



Energiesprong UK

# PERFORMANCE OVERVIEW

*2021/2022*

Comparing design and actual performance across a range of Energiesprong pilot projects.

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# Table of Contents

# Executive summary

Energiesprong is a revolutionary approach to domestic energy retrofit that has now been applied to 173 properties across nine schemes in the UK, with more to follow in 2022/23.

One of the innovations that underpins the 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.

The Performance Guarantee encompasses the following elements (and more) with corresponding, typical, targets.[1] These targets apply per property across a scheme. (See Figure 1 below).

## What this report covers

In this report, performance data obtained from Solution Provider monitoring systems and performance reports is analysed in detail to compare design and actual performance across a range of Energiesprong pilot projects.

The performance of 69 retrofitted properties across six pilot schemes are summarised in this report. The schemes reviewed are all pilot projects intended to establish and demonstrate the Energiesprong business case in the UK. They are also intended to develop detailed learning and insight regarding the performance of different systems and solutions for widescale rollout of deep retrofit in the UK.

| Performance element | Performance Guarantee typical target |
|---|---|
| Space heating energy demand | Less than 40 kWh/m²/yr |
| Hot water allowance | Between 100 – 140 litres/day @ 45°C |
| Net energy consumption | Less than 1,500 kWh/yr |
| Tenant energy costs | Less than prior to the retrofit (based on same utility prices) |
| Internal temperatures | 18°C in bedrooms and 21°C in all other rooms during heated periods (9 hrs weekdays, 16 hrs weekends) |
| Resident electricity use allowance | 2,300 kWh/yr |

**Figure 1: Energiesprong UK performance guarantee typical targets**

[1]The targets are subject to change on a project-by-project basis and/or on agreement between the Client and the Solution Provider.

The metrics analysed include:

*Metrics which are considered the responsibility of the Solution Provider (directly or indirectly as part of the Performance Guarantee):*

- Space heating energy consumption
- Net energy consumption
- PV generation
- Heat pump Seasonal Coefficient of Performance (SCOP)
- Grid electricity consumption (imported electricity)
- Overall fabric thermal performance[2]

*Metrics which do not directly form part of the Performance Guarantee but have an impact on annual energy consumption:*

- Domestic hot water energy consumption
- Internal temperatures
- Tenant energy consumption

## How have we measured performance?

For each metric, average performance across all properties is compared proportionally to the design value. Because residents can choose to use electricity, heat, and hot water differently than the design model, some adjustments are required to directly compare the design with in-use performance.

Any adjustments made to enable direct comparison are reported in the relevant section(s) and any unadjusted values are identified on performance graphs to highlight that those results are potentially outside of the performance guarantee.

The summary findings from these analyses are shown below highlighting those metrics which are performing "better" than design (in the green area) and those which are performing "worse" (in the red area).[3]

Subsequently in the report, additional detail is provided for each metric by outlining the comparative performance of each individual property.


[2]Determined by the Heat Transfer Coefficient, HTC, which is a measure of all the heat lost from a dwelling during the winter, through the walls, roof, floor and windows, and by air movement from outside to inside the home.
[3]Note that generally, "better" performance = lower energy consumption or higher outputs from systems (i.e. PV systems or heat pump SCOPs) and "worse" performance = higher energy consumption or lower outputs from systems. However, in the case of hot water consumption, "better" is defined as consumption below the design target (i.e. homes are consuming less hot water than designed). Similarly, in the case of internal temperatures, "better" is defined as temperatures warmer than design values (i.e. homes are operating warmer than predicted in the winter).

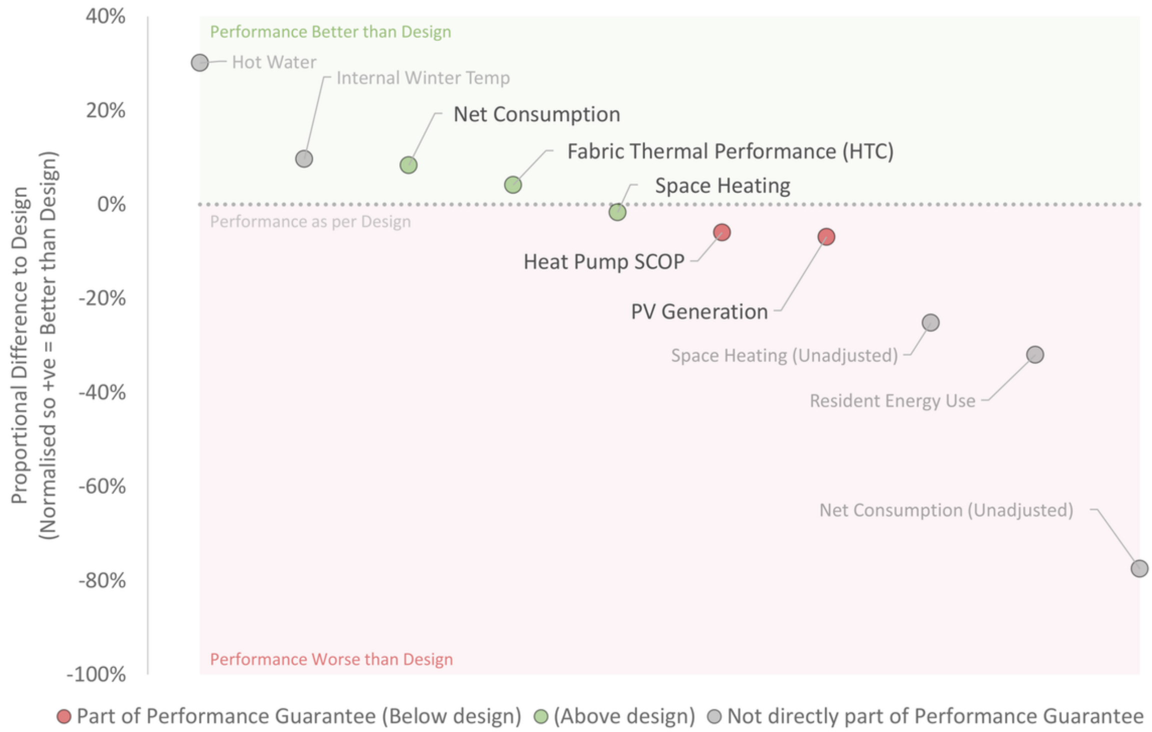



**Figure 2: Summary performance statistics - Energiesprong UK pilot projects**

## What have we found out?

The results from the high-level and detailed performance review can be summarised as follows:

### On average, the retrofitted homes are performing well thermally.

71% of properties had a measured fabric thermal performance within +15% of the design value. On average, annual space heating energy consumption (when adjusted for internal temperatures) is also in line with design targets, only 2% below the design value on average. This would equate to a space heating demand of 41 kWh/m²/yr for those projects with a target value of 40 kWh/m²/yr.[4] For the properties monitored, the average adjusted space heating energy consumption was 48 kWh/m²/yr.

### PV systems and heat pumps are both underperforming slightly on average (but within 10% of design values).

Therefore:

- Incorporating realistic Seasonal Coefficients of Performance (SCOPs) into design models is essential to uphold the performance guarantee element of an Energiesprong retrofit (performance data is fed back to Solution Providers)
- Improved installation, commissioning, control and user feedback regarding use and performance may be beneficial to improve the operational efficiency of heat pump systems. Conversely, learning about how heat pumps are used is important to develop optimal solutions in the future
- Accurate modelling of PV systems across the retrofit stock is important to minimise the impact of local variations between properties (i.e. orientation, overshading etc.)

[4] Noting that a target of 40 kWh/m²/yr was not applicable in all pilot projects.

**Internal temperatures during winter are, on average, almost 2°C higher than design values. But the properties are still using more than 70% less energy on average compared to other local homes.**

There is an inherent energy impact of higher temperatures, but the impact of this increased demand is minimised due to the efficiency of the heating system (heat pumps), overall thermal efficiency of the properties, and contribution of energy from solar PV systems.

For instance, compared to Typical Domestic Consumption Values (TDCV) and local postcode area energy consumption data, the retrofitted properties are using more than 70% less energy per year on average (as per graph below for four sites where this data was available). Additionally, they are now contributing electrical energy to the national grid via PV export. The combination of whole house insulation, solar PV, and efficient heating systems leads to drastically reduced grid energy demand.

**Hot water consumption is significantly lower (30%) than the Energiesprong performance guarantee allows for. However, resident electricity consumption is significantly higher (> 30%).**

It is estimated that only ~1 kWp additional PV (per property) would be required to offset the average increase in resident electricity consumption (i.e. for appliances, cooking and lighting). With improvements to PV technology (i.e. significantly increased outputs from individual panels), this may be feasible to achieve on future projects without increasing the physical system size. This is important for projects where the whole roof has already been used for PV.

It is always recommended and encouraged that Solution Providers maximise the size of PV array installed on any project, regardless of the specific project targets, as it is generally attractive both economically and in terms of meeting the performance specification.

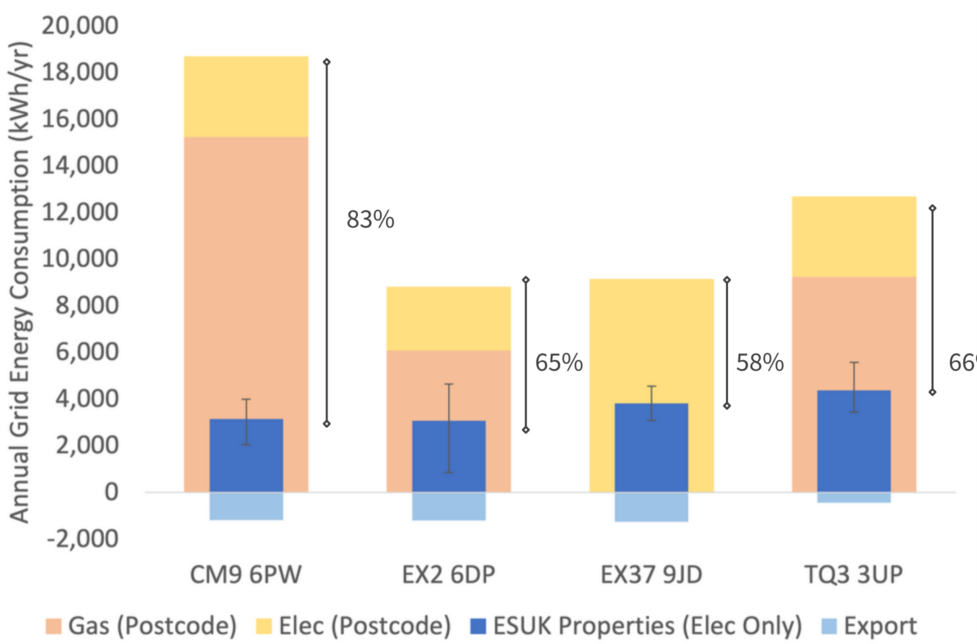



**Figure 3: Comparing ESUK properties with Typical Domestic Consumption Values (TDCV) and local postcode area energy consumption data**

It is noteworthy that in the pilot projects, backup electric immersion heaters for domestic hot water (DHW) were regularly metered as part of the resident energy usage rather than the energy services. It is therefore possible that excess resident consumption was entirely due to unaccounted for DHW production and that both metrics are actually performing in line with the specification on average.

Regardless, the comfort plan does not constrain how much energy or hot water residents can use. But it is useful to identify these differences so that the comfort plan can be iteratively adjusted to provide residents what they require, and so that monitoring systems are appropriately designed and installed to segregate end uses sufficiently to uphold the Performance Guarantee.

**Adjusted for excess resident electricity consumption, the net energy consumption of the properties is on average 8% better (lower) than design. However, the actual measured net energy consumption of the properties is, on average, 78% lower (worse) than design.**

Resident electricity consumption above the design allowance (2,300 kWh/yr) and higher than expected internal temperatures are contributing significantly to this difference which complicates the desire for net zero housing in the UK. This finding suggests energy efficiency retrofit can lead to increased consumption and so there may be increased requirements for improved handover, induction, feedback, education, and guidance in the future.

Despite this finding, these properties are still using more than 70% less energy on average compared to other local homes and so the benefit of deep retrofit is significant.

**There is a wide variation between maximum and minimum consumption (or performance) of individual properties across all metrics.**

For many metrics (i.e. internal temperature, resident energy consumption, hot water consumption etc.), this is most likely due to differences in resident preferences and use of homes and services. For metrics that are the responsibility of the Solution Providers during the guarantee period (i.e. fabric thermal performance, PV generation, heat pump SCOP etc.), properties with low performance can be readily identified for further investigation and resolution. Likewise, properties with excellent performance can be assessed to replicate factors contributing to success.

Properties are using 70% less energy on average than other local homes

**-70%**

**Further work is required to understand resident comfort and satisfaction with the installed solutions to gain further insight into performance successes and failures.**

This will also provide valuable information on the need for better resident focussed elements of the process and system (i.e. handover, induction, feedback, controls etc.) to minimise energy waste. A detailed occupant satisfaction survey, which complies with the requirements of BS40101:2022 on Building Performance Evaluation and PAS2035:2035 on Retrofit Coordination, is now being implemented across all schemes (including retrospective schemes where possible).

**Data quality from monitoring systems is occasionally unreliable and reporting of performance metrics can be misinterpreted by the Solution Providers.**

In response to these findings, Energiesprong UK has developed pro-formas and additional guidance for monitoring systems and reporting performance data which will be applied to future projects.

**Performance monitoring is essential to learn, develop, improve, and consistently achieve/exceed targets now and in future projects.**

It provides:

- Insight into the performance of individual elements of the homes compared to design targets
- Vital feedback to Solution Providers to significantly reduce risks associated with implementing the performance guarantee now and in the future
- Information for clients and funders to demonstrate return on investments
- Data for residents and Housing Providers in the case of an underperformance charge (i.e. where the Solution Provider hasn't met their contractual obligations).

**173**

173 homes have been retrofitted using the Energiesprong approach

**71%**

71% of properties had a measured fabric thermal performance within +15% of the design value

**48**

For the measured properties, average adjusted space heating energy consumption was 48 kWh/m²/yr

# 1 Introduction

## Why measuring performance is key to the success of whole house retrofit

A unique feature of every Energiesprong project is the inclusion of detailed in-use measurement (and reporting) to demonstrate that individual properties are performing in accordance with the Energiesprong performance specification. Residents and Housing Providers are protected from potential underperformance via contractual charging mechanisms. Likewise, Solution Providers (contractors) are incentivised to maximise the operational performance of their solutions and are protected against incorrect underperformance claims by residents.

Energiesprong projects are highly innovative, encouraging the use of offsite manufacturing techniques and high performance mechanical and electrical services.

In the UK – due to the immaturity of the market – some of these pilot projects have used more traditional technologies and methods of insulation. We are working to take the learning from these schemes and share widely as the industry gears up to deliver offsite retrofit and energy innovation at scale.

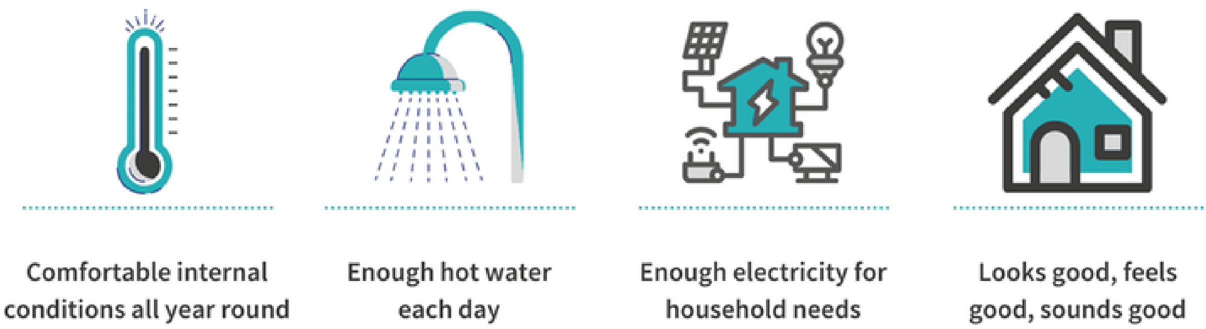
There is not a "one-size-fits-all" solution to retrofit and so we continuously need to learn from project successes and failures to iteratively move towards achieving demonstrably net-zero (energy and carbon) homes in the future.

## What does the data cover?

This report presents and summarises the findings from a comprehensive review of the performance measurements taken from 69 sample completed properties across six different schemes to date.

## The Energiesprong promise

Energiesprong UK performance requirements



This is intended to provide insight into both how the Energiesprong concept works, and how retrofitted homes in the UK are really used and operated. The properties have been selected without bias, rather based on data availability, suitable monitoring periods (typically > 12 months), and representation of a range of archetypes and retrofit solutions.

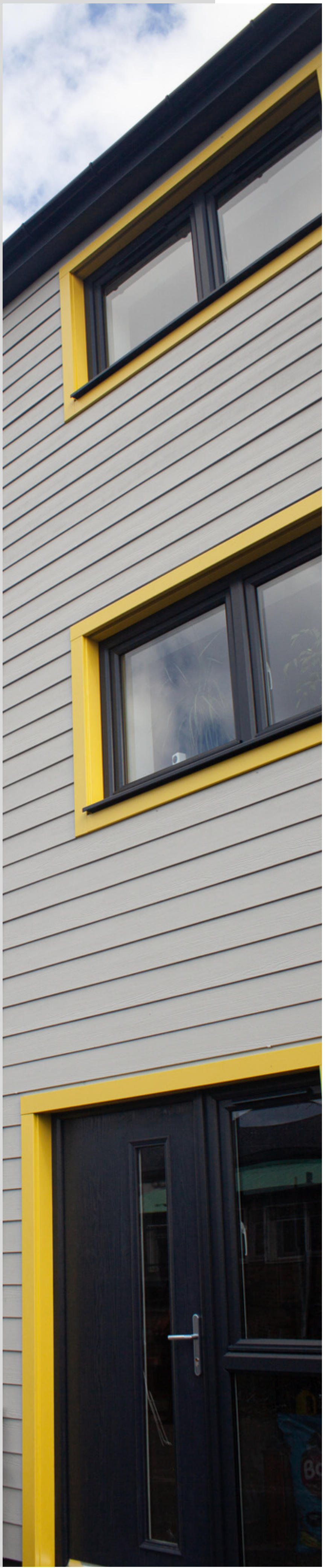
All homes include the following elements as a minimum, although the specification of each varies between scheme (since Energiesprong has output specification requirements rather than inputs):

- Wall insulation
- Roof insulation
- High performance window upgrades
- Heat pump (air source or ground source) heating technologies either per property or via communal/district system
- Improved ventilation (MVHR or demand-controlled ventilation)
- Solar photovoltaics (PV).

The reported performance metrics are separated into two sections in this report:

Section 3 summarises the performance characteristics that are directly within the control of the Solution Provider and form a fundamental part of the performance guarantee (either directly or consequentially).

Section 4 summarises the performance characteristics that are not directly within the control of the Solution Provider. These factors have an impact on the actual energy consumption of the home and so are important to learn from to maximise occupant satisfaction and optimise solutions in the future, but they are not directly assured by the performance guarantee.



# 2
# The projects

| Housing provider | Solution provider | Location | Property details | Retrofit measures |
|---|---|---|---|---|
| Moat Homes  | Equans | Maldon, Essex | 5x semi-detached bungalows | • Solar PV<br>• Onsite framed wall insulation<br>• Triple glazed windows<br>• ASHP<br>• MVHR<br>• Battery storage<br>• Enervalis montioring |
| Exeter City Homes  | Bell Group | Exeter | 6x semi-detached houses | • Solar PV<br>• Onsite traditional wall insulation<br>• Triple glazed windows<br>• GSHP<br>• MVHR<br>• Battery storage<br>• Daizy/Simble monitoring |
| North Devon Homes  | Bell Group | Burrington, North Devon | 2x terraced houses | • Solar PV<br>• Offsite panelised wall insulation<br>• Triple glazed windows<br>• GSHP<br>• MVHR<br>• Battery storage<br>• Daizy/Simble monitoring |

| Housing provider | Solution provider | Location | Property details | Retrofit measures |
|---|---|---|---|---|
| Sanctuary Housing  | Bell Group | Paignton, Devon | 8x flats in 2x two-storey blocks | • Solar PV<br>• Onsite traditional wall insulation<br>• Triple glazed windows<br>• GSHP<br>• MVHR<br>• Battery storage<br>• Daizy/Simble monitoring |
| Nottingham City Homes  | Melius Homes | Nottingham | 18x terraced houses<br>13 x terraced bungalows<br>12x terraced flats | • Solar PV<br>• Offsite panelised wall insulation<br>• Triple glazed windows<br>• Communal GSHP system demand controlled MEV<br>• Communal battery storage<br>• Core Controls monitoring |
| Sutton Housing Partnership  | Equans | Coulsdon, Sutton | 5x semi-detached houses | • Solar PV<br>• Onsite traditional wall insulation<br>• Triple glazed windows<br>• ASHP<br>• MVHR<br>• Solar diverter (DHW)<br>• Carnego monitoring |

Note: This table only provides the details of the projects covered in this performance report (i.e. six of the nine UK schemes to date). Other schemes where data was not available (i.e. because they were only recently completed) will be reviewed in future performance reports wherever possible

# 3 Performance Overview Pt I

## Metrics directly assured by the Performance Guarantee

In this section, the performance characteristics which form a direct (or indirect) part of the Energiesprong UK specification are presented. The section starts with a high-level summary of all projects collectively (via average performance for each metric) and subsequently presents the performance measurements from each sample property (anonymously) for a more detailed analysis (demonstrating any variability across schemes and properties).

The six key metrics reported in this section include:

**Net energy consumption, adjusted (kWh/yr)**

Net energy consumption is a direct Energiesprong specification requirement (typically < 1,500 kWh per year is required). It is defined as the import minus export electricity. Measured net energy consumption is affected by resident energy consumption outside the performance guarantee "allowances", including electricity for appliances beyond 2,300 kWh/yr and additional heating / hot water consumption.

For simplicity, this metric is reported by adjusting the tenant electricity consumption to 2,300 kWh/yr and then adding or subtracting the difference from actual net consumption.

Note that this is not equal to the grid imported energy (net grid import) which is defined below.

**Fabric thermal performance, Heat Transfer Coefficient (HTC, W/K)**

The HTC is a measure of a property's overall heat loss, analogous to a U-value for the whole property. While values for the HTC are not directly stipulated in the Energiesprong performance specification, it is an implicit metric to achieving the space heating energy use intensity target of <40 kWh/m$^2$/yr. The HTC is calculated in both SAP and PHPP models and so actual performance can be compared to design.[5]

[5] Energiesprong UK uses a system called SmartHTC (developed by Build Test Solutions) to measure the HTC. More information about the technology can be found here: https://www.buildtestsolutions.com/building-performance/smart-htc-heat-loss-calculation.

The Heat Loss Parameter (HLP) is a more useful metric for comparing performance between properties. It is simply the HTC divided by the floor area of the property to give a normalised heat loss rate. Typically, an HLP below 1 $W/m^2.K$ is considered to be excellent (a thermally efficient property), whereas an HLP above 3 $W/m^2.K$ is considered to be very poor (a thermally inefficient property). Note that the HLP is not analysed in this report as it would show the same comparison to design values as the HTC.

**Space heating energy use intensity, adjusted (EUI, $kWh/m^2/yr$)**

The energy consumption for space heating (normalised by gross internal floor area) is a direct Energiesprong specification requirement (typically <40 $kWh/m^2/yr$).[6]

Actual space heating energy consumption is monitored in all projects along with internal temperatures. For this metric, the measured consumption is adjusted to account for the difference between operational and design temperatures,[7] as the Energiesprong specification does not constrict residents preferred temperatures and schedules.

**Heat pump Seasonal Coefficient of Performance (SCOP, kWh/kWh)**

Heat pumps use electricity to “upgrade” heat energy from the environment (typically in the air or the ground) into temperatures that can be used to heat the home.

The ratio of annual electrical energy input to heat energy output is known as the Seasonal Coefficient of Performance (SCOP) and is typically monitored in Energiesprong projects. Measured values are compared directly to the design values (where available) to identify any over or underperformance of the heat pumps.

**PV generation (kWh/yr)**

Solar PV forms an integral part of all Energiesprong projects to achieve the net energy consumption targets (typically < 1,500 kWh per year). PV generation is monitored directly for each property and measured values are subsequently compared to the design values.

[6]Based on at 21/18°C in living and other spaces, and bedrooms respectively during SAP heating periods
[7]Adjustment is based on the following approximation equation:

*Adjusted space heating energy consumption = Space Heating Energy Consumption / [(Measured Average Winter Temp - 8.1°C)*(Design Average Winter Temp - 8.1°C)]*

Note that the 8.1°C baseline temperature is calculated via PHPP modelling to identify the balance point temperature where there would be no space heating demand in a typical property. In the future, it is proposed that design models are adjusted to reflect actual operational temperatures (and the calculated space heating demand is then compared to the measured value rather than adjusting the measured value to match the design model temperatures). However, this is not possible for these pilot projects as the full design models were not available in most cases.

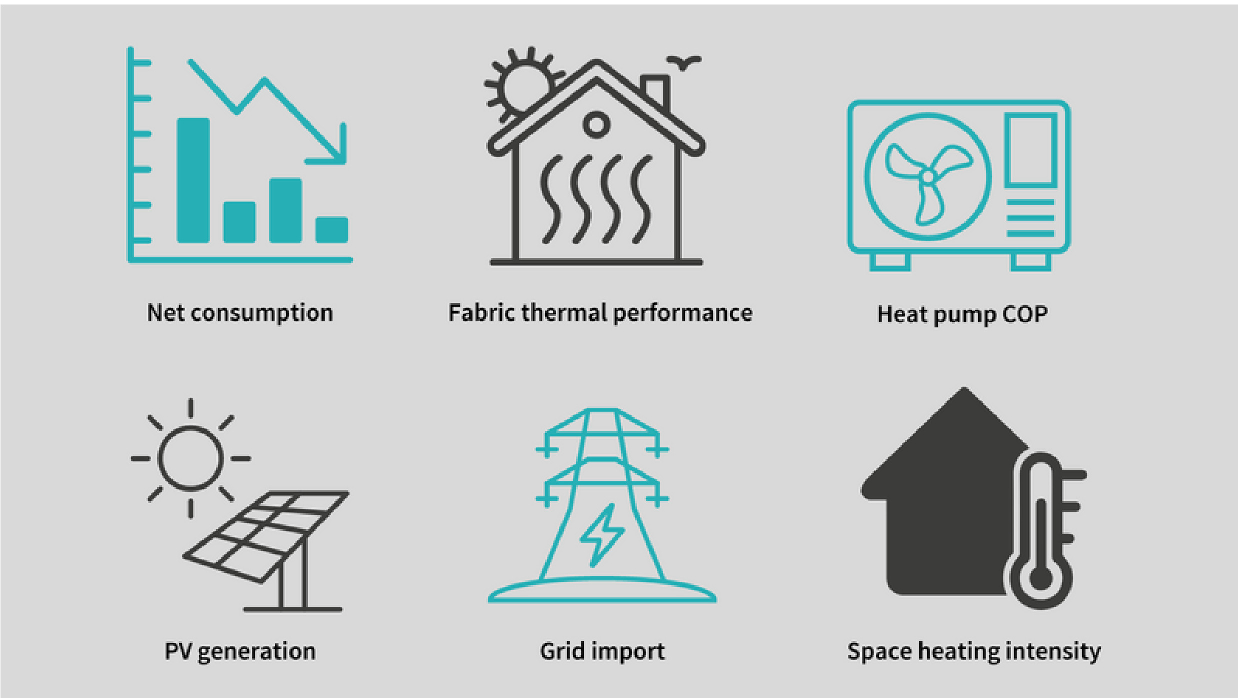
**Grid imported electricity (kWh/yr)**

The Energiesprong financial model relies on applying a “comfort charge” to recover some of the retrofit costs over a 30-year period. The performance guarantee requires that operating costs (including the comfort charge) must not exceed pre-retrofit energy costs. Therefore, it is implicit that there is a reduction in imported energy costs (noting that gas is completely removed).

Note that design values for grid imported electricity are not available for these initial projects under review and so only the absolute values are presented. However, in the future it should be possible to compare this to design as it is now a requirement for Solution Providers to report the predicted import electricity values.

The performance guarantee ensures that retrofits perform in reality, not just on paper.

**Performance guarantee**



## 1.1 General performance overview – all projects (ESUK Specs)

The graph below shows the average scheme-wide performance measurements from these key metrics (excluding grid imported electricity). Each metric is compared proportionally to the target / design value for each individual property. Comparisons are normalised so that performance better than design is shown in the top half of the graph (in green) and performance worse than design in the bottom half (in red). In the detailed performance review of each individual metric, further detail is given on the design and measured values for reference.

All performance metrics are, on average, within ±10% of the design values which is an excellent result.

Net energy consumption (adjusted) is better (lower) than designed, outperforming target values by approximately 8%.[8]

This is an excellent result and suggests that, if the homes are used as per the design (in terms of internal temperatures and resident energy consumption) then the impact on the energy grid of these homes is very low.

It is worth noting that (as shown in Section 4 and 4.2.5), actual net energy consumption in the properties is, on average, significantly worse than design (higher). This is in particular due to higher internal temperature preferences and tenant electricity consumption, both of which are outside the control of the Solution Provider but should be learnt from for future projects.

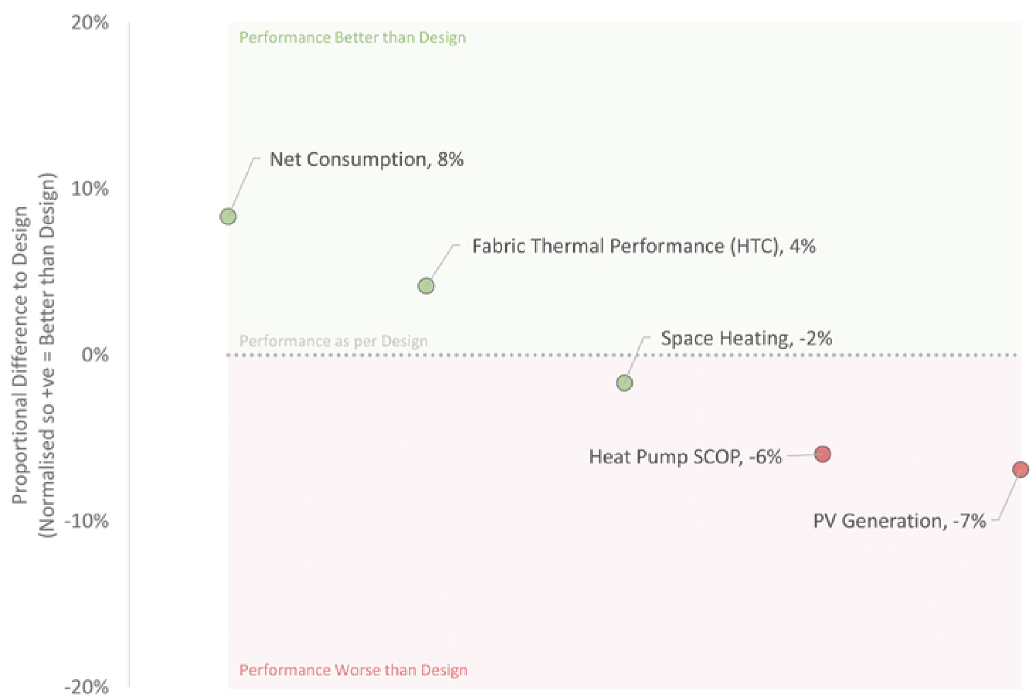



**Figure 4: Summary performance statistics - Energiesprong UK pilot projects (metrics directly assured by performance guarantee)**

[8]To demonstrate this finding, on average net consumption would be 1,380 kWh/yr compared to a target value of 1,500 kWh/yr (if the tenant allowance of 2,300 kWh/yr was exactly met in operation).

Fabric thermal performance (HTC) measurements are slightly lower than design values, meaning that the properties are marginally better insulated than modelled (4% better on average).[9] This is an excellent result as it means that homes should use slightly less energy for space heating than expected.

Space heating (adjusted) results show that, when internal temperatures are corrected for, the properties are using approximately 2% more energy than anticipated. Given the potential errors in adjusting the data and the corresponding measurement accuracies (of space heating demand and fabric thermal performance), this result is considered well within an acceptable design tolerance, hence the result is shown in green.

Heat pump SCOP measurements of heat pumps are slightly worse than designed (6% lower on average) meaning that electricity consumption is slightly higher for the same heat output. Typically, SCOPs of approximately 2.6 are modelled and, for reference, for a property with a heat demand of 4,000 kWh/yr, a 6% reduction in the SCOP (to 2.44) results in approximately 100 kWh/yr increase in electricity consumption which is relatively minor.

Possible causes for this underperformance include (but are not limited to); inefficient operation (i.e. short intervals with high temperature changes), high energy consumption (due to increased internal temperatures), colder than average external temperatures, and sub-optimal setup and commissioning.

On average, the performance of monitored heat pumps is within acceptable design tolerances. However, increasing the SCOP (either via equipment selection, operation, and/or setup and commissioning) is desirable for future projects and so, like other metrics, will continue to be monitored and reported.

Annual PV energy generation is slightly worse than design estimations (7% lower). Typically for Energiesprong projects, archetypal designs are submitted which include PV generation. However, individual PV systems can be affected by local overshading, individual issues with systems (i.e. inverter fault or temporary disconnection of PV services), slight variations in orientation, or other issues.

Hence, it is unfortunately more likely that PV systems underperform than overperform and this reduces the average measured performance of systems. The learning from this result is that individual factors affecting a stock of properties should be assessed at an early stage and incorporated into archetype designs.

It is also worth noting that adjustment for year-to-year solar gain has not been made and so some years PV generation may be higher (on average) than designed. It is possible to assess this in the future as monitoring continues for the duration (10+ years) of an Energiesprong performance guarantee.

[9] Note that the measurement accuracy of the HTC is typically in the region of ±15%.

Annual grid imported electricity cannot be directly compared to design target values as they are not available for all projects.

However, results show that these retrofitted homes are using approximately 73% less energy on average compared to typical UK dwellings (according to Ofgem TDCV figures). Even the home with the highest monitored grid electricity import value (5,565 kWh/yr) is using 43% less total energy than the lowest TDCV figure (9,800 kWh/yr) and 56% less than the local postcode average (12,693 kWh/yr). The benefit of retrofitting homes in the UK to reduce demand on the utility grid is clear.

## 3.2 Detailed performance overview – individual properties (ESUK Specs)

In this section, further data is provided for each of the measured performance characteristics which are included in the Energiesprong UK performance specification (and are therefore considered part of the responsibility of the Solution Provider). For performance characteristics that are outside the control / influence of the Solution Provider (i.e. resident electricity consumption, internal temperature preference etc.) please refer to Section 4.

This detailed presentation of results demonstrates the importance of the Energiesprong monitoring requirements for residents, Housing Providers and Solution Providers alike.

Individual underperformance issues can be investigated further and resolved appropriately, and likewise overperformance can be learnt from and replicated for future schemes. After all, “You can’t manage what you don’t measure” (Peter Drucker, Systems Thinking).

### 3.2.1 Net energy consumption (adjusted)

On average, adjusted net energy consumption[10] was 8% better (lower) than designed, meaning that the properties can export more energy to the grid than they were designed to. The result is equivalent to 1,380 kWh/yr net consumption compared to the typical Energiesprong target of 1,500 kWh/yr. This is a positive finding as it means that Energiesprong homes can contribute more than anticipated to reducing the UK grid carbon emissions.[11]

> You can't manage what you don't measure.
>
> **Peter Drucker**

[10]Adjusted to account only for the designed resident electricity consumption of 2,300 kWh/yr (i.e. consumption above or below this limit is not included in the adjusted net energy consumption results). The calculation of this is simply:

*Adjusted net energy consumption = Measured net energy consumption - Measured resident electricity consumption + 2,300 (kWh/yr)*

[11]See 4.2.4 Resident Electricity Consumption for further details regarding the resident electricity consumption measured in the pilot properties.

One property with very low consumption is demonstrably net zero energy (even without adjustment, see 4.2.5), producing almost twice the energy it uses annually. However, there is a wide range of adjusted net consumption results from the monitored homes, almost evenly spread around the target value (1,500 kWh/yr) ranging from +107% (i.e. consuming double the target value) to -186% (i.e. producing 86% more energy than it consumes).

This suggests that variation in the solar PV generation, fabric thermal performance (and thereby space heating energy demand), heat pump efficiency, and energy use for hot water, between homes contributes significantly to the net energy consumption.

It is also worth noting that this metric aims to exclude occupant factors (such as electrical energy use for appliances, and internal temperature preference) but is based on simple adjustments which may lead to some erroneous data. It is a summary metric, and so analysis of other metrics is more useful to highlight any particular areas of concern for Solution Providers to resolve on individual properties.

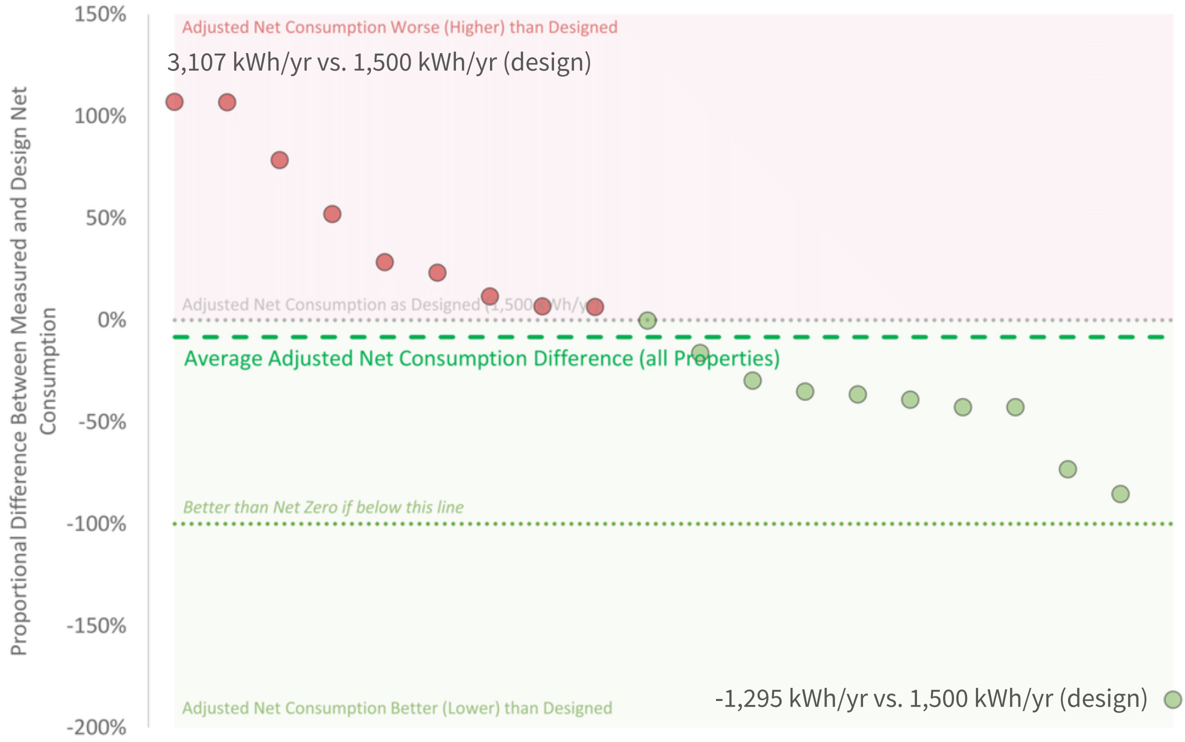



**Figure 5: Adjusted net consumption (using 2,300 kWh/yr vs. design)**

### 3.2.2 Fabric thermal performance, Heat Transfer Coefficient (HTC)

On average, the measured HTC of properties was 4% better (lower) than design. 71% of properties measured had an HTC within design and measurement tolerance. One outlier property had an HTC 48% worse than design and will be reviewed further.[12]

Properties with 15% - 30% underperformance will continue to be monitored, including review of other performance metrics, to identify whether there are any underperformance issues that need resolution.

Properties within +15% of the design value are considered to be within design tolerance and measurement accuracy (which is typically ±15%) and so do not warrant further investigation at this stage.

A performance gap between design and measured HTC can occur for a variety of reasons including:

- Accuracy of modelling inputs including U-values, air permeability, thermal bridges etc
- Material performance in operational environment vs. laboratory test environments (as per manufacturer specifications)
- Consistency and homogeneity of insulation material as built i.e. variations in material thickness not accounted for in design
- Quality of workmanship onsite and ability to install as per design
- Unreported changes to material / product specification in construction
- Unidentified issues with HTC measurement period i.e. windows left open, unusual energy consumption etc.

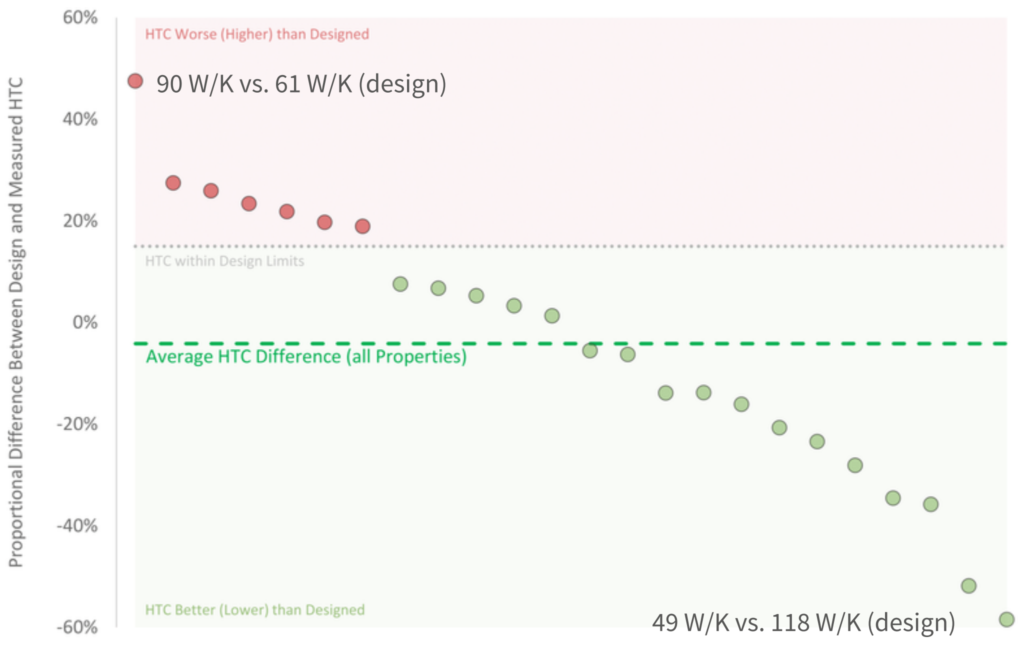



**Figure 6: Measured Heat Transfer Coefficient (HTC) vs. design**

[12]±15% is considered within design tolerance due predominately to the measurement accuracy of SmartHTC.

### 3.2.3 Space heating energy use intensity (EUI), adjusted

On average, the adjusted space heating energy use intensity for all properties is 2% higher (worse) than designed. Based on an Energiesprong design target of < 40 kWh/m²/yr, this equates to 41 kWh/m²/yr.[13] For the properties included in this report, the adjusted space heating energy use intensity was approximately 48 kWh/m²/yr.

55% of properties consume less energy for space heating than designed, but 45% consumed more. A ±5% tolerance is applied to this measurement because of potential errors with adjustment of consumption data to correspond with designed internal temperatures[14] and the overall results are therefore in line with design expectations.

Analysing results from individual properties, a large variation in space heating energy use is identified (from +97% i.e. consumption is twice the design, to -75% i.e. consumption is one quarter the design prediction).

Those properties with consumption >40% above design will be reviewed further to assess the causes for increased consumption and whether any resolution is required. All properties will continue to be monitored and those persistently above the design targets will be investigated further.

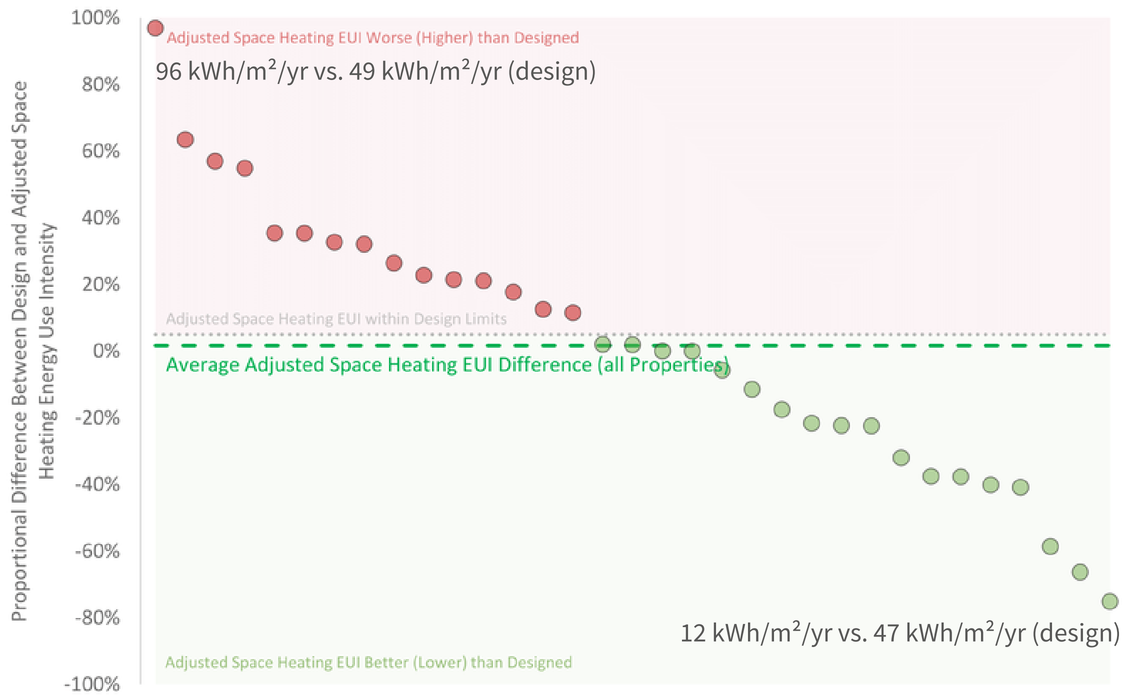



**Figure 7: Temperature adjusted space heating energy use intensity (kWh/m²/yr) vs design**

[13] It should be noted that due to the nature of the pilot projects, the contracted space heating energy consumption was not always <40 kWh/m²/yr. The results presented in this report have always been compared to the agreed target (rather than the overarching Energiesprong target which should apply to non-pilot projects).

[14] In the future, it is proposed that rather than adjusting measured space heating energy consumption data to align with design internal temperatures, the design is more simply remodelled using the measured average internal operating temperatures. For this report, it was not possible to conduct that exercise as Energiesprong do not have access to all of the detailed design calculations (i.e. PHPP models or otherwise).

The causes of a performance gap in space heating energy consumption might include:

- Fabric thermal performance different to design (see 3.2.2)
- Heat pump efficiency (SCOP) different to design (see 3.2.4)
- Excessive use of windows causing overventilation
- Inaccurate heat metering on heat pump space heating output (including if any hot water energy is included in space heating measurements)

### 3.2.4 Heat pump Seasonal Coefficient of Performance (SCOP)

On average, the measured SCOP of heat pumps was 6% worse (lower) than designed and only 18% of installations exceeded their design target.

It was also found that, on average, hot water consumption was significantly lower than the designs allowed for (see 4.2.1) and so the lower SCOP is unlikely due to the balance of space heating and DHW energy.[15]

Possible causes for this underperformance include (but are not limited to):

- inefficient operation (i.e. short intervals with high temperature changes), high energy consumption (due to increased internal temperatures);
- colder than average external temperatures, and;
- sub-optimal setup and commissioning

On average, the performance of monitored heat pumps is within acceptable design tolerances.

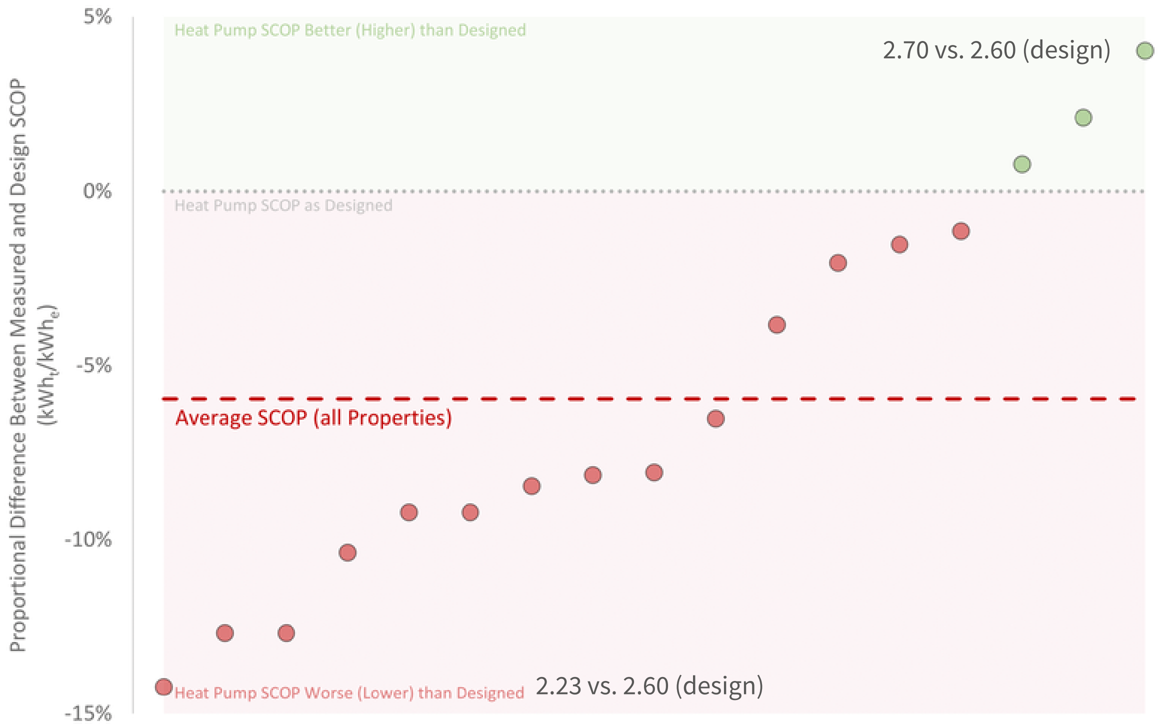



**Figure 8: Heat pump SCOP per property vs. design**

[15]Due to the temperatures required for DHW, the COP of delivering it is (typically) lower than that for space heating and so excessive DHW consumption would be expected to reduce the overall SCOP of a heat pump.

However, increasing the SCOP (either via equipment selection, operation, and/or setup and commissioning) is desirable for future projects and so, like other metrics, will continue to be monitored and reported. These findings are communicated to Solution Providers during the design process to ensure that performance guarantees are based on realistic SCOPs.

### 3.2.5 Solar PV energy generation

On average, the annual energy generated from solar PV systems is 7% below the design target (i.e. there is less available PV energy than designed). Only 10% of properties generated > 110% of the Solar PV energy compared to design, whereas 37% generated < 90% of the design output.

Individual PV systems can be affected by local overshading, individual issues with systems (i.e. inverter fault or temporary disconnection of PV services), slight variations in orientation, or other issues.

Hence, it is (unfortunately) intuitive that PV systems are more likely to underperform than overperform and this reduces the average measured performance of systems.

The learning from this result is that individual factors affecting a stock of properties should be assessed at an early stage and incorporated into archetype designs by Solution Providers.

Equally, methods to improve the real-world output of solar PV systems irrespective of unforeseen local conditions (i.e. MPPT power optimisers) should be investigated by Solution Providers. Properties with < 90% of the target PV output will be reviewed as a priority to identify any resolutions that can be made and further lessons that can be learnt from the systems.[16]

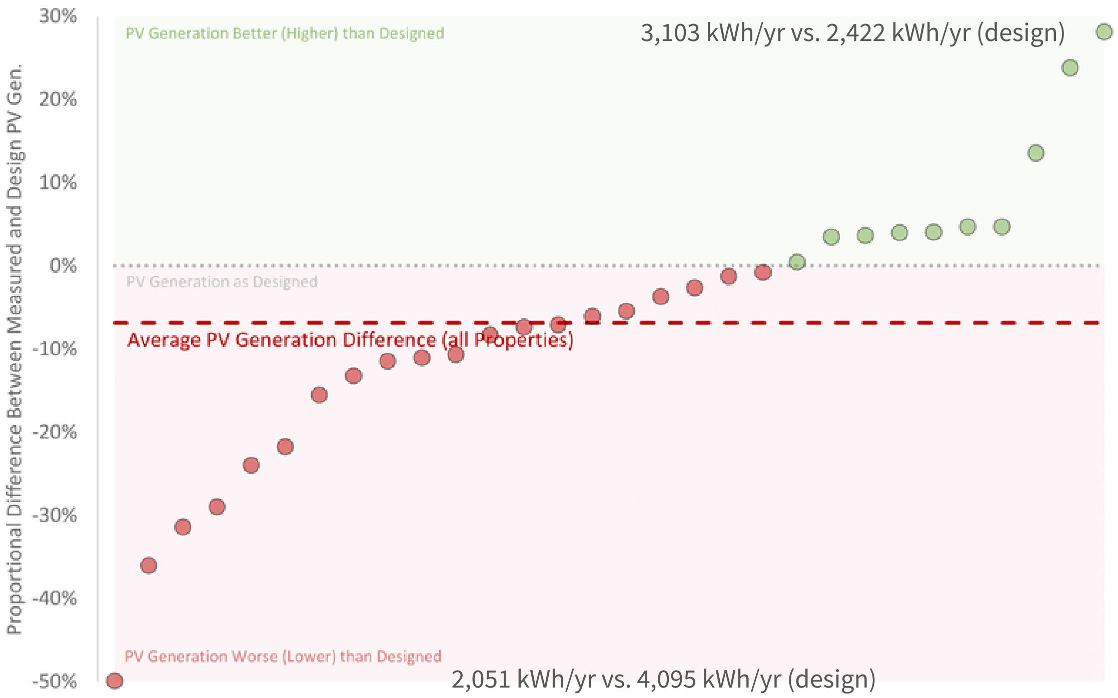



**Figure 9: PV generation vs design**

[16]Note that these results have not been normalised for the specific period monitored and therefore it is not possible to review whether some of this underperformance is due to lower annual levels of solar irradiation (which may vary by ±10%).

### 3.2.6 Annual grid imported electricity

The Energiesprong financial model incorporates some capital cost recovery over a 30-year period via charging a "comfort charge" to the resident. This is achieved by reducing the operational energy costs (via retrofit), and the difference between pre-retrofit and post-retrofit running costs is considered the maximum comfort charge that could be applied to a property. Thereby, residents will pay the same or less than they did previously for a warmer, more comfortable home.

The annual grid electricity import is therefore an important factor to measure as it determines the annual running costs of the home.[17] However, for these initial projects analysed, it was not possible to ascertain the design value for grid import, and so only the absolute consumption values are presented below.

On average, the annual grid import electricity post-retrofit was 3,629 kWh/yr, with a significant range from 844 kWh/yr to 5,565 kWh/yr. For reference, compared to Typical Domestic Consumption Values (TDCV) as published by Ofgem[18], this represents an average energy saving of approximately 76%, a significant reduction in total energy demand.

This reduction is a consequence of both the improved thermal performance of the retrofitted homes (better insulation, improved airtightness etc.), the efficiency of heat pump technology used to supply the heating and hot water demand, and the self-consumption of energy generated from PV panels. Even the home with the highest monitored grid electricity import value is using 43% less total energy than the lowest TDCV figure (9,800 kWh/yr).

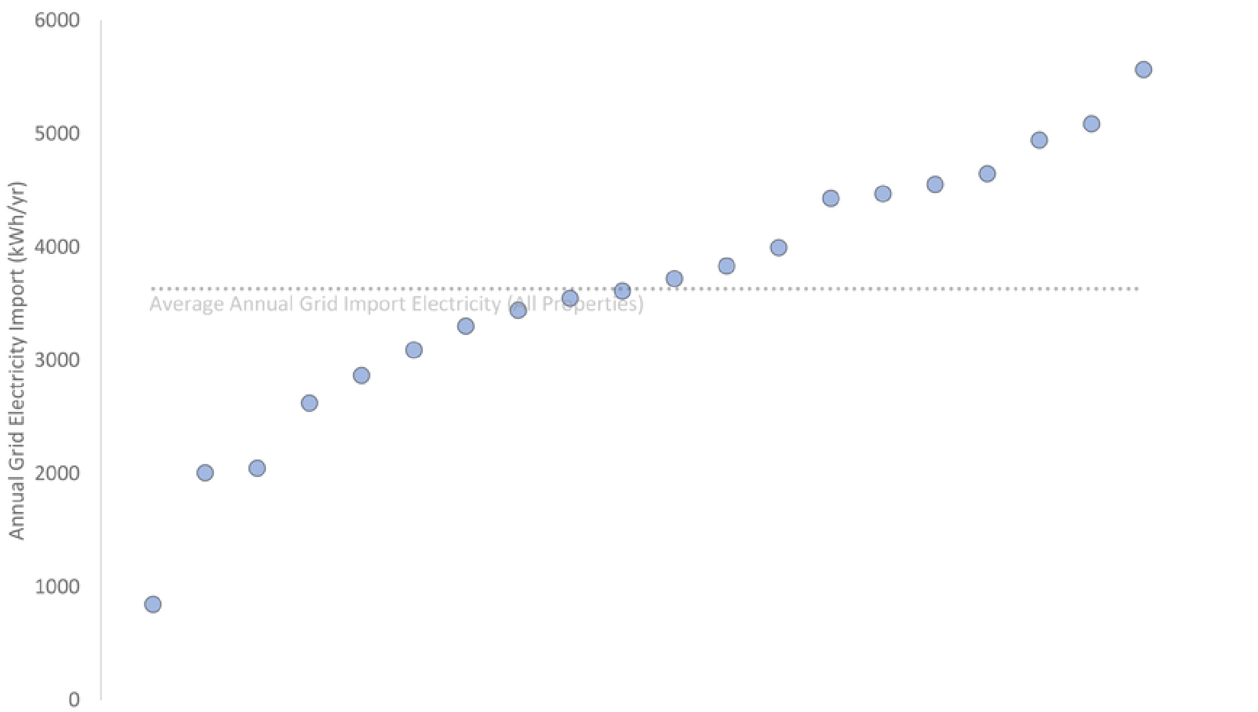



**Figure 10: Annual grid import electricity (kWh/yr)**

[17]Note that annual grid import is not equal to net energy consumption as it makes no account of exported energy from the PV system.

[18]https://www.ofgem.gov.uk/sites/default/files/docs/2020/01/tdcvs_2020_decision_letter_0.pdf

| | TDCV gas | TDCV elec | Total | ESUK total | Saving |
|---|---|---|---|---|---|
| Low | 8,000 | 1,800 | 9,800 | 844 | 91% |
| Medium | 12,000 | 2,900 | 14,900 | 3,629 | 76% |
| High | 17,00 | 4,300 | 21,300 | 5,565 | 74% |

**Figure 11: Typical Domestic Consumption Values in kWh (Ofgem, UK) compared to ESUK properties**

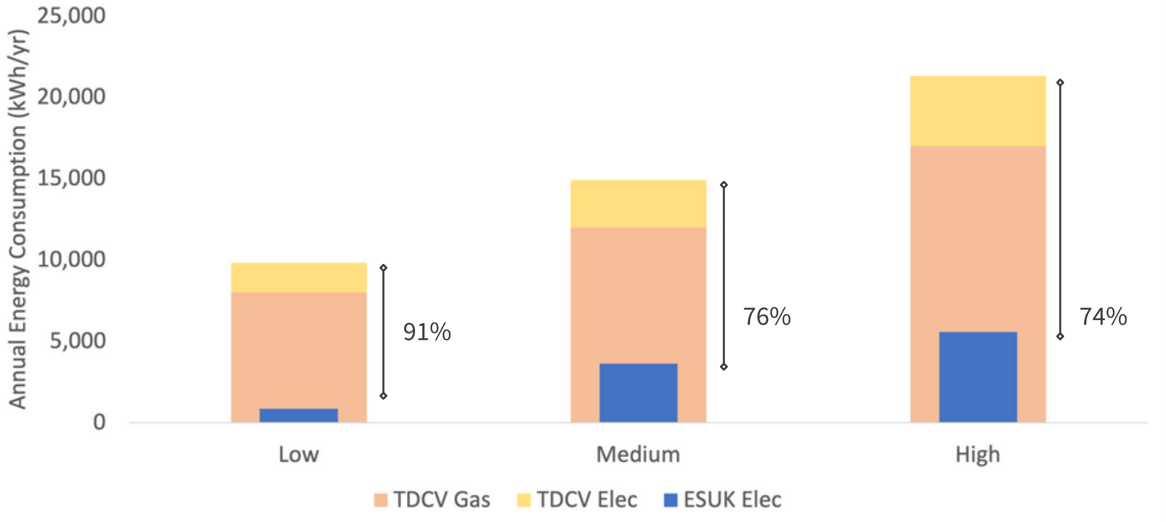



**Figure 12: TDCV vs ESUK annual energy consumption**

BEIS also provides postcode level electricity and gas consumption data[19] which has been used to compare the grid energy consumption of the retrofitted properties to the postcode average for the area. The results, shown in Figure 13 overleaf, show the comparison for four sites where grid import data and postcode-level consumption data are available.

[19]https://www.gov.uk/government/publications/postcode-level-domestic-gas-and-electricity-consumption-about-the-data/postcode-level-domestic-gas-and-electricity-consumption-notes

On average, the retrofitted properties are consuming 73% less energy from the grid than the postcode average (very similar to the results from the high-level TDCV analysis). Even the highest consuming retrofitted property (as shown by the error bars on the ESUK data) is consuming 47% less energy than the equivalent postcode average.

Additionally, the properties are contributing electrical energy to the national grid via export of excess generated solar PV.

The benefit of retrofitting homes in the UK to reduce demand on the utility grid is clear.

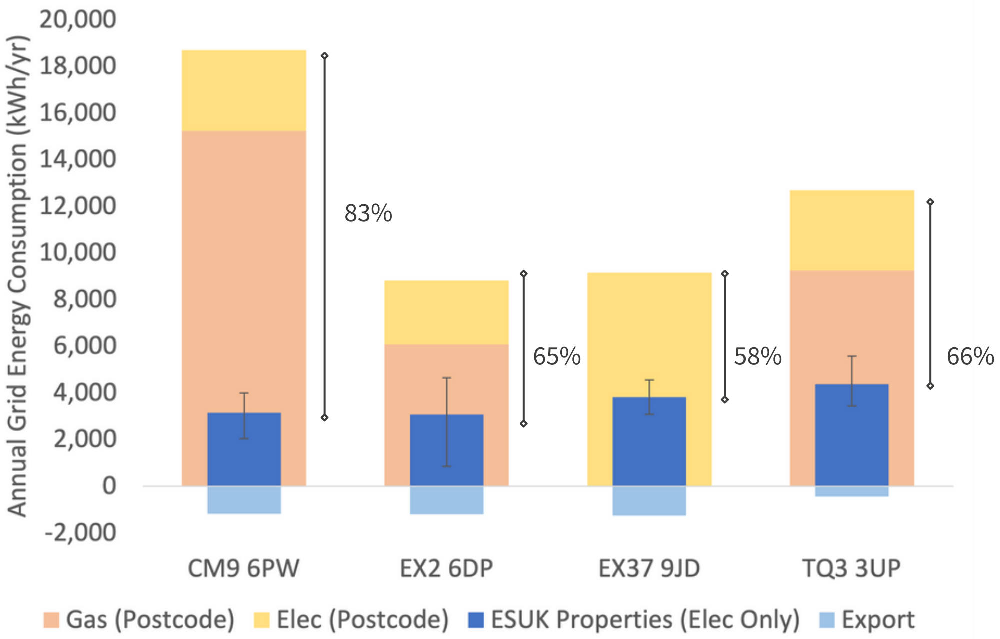



**Figure 13: Annual Grid Energy Consumption – Energiesprong Properties vs. Postcode Average**

# 4 Performance Overview Pt II

## Metrics not directly assured by the Performance Guarantee

In this section, the performance characteristics which do not form a direct part of the Energiesprong UK performance guarantee, are presented. The section starts with a high-level summary of all projects collectively (via average performance for each metric) and subsequently presents the performance measurements from each sample property for a more detailed analysis (demonstrating any variability across schemes and properties).

The five key metrics reported in this section include:

**Domestic hot water consumption, DHW (kWh/yr)**

The Energiesprong specification requires Solution Providers to account for either 140 litres/day or 64+26N (litres/day) domestic hot water consumption, where N is the number of occupants calculated according to SAP protocols.[20] This forms part of the comfort plan for the residents. The difference between the hot water allowance and actual consumption is reported and analysed.

**Average internal winter temperature (°C)**

The Energiesprong comfort plan allows for internal temperatures during the heating season of 18°C in bedrooms and 21°C in living and other rooms during heating periods (as defined by SAP).[21] The actual internal temperatures are compared to the design allowance to analyse how the retrofitted homes are operated in reality.

**Space heating energy use intensity, unadjusted (kWh/m²/yr)**

Energy consumption for space heating is recorded as part of the Energiesprong monitoring requirements and the results are compared to the design target values. The Energiesprong specification requires < 40 kWh/m²/yr but the specific value agreed is different per project accounting for constraints and client requirements.

[20]See Table 1b, SAP 9.92.
[21]Weekdays: 07:00 – 09:00 and 18:00 – 23:00 [7 hours], Weekends: 07:00 – 23:00 [16 hours].

The measured values presented in this section are unadjusted and therefore do not account for any difference in internal temperatures compared to the design values (i.e. if the resident heats the property to a higher temperature or for longer than the design accounts for, the space heating energy consumption will inherently be higher than the design target).

**Resident electricity consumption (kWh/yr)**

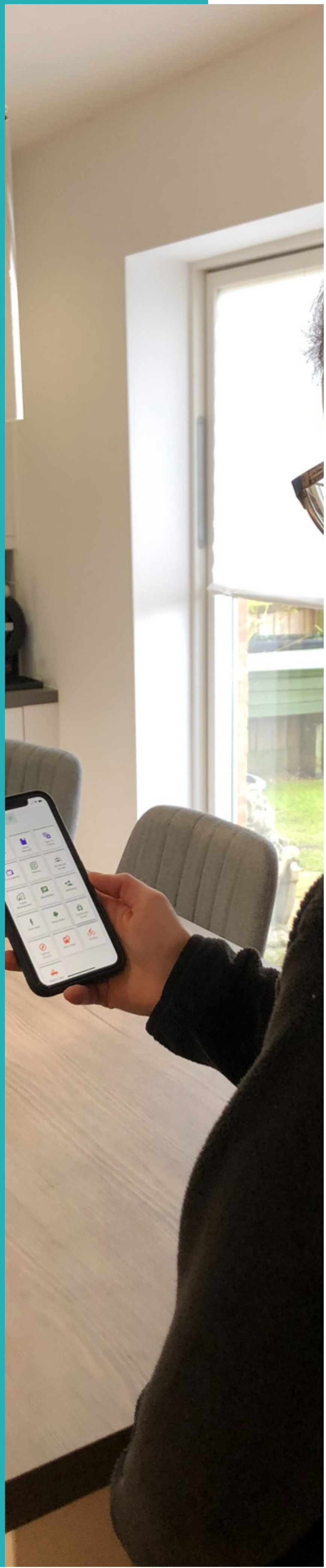
The Energiesprong comfort plan includes an allowance of 2,300 kWh/yr for resident electricity consumption (i.e. for cooking, lighting, appliances, etc.). The actual energy consumption is monitored as part of the Energiesprong monitoring requirements, and so the measured values are compared to the comfort plan allowance in this section.

**Net energy consumption, unadjusted (kWh/yr)**

The Energiesprong specification targets a net energy consumption[22] of $< 1{,}500$ kWh/yr. This helps to minimise the resident energy costs so a comfort plan can be charged, and to reduce the impact of the retrofitted homes on the power grid. Annual import and export of energy consumption are monitored in retrofitted homes, and so unadjusted net energy consumption is reported and compared to the design target.

However, this value is unadjusted, and therefore does not account for any difference in resident energy consumption, hot water consumption, and internal temperatures, compared to the comfort plan allowances and design targets.

[22]Imported electricity minus exported electricity.



## 4.1 General performance overview all properties (Non-ESUK Specs)

The graph below shows the average scheme-wide performance measurements from these key metrics. Each metric is compared proportionally to the target/design value for each individual property. Comparisons are normalised so that performance better than design is shown in the top half of the graph and performance worse than design in the bottom half.[23]

Domestic hot water consumption is significantly lower (30% less) on average than the comfort plan allowance; residents in these monitored homes typically use considerably less hot water than has been accounted for in design. The comfort plan hot water allowance is under review because of this finding to ensure Solution Providers can appropriately innovate and design energy systems to best meet the needs of the residents.

However, the monitoring systems are also under review to ensure that any backup electric immersion energy consumption is metered as part of the energy services rather than resident consumption.

Internal winter temperature in the retrofitted homes is significantly higher (10%) than the Energiesprong specification values (this is equivalent to approximately 2°C increase on design values). Residents appear to prefer warmer temperatures within their homes than SAP averages suggest. There is a direct impact on space heating energy consumption as warmer temperatures require more energy to achieve.

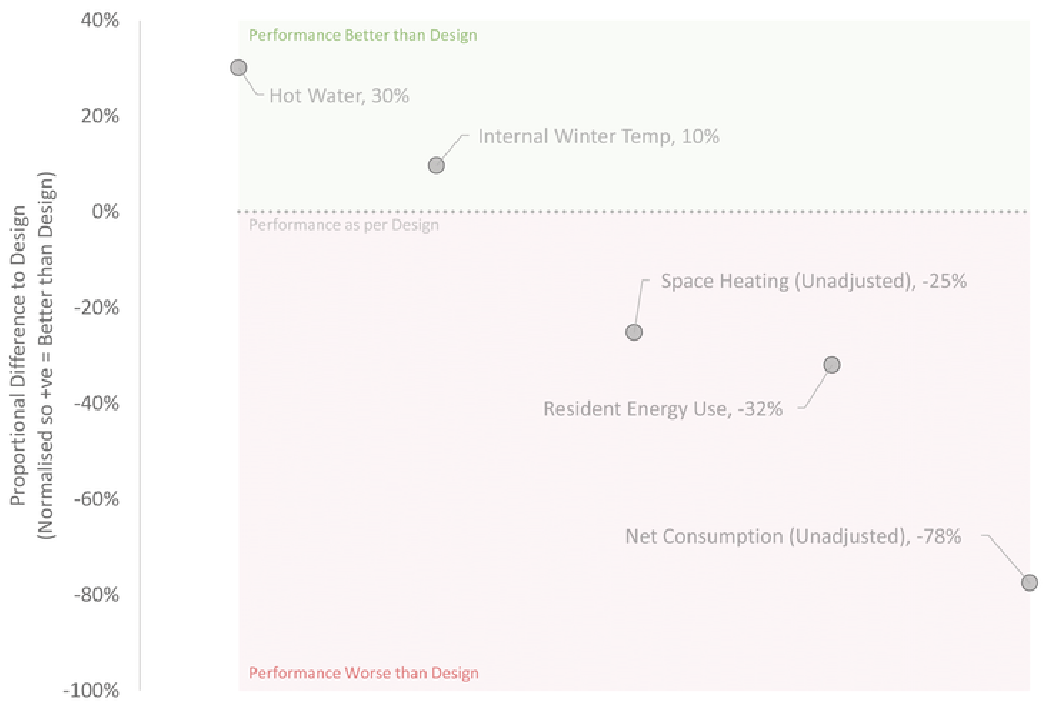



**Figure 14: Summary performance statistics - ESUK pilot projects (metrics not directly assured by the performance guarantee)**

[23]Note that for internal temperature, a winter value above the design value is considered a positive result (i.e. homes are warmer than expected in the winter). For domestic hot water, consumption below the design value is considered a positive result (i.e. hot water consumption is less than expected)

Space heating energy use (unadjusted) is significantly higher (25%) on average than design values. Based on a design target of 40 kWh/m$^2$/yr, this would equate to 50 kWh/m$^2$/yr in operation. However, when this value is adjusted for actual internal temperatures (which are higher than designed on average), energy consumption for space heating is in line with expectations. The results analysed here are the unadjusted values, and so do not account for any difference in internal temperatures compared to design.

Resident energy use is on average significantly higher (32%) than the Energiesprong comfort plan allowance of 2,300 kWh/yr.[24] Residents are typically using considerably more energy for their own purposes (i.e. appliances, cooking, lighting etc.) than the comfort plan allowance accounts for.

It is not possible to ascertain the exact reasons for higher than anticipated consumption in these homes, but it may be a consequence of:

- having reduced operating costs for space heating and hot water
- a relaxation of energy efficient behaviours due to living in an energy efficient home, ownership of inefficient appliances (i.e. fridges, freezers, washing machines etc.)
- use of direct electric heating (for space heating and/or hot water)
- and/or inclusion of backup electric immersion elements on the resident energy meter rather than the energy services meter(s).

Where pre-retrofit energy consumption data is available (in future projects), it may be possible to analyse any change in resident electricity consumption because of the retrofit. Additionally, the performance specification allowance is under review because of this finding.

Net energy consumption (unadjusted) is significantly higher (worse) than designed with homes, on average, importing 78% more energy (net) than designed. Noting that resident electricity consumption and average internal temperatures are significantly higher than designed, when adjusted the net consumption value is 8% better (lower) than designed. The unadjusted net energy consumption data is analysed here for information only.

The retrofitted homes are typically 2°C warmer than the comfort plan accounts for

+2°C

[24]Note that for some building types (i.e. small flats) this allowance may be varied in agreement with the client and Solution Provider. 2,300 kWh/yr is the typical comfort plan allowance value used in Energiesprong contracts

## 4.2 Detailed performance overview – individual properties (Non-ESUK specs)

In this section, further data is provided for each of the measured performance characteristics which are related to the Energiesprong UK specification but are not considered a direct part of the responsibility of the Solution Provider. For performance characteristics that are directly within the control/influence of the Solution Provider (i.e. fabric thermal performance, heat pump SCOP, etc.) please refer to Section 3.

This detailed presentation of results demonstrates the importance of the Energiesprong monitoring requirements for residents, Housing Providers and Solution Providers alike. The performance factors presented give insight into the actual operation of retrofitted homes and tenant behaviours. Results can be used for a multitude of reasons, including (but not limited to):

- Identifying occupant factors which could be incorporated into future design solutions
- Ascertaining the absolute performance of the retrofitted homes, beyond of specification requirements and comfort plan allowance(s)
- Modifying the design and installation of metering and monitoring systems to enable accurate accounting of individual end uses.

### 4.2.1 Domestic hot water (DHW) consumption

On average, domestic hot water consumption was found to be 30% lower than the comfort plan allowance. The ESUK specification requires Solution Providers to model DHW consumption either based on a fixed 140 litres/day allowance, or via a modified SAP calculation of 62+26N (litres/day), where N is the number of occupants calculated according to SAP protocols. This equates to a comfort plan allowance of approximately 133 litres/day for these pilot properties, compared to an average monitored consumption of 88 litres/day.

86% of the properties analysed used less DHW than design models allowed for. It is worth noting that there was also a large range of over/under-consumption, from 45% more to 75% less DHW consumption.

The impact of reducing the DHW allowance in the Energiesprong specification will be investigated because of these findings, as over specifying DHW may lead to a misallocation of capital and innovation.

Conversely (and as noted in 4.2.4 Resident electricity consumption and 4.2.5 Net energy consumption, unadjusted), energy use for backup electric immersion systems should always be metered by the Solution Provider as part of the energy services rather than resident electricity consumption, as instances were noted in the pilot projects where immersions were operating but consumption was logged as resident consumption.

If all the excess resident electricity consumption was allocated to DHW production (via electric immersion), then the average DHW and resident electricity consumption would both be in line with the ESUK targets. However, it cannot be determined if this is an accurate assumption for the pilot projects and so it is highlighted for information purposes only (see 4.2.4 Resident electricity consumption for further detail).

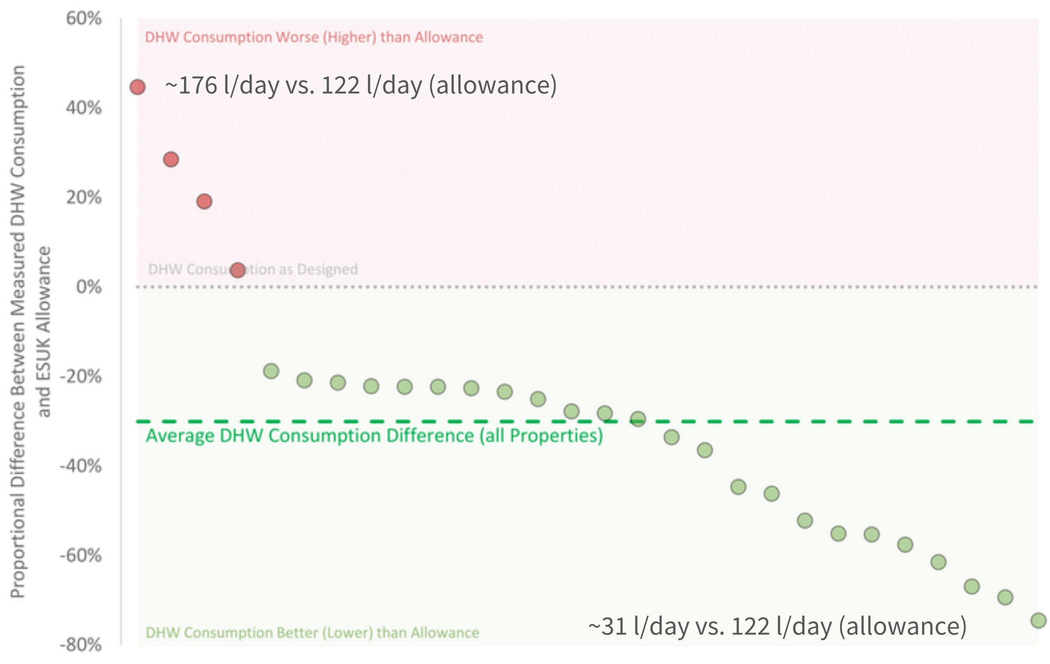



**Figure 15: DHW consumption vs ESUK allowance**

### 4.2.2 Average internal winter temperature

On average, the internal winter[25] temperature in monitored properties was 1.9°C higher than designed. The Energiesprong specification requires temperatures of 18°C (in bedrooms) and 21°C (in all other rooms) to be maintained during standard SAP heating periods.[26]

While this does not result in a fixed internal temperature across all properties (due to the nature of their individual thermal performance), it typically equates to an average internal winter temperature of between 17°C and 20°C.

Many Solution Providers use PHPP modelling software which typically uses a fixed 20°C internal temperature throughout the heating season (unless it is adjusted using the internal temperature plugin).[27]

Average internal winter temperature varies significantly between the monitored properties, from 2.6°C below to 5.9°C above the design target.

77% of the properties are operating warmer than the design value and only 23% are colder than the design. It cannot be determined from this data whether the increased temperatures are a result of occupant preference and/or system operation (and insulation performance).

Energiesprong UK is now using an occupant surveying method (which complies with the requirements of BS40101:2022 and PAS2035:2019) which will enable a deeper insight into occupant factors to be included in future performance reporting.

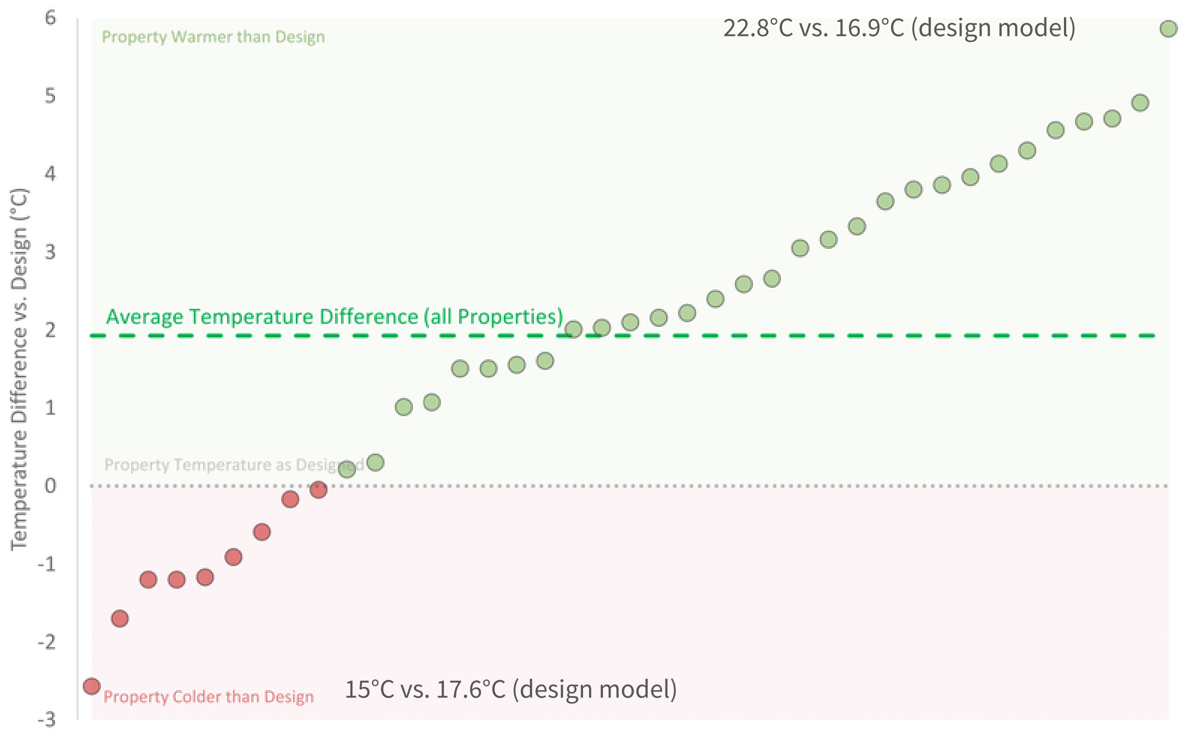



**Figure 16: Measured average internal temperature difference vs. design**

[25]Defined between October and March (typically considered the UK heating period).
[26]Weekdays: 07:00 – 09:00 and 18:00 – 23:00 [7 hours], Weekends: 07:00 – 23:00 [16 hours].
[27]Where a fixed temperature was used in any PHPP design, this value was used to compare actual and design temperatures.

**4.2.3 Space heating energy use intensity, unadjusted (EUI)**

On average, the unadjusted space heating energy use intensity was 25% higher (worse) than design values.

However, when values are adjusted to account for differences in the designed and measured internal temperatures, this value is only 2% lower on average than the target value (see 3.2.3).

High internal temperatures (compared to the comfort plan allowance) are leading to increased space heating energy consumption.

It is perfectly acceptable for residents to heat their properties warmer than the performance specification and it is accounted for in the Energiesprong performance guarantee.

However, in the future if an issue with space heating energy consumption is raised, rather than adjusting the measured consumption (as in this report), Solution Providers will be required adjust the design model calculations by inputting the measured internal temperatures.

This will provide a more reliable comparison of design expectations and measured consumption.[28]

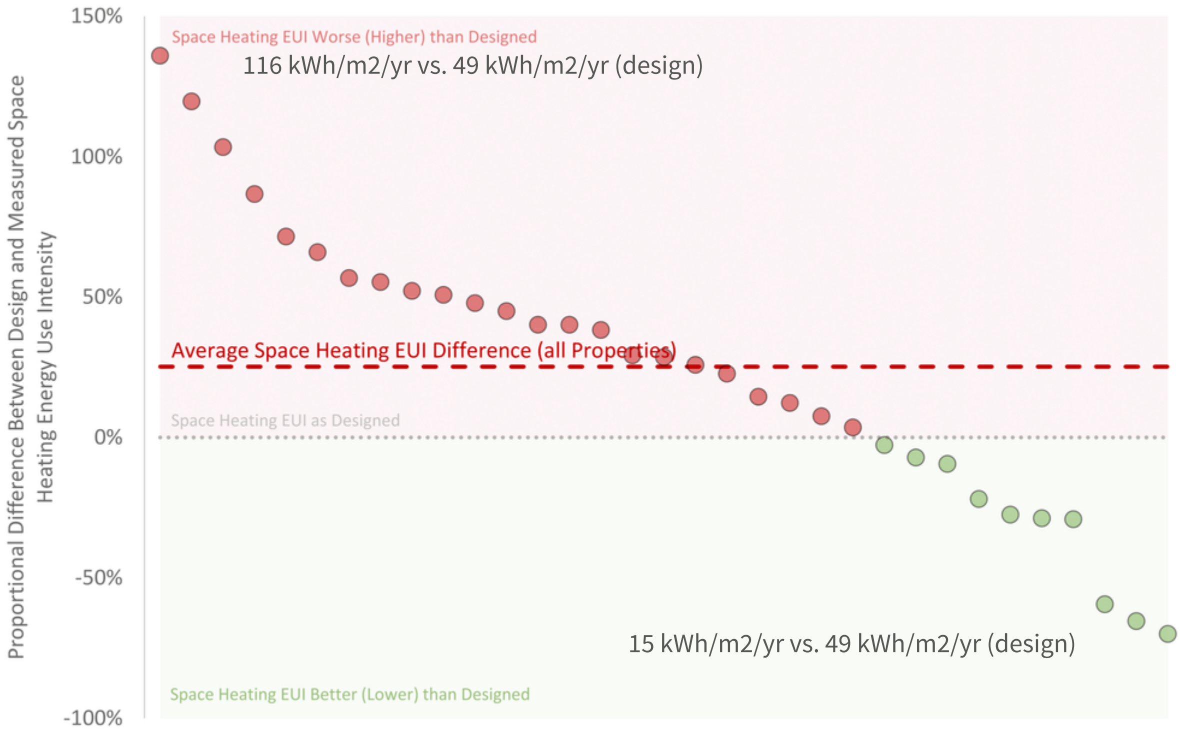



**Figure 17: Measured space heating energy use intensity (kWh/m²/yr) vs. design**

[28]It was not possible to adjust the design models for this performance review as the full design models are not available for all these initial projects.

There is a large variation in measured space heating energy consumption compared to design across the projects, ranging from 136% more energy use to 70% less. Note that these absolute values are not used for any underperformance investigation as temperature adjustment is required as it is a key factor determining space heating energy consumption.

It is also useful to refer to the annual grid import results presented in 3.2.6, which showed that, on average, the retrofitted properties are consuming 73% less energy from the grid than other dwellings in the postcode area, and the minimum saving is 47% (based on the property with the energy consumption closest to the postcode average).

The combination of efficient space heating technology (heat pumps), solar PV energy generation, and energy storage technologies (both PV hot water diverters and batteries), helps to reduce the impact of overconsumption when it does occur.

**4.2.4 Resident electricity consumption**

On average, resident electricity consumption is 32% higher than the Energiesprong comfort plan allowance (3,036 kWh/yr vs. 2,300 kWh/yr). There is also a large range of consumption, from over double the allowance (113% higher) to less than a quarter of the allowance (78% lower).

Resident electricity consumption is not constrained by the Energiesprong comfort plan or performance guarantee and so residents are able to consume electricity however they choose.

High consumption may be a consequence of energy saving made on space heating and hot water (and contribution from solar PV generation) and it may vary year on year as the cost of energy changes and residents grow accustomed to the performance and costs of their retrofitted home.

It is estimated that only approximately 1 kWp additional PV (per property) would be required to offset the average increase in tenant electricity consumption that was measured across the pilot projects.

With improvements to PV technology (i.e. significantly increased outputs from individual panels), this may be feasible to achieve on future projects without increasing the physical system size. This is important where the whole roof has been used already for PV.

It is always recommended and encouraged that Solution Providers maximise the size of PV array installed on any project, regardless of the specific project targets, as it is generally attractive both economically and in terms of meeting the performance specification.

It may also be due to inclusion of electric immersions (for hot water) on the tenant electricity meter, where this should be on the “energy services” meter and this has been communicated with Solution Providers for future projects.[29] It may also require guidance and advice to ensure that residents are not overconsuming under the assumption that all their energy is being provided by solar panels and so is zero cost.

Resident engagement and expectations management is a critical element in the success of any retrofit project and should be improved upon wherever possible. The inclusion of a detailed occupant survey (meeting the requirements of BS40101:2022 and PAS2035:2019) in all forthcoming ESUK projects is the first step to gathering more insight and learnings from projects and thereby engaging better with the residents.

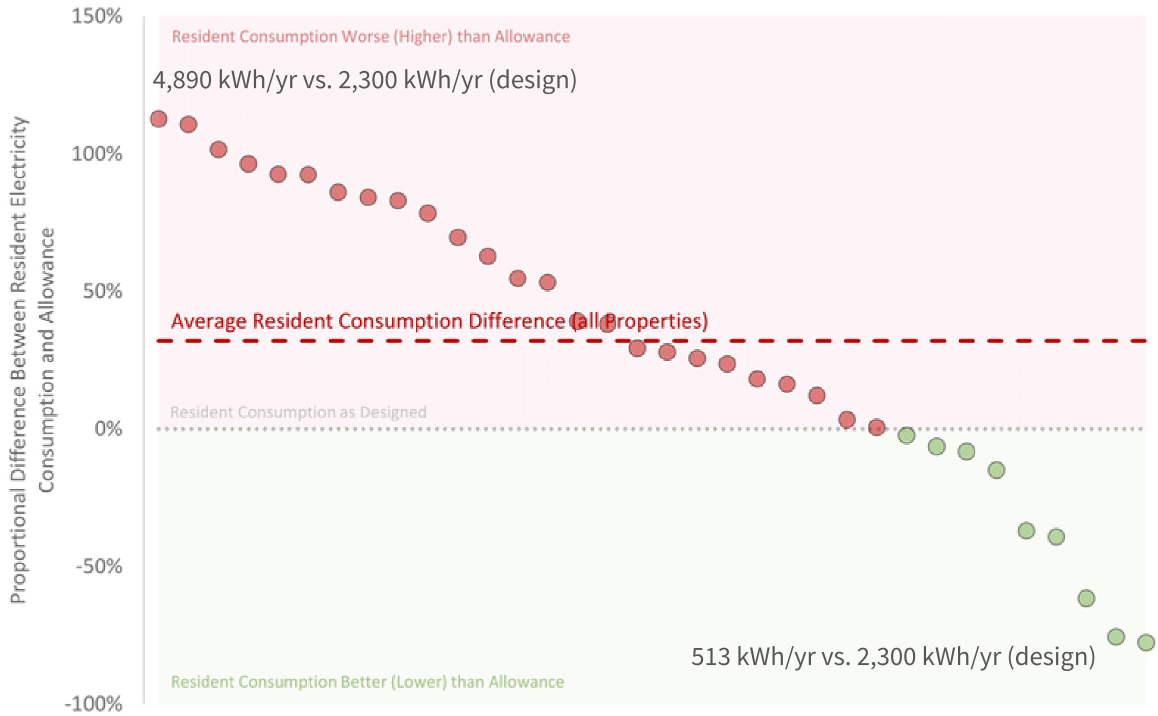



**Figure 18: Resident electricity consumption vs. ESUK allowance**

[29]The measured average overconsumption of resident electricity in the pilot projects was 736 kWh/yr. If this was all used as DHW, it would correspond to approximately 38 litres/day additional DHW usage. The measured under-consumption of DHW in the pilot projects was approximately 40 litres/day (based on the average target of 133 litres/day). It is therefore possible that the electric immersion metering issue accounts for a significant proportion (if not all) of the reported resident electricity over-consumption. Further metering, monitoring and analysis would be required to determine this for the pilot projects which is not feasible and so this additional analysis is provided for information only.

#### 4.2.5 Net energy consumption, unadjusted

On average, unadjusted net energy consumption (i.e. including full resident electricity consumption and not accounting for differences in design and actual internal temperatures) is 78% higher than designed.

There is a large range of net consumption values, from approximately 270% above target (4,890 vs 2,300 kWh/yr) to 164% below (513 vs. 2,300 kWh/yr). When adjusted (as reviewed in 3.2.1) net consumption is, on average, 8% better (lower) than designed. Intuitively, high resident energy consumption and internal temperature preferences directly increase the measured net energy consumption.

However, the performance of PV systems, efficiency of the heating system (SCOP), and thermal performance of the fabric also contribute to variation in measured net energy consumption and improving all these factors will help to minimise net energy consumption regardless of resident factors.

As presented in 3.2.6 Annual Grid Imported Electricity, regardless of the differences in resident electricity consumption and internal operating temperatures (compared to design), the properties are at worst consuming approximately 50% the total energy of the local postcode average properties and on average are consuming 73% less total energy. This is an excellent result as it shows the potential for deep retrofit to drastically reduce the energy impact of housing in the UK.

Furthermore, the potential issue of backup immersions being metered on resident supplies rather than the energy services meters will be resolved in future projects either by additional metering or reallocation of circuits, as this may be negatively impacting the operation of the properties and in turn the net energy consumption (for instance, if electric immersions are operating rather than heat pumps to deliver DHW).

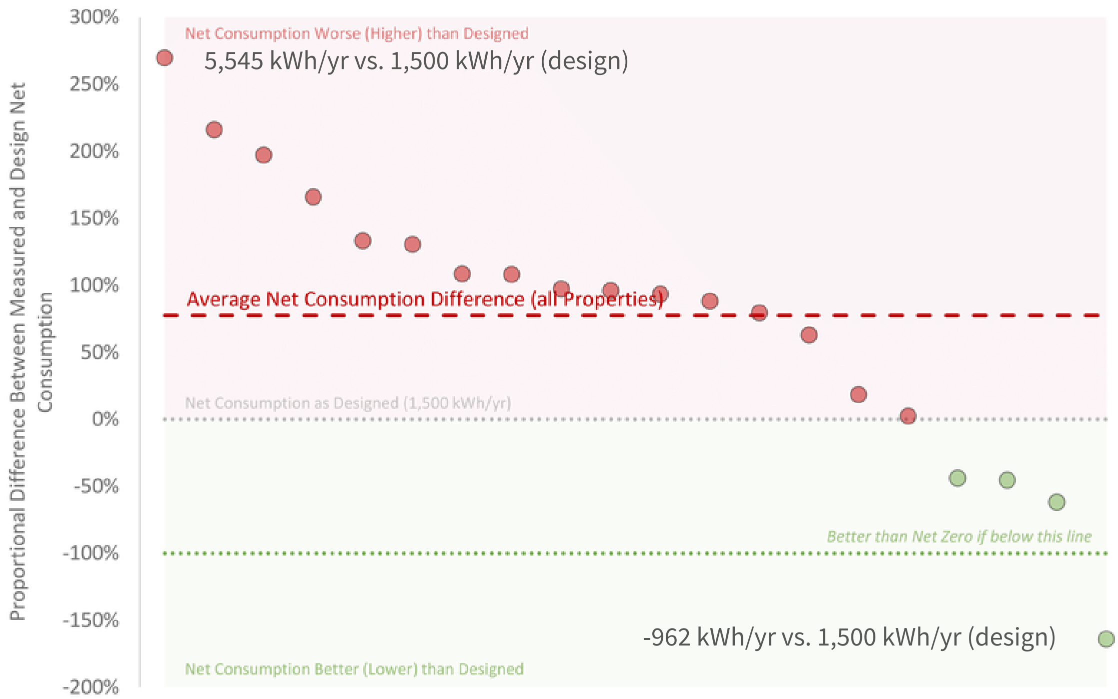



**Figure 19: Measured net consumption vs. design**

# 5 Conclusions

The results from the high-level and detailed performance review can be summarised as follows:

On average, the retrofitted homes are performing well thermally. 71% of properties had a measured fabric thermal performance within +15% of the design value. On average, annual space heating energy consumption (when adjusted for internal temperatures) is also in line with design targets, only 2% below the design value on average

PV systems and heat pumps are both underperforming slightly on average (but within 10% of design values). Therefore:

- Incorporating realistic Seasonal Coefficients of Performance (SCOP) into design models is essential to uphold the performance guarantee element of an Energiesprong retrofit (performance data is fed back to Solution Providers)
- Improved installation, commissioning, control and user feedback regarding use and performance may be beneficial to improve the operational efficiency of heat pump systems. Conversely, learning about how heat pumps are used is important to develop optimal solutions in the future
- Accurate modelling of PV systems across the retrofit stock is important to minimise the impact of local variations between properties (i.e. orientation, overshading etc.)

Internal temperatures during winter are, on average, almost 2°C higher than design values suggesting that residents prefer significantly warmer temperatures than modelled. There is an inherent energy impact of higher temperatures, but the impact of this increased demand is minimised due to the efficiency of the heating system (heat pumps), overall thermal efficiency of the properties, and contribution of energy from solar PV systems.

For instance, compared to Typical Domestic Consumption Values (TDCV) and local postcode area energy consumption data, the retrofitted properties are using over 70% less energy per year on average (as per graph below for 4 sites where this data was available). Additionally, they are now contributing electrical energy to the national grid via PV export. The combination of whole-house insulation, solar PV, and efficient heating systems leads to drastically reduced grid energy demand.

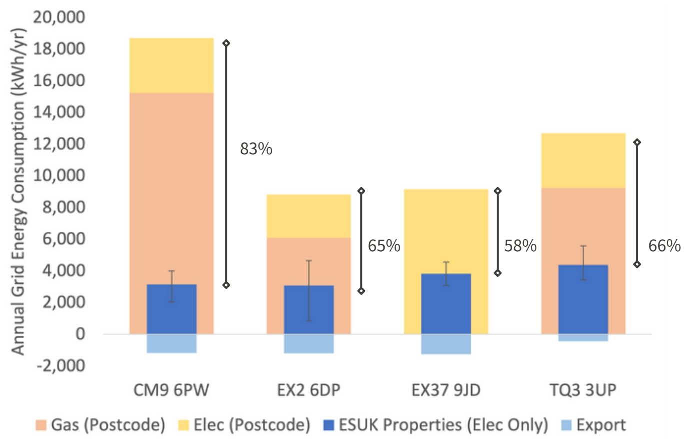



**Figure 20: Comparing ESUK properties with local postcode area energy consumption data**

Hot water consumption is significantly lower (30%) than the Energiesprong performance guarantee allows for. However, resident electricity consumption (i.e. for appliances, cooking and lighting) is significantly higher (>30%) than the performance guarantee allows.

In the pilot projects, backup electric immersion heaters (for DHW) were regularly metered as part of the resident energy usage rather than the energy services and so it is possible that excess resident consumption was entirely due to unaccounted for DHW production (and both metrics are performing in line with the specification on average).

Regardless, the comfort plan does not constrain how much energy or hot water residents can use, but it is useful to identify these differences so that the comfort plan can be iteratively adjusted to provide residents with what they require. It is estimated that approximately 1 kWp additional PV (per property) would be required to offset the average increase in tenant electricity consumption.

With improvements to PV technology (i.e. significantly increased outputs from individual panels), this may be feasible to achieve on future projects without increasing the physical system size (which is important where the whole roof has been used already for PV). It is always recommended and encouraged that Solution Providers maximise the size of PV array installed on any project, regardless of the specific project targets, as it is generally attractive both economically and in terms of meeting the performance specification.

Measured net energy consumption of the properties is, on average, 78% lower (worse) than design. However, when data is adjusted for internal temperatures and tenant electricity consumption, it is 8% better.

Tenant electricity consumption and internal temperature preferences are contributing significantly to this difference which complicates the desire for net zero housing in the UK. This finding suggests that energy efficiency retrofit can lead to increased consumption and so there may be increased requirements for improved handover, induction, feedback, education, and guidance in the future.

There is a wide variation between maximum and minimum consumption (or performance) of individual properties across all metrics. For many metrics (i.e. internal temperature, resident energy consumption, hot water consumption etc.), this is a common finding simply due to differences in resident preferences and use of homes and services.

For metrics that are the responsibility of the Solution Providers during the guarantee period (i.e. fabric thermal performance, PV generation, heat pump SCOP etc.), properties with low performance can be readily identified for further investigation and resolution. Likewise, properties with excellent performance can be assessed to replicate factors contributing to success.

Further work is required to understand resident comfort and satisfaction with the installed solutions to gain further insight into performance successes and failures. This will also provide valuable information on the need for better resident focussed elements of the process and system (i.e. handover, induction, feedback, controls etc.) to minimise energy waste.

A detailed occupant satisfaction survey, which complies with the requirements of BS40101:2022 on Building Performance Evaluation and PAS2035:2035 on Retrofit Coordination, is now being implemented across all schemes (including retrospective schemes where possible).

Data quality from monitoring systems is occasionally unreliable and reporting of performance metrics can be misinterpreted by the Solution Providers. In response to these findings, Energiesprong UK has developed pro-formas and additional guidance for monitoring systems and reporting performance data which will be applied to future projects.

Performance monitoring is essential to learn, develop, improve, and consistently achieve/exceed targets now and in future projects. It provides:

- Insight into the performance of individual elements of the homes compared to design targets
- Vital feedback to Solution Providers to significantly reduce risks associated with implementing the performance guarantee now and in the future
- Information for clients and funders to demonstrate return on investments
- Data for residents and Housing Providers in the case of an underperformance charge (i.e. where the Solution Provider hasn’t met their contractual obligations).

# About Energiesprong UK

Energiesprong UK is a non-profit organisation that's working to create the market conditions needed to unlock whole house retrofit – from aggregating demand and offering technical advice to supporting the supply chain and championing financing and policy change.

We're using the social housing sector as the launchpad for the revolutionary Energiesprong retrofit model, with a view to later scale to the private homeowner market. With 165+ pilot homes already delivered, there's a ~1,500 home pipeline in place.

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