Summary Report

Name of sponsoring supplier	Innovator / manufacturer	Name of demonstration action / product
British Gas	Energiesprong UK	Energiesprong

Description of measure

Energiesprong is a Whole-House Retrofit (WHR) model that aims to deliver net-zero energy, warm, affordable to heat and comfortable homes. The model integrates low-carbon technologies including heat-pumps, a super-insulated wrap system including new windows, doors and roof, solar PV, and energy storage. Gas meters and gas supplies are removed with a shift to electric heating. Where gas cookers are used pre-retrofit, these also require replacement. To enable investment and financing, suppliers provide a 30-year performance and maintenance warranty.

The Energiesprong model takes a different approach to contracting by specifying a performance outcome. The 'Solution Provider' is responsible for designing and installing - and evidencing - the real-world performance of the outcome specified in order to provide the required long-term performance guarantee. It is hoped this focus on outcomes enables the Solution Provider to innovate to reduce cost.

Offsite manufacture is also required, with homes aimed to be retrofitted in less than 15 days on site. This drives solutions such as energy modules, with M&E systems fitted into the module in the factory, which is hoped to improve quality, and façade solutions which can be craned-on in a day.

A summary of the performance warranty follows:

- The tenant will not receive an energy bill of greater than, typically, c2,000 kWh/year of electricity. This is confirmed by the Solution Provider at the outset, including the PV contribution.
- The tenant receives a guarantee that they can heat to 21°C, draw off 140 litres of hot water per home per day, and use 2,300 kWh a year for appliances. Tenants can use more electricity and/or water if they wish and their energy bill will only increase slightly, as they will benefit from the efficiency and technologies provided by the solution.
- The aim is that solutions achieve net-zero consumption. For this Demonstration Action the net-consumption can be up to 1,500 kWh/yr. This is roughly a 90% energy/CO_2 saving.
- Solution Provider designs must also meet targets in relation to noise, overheating, visual appeal and humidity in order to ensure occupier comfort and desirability.
- Housing providers benefit as maintenance costs are guaranteed not to exceed those stated in the maintenance plan.

As the Energesprong approach is about outcomes and is technology and manufacturer agnostic, different Solution Providers can use different systems to achieve the targeted performance outcome.

Sample size and composition

Eleven dwellings underwent significant 'deep' retrofits including super-insulation of walls, roof and floor, and installing whole-house ventilation and heat pumps to provide space and water heating. Of these, ten had sufficient relevant data to be included in the demonstration action. Costs were incurred for eleven homes.

Dwellings were recruited from two different regions of the UK: Sutton in south London – representing Southern England – and Nottingham to represent the North of England. Six concrete and timber frame terraced houses in Nottingham and six two- or four-in-a-block cottage brick cavity homes in Sutton were initially selected.

In Nottingham after selection and pre-works monitoring, one of the tenants refused the works. This property was omitted from the programme, leaving five properties remaining in the sample. One of these properties became void before works took place, but it was used as a site office and monitoring was carried out before and after. The five homes in Nottingham also received a conversion from their garage to a useable room, increasing the floor space by 20m2 from 82 to 102m2. The data for the property which was used as a site office was excluded from the analysis on the basis the heating and hot water patterns were different, and consistent before and after occupier surveys could not be provided. This means four homes were included from Nottingham for the data analysis.

Whilst one tenant dropped out in Sutton, another home was recruited, meaning six homes in Sutton were included. As a result, a total of eleven homes were included in the demonstration action.

The measures selected in Nottingham included facades manufactured offsite with factory fitted windows and doors, but due to external space restrictions, internally located separate air source heat pumps and 5kW battery storage were required, rather than integrated energy modules.

In Sutton, the Solution Provider opted for an innovative cavity fill approach, and their integrated energy module was manufactured offsite, within a new porch, which was installed in a day.

Parameters monitored

Measurement	Equipment	Logging Frequency	Responsible Party
Internal temperature and relative humidity	ALTA Wireless Humidity & Temperature Sensor - Coin Cell Powered Elitech RC-4HC Temperature ±0.6^{O}C, RH ±5%	15 minutes in each room 10 minutes	Energiesprong UK
Manual Meter Readings	N/A	Start and end of monitoring periods	Energiesprong UK

Energy Bills	N/A	Collected for 12 months pre works	Energiesprong UK
Comfort surveys	Undertaken by Energiesprong UK, Sutton Housing Partnership and Nottingham City Homes	At 2 points: - Pre-works - Post-works	Energiesprong UK
External temperature data for calculating Heating Degree Days	Weather data for the BTS calculation is accessed from the Weatherbit.io weather API which has a resolution of 15-25km depending on location. The Nottingham weather centre is just under 6 miles from the site. The Sutton weather centre is 6.5m away from the site. The system also corrects for altitude and shading (based on satellite images of cloud cover) to the particular location.	Half hourly averages	Build Test Solutions as part of the HTC calculation
Installed monitoring	Sutton: Ventive Home energy module, LuxPower battery/ inverter (2 homes), PV inverter (4 homes) Nottingham: Multi-circuit electricity meter (Class 1 – MID certified). Heat meter on the output of the ASHP(MID certified). Temperature and humidity sensors. Hot water meter.	At least hourly Half hourly data, based on data logging every 2 – 3 mins.	Bowtie (and thir sub-contractor -Ventive) Melius Carnego systems (monitoring solution for both projects

Some issues were experienced with collecting data. Details of how these were resolved are included below.

Monitoring duration

Sutton Details

Measurement	Dates installed/monitored	Issues and resolution
Internal temperature and relative humidity	w/c 28th Feb – 31 March.	Data recorded, no issues
Manual Meter Readings	Multiple meter readings pre- and during monitored period.	Only limited smart-meter data was available
Comfort surveys	Pre and post-retrofit	Data recorded, no issues
External temperature data	30th April 2020 to 31 March 2022	Purchased postcode-level satellite data from Solcast
Installed monitoring	Battery/inverter (2 properties) – 1st and 10th Mar onwards. Import/Export/PV generation Inverter (4 properties) – 11th Mar onwards. PV generation Ventive Home pod – 18th Mar onwards. Import/Export/PV generation. Heating system electrical input, total heat output (derived).	PV/import/export data for some properties was lost before 11th March due to technical issues with the metering on site. Ventive Home pod monitoring was installed from around 18th March. Total heat output cannot be measured directly due to the system setup, so has been derived from the temperature data recorded.

Nottingham

Measurement	Dates Installed / Monitored	Issues and Resolution
Internal temperature and relative humidity	Pre-Works December 2020. Post works 22nd to 26th February 22 until 30th – 31st March for Elitech sensors. 3 – 4 sensors per property. 22nd February 11 ongoing for Carnego sensors. 1 – 2 sensors per property.	No issues with Elitech sensors. Carnego systems temperature & humidity sensors not working in Notts 5 until 18th March 2022.

Electrical Import and Export	Carnego in 3 homes from 21st February 2022. Carnego in 1 home from 18th March 2022. Daily readings for imported electricity from September 21 to 31 March 2022. from Smart meter for 1 home.	In Notts 4 and 5 the electricity meters were not working correctly. This was spotted whilst reviewing data early March, and a site visit took place on 18th March to resolve. The actions taken resolved issues in Notts 5 so data is available from that point. An HTC has been carried out running into April, along with a short HTC which was carried out between 18th March and 31st March. The HTC used in this analyis is the short HTC, with no data from April. The visit on 18th March did not resolve the issues with Notts 4. Electrical import and export meters not working correctly. Further analysis shows these have been wired incorrectly so the readings are not correct. Import readings have been gathered from Utilita. Smart meter data is expected to follow. This does not record Export readings so this has been derived based on the average of the other similar properties.
Electricity Generation	Carnego from 21st January 2022	No issues.
Heat Pump Electricity Input	Carnego from 21st Jan 2022	No issues
Heat Pump Output	Carnego from 21st Jan 2022	Notts 3 had a faulty heat meter. Carnego tried to rectify this on 18th March but it continued to be faulty. The heat output has been calculated based on the minimum, maximum and mean COP of the other heat pumps (taking out Notts 2, which was the site office and used minimal hot water). The HTC calculations were carried out based on each scenario.
Manual Meter Readings	Meter readings taken to support HTC calculations before works and after works.	Meter readings were taken before works and used to calculate HTCs. There are some challenges with the reliability of post completion meter reads due to smart meters having an inconsistent approach to access full data (Rate 1, Rate 2, Import / Export). Carnego data has been used instead of meter reads for post completion HTCs.
Energy Bills	Energy bills collected for 12 months before the works were carried out.	One of the properties (Notts 2) became void before works started, and then was used as a site office for the duration of the works. Energy bill data has been gathered for all other properties, although in some cases they are based on estimated readings.
Occupier Comfort Surveys	Collected before and after works	Due to one property being void, only four before / after comfort surveys are available for the Nottingham part of the DA.

Average annual cost saving	Expected lifetime cost savings
Taking into account issues experienced with the Sutton heating systems, the range of cost savings experienced during the Demonstration action was -£6 to £408 p/a resulting in an average of £201 p/a saving. Once the heating and ventilation units in Sutton are working with the same efficiency as those in Nottingham, the average savings are expected to increase to: £426 p/a average, with a range of £292 to £555 p/a which is a mean of 46% saving from pre works energy costs. Basis for percentage: We performed a simplified heat balance calculation to disaggregate energy demand before the retrofit, calibrated to the bills, and then we modelled the post-retrofit energy demand and hence the energy bill. We then compared the cost of heating the homes pre- and post-retrofit, using the current SAP energy prices. It is worth noting that gas and electricity prices have already risen substantially compared to the SAP energy prices which are used to calculate the cost savings. The Ofgem price caps introduced in April 2022 increased gas prices by 103% (i.e. more than double) compared to the SAP prices, and electricity prices by 78%. This means the cost savings today would be substantially higher than those stated above. It also seems likely that energy costs will continue to rise – above background inflation – so the true savings over 15 years could be more than double those shown Main heating source[1]: Electrical heat pumps Main house type: 2 house types were included. One modelled using PHPP and one using full SAP V9.2.	Based on a conservative 15-year lifetime (with fabric expected to perform for up to 60 years), the lifetime bill savings range from £-90 to £6010, with an average of £3020. Once the heating systems in Sutton are working the lifetime savings are increased to £6390, or up to £8,320. If the expected lifetime is extended to 60 years, and maintenance is factored in, the average lifetime bill saving is £10,960, with a range from £760 to £20,860. This is based on an average annual saving of £316 (£146 – £481) which takes a cautious estimate of the heat pump performance, including Sutton at a COP of 1.85 compared to 2.7 COP in Nottingham, and not factoring in improvements in efficiency which are expected as technology improves. The lifetime bill savings are also reduced as they assume heat pump replacement costs are required at 15, 30 and 45 years, with these costs taken off the savings. Basis for LBS: We performed a simplified heat balance calculation to disaggregate energy demand before the retrofit, calibrated to the bills, and then we modelled the post-retrofit energy demand and hence the energy bill. We then compared the cost of heating the homes pre- and post-retrofit, using the current SAP energy prices. The savings were multiplied by 15 years and 60 years to show the range of lifetime bill savings, factoring in maintenance costs as detailed above. Main heating source: Electrical heat pumps Expected lifetime: Up to 60 years 2 house types were included. One modelled using PHPP and one using full SAP V9.2.

[1] SAP 2018 fuel tariffs are normally used for ECO3.

Summary of Discussion and Conclusion

Analysis was undertaken on pre and post Heat Transfer Co-efficient calculations (HTC), pre and post temperatures and energy bills and occupant surveys.

The improvement in Heat Transfer Coefficient was statistically significant, and the average (mean) improvement in HTC was 33 W/K (minimum 5 W/K, maximum 61 W/K), or a 21% reduction in heat loss. The average savings in HTC in Nottingham were lower than expected, but this could be partially explained by the increase in floor area of c20m2 as part of the Energiesprong action which impacts on the HTC. This additional space creates a more desirable home for occupiers, helping to incentivise a deep retrofit, but it impacts on the energy savings. There were technical problems with the heat pumps and ventilation system installed in Sutton homes, so actual bill savings were disappointing there. Including the very weak performance of the Sutton heating system, the average bill saving was still £201 (minimum a cost rise of £6, maximum saving of £408) a year, or a 22% saving (-0.6%/+45%). However, if the Sutton heat pumps had performed at the same efficiency as those installed in Nottingham, the average bill saving would have been £426 (minimum £292, maximum £555) a year, or 46% (31%/60%). Lifetime savings were calculated above based on a cautious estimate of performance of the Sutton heating system, and with costs for replacement of ASHP, and these resulted in an average of £10,960, over the course of 60 years, but up to £20,860, based on SAP energy prices.

The mean internal temperature increased from 19.2°C before to 20.0°C after the retrofits, but this was not statistically significant. One home with very low pre-retrofit temperatures (14°C) increased by 3°C, bringing a meaningful improvement in comfort, and potentially health, wellbeing and fuel poverty. Properties with higher initial temperatures tended to witness a smaller change. Generally, there were also more even temperatures between rooms and over time once the retrofit work was complete.

Energiesprong UK routinely assess the post-retrofit HTCs of projects using SmartHTC, and they compare these against the Design HTCs to identify any potential problems. However, they do not normally carry out pre-retrofit HTC calculations. The mean HTC across 20 other properties that underwent Energiesprong retrofits, was 90 W/K (Confidence Interval: 78-113 W/K). (These HTCs are from a mixture of semi-detached houses, terraces and bungalows.) In five of these cases the central estimate for HTC was higher (worse) than the design estimate, but for all the other 15 the central estimate was the same or better than the design estimate. This compares to the mean HTC after retrofit work in this Demonstration Action of 123 W/K (CI: 90-154 W/K). In this study fully nine out of 10 properties had central estimates of HTC that were higher (worse) than the design estimates. Both of these suggest that the outcomes of this Demonstration Action were not as positive as previous Energiesprong retrofits, and it is not yet clear whether this is a temporary situation due to the compressed monitoring period which will be resolved through the Energiesprong performance guarantee, or whether it is due to the particular homes or solutions included to meet the Energiesprong performance guarantee in this case.

There were a number of limitations with the study which it is worth identifying. Primarily these were due in part to the small sample size, but significantly due to the delays in starting and then completing the demonstration action, which resulted in a shortened post completion monitoring period.

Ideally 12 months of energy bills before and after works would be required. ESUK will continue to monitor the actual energy savings, but this falls out of the Ofgem monitoring period. As a result, annual savings were extrapolated using a simplified heat balance calculation to disaggregate energy demand before the retrofit. This was calibrated to the bills, and then the post-retrofit energy demand and hence the energy bill was modelled. The cost of heating the homes pre- and post-retrofit was then calculated, using SAP costs.

The small sample number means it is much harder to achieve a sample that is representative of different house types and household types. It also means there are a limited number of replacements to fall back on if

households withdraw or there are technical problems with monitoring equipment or building services equipment installed in the dwellings. However, Energiesprong did manage to replace one household that dropped out at a late stage with limited impact on the study, and also collected data from one dwelling where the household moved out, by working creatively (in the latter case, by heating the dwelling and using it as a site office, however the data was not employed in the statistical analysis).

The HTC estimates rely on SmartHTC, which is economical and does not force occupants to move out but is arguably less accurate than a co-heating test. This is in line with the Energiesprong ethos, and the idea that retrofit work should avoid disrupting residents as much as possible, as well as minimising time on site.

Variations in external temperature between the pre- and post-retrofit weather were adjusted for in the HTC estimates, and in the comfort/internal temperature analysis presented in the independent report. There is also an unknown impact of wind variations and solar gain – which can both affect HTC estimates – but these are likely to be small, notably because the post-retrofit airtightness was very good.

Comfort-taking by residents may also have affected results, and this demonstrably happened in Nottingham, where average internal temperatures rose. This underestimates efficiency savings in bills (which would have fallen further in Nottingham if mean internal temperatures had stayed the same). However, this very likely reflects what would happen in other social housing homes that undergo similar deep retrofits, so in some respects this is useful.

Interview responses showed that many householders in the study were concerned about high energy costs. This means that energy-price rises in December may have resulted in more frugal heating and appliances use, which could have distorted energy practices somewhat between pre- and post-retrofit monitoring. It is possible, if energy prices had remained the same, that households would have taken still more of the benefit from improved efficiency as improved thermal comfort. However, these price rises (especially after the end of the study) are outside Energiesprong's control.

The defective heating system controls in Sutton homes is very obviously a limitation in the study. If the exhaust-air heat pumps had worked as intended, the heating coefficients of performance could have been better or worse than those achieved in Nottingham. It would be much better to rectify the controls problem and use the new COPs to calculate cost savings in Sutton, and Energiesprong UK intends to do this next winter.

A further limitation to this study, but which does not apply to many other ECO Demonstration Actions is the fact that Energiesprong combines together multiple upgrades, all carried out together. This is a strength in achieving very significant energy savings, but it also brings a weakness because it is impossible to separate savings attributable to each of the fabric efficiency measures – which might be useful in other contexts.

Delays and the short window for HTC calculations meant that the usual three-week minimum that is needed to run SmartHTC was not always available. However, Energiesprong UK ad BTS intervened to carry out special treatment, with a manual HTC calculation, so HTCs could still be generated for all 11 homes. The shorter periods of data in some cases increases the confidence intervals somewhat for these cases, but this was unavoidable to meet Ofgem's deadline at the end of March.

HTC estimates in the North were also distorted by combining energy efficiency upgrades with extensions to living/heated area. HTCs would doubtless have been lower if the useable floor area had remained the same, and - this reduced the measured savings in Nottingham homes. However, reporting the Heat Loss Parameter (per m^2) adjusts for this, and this approach partly eliminates this problem.

Different upgrade measures in the North and South also complicates analysis and represents a limitation to the study. Had identical fabric and heating system upgrades been applied in both locations the empirical evidence would have been stronger. However, this does not reflect how Energiesprong works, with contractors permitted and encouraged to innovate to find their own ways to meet the performance outcome, and also varying the approach depending on the condition and circumstances of the specific homes to be upgraded. Arguably, it would be misleading to suggest that Energiesprong retrofits are uniform and always achieve the same results. In this study, some of the true diversity of Energiesprong retrofits is reflected.

Summary of actual costs incurred						
Total Cost	£1,155,189					
Recruitment	Product / installation	Performance monitoring	Analysis / reporting	Technical monitoring	Supplier administration	Aftercare
24,716	1,055,083	40,936	14,454	1,250	18,750	N/A