which led to political decisions to proceed being made more rapidly in order to meet the funding deadlines.

Recognition of the need for external finance to deliver scale – social landlords (especially councils and smaller organisations) are unlikely to be able to make the level of investment needed to deliver the scale required; the risks are too high, and they are under-resourced. External finance can provide part of the capital required, based on repayment through a comfort charge, PV export and battery grid services. This needs to be easier to access and linked to solutions which have been tried and tested. The Mayor of London’s Retrofit Accelerator – Homes Innovation Partnership set up during this process is intended to provide a staged approach with finance being levied at later stages, once the initial stages had proven the solutions worked. The Mayor of London also has a green finance fund. One of the other landlords we have supported progressed through the application process for this, but ultimately withdrew before funding was secured, citing the risk of borrowing on balance sheet. Hence off-balance sheet options or innovative solutions are going to be required in order to appeal to social housing owners.

Cost vs. scale – Housing Providers need a viable cost to commit to scale delivery, suppliers can only achieve a viable cost with a commitment to scale delivery. Even if that catch-22 can be overcome, there is uncertainty in the innovation and scale-up process. This has been evidenced through the Mayor of London Innovation Partnership process where costs and numbers of properties fluctuated significantly, creating a vicious cycle of costs / home increasing and then landlords reducing numbers to meet overall budget at which point costs per home increased due to overheads being split across fewer properties. Confidence from all parties then reduces, and suppliers have then shown they are less willing to invest in innovation to further reduce cost, without having the certainty of higher future numbers.

Process, risk, governance and contracting – How can we best share risk and collaborate to achieve the overall goal of a cost-effective, scalable retrofit solution? A traditional main contractor approach often leads to adversarial relationships, where collaboration and shared risk are required. Contracts and procurement are currently structured in a way that does not work well for retrofit, when many of the risks are with the existing building, and landlord stock data is not of sufficient quality or detailed enough for them to truly push the risk onto contractors. We have seen this through the projects being delivered within this project. Clients ultimately need to hold a large portion of the risk on retrofit projects, so they need to be equipped to make decisions quickly.

Understanding the level of risk which is taken on by the landlord and giving them tools to better manage the risk is key to projects being delivered at lower out-turn costs. Also finding ways to help landlords improve the data on their properties would help. Additional costs for remedials are much greater when the issue materialises during the construction phase. The example on the WHR Sutton project of asbestos being found in cavities created additional cost, but primarily for prelims rather than works. Additional works results in contractors being onsite for longer, with all the project costs therefore extended (people, plant, site cabins, health and safety, residents liaison officer, etc.) Carrying out further surveys and sample tests can result in ''standing time", re-programming, storage of materials, and creating new design approaches. The contract durations are intended to be very short, but these additional requirements to remain onsite just serve to extend the disruption for residents and increase the project costs for landlords. ESUK is beginning to collate the data and findings from each project. This central 'databank' on risk feeds back retrofit project information and could be a way to improve predictability of the issues that are likely to arise on each project.

Cross-tenure – pepper-potting is a reality and for multiple reasons the ability to be able to deliver multi-tenure schemes would be extremely beneficial. But this requires alignment of drivers for all parties and coherent cross-tenure financial support (grants and finance).

Addressing legacy under-investment – deep retrofit will uncover the need for remedial works resulting from historic under-investment. This is an additional cost of doing retrofit – who pays for this?

Right to buy – the level of investment required from Housing Providers to achieve the Energiesprong performance specification makes right to buy an extremely high risk for them. A resident can purchase the property (including insulation works) at a significant discount, which the Housing Provider cannot recover. The RTB discount can be up to 70% of the market value, and a maximum of £15k of investment can be protected.

Planning – planning is slow and inconsistent, and often not aligned with local or national carbon reduction targets. ESUK's planning policy paper[8] sets out some ideas on how this could be improved, with some case studies where planning has been supportive and worked well.

Pay-as-you-Save/Comfort Plan mechanism – It has been recognised for a long time that a Pay as You Save model is helpful for improving housing, by using energy savings to pay back the cost of investment. Gentoo housing delivered an initial pilot around 2013 where they charged residents a small extra weekly fee for insulation measures and new windows. The Green Deal was also instigated at around the same time. The Energiesprong model in the NL is based on an energy performance fee (EPV) which is built into policy. ESUK has developed a pay as you save mechanism – the Comfort Plan – which along similar lines

[8] DC.4.1 - Knowledge Paper Policy Paper - Planning regulation and process for scaling up net zero retrofit September 2023.pdf

of the Pay has the potential to generate income to cover part of the cost of retrofit. However, unlike in the Netherlands, it is not written into legislation. Enforcement is untested, and this makes it higher risk as the basis for financing projects. Some of this is due to the early stage of the concept, but government legislation or guarantees would help this concept to develop. SHP decided not to implement the Comfort Plan on this project due to the small number of homes included and the challenge of changing processes to deal with a very few tenants. Following this project, ESUK is developing an approach to support landlords with this challenge, through the DESNZ funded heat pump ready programme. There is growing interest in this policy area, with Warm Rents are being called for by various parties now, including The Housing Forum Linking social rents to energy efficiency – how might it work? : The Housing Forum in this recent paper.

Resident refusals – finding a way to incentivise residents to consent to retrofit is key. Marketing campaigns, understanding drivers and having social housing wide votes to change retrofit decision-making from individual to collective are all ideas which could be explored further. Other countries use the latter of these to ensure whole blocks can be retrofitted, which creates a technically simpler (and cheaper) project. Residents dropping out part way through projects is particularly disruptive and costly. For social housing organisations where they are responsible for maintaining the asset, perhaps there could be a national consultation on tenancy agreements being amended to favour retrofit unless there are mitigating factors which prevent it being delivered and which cannot be accommodated such as ill health. Otherwise, social housing organisations end up spending more money to retrofit fewer homes, and then they must return to do those which opted out later which adds cost and complexity.

6. Post-retrofit benefits and performance

6.1 Unintended consequences around retrofit works

It has been mentioned elsewhere that residents often had longstanding maintenance issues and other complaints about their property addressed as part of the retrofit. A good example is damp and mould already present in many properties.

Residents had the opportunity to understand much more about how their energy systems work, and how to control and manage these efficiently to help keep their energy costs down.

Some residents have stated that following the insulation and new windows and doors, the sound levels from outside are hugely improved.

6.2 Variance between predicted energy use and actual energy use in retrofitted homes

Results so far are showing performance is good or in some cases better than designed for. Residents have commented on the improved level of comfort and environments they now live in (post-retrofit), alongside lower energy bills.

A comprehensive report on performance is included as Appendix 1. More data was available from the first two phases to complete. The latter two have been analysed based on a shorter period of available data, and further analysis will be carried out in 12 months.

6.3 Post-retrofit performance monitoring

Internal Air Quality (temperature and relative humidity) in a minimum of two spaces; main bedroom and living room. This data provides detailed insight into the internal conditions within the property and validation that they are comfortable and aligned with (or better than) the performance guarantee requirements. This covers heating and ventilation performance.

Detailed energy consumption data is also collected and compared to design calculation to validate the performance guarantee. Data includes:

- Grid import and export;
- PV generation;
- Energy systems consumption (heat pump and ventilation);
- Space heating output;
- Hot water consumption.

This data can be analysed to understand the performance of individual systems (i.e. the Seasonal Coefficient of Performance of the heat pump) and the overall performance of the dwelling (i.e. net energy consumption). It is all linked directly to the performance guarantee and thereby residents are protected if there is ever underperformance identified (and not rectified).

6.4 Advice and training for residents post retrofit

From the beginning of the contract, ESUK encourages contractors to prepare for a well-thought-out handover to residents as this is a critical part of a successful retrofit project. If residents are not provided with clear guidance on how to use their new energy systems, they could find they use more energy than they need to – which also leads to greater than expected carbon emissions.

ESUK does not want residents to struggle with their new heating and ventilation systems, because they will not benefit from the comfort and health benefits that they have been promised. ESUK have also found that both good news and bad news travel 'fast' during and after retrofit and a negative outcome can make it more difficult for the landlord to build support for future retrofit projects.

At the end of the works, ESUK expects the contractor to know whom will lead on handovers, who will be present at these handovers (resident, landlord, contractor, suppliers), what information and instruction will be given and to provide an opportunity to repeat if necessary. This is conducted face to face, and then reconfirmed in a handover document (please see Figures 12 and 13 for examples of handover pack materials).

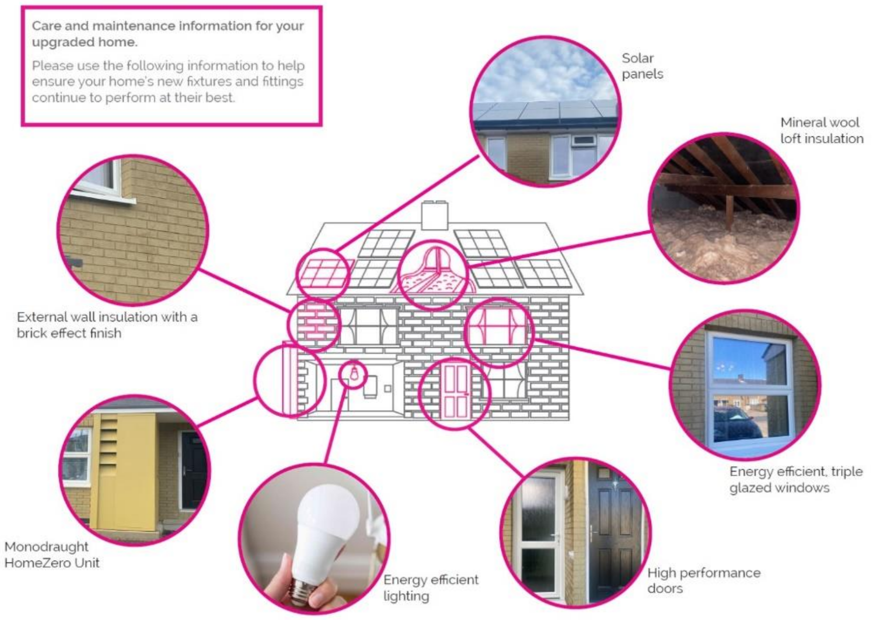


FIGURE 12 EXAMPLE OF INFORMATION IN OSBORNE PROPERTY SERVICE'S TENANT HANDOVER PACK #1

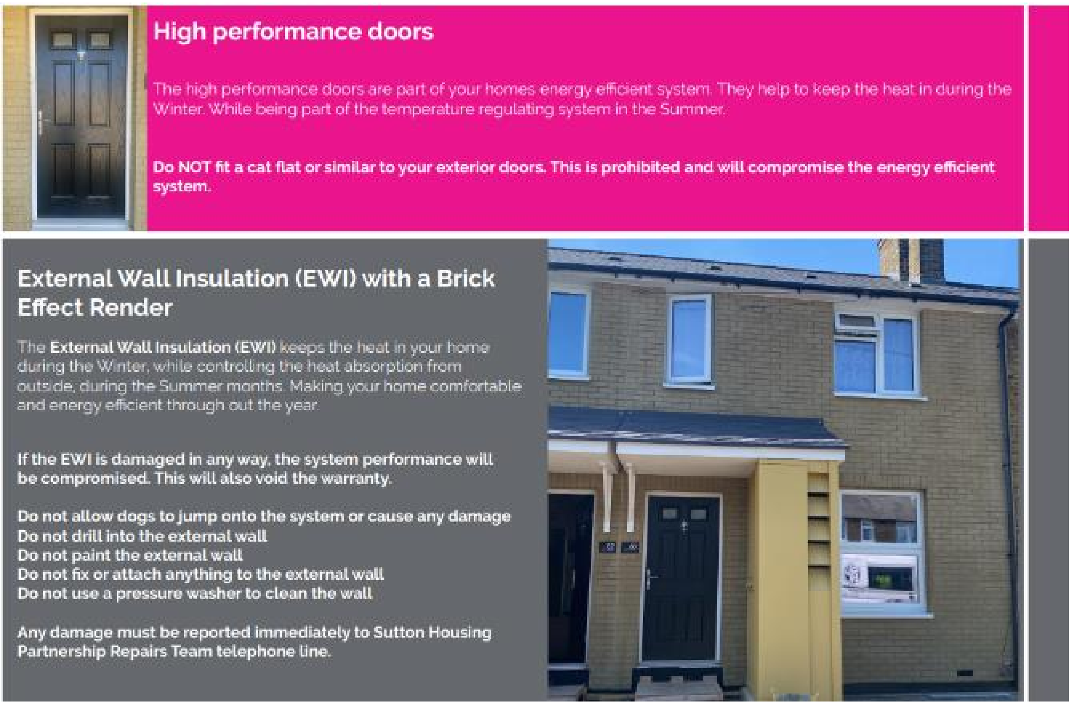


FIGURE 13 EXAMPLE OF OSBORNE PROPERTY SERVICES' TENANT HANDOVER PACK #2

6.5 Impacts/benefits to tenants post-retrofit

ESUK has found that the smoother the entire process, from initial contact to handover, the greater the satisfaction level and impact on the resident's life. Therefore, it pays to invest in constant improvement through processes such as this one.

From Phase 1a to 4, the entire resident experience and outcome has been improved, although there have been challenges on the 'journey'. The post-retrofit interviews demonstrate how satisfied residents are and how impactful the works have been – in a positive way. However, ESUK has learnt from negative feedback or criticism too, because it is important to share the good and bad with the various stakeholders.

Two tenant interviews are available to watch here: https://vimeo.com/792574578

7. Employment

7.1 Potential new businesses or roles that have been created as a result of the project

Although at early stages still, established offsite manufacturers (typically for new build) are beginning to research how their products and services could be applied to retrofit. This creates new roles for research and development staff in those organisations, which are across the UK. Some of these manufacturers are mentioned in this report, but there are many others beginning to consider the market opportunities. Therefore, if the new-build housing market falters, they have a contingency plan that could prevent redundancies and downsizing – thanks to the ever-growing retrofit market.

In the supply chain, main contractors and their subcontractors are training and developing staff for the revised skill sets required, with scope to offer new apprenticeships and other additional roles in their organisations as they grow 'low-carbon' offers within their businesses. This applies to the phases in this project too, which witnessed new staff and skills at Osborne, Bow Tie, and Monodraught.

In ESUK, the team has had the opportunity to learn about new archetypes and extend this knowledge to other landlords in London and the UK, which will ensure the team prospers and grows.

8. Conclusion

The Whole House Retrofit project was a great opportunity for testing and developing new approaches to tackling one of the hardest decarbonisation challenges, retrofitting our aging housing stock. The project met some but not all the specific objectives set out at the start of the programme. Partly due to COVID-19 at the outset of the project, and partly due to costs increasing through inflation due to the Ukraine war, the number of homes which were retrofitted was significantly reduced from 100 to 23. This led to the project being unable to evidence cost reduction through delivering larger numbers of homes, with the number stated by the supply chain at the start of the project as being between 20 – 50 homes in one phase. Each of the phases delivered within the project was significantly smaller than this, ranging from 2 to 10 homes. Consequently, costs remained higher than is viable, and a main aim of evidencing cost reduction was not achieved within the duration of this project. While not delivering on the objectives of scale delivery and cost reduction, the project did deliver on other key aims:

- Innovative solutions were developed and tested for the first time during this project, including the Bow Tie Porch Pod and Zip-Up solutions, and the Monodraught energy module. Three contractors delivered the project across the four phases, showing valuable supply chain activation, with expertise being developed by contractors which is now informing and improving future projects.
- A whole house performance outcome specification was tested and refined through the learning from this project. The homes which were retrofitted are performing well, with monitoring data evidencing real world performance. Learning from this project has developed ESUK's approach to specification and selection of M&E equipment at the start of a retrofit project, with a view to reducing the cost of accessing performance data, using the manufacturer's monitoring solutions wherever possible.
- Homes have been improved significantly for their residents, with many of the homes being in a very poor condition before works were carried out, increasing the risk of poor health impacts.

Residents are now warm and able to maintain comfortable temperatures for very minimal energy costs. Their feedback has been positive.

- A deeper understanding of the process for delivering retrofit and the risks which are likely to occur has led to all project participants being involved in developing new approaches for future programmes of work. Bow Tie and ESUK are involved in the Innovate UK funded Transform-ER project, which is building on the learning from this project to develop new approaches, which could help better identify and manage risks, and help innovative suppliers to bring new products to market. Both Equans and Osborne (now Cardo) are still delivering deep retrofit projects under the Mayor of London's Innovation Partnership, and learning from this project is being applied to help reduce costs in subsequent phases.

Having the chance to test solutions on a small number of homes is important for suppliers and ultimately this project provided a chance for testing innovations in approach and technical solutions in the real world, rather than evidencing cost reduction through scale. To reduce the capital costs of retrofit, which are clearly identified as being too high within this report, suppliers need to have a straightforward way to scale their solutions to a greater volume of homes.

The Retrofit Accelerator – Homes Innovation Partnership (RA-HIP), set up during this project, was structured to enable the continuation of works following prototyping through a pilot and a scale up phase, to the launch of a £10bn framework. Whilst not currently moving forward directly with Sutton, Cardo (previously Osborne) are now on their second phase of delivery through the RA-HIP with another Local Authority, delivering deep retrofit to 120 homes following their initial 10 home pilot. ESUK is supporting them through the next phase, and the valuable lessons learned from this project are being shared by both Cardo and ESUK. Significant cost reduction from £120k to £60k is being targeted in this phase, potentially with some additional finance support for energy system top ups to fabric improvements. This phase is being funded through SHDF and the landlord's planned asset management budget. This subsequent phase of works should evidence the savings which were initially expected to be delivered through this project, had the project proceeded with the numbers of homes expected.

This project provided an enormously valuable opportunity to test approaches to deep retrofits and has resulted in a multitude of lessons which are shared within this report, and which are improving the approach to retrofit through a growing eco system of suppliers and clients.

Appendix 1 WHR – Performance Summary

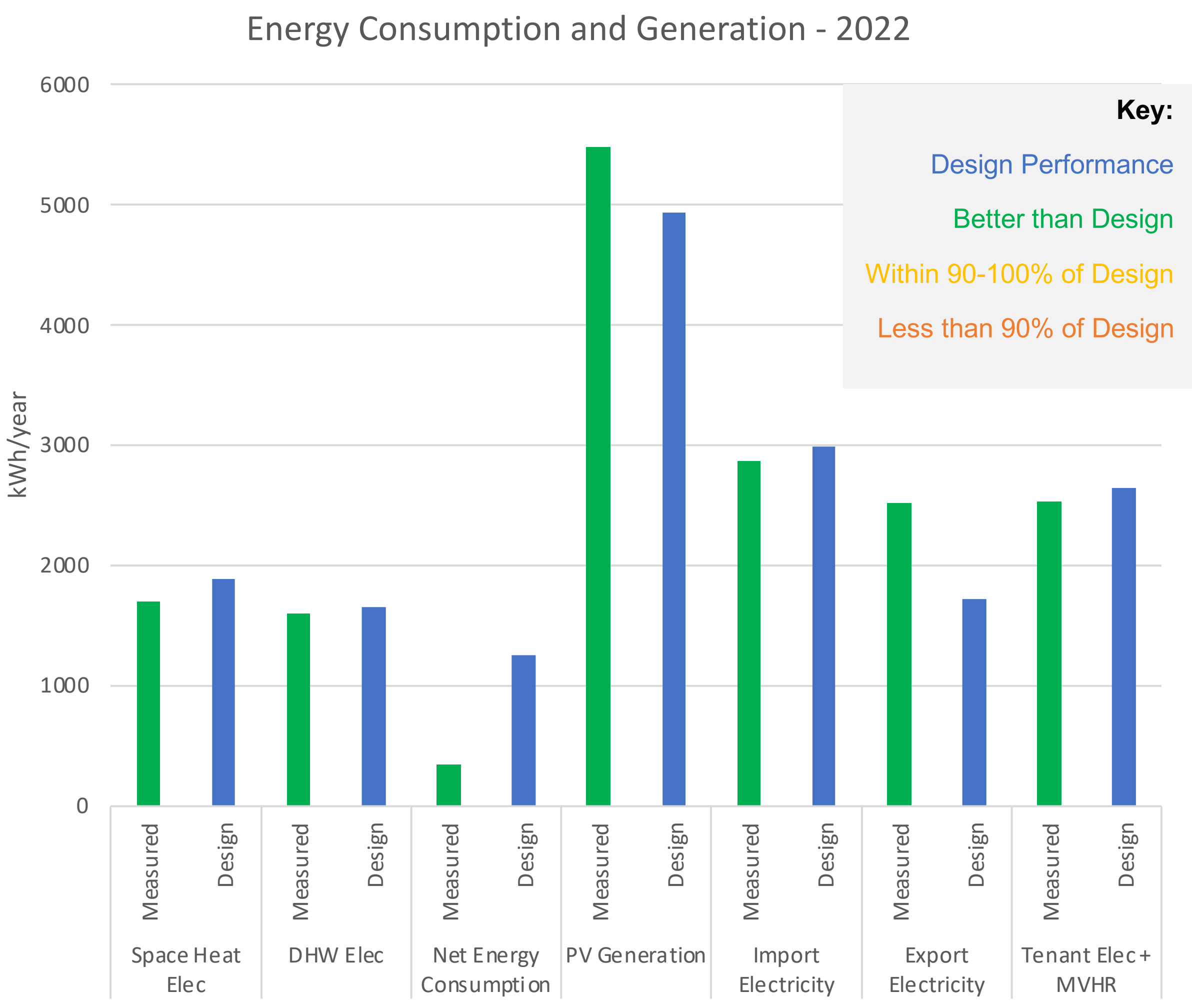
Performance Overview of 4x WHR Schemes

Dr. Zack Gill (Net Zero Technical Analyst)

22 June 2023

Phase 1a – Coulsdon (Equans)

Two full years (2022 and 2023) of performance data are available for the 5x properties in the Phase 1a, Coulsdon, scheme. Average results from all 5x properties are graphed below (please see Figure 14) to compare measured and design performance across each year individually. Commentary is provided for each pair of graphs.



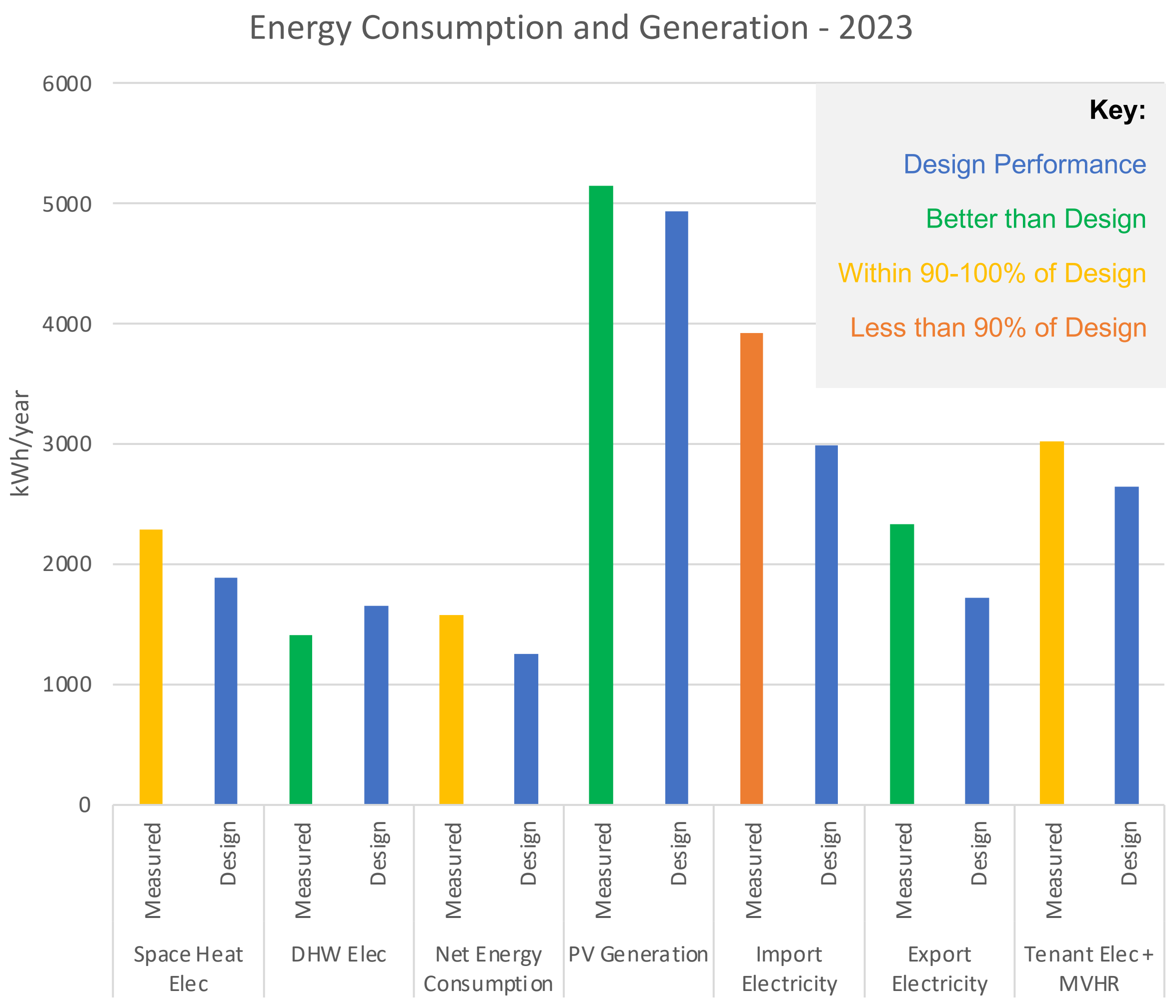


FIGURE 14: PHASE 1A, COULSDON (EQUANS), ENERGY PERFORMANCE (2022, TOP, 2023 BOTTOM)

During 2022, the average energy performance of the homes met and exceeded all ESUK performance targets. In 2023, tenant electricity consumption has increased by approximately 500 kWh/yr which suggests that residents may have increased their personal consumption because of relaxation over total energy bills following the retrofit. Space heating electricity consumption also increased primarily due to a decrease in the seasonal coefficient of performance (SCOP) of the heat pumps (please see below). The overall space heating demand of the properties is still lower (better) than the design targets and internal temperatures are slightly above (better) than the target too. This increase in overall consumption is therefore not of concern but will continue to be monitored throughout the life of the project.

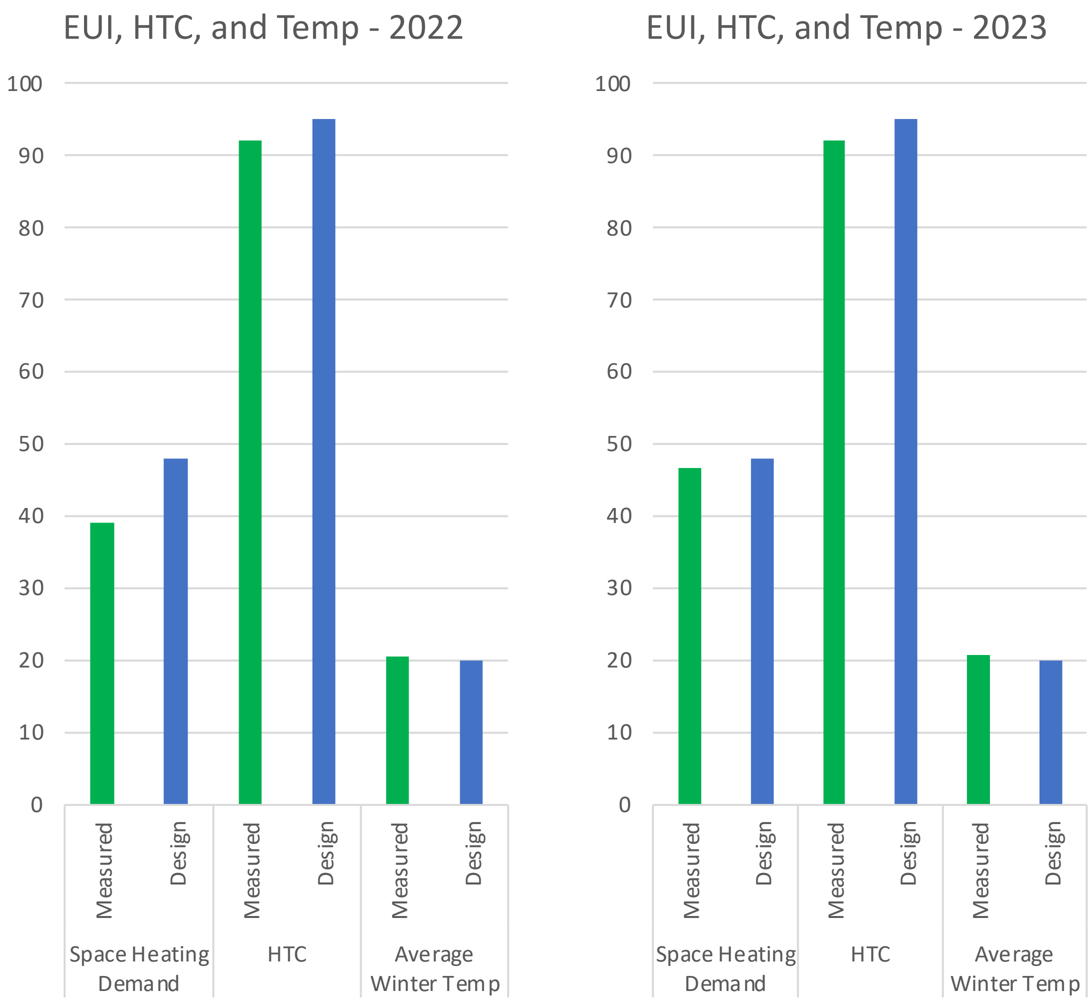


FIGURE 15: PHASE 1A, COULSDON (EQUANS), FABRIC PERFORMANCE (2022, LEFT, 2023 RIGHT)

Space heating energy demand is lower (better) than the design target of 48 kWh/m^2/yr across both years (please see Figure 15). The Heat Transfer Coefficient (HTC) is slightly lower (better) than the design target suggesting that the insulation and airtightness is performing well. Finally, average internal temperatures over winter are slightly higher (better) than the design, so the average internal temperature of the homes is excellent. All these parameters are excellent demonstration of the overall fabric performance of the homes.

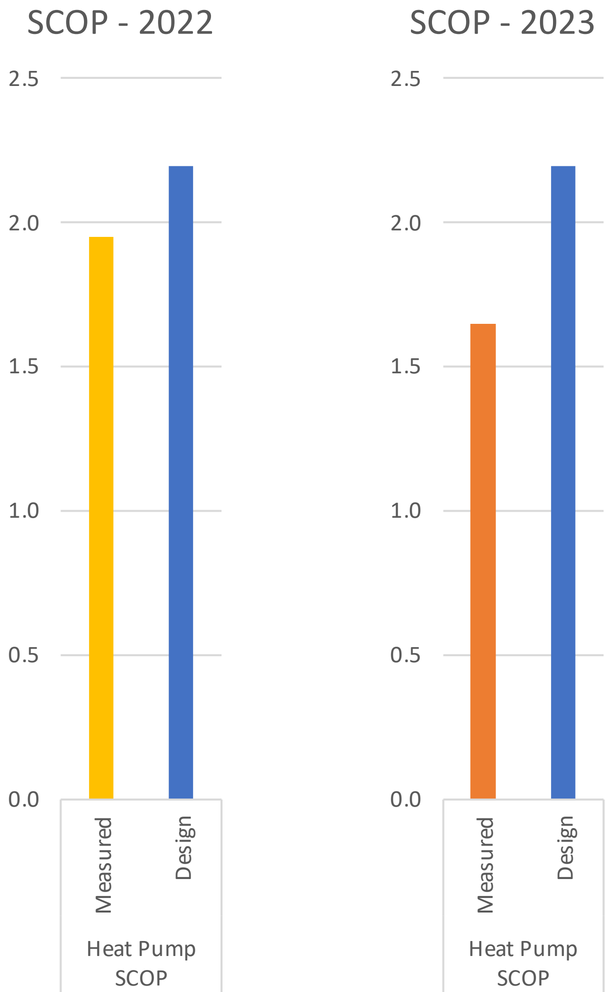


FIGURE 16: PHASE 1A, COULSDON (EQUANS), HEAT PUMP PERFORMANCE (2022, LEFT, 2023 RIGHT)

Heat pump performance is reportedly lower (worse) than design targets across both years, although this has only slightly impacted the overall performance which is still meeting the specification (please see Figure 16). The SCOP is being reported from a heat meter on the space heating pipework only. This means that the energy generated by the heat pump for hot water is excluded from the calculation, meaning that these values are understandably lower (worse) that design. Whilst an exact calculation of the energy delivered for DHW by the heat pump cannot be made (only the contribution from the immersion element is metered and reported above), it is expected that the heat pumps are performing better than the relatively low design target of 2.0 if it was included, especially given the overall performance of other parameters.

Phase 1b – Worcester Park (Bow Tie)

A full year of data (2023) has been analysed for Phase 1b, Browning Avenue, properties. The properties show excellent performance across the board, meeting or exceeding the ESUK performance targets. The only item to note is that minimum relative humidity measured during the winter is quite low (dry) and shall be investigated further to understand whether there is any impact to residents. Average and maximum relative humidity conditions are in a normal operating range (for comfort) and minimum values are therefore shorter periods with low impact on residents.

A summary of the performance data (and comparison to target values) is provided in the table below.

Phase 1b – Worcester Park (Bow Tie), Browning Avenue (2023 Data)					
Energy and Water					
	Unit	**A**	**B**	**Design**	**Comments**
Import	kWh/yr	1706	1831	3313	47% better than design
Export	kWh/yr	1358	1132	2951	Self-cons. 58% better than design
Net Consumption	kWh/yr	348	699	1500	65% better than design
PV Gen	kWh/yr	3934	3979	4277	Close to design (within expected limits)
Self-Consumption	kWh/yr	2576	2847	1326	Self-sufficiency 105% better than design
ASHP + MVHR	kWh/yr	1487	1993	2338	26% better than design
Immersion	kWh/yr	466	0	-	No immersion boosting in B (TBC)
DHW	l/day	103	182	121	Higher than design use in B but no issue
ASHP SCOP	-	4.31	3.97	3.00	38% better than design
Internal Conditions - Winter (Dec - Feb)					
Max Temp	°C	23.0	23.8	<26°C	Excellent
Average Temp	°C	21.5	21.9	~20°C	Excellent
Min Temp	°C	20.1	19.0	>15°C	Excellent
Max RH	%	58.9	55.0	<85%	Excellent
Average RH	%	40.6	40.0	<65%	Potentially dry. Assess via survey
Min RH	%	28.1	30.4	>40%	Potentially dry. Assess via survey
Max CO2	ppm	1158	948	<1500	Excellent
Average CO2	ppm	621	610	<1000	Excellent

Min CO2	ppm	466	397	-	N/A
Internal Conditions - Summer (Jun - Aug)					
Max Temp	°C	24.4	24.5	<26°C	Excellent
Average Temp	°C	22.1	23.5	~20°C	Excellent
Min Temp	°C	20.0	21.9	>15°C	Excellent
Max RH	%	65.1	61.8	<85%	Excellent
Average RH	%	56.1	53.2	<65%	Excellent
Min RH	%	45.1	41.7	>40%	Excellent
Max CO2	ppm	654	810	<1500	Excellent
Average CO2	ppm	501	629	<1000	Excellent
Min CO2	ppm	406	430	-	N/A

TABLE 6: PHASE 1A, WORCESTER PARK (BOW TIE) 2023 PERFORMANCE SUMMARY

Phase 2 – St Helier (Bow Tie) ECO6 (Feb - Apr Data, not a whole year as per design)									
Energy and Water									
	Unit	**A**	**B**	**C**	**D**	**E**	**F**	**Design**	**Comments**
Import	kWh/yr	756	1078	462	-	-	382	3316	A, C, and F look to be better or in line with the target. B likely in line with target (potentially high tenant usage as ASHP consumption is good). Data issue at D and E to be resolved
Export	kWh/yr	341	91	384	-	-	281	2010	Will review after 12 months with Viessmann systems but look like self-consumption might be better than design
Net Consumption	kWh/yr	415	987	78	-	-	101	1500	B potentially high due to high tenant usage. Other properties look on track
PV Gen	kWh/yr	-	-	-	-	-	-	2871	See table below for PV data
ASHP + MVHR	kWh/yr	528	405	262	-	469	186	1877	Data issue with D (to be resolved). Other properties likely to be in line with or better than design
DHW	l/day	121	-	117	274	89	45	140	High water consumption in D. Data issue to be resolved in B. A, C, E, and F all look to have normal water usage
ASHP SCOP	-	4.40	4.28	4.50	4.65	-	3.90	~3.5	Excellent
Internal Conditions - Winter (Feb – Apr)									
Max Temp	°C	21.6	21.9	19.2	17.6	23.3	20.5	<26°C	High temperatures in A, B, C, D, and E. Not overheating as must be from high usage of heating systems
Average Temp	°C	20.5	21.0	15.2	16.0	19.1	16.3	~20°C	A, B, and E are Excellent C, D, and F are cold but low heat outputs so correlates with low heating usage
Min Temp	°C	19.1	15.7	12.0	13.7	15.1	13.3	>15°C	Cold min temps in B, C, D, E, and F. Consequence of holidays / vacant periods

									and some underheated properties
Max RH	%	75.6	75.7	76.3	57.6	52.9	66.2	<85%	Good
Average RH	%	51.7	53.8	60.6	47.3	41.9	57.4	<65%	Excellent
Min RH	%	36.5	28.0	34.9	26.1	26.4	44.4	>40%	Potentially too dry. Assess via survey after 1 year

TABLE 7: PHASE 2, ST HELIER (BOW TIE) 2023 PERFORMANCE SUMMARY

Phase 2 – St Helier (Bow Tie)

Due to the change of heating system in the Phase 2 (ECO6) properties, performance data of the completed properties is only available from early 2024 (Feb – Apr). There are also some issues with the solar monitoring systems meaning that generation data isn't available for all properties over the same monitoring period. However, some historic data is available (and these systems have not changed) so that has been used for the evaluation. A full performance analysis (and comparison to design) will be conducted after 12 months.

All results have been collated in the table below and compared indicatively to the annual targets to estimate whether the performance is in line with expectations.

PV generation data is available via separate monitoring systems integrated with the PV inverters (rather than directly through the Carnego monitoring systems). The historic data has been recorded and presented in the table below. There are numerous issues with data connectivity (likely linked to the fact they are communicating via the resident's broadband rather than a dedicated system). Property A has relatively complete data (with only a small data drop out in April-23). Annual production is approximately 2,690 kWh/yr which is in line with the design target of 2871 kWh/yr (accounting for expected annual variation of at least ± 10%). Where overlapping monthly data is available from other properties, they are producing similar or more than Property A and the Carnego data is showing Export. We are therefore confident that the PV systems are still working, but the monitoring is currently simply offline (to be investigated).

PV Gen (kWh)	**A**	**B**	**C**	**D**	**E**	**F (2022)**
Jan-23	91	36	101	No data	118	-
Feb-23	73	-	83	-	191	73
Mar-23	174	147	205	-	228	225
Apr-23	71	65	85	-	415	308
May-23	227	-	-	-	523	350
Jun-23	441	-	-	-	-	432
Jul-23	368	-	-	-	-	423

Aug-23	366	-	-	-	-	361
Sep-23	303	-	-	-	-	186
Oct-23	195	-	-	-	-	-
Nov-23	113	-	-	-	-	-
Dec-23	39	22	-	-	-	-
Jan-24	104	25	-	-	-	-
Feb-24	106	108	-	-	-	-
Mar-24	200	201	-	-	-	-
Apr-24	156	171	-	-	-	-

TABLE 8: PHASE 2, ST HELIER (BOW TIE) AVAILABLE PV GENERATION DATA (RED = PARTIAL MONTH)

Comparing the performance of the initial pilot and Viessmann energy systems, there is a clear performance improvement that has been achieved and performance is now in line with design expectations. Similar average internal temperatures are being achieved (including a range of warmer and colder properties) but energy consumption is approximately 75% lower than previously (please see Table 9).

House	**kWh**	**Lounge °C**	**Bed °C**	**Average °C**
5 - Pilot supplier	724	18.4	17.4	17.9
6 - Pilot supplier	867	14.5	16.3	15.4
4 - Pilot supplier	1954	20.3	21.8	21.05
3 - Pilot supplier	1689	19.6	18.4	19
2 - Pilot supplier	1644	20.3	-	20.3
Average (Feb – Apr 2023)	1376	18.6	18.5	18.7
Viessmann (Feb – Apr 2024) – Average All Properties	370	-	-	18.0
Saving	1006	@26p/kWh	£262	

TABLE 9: INITIAL PILOT MODULE SUPPLIER VS VIESSMANN ENERGY PERFORMANCE

Phase 4 – St Helier (Osborne)

Phase 4 properties were completed at the end of 2023 and only limited data is therefore available to review performance against. Available data has been analysed below, and a full (12-month) performance assessment will be conducted after 12 months of operation.

Monodraught systems installed at the Phase 4 St Helier directly monitor the internal conditions within the property (temperature and CO2 concentration). The data from Dec-23 to Mar-23 is tabulated below to demonstrate the comfort levels achieved within the property. Property addresses have been anonymised and given IDs instead.

Phase 4 - St Helier (Osborne) – Internal Conditions													
Property		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**Design**
Internal Conditions - Winter (Dec - Mar)													
Max Temp	°C	23.8	-	22.9	25.2	24.1	22.5	22.0	22.3	25.5	25.7	22.9	<26°C
Average Temp	°C	21.2	-	20.4	22.1	21	16.0	20.0	19.3	22.1	20.6	20.4	~20°C
Min Temp	°C	18.3	-	16.5	18.55	17.7	11.5	16.5	16.25	17.9	16.8	17.4	>15°C
Max CO2	ppm	1020	-	1435	1167	1259	1501	1188	1437	1240	1130	1805	<1500
Average CO2	ppm	526	-	618	643	592	488	555	628	612	538	650	<1000
Min CO2	ppm	376	-	400	405	404	404	406	404	402	404	402	-

TABLE 10: PHASE 4, ST HELIER (OSBORNE) INTERNAL TEMPERATURE AND CO2

Maximum average temperatures are all excellent. Some properties do heat to high temperatures (near 26°C) but this is not overheating as it is an active choice. Property 6 appears to be colder than design on average, but all other properties are in line with, or better than, the performance target. Some cold minimum temperatures are recorded potentially due to holidays or unoccupied periods. CO2 concentration is also generally excellent indicating that the ventilation systems are operating effectively. Marginally high peak CO2 as recorded in Property 11 will be monitored further and investigated if necessary (but they are not sustained nor frequent, so it is a low-risk issue).

PV monitoring has now been installed in most properties and some historic data has become available following the install (Property 7, 8 and 11 remain to be installed). The data shows excellent performance of the PV systems and likely over-generation compared to design estimations. The data will be continually reviewed throughout the first 12 months (and beyond) to confirm the performance.

Phase 4 - St Helier (Osborne) – PV Generation (partial year)												
Energy and Water	**Unit**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
PV Gen	kWh	2340	558	1132	1249	1060	2377	700	695	-	2555	-
Design	Annual	3580	4082	3357	3354	3356	4104	TBC	TBC	3937	4104	TBC
Period		Mar - Apr	Apr	Mar - Apr	Feb - Apr	Apr	Mar - Apr	Apr	Apr	-	Mar - Apr	-

TABLE 11: PHASE 4 – ST HELIER, PV GENERATION FOR PARTIAL YEAR (BETWEEN 1 AND 3 MONTHS) AND ANNUAL DESIGN TARGET

Import and export energy consumption is not currently available from any of the monitoring systems. Osborne (Cardo) are investigating whether the PV monitoring system can include this data and it will be updated if possible. Future versions of the Monodraught HomeZERO could potentially be specified to include main meter monitoring but that was not available for these demonstrators. To explore the overall energy performance of the homes, physical meter readings were taken at 6 homes where it was possible to access the meters with the resident's permission.

Phase 4 - St Helier (Osborne) – Import Electricity							
Property	**Unit**	**3**	**4**	**5**	**6**	**7**	**8**
Import	kWh	1500	2385	1497	2260	2142	1233
Design	Annual	4065	4004	4047	3867	4065	4065
Period		Dec - Mar	Dec - Mar	Nov + Feb - Mar	Dec - Mar	Jan - Mar	Dec - Jan
Comments		High due to winter data only but likely in line with target			High compared to target. To be investigated after 12 months data available		In line with target

TABLE 12: IMPORT ELECTRICITY CONSUMPTION FOR PROPERTIES WHERE METERS COULD BE ACCESSED

The Monodraught HomeZERO system also monitors the energy consumption of the heat pump, ventilation system, and associated controls (including pumps etc.). The table below shows the result from properties where data is available during Feb-23 and Mar-23. Data shows that all properties have consumed less than 25% of the target value during 16% of the year (2 months). Given that these months are winter periods, it is expected that all properties will show total annual consumption in line with or below the target value. Monitoring over a full 12-month period will confirm this performance. These results also suggest that high imported electricity consumption is due to tenant electricity consumption (which does not form part of the guarantee) rather than the energy systems.

Phase 4 - St Helier (Osborne) – Monodraught Energy Consumption (Feb-23 to Mar-23)										
Property	**Unit**	**3**	**8**	**6**	**4**	**5**	**10**	**11**	**7**	**1**
Monodraught Consumption	kWh	223	660	329	573	634	177	454	641	585
Target	Annual	2604	2659	2593	2543	2767	2777	2659	2659	2777

TABLE 13: MONODRAUGHT HOME ZERO ENERGY CONSUMPTION (ASHP + MVHR + CONTROLS)

Lessons Learned

This performance assessment of the completed WHR properties has enabled deep insight into the real-world operation of the homes and justification of the approaches taken. Some pertinent lessons have been learned throughout the process of performance evaluation and a summary of this is provided below.

> Overall, the ESUK spec can be achieved in reality and therefore guaranteed. Excellent performance is being demonstrated in the majority of these pilot homes. They are comfortable and efficient.
> Innovative energy modules need to be specified to include full monitoring systems to meet the ESUK monitoring specification (for future iterations) or alternatively additional monitoring will be required to fully validate performance.
> It is beneficial to use on-board metering with heat pumps, solar PV etc. to minimise monitoring complexity and the capability of equipment to deliver this is now reviewed up front in all ESUK retrofit projects. We are working closely with manufacturers to establish the capability of their technologies to deliver this in future projects.
> Contracting for monitoring and performance guarantees needs to improve to clearly identify the metrics and methods required. Furthermore, it should clearly define roles and responsibilities for reporting (monitoring and processing) and providing feedback.
> The ESUK specification has been reviewed and a new draft produced (in part) to facilitate more effective monitoring and performance feedback from post-retrofitted schemes.
> Pre-retrofit monitoring data continues to be complex and difficult to obtain. Pragmatic sampling is recommended to establish a baseline which post-retrofit performance can be compared against.
> Standardisation of design outputs, including a monthly breakdown, is required (and has been formalised by ESUK) to streamline the performance assessments. This will avoid waiting for 12 months before a full performance assessment can be determined.

Appendix 2 – Comfort Plan Explainer

The Energiesprong approach includes a 'Comfort Plan'. This is a Pay as You Save (PAYS) scheme, similar in concept the Green Deal. It is a way of addressing the 'split incentive' for landlords to invest in homes. The resident receives a warm, comfortable and desirable home, and pay the same or less than they did before the works were delivered. The landlord gets additional income to support the business case.

The Comfort Plan is made possible because the Energiesprong approach includes a performance guarantee, which means the landlord has confidence in guaranteeing a warm and comfortable home to their resident after the retrofit. If the home doesn't work as it is supposed to, the landlord can ask the Solution Provider to rectify, so neither the tenant nor the landlord loses out.