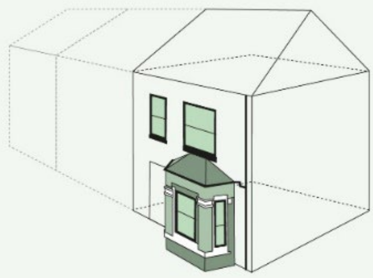
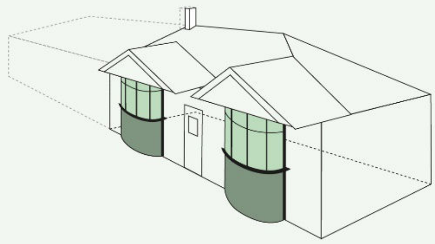
Heat pump feasibility & housing archetypes in Plymouth

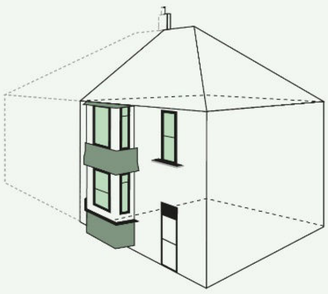
Report by Plymouth Energy Community funded by MCS Charitable Foundation - July 2022



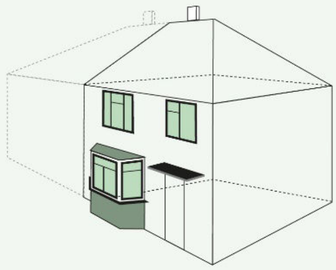
BAY FRONTED VICTORIA TERRACE



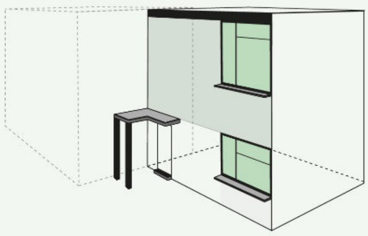
BRICK OR RENDERED DOUBLE BAY FRONTED 1930S BUNGALOW



1930-1960s SEMI-DETACHED HOUSE



EASIFORM HOUSE



CROSSWALL TERRACE (FLAT ROOF)

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Glossary

ASHP	Air Source Heat Pump
dMEV	Decentralised Mechanical Extract Ventilation
CWI	Cavity Wall Insulation
EPC	Energy Performance Certificate
EWI	External Wall Insulation
IWI	Internal Wall Insulation
LETI	The London Energy Transformation Initiative
MCS	Microgeneration Certification Scheme
MEV	Whole house Mechanical Extract Ventilation
MVHR	Mechanical Ventilation with Heat Recovery
NSH	Night Storage heater
rdSAP	Reduced Data Standard Assessment Procedure
RIRI	Room in Roof Insulation
SAP	Standard Assessment Procedure
TRV	Thermostatic Radiator Valve
UFI	Under Floor Insulation

Executive summary

This report captures the key learning from this project where we explored the viability of installing an Air Source Heat Pump (ASHP) in five prevalent Plymouth house archetypes which included a Victorian bay windowed terrace, crosswall flat roofed terrace, Easiform, bay fronted 1930s bungalow and 1930-1960s semi-detached house.

For each archetype we managed to find at least one property to survey, and managed two surveys for the Easiform, Victorian Terrace and semi-detached house. As such, the findings are from a small sample size, but we have looked at each of the properties in detail.

- In all properties it was possible to install an ASHP. The most significant challenges were siting of the ASHP (due to proximity to neighbours and need to maintain specified distances from their door and window openings) and siting of a hot water tanks (as there was no longer an allocated space for this and a new space needed to be found). These issues were not insurmountable but required the additional complexities of planning permission or non-optimum siting of the hot water tank (or heat pump itself) to be resolved.
- In all cases the existing pipework and most of the radiators could be reused, though this was on the basis fabric improvements would be made to allow the system to perform at its best. Most properties needed at least one radiator to be replaced with a radiator with a larger surface area, with five requiring replacement in one property (again, to increase the heat output into the rooms in question).
- In the case of the semi-detached properties, a rise in annual fuel bills of 26%-34% was predicted where an ASHP was installed to replace a gas boiler with the current fabric standards for those properties. Only the terraces saw a greater predicted increase in fuel bills for replacing a gas boiler with an ASHP (32% average increase). The lowest predicted increase was seen in system build properties, averaging only 13.5%.
- In the case of night storage heaters (NSH) the project also presented some interesting findings. In all but one terrace property, with the properties in their current condition, ASHPs proved cheaper[1] to run by an average of 18% in terms of annual fuel bills than NSHs. However, how heat pumps compare to storage heaters in terms of annual fuel bills warrants further consideration as:
    - The cost of storage heaters is likely to be significantly less than ASHP, and with the three system build properties only 3-16% more expensive to heat with storage heaters than ASHP, this suggests further consideration of upfront cost vs. running cost would be valuable
    - High heat retention storage heaters have been modelled and so this comparison should only be drawn on that basis i.e., not with older, less efficient storage heaters
    - In all cases NSH resulted in in higher Energy Use Intensity figures than with ASHP, which could be worth further consideration in terms of impact on the grid as part of decarbonisation of heat, though the impact will be heavily dependent on energy mix on the grid, with much of this load due only to be at night with storage heaters
    - Most strikingly, once the fabric of properties was improved (albeit to high standards) then ASHP were on average 13% <u>more expensive</u> to run than NSH. This was based on SAP 2022-unit costs rates that show the current benefit of reduced nigh-time 'off-peak' rates. As we move away from economy 7 tariffs towards time-of-use tariffs and with the increase in prevalence of smart controls, then a more sophisticated comparison of how predicted fuel bills for ASHP and NSH will be required
    - Notably, in five out of eight cases NSH were also cheaper than gas in terms of annual fuel bills once the thermal performance of the property had been improved

[1] Rates used for modelling as follows: £0.21 daytime and £0.08 per unit night-time was used for NSH fuel bill costs - space heating energy use is 80% low tariff and 20% high tariff, and water heating is 100% low tariff. Stanadard (non-Economy 7) unit = £0.1944. Electric standing charge = £97

- We looked at two Easiform properties. First built in 1919, there are reported to be 85,000 Easiform properties in the country with most built between 1946 and 1970[2]. The properties are built with cast-in-situ concrete. The prevailing perception around these, and other system 'non-traditional' build properties of this era is they perform poorly on energy efficiency terms. However, the findings from this report are contrary to those perceptions. The two properties we considered showed the lowest expected increase in bills for replacing a gas boiler with an ASHP, as well as some of the lowest heating demand figures (before and after retrofit improvements). Although it is of note that in both cases this considers the benefit of having CWI as well as EWI on these properties.
- The heat load was significantly bigger for the larger terrace property that for the smaller one (17.1kW vs 8.2kW), resulting in the requirement for a significantly larger heat pump. Given that these properties are ostensibly very similar, this shows the importance of property specific advice. As a result of this we have decided to purchase the Parity Projects Plan Builder tool, an example of this can be found in the Cosy Homes Oxfordshire project: https://app.cosyhomesoxfordshire.org/ . This allows you to build property specific plans based on EPC data and will replace our planned archetypes calculator along with creation of archetype heat pump case studies, which have been submitted in draft alongside this report.
- The calculation of heat load varied significantly between that modelled by SAP and a full MCS Heat Loss Calculator. The variance was between 2-38% (with one outlier at 99%) in both direction with no meaningful patterns. This is an important consideration in terms of PAS2035 and the customer retrofit journey – a Retrofit Assessment could be carried out that provided one recommendation for a heat pump approach that could be later contradicted once a heat pump installer has carried out a full MCS Heat Loss Calculation.
- Property heat load is important in sizing the appropriate heat pump. This is relevant for sizing the right heat pump for current building fabric, occupancy and heating patterns, but also in the context of how these variables might change in the future. As such, we considered the potential for low carbon retrofit in this study and a fabric first approach was taken wherever possible. This indicated a potential for an average reduction in heat load of 44% achievable with the retrofit measures recommended. This shows the importance of heat pump sizing relative to retrofit plans. In all cases for this project, the ASHP size proposed based on current performance standards was likely to be oversized once properties had reached the end of their retrofit journey. Customers must be advised well on this as part of their retrofit plans so they can make well informed decisions about sequencing in their approach.
- The project has also shown the impact on overall energy use of the non-regulated side of energy (e.g., water heating, appliances, cooking, lighting, fans and pumps) becoming increasingly important as you drive down heating and hot water energy demand. For example, much of the increase in Energy Use Intensity in the second terrace property when compared to the first, can be attributed to additional unregulated energy use based on consumer behaviour and the performance and abundance of the related goods (e.g., appliances). Consumer advice is obviously key here as are the potential benefits of the energy efficiency of these goods which are often simple, non-disruptive measures to implement.
- In five of eight cases, the heating demand when modelled based on actual occupancy and heating patterns was actually lower than when modelled in SAP. While generally this was a difference of less than 20%, in one case the heating demand based on actual occupancy was only 54% of that based on standard occupancy patterns. While it is widely accepted that SAP can overestimate heating patterns, this does also suggest the risk of underheating in these properties.

[2] Laing Easiform Cast-in-Situ House - Non-Standard House Construction - Information & Resource Centre (nonstandardhouse.com)

About Plymouth Energy Community

This project has been undertaken by Plymouth Energy Community (PEC) with support and input form Plymouth City Council (PCC). Plymouth Energy Community (PEC) is a multi-award-winning charity and a social enterprise, with a cooperative ethos. PEC's mission is to enable our community to create a fair, affordable, zero carbon energy system with local people at its heart. It includes a family of community led organisations with projects that: bring local people together to tackle fuel poverty and the climate crisis, increase local ownership and influence over local energy solutions; improve community confidence to engage in the zero-carbon transition; and enable people to heat and power their homes affordably.

Since 2013 PEC has:

- Developed and generated 33 MWh of clean power from Ernesettle community solar farm and 32 roof top arrays.
- Saved schools and community organisations over £800,000 from their energy bills through renewable power and energy efficiency improvements.
- Helped 30,589 households and carried out 5,298 homes visits, saving each an average of £764 per year
- Saved a total of 25,254 tonnes of carbon.
- Grown to a turnover of £1.5m per year with a dedicated team of 24 employed staff.

PEC is now working with local businesses to install new solar arrays; trailing models for community owned renewable heat and providing a domestic energy advice and retrofit service targeted at helping the fuel poor and those with long-term health conditions. It is dispersing grants to fuel poor households as part of the City's Covid response package and has established a community led housing developer, to focus on the innovation required to deliver affordable homes in a way that is consistent with the UK's carbon reduction targets.

Introduction

The UK Government has declared a climate emergency and pledges to be carbon neutral by 2050. Plymouth City Council (and many others across the UK) have also declared climate emergencies and have set ambitious targets, with many aiming to reach carbon neutrality by 2030. To achieve these targets and to tackle the global problem of climate change, it is imperative that more focus is dedicated to the decarbonisation of heat.

One of the proposed solutions for the decarbonisation of domestic heat is the replacement of natural gas boilers with heat pumps. While this is a logical proposition in the context of the ongoing decarbonisation of the electrical grid, there remain many hurdles to overcome before widespread adoption of heat pumps is realised, particularly in the existing housing stock where insulation standards are lower and there are less regulatory opportunities for enforcement.

These hurdles include cost, the perception of the comfort that can be achieved, the practical challenges in existing properties as well as the risk of increasing customer fuel bills while gas remains relatively cheap. This project seeks to take five prevalent Plymouth housing archetypes in which to unpick these perceived challenges in detail, to show where and where not viable solutions can be found.

Through this approach and sharing our learning, this project aims to enable local authorities and community energy organisations to provide improved information for households with questions regarding the feasibility of heat pump adoption. The project will provide an understanding of the base line energy efficiency of these five main housing archetypes and their general suitability for heat pump retrofits, with and without fabric improvements.

Housing archetypes and heat pumps nationally

As heat pumps have been identified as one of the primary solutions to achieve a decarbonisation of residential heating, some largescale studies have been undertaken to assess the feasibility of heat pump deployment in the various housing types in the UK. The UK has one of the oldest housing stocks in Europe and a large proportion of homes were built between 1918-1990. The housing types themselves present a fundamental challenge to heat pump deployment due to the vast diversity of home construction in the UK.

Studies utilizing archetypes vary widely by the number of housing archetypes chosen to model ranging from 5[3] to 20,000[4]. These studies have attempted to identify the principal housing archetypes across the UK and how appropriate these archetypes may be for heat pump deployment. They provide valuable learnings towards understanding how 'heat pump ready' some housing types are compared to others and what types of measures may be required to these homes to prepare them for heat pump deployment. A summary table of recent reports containing relevant information on housing archetypes and heat pumps can be seen below in Table 1.

These reports and studies have identified archetypes by assessing Energy Performance Certificate (EPC) data which can be a suitable indication of the energy efficiency of housing stock, though is often considered quite a blunt tool in assessing potential heat pump suitability. The statistics and housing characteristics provided by EPC data in these reports have been aggregated into the models to determine the archetypes heat pump retrofit options appraisal.

Table 1 – Existing archetype heat pump suitability work

Report	Number of Archetypes	Findings	Methodology
How to Heat Scotland's Homes – NESTA/Catapult Energy Systems, 2021.	5	Energy efficiency data was analysed for several dwelling archetypes. Detailed modelling was carried out. • Over 70% of Scottish dwellings have a D or C EPC rating with 15% having E, F, or G ratings. • Barriers to installation of heat pumps, including cost, supply, public awareness and practicalities such as space, exist across all housing types in Scotland. • Older, pre-1914 housing stock such as tenement blocks would require substantial and costly energy efficiency measures including to the fabric of the buildings (often prohibited by current planning restrictions), in order for heat pumps to meet an acceptable standard of comfort and cost (Nesta, 2021).	EPC data combined with modelling of measures and housing types.
Heat Pump Retrofit in London – Carbon Trust, 2020.	15	• Heat pump technology is varied, versatile and can work in all London building types. • Heat pumps are not a like-for-like replacement for gas boilers or conventional	EPC data and building surveys heat pump retrofit options appraisals for 15 example buildings in London that are

[3] C. Holland, A. Knight, S. Mohammadi and G Cucca, 2021, How to Heat Scotland's Homes, Report prepared by Energy Systems Catapult on behalf of Nesta in Scotland.
[4] B. Boardman, S. Darby., G. Killip, M. Hinnells, C.N. Jardine, J. Palmer, G. Sinden, K.
Lane, R. Layberry, A. Wright, M. Newborough, S. Natarajan, A. Peacock, 2005, 40% House,
Environmental Change Institute, University of Oxford, Oxford.

		electric heating and good practice system design is essential. • Improved energy efficiency in buildings is a pre-requisite for heat pump retrofit at scale and will require significant investment. • Flexibility of heat demand is essential for a net zero carbon energy system and can bring significant financial rewards at the individual building level. • Based on current gas and electricity prices, heat pumps will reduce fuel bills compared to conventional electric heating but could increase fuel bills compared to gas unless paired with energy efficiency, best practice system design and flexible use of heat. • The up-front cost of heat pumps is higher than traditional alternatives and many building types will require additional up-front financial support. However, the lifetime financial case for heat pump retrofit is already strong in some building types, such as electrically heated buildings, buildings with a high cooling demand and buildings that already require major renovations. These building types should be prioritised for heat pump retrofit (Carbon Trust, 2020).	typical of common building types in the London stock.
Supplemental report for options appraisals for heat pump retrofit in 15 London buildings by Carbon Trust, 2020.	15	This contains high level technical and financial appraisals of heat pump retrofit for 15 real buildings. The '15 example buildings' are referred to in the analysis throughout this report.	Same as above
Cost-Optimal Domestic Electrification (CODE), BEIS Research Paper, 2021.	12	The objective of this study was to assess costs based on the perspective of the consumer. It only considered costs that directly impact the consumer such as the upfront cost of equipment, and maintenance costs. • Detailed modelling of energy costs and evidence-based assumptions about capital costs found only small differences in costs over 15 years between low- or high-temperature heat pumps, air-to-air heat pumps, or storage radiators. Typically, the difference was only 10% between the highest and lowest cost. • The model found that heat pump systems were considered cost optimal for all housing archetypes when time of use (TOU) electricity tariffs are applied, though differences were marginal. Half of the house types using low temperature air-source heat	An approach was developed for classifying the UK housing stock into groups, each represented by a representative house type, or 'archetype'. The archetypes were selected to represent as much as possible of the total stock. However, subsequent analysis using the archetypes was very complex – with large numbers of measures applied to each archetype – and too many archetypes would be impractical. We chose archetypes which represent the range of the most important parameters (BEIS, 2021). Their method had two phases: classifying according to building

		pumps and the other half, air-to-air heat pumps.	form (based on wall to floor and other ratios), and then by construction type (floor, wall, roof and window construction).

Housing context in Plymouth

Like many other cities in the UK, Plymouth has its share of pre-war housing with many solid wall terraces stretching on the hills that reach up from the coastal front. These terraces, often constructed in brick with no wall insulation or cavity, present a common challenge for heat pump installation across the UK with constrained access and interior space as well as relativity high heat loss through the externally exposed façade.

Similarly, Plymouth also has significant proportions of housing built between 1950 and 1970, and while the fabric standards are relatively low as built, improvements are more prevalent and achievable than in most pre-1919 properties.

The most notable difference in the Plymouth housing stock is the prevalence of post second war non-standard construction housing. While these property types exist in some number and variety across the UK, there is a particularly high concentration in Plymouth.

Plymouth was one of the most devastated cities in the UK during the blitz, with over 4,000 casualties, 4,000 homes destroyed, 18,000 homes seriously damaged and over 20,000 displaced citizens. The repercussions of these events are still felt today in the post war prefabricated dominant housing stock, initially meant as a temporary fix for the rapid reconstruction of the city. These homes often have very poor fabric standards, with a greater degree of complexity to improving the thermal performance of walls. As such, they have the potential to prove challenging when installing a heat pump while keeping customer fuel bills down.

Figure 1. Map of documented bombs dropped on Plymouth from 1941-1944 (Excluding military targets) Courtesy Plymouth City Council Archives.

Choosing our five Plymouth archetypes

We decided to take a qualitative approach first to identification of our five archetypes for the following reasons:

- EPC driven archetypes can be too broad in their energy performance parameters to provide customer friendly information about heat pump suitability. Our intention is that our archetypes are sufficiently granular in their description that a customer would recognise them as their own and feel like the advice is genuinely applicable to their property.
- We were keen to tackle some of the more challenging archetypes that are distinctive to Plymouth, not just be drawn to those properties with the highest statistical prevalence
- We wanted to build on the knowledge of local housing professionals about those housing types in Plymouth where the key challenges might lie in the electrification and decarbonisation of heat

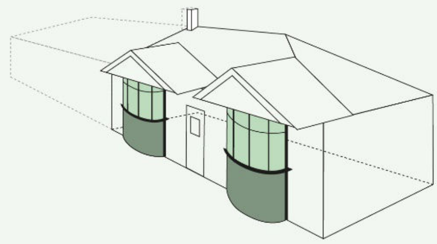
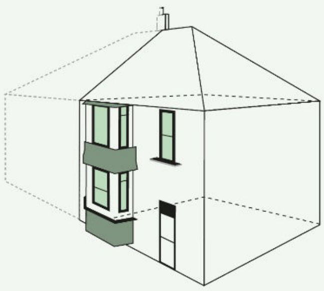
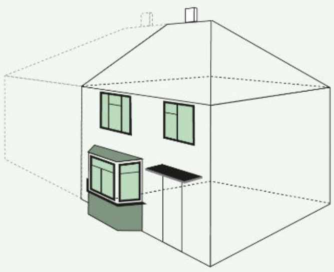
To that end we have spoken to housing professionals across Plymouth as to which archetypes to focus on, this has included Plymouth University, teams across Plymouth City Council, the PEC Energy and Retrofit teams as well as range of private sector housing professionals. This included sharing a list of the key housing types in Plymouth to request feedback on prevalence, location, general feasibility for heat pump installation and any additional information on types or background that they could provide. They responded with valuable background information and contextual knowledge including on the non-standard homes which have proven difficult to obtain dependable data on in the past.

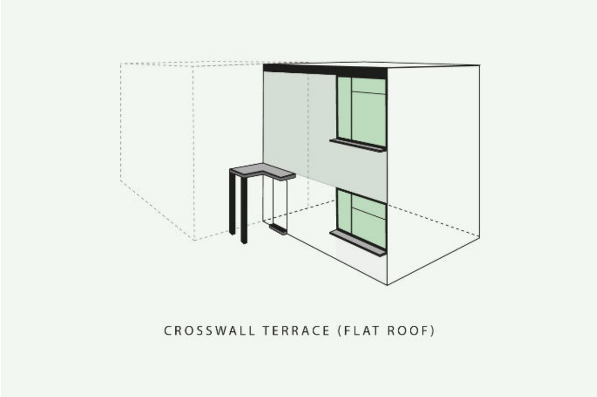
This work has provided our archetype list which is detailed below. We have also grounded, and truth tested prevalence using the latest EPC data. This has shown that our archetypes are relevant at scale to Plymouth, but also highlights the shortcomings of the EPC data (e.g., 'system build' is the most granular description available of the range of non-standard construction properties that exist). We have then supplemented this using more extensive data that we have purchased from Parity Projects. This data build on the RdSAP data that sits behind an EPC as well as filling in the gaps where EPC data is not available.

This work has provided our archetype list which is detailed below. We have also grounded, and truth tested prevalence using the latest EPC and Parity data. This has shown that our archetypes are relevant at scale to Plymouth, but also highlights the shortcomings of the EPC data (e.g., 'system build' is the most granular description available of the range of non-standard construction properties that exist).

Table 2 Five Housing Archetypes in Plymouth

	House Description	Picture	Places found in Plymouth	Comments
1	Brick/Stucco Single fronted Victorian Terrace with front bay window **EPC number of properties of this type in Plymouth = 10,542* Parity Projects number of properties of this type in Plymouth = 24496**		Bay window variant: Keyham ladders – Fleet Street, Cotehele etc. and Wolseley Road, around Mutley Non-bay window variant: Sithney Street, St Budeaux.	This property type is also common without the bay window. We will look to focus on the bay window version due to the increased complexity.

	EPC parameters = House, terrace, solid wall			
2	Brick/rendered bay fronted 1930s bungalows (some with loft conversions and dormers) **EPC number of properties of this type in Plymouth = 952 Parity Projects number of properties of this type in Plymouth = 1041** EPC parameters = bungalow, semi, cavity wall, suspended floor	 BRICK OR RENDERED DOUBLE BAY FRONTED 1930S BUNGALOW	Pemros Road. Also, quite a few in Plympton, St Budeaux and Crown Hill Road	
3	1930- 1960s Bay window, cavity walled semi-detached house **EPC number of properties of this type in Plymouth = 5,689 Parity Projects number of properties of this type in Plymouth = 11487** EPC parameters = house, semi, cavity wall, suspended floor	 1930-1960s SEMI-DETACHED HOUSE	Abbot's/Glenwood Road, Peverell; Fairview Avenue area, Efford; Saltburn Road, St Budeaux	
4	Easiform (System Build) **EPC number of properties of this type in Plymouth = up to 7,647 (this represents the number of 'system builds') Parity Projects number of properties of this type in Plymouth = 6495** EPC parameters = house, system build	 EASIFORM HOUSE	Efford, Whitleigh and Ernesettle	Cavity walled but very narrow so not great to cavity fill. Repetitive units although there are several types.

5	Crosswall/rationalised construction terraces with flat roofs EPC number of properties of this type in Plymouth = up to 7,647 (this represents the number of 'system builds') Parity Projects number of properties of this type in Plymouth = 6495 EPC parameters = house, system build		Clittaford Road, Lundy Close, Godding Gardens, Hurrell Close	

* There are currently only 73,800 properties with an EPC in Plymouth. As there are 121,400 properties in Plymouth and the EPC data is not granular enough to identify the specific archetypes, then numbers are likely to vary. To account for this, we have used the Parity Projects data which, for each property that does not have an EPC, makes some intelligent assumptions about what the building might be and how it might perform.

<u>Finding suitable properties</u>

Our plan was to survey 2 households for each archetype. In practice, finding 2 households to survey for each archetype was challenging for the following reasons:

1. The surveys were time consuming for householders with significant time required in their property
2. There was no motivation of any onward funding for low carbon improvements as a result of the survey

Our most significant success in attracting people to have the surveys undertaken was through using the established network of PEC supporters in Plymouth. For three of the archetypes, we were able to allocate two surveys comfortably, this is in no small part due to the abundance of these archetypes within Plymouth.

In the case of the Crosswall and Bay Fronted Bungalow archetypes, we only managed to complete one survey for each due to:

- A last minute drop out of our second bungalow allocated for survey
- The difficulty of finding an additional owner occupied Crosswall occupant willing to participate – many of these properties are still in social housing ownership

Survey approach

Our survey approach was established with support from a technical expert working group that included representatives from Stroma, the South West Net Zero Hub, Regen, WARM, Norley Energy Services and Matrix Energy Systems. The approach was designed to strike the balance of collecting meaningful information while minimising disruption for those participating in the scheme.

Survey type

The surveys we carried out were designed to cover the following areas for each archetype:

1. Assess current modelled energy performance – provide baseline and opportunity to model multiple scenarios for upgrade approach
2. Identify risks of performance gap between modelled and actual performance and opportunities to rectify through adjustments to modelled survey data
3. Establish practical realities of heat pump installation in each property type to include:
   a. Requirements to upgrade existing heating infrastructure
   b. Hot water tank siting
   c. Heat pump siting
   d. Cost of installation

To achieve the above, we carried out the surveys in Table 3 below

Table 3 – Survey types

Survey number	Survey type	Survey objectives	Who did the survey
1	*Carbon Co-op Home Energy Planner Tool using trained Retrofit Assessor	Assess current modelled energy performance and opportunities for heat pump, fabric, and airtightness upgrade	Existing PEC partner assessor with support from Carbon Co-op for multiple scenarios
2	Initial ASHP feasibility assessment	To look at the practical viability of installing an ASHP	Existing PEC partner assessor
3	MCS heat loss survey	Identify key heat loss areas in property	Heat pump installer
4	Heat pump specification and costing survey	To establish cost and practical realities of heat pump installation	Heat pump installer

*The Carbon Co-op Home Energy Planner Tool is a SAP based tool that allows:

- Adjustment of modelling based on actual energy use data
- Scenario modelling and comparison of retrofit options
- More detail can be found in here: Our Services - Stage 2 — People Powered Retrofit

In addition to this, for three of the properties we carried out a PULSE airtightness test: Pulse - Air Tightness Testing - Build Test Solutions

Scenario modelling

We then used the Carbon Coop tool to model a range of scenarios. For each archetype we wanted to understand the outcomes (in terms of install costs, bill costs and carbon saving) for a range of different approaches to wider retrofit alongside a heat pump. This allowed us to identify the optimum solutions to installing a heat pump for each archetype, as well as understand the impact of a range of different retrofit scenarios.

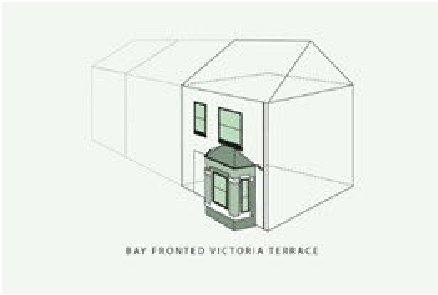
Initially we had hoped to use an 'as built' scenario to be our baseline for each archetype and then model common fabric improvements across each archetype to assess the impact. In practice we ended up using each properties current condition as the baseline and the improvement plan developed with each customer as part of the survey process for the modelled improvements for the following reasons:

- Having done a detailed property specific SAP survey, we would have lost the benefit of the granular detail by trying to backwards model the baseline to a notional 'as built' starting point
- The initial proposed approach would not have allowed us to capture the practical realities of what improvements people had already done, as well as what were practical improvements people were willing to do in the future (in theory at least).

While this made comparison between different properties more difficult, it was felt that this approach was none-the-less more valuable as it gave a more realistic assessment of the properties in question.

Learning by archetype

Single fronted Victorian terrace with bay window



<u>Summary of findings</u>
We looked at two Victorian terrace properties with bay windows. Both properties were mid terraced meaning that their heat loss areas were significantly less than an end terrace, and so the findings should be considered in that context. However, as is often the case, both properties had a rear extension. In addition to this, Terrace 1, was a large property for its type.

The retrofit measures that were considered appropriate for each terrace based on the practical realities of the properties and consumer preference were as follows. The improvements are mapped out in scenarios that progressively improve the performance of the property. A fabric first approach was taken wherever possible:

Terrace 1:

Improvements	Cost (cumulative)
Scenario 1 – Increase RIRI, increase loft insulation, UFI, draught proofing	£12,630
Scenario 2 – Scenario 1 + EWI, flat roof insulation	£13,150 (£25,780)
Scenario 3 – Scenario 1 + 2 + ASHP and insulated pipework	£11,700[5] (£37,480)

Terrace 2:

Improvements	Cost (cumulative)
Scenario 1 – Increase insulation, draught proofing	£2,190
Scenario 2 – Scenario 1 + CWI (extension), EWI, improved doors and windows on extension	£13,150 (£15,340)

[5] For consistency the Carbon Coop price for an ASHP has been used in this table rather than the quote provided by the MCS installer. It is of note though that the quotes were consistently higher than the carbon coop tool predicted.

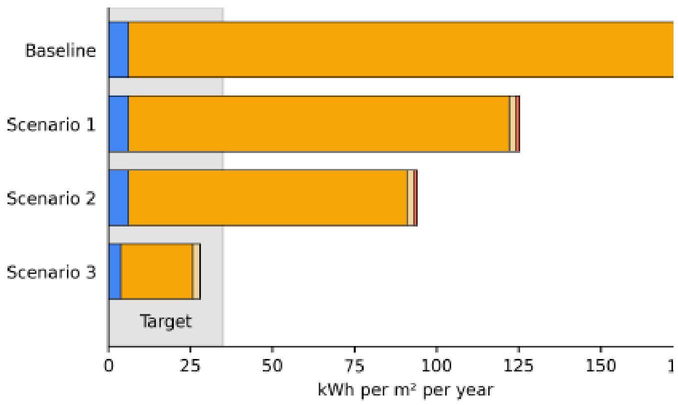
Scenario 3 – Scenario 1 + 2 + advanced airtightness, ASHP, Solar PV	£11,700 (£27,040)

The current heating demand for both properties was actually very similar at 131-133 kWh/m². Both also had the potential to get to a heating demand of around 70 kWh/ m² with the fabric improvements proposed. However, the heat load was significantly bigger for the larger Terrace 1 property pump (17.1kW vs 8.2kW)., resulting in the requirement for a larger and more expensive heat pump. This shows the importance of property specific advice, given two seemingly similar archetypes, but it is also notable that the larger terrace dropped only to a load of 9.4kW even with all the suggested improvements – higher than any other archetype we considered. However, in both cases the heat load could be dropped by an average of 41% with the improvements suggested.

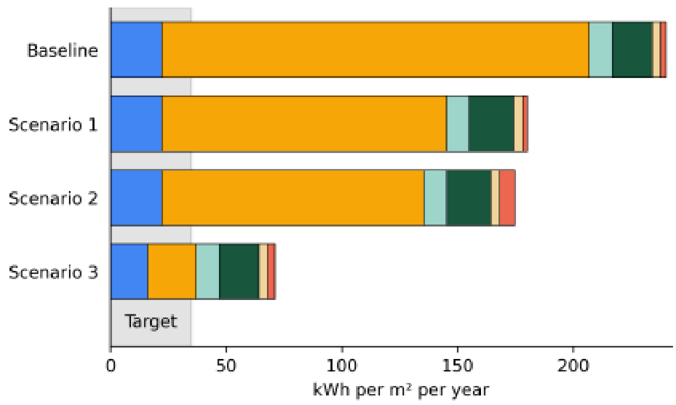
Energy Use Intensity (EUI) is a good way of assessing the demands of a property relative to its size. It includes the heat demand for the property as well as the unregulated energy use. It is the focus of development for new build energy efficiency standards and LETI have suggested standards which have featured in local planning policy development: 252d09_d2401094168a4ee5af86b147b61df50e.pdf (leti.london). In addition LETI have produced a retrofit guide that suggest a best practice EUI of 50 kWh/m²/year: 252d09_dfb04901638144518eca9b4554bfd1be.pdf (leti.london)

The EUI performance for each of the terrace properties before and after improvement can be found below. The target shown is the LETI new build target.

Terrace 1



Terrace 2



Water heating
Cooking
Lighting
Space heating
Appliances
Fans and Pumps

Notably, the larger Terrace 1 is able to reach well below the LETI best practice target, where Terrace 2 is not. Again, this shows the relevance of consumer preference and property specific advice. For example, Terrace 1 includes underfloor insulation in the improved approach where Terrace 2 does not and also had a smaller area of external wall where EWI could be added.

In addition, this also shows the impact on overall energy use of the non-regulated side of energy e.g., water heating, appliances, cooking, lighting, fans and pumps. Much of the increase in EUI the second terrace can been seen to be down to additional use in these rates based on consumer behaviour and the performance and abundance of the related goods (e.g., appliances). For this reason, these figures should be treated with some caution due to the impact of the quality of information on unregulated energy use provided by the customer, when modelled with a standard figure for unregulated energy (2,200kWh/year) then Terrace 1 drop from 154-33 kWh/m2/year (unimproved - improved) and terrace 2 from 173-65 kWh/m2/year.

None-the-less consumer advice is obviously key here as the potential benefits of the energy efficiency of appliances which are often simple, non-disruptive measures to implement, become increasingly important as heat and hot water demand is reduced

ASHP cost and practical considerations

The cost of installing the heat pump for Terrace 2 was comparable with other archetypes at £14,700. Though this was more than £1k higher than all other properties apart from the bungalow.

The large Terrace 1 had a very significant cost of £30k due to the need for two 14kW heat pumps to meet a heat load modelled through the MCS Heat Loss survey of 22.48 kW.

Practical considerations that came up included:

- Planning permission may be required depending upon a number of factors including levels of noise from the heat pump, distance from the heat pump to the nearest habitable room, etc.
- Fabric improvements should be made to improve performance
- Slimline water cylinder required for reduced space
- Additional pipework requirements where only siting location for hot water tank is some distance from heat pump

Optimum ASHP approach and impact on fuel bills

Using the carbon coop tool, we were able to model a range retrofit scenarios using the properties existing fabric standards as a baseline. This also allowed us to consider the impact of heating type of fuel bills for each of these retrofit scenarios.

In the case of these terrace properties, a rise in annual fuel bills of 24%-40%[6] in the properties with their current fabric standards was predicted where an ASHP is installed to replace to gas boiler. This is the highest predicted increase in fuel bills for an ASHP across all archetypes. However, should the property fabric be improved in line with what has been possible based on consumer preference and the practical realities of the properties in question, then an ASHP is shown to only cost 11-19% more than an gas boiler in annual fuel bills at today's prices.

In the case of comparing an ASHP to storage heaters then the picture was more mixed. With the properties at their current fabric standard, terrace 1 was modelled to be 31% cheaper to heat with an ASHP than with a storage heater. However, with terrace 2, an ASHP is predicted to be 3% more expensive in terms of fuel bills than an NSH. Additionally, once the thermal performance of the properties has been improved, then an ASHP is predicated to be 5% (terrace 1) – 37% (terrace 2) more expensive to run than NSH. The predicted fuel bill for different heating bills can be seen in the Charts later in this document along with a discussion on the potential impact of tariff and fuel cost changes on this finding.

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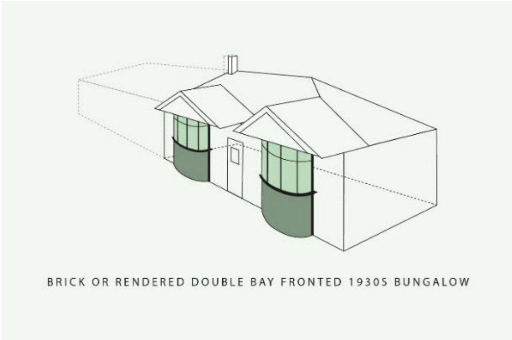
[6] SAP unit cost for energy were used for the purpose of comparison as follows: Electric unit = £0.1944. Electric standing charge = £97Mains gas unit = £0.0363. Mains gas standing charge = £95. The impact of price changes is discussed in a later section

Both quotes for ASHP installations recommended fabric improvements before installing an ASHP including:

- Floor insulation
- Solid wall insulation
- Improved double glazing
- Loft insulation
- Party wall insulation

Brick/rendered bay fronted 1930s bungalows



Summary of findings

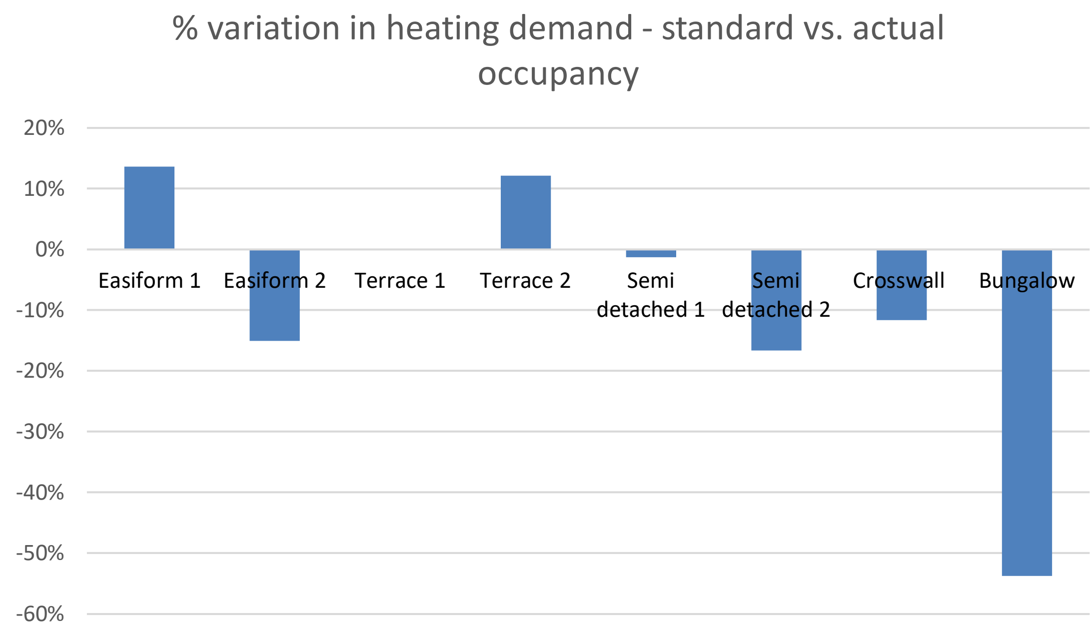
We were only able to identify one bay fronted bungalow to survey as part of the programme. This was single fronted, bay windowed semi-detached bungalow with solid external walls. The property was relatively unusual with the front door located on the side of the building.

Underfloor insulation had also already been partially retrofitted to the property. The retrofit measures that were considered appropriate for this bungalow based on the practical realities of the properties and consumer preference were as follows:

Improvements	Cost (cumulative)
Scenario 1 – Increase UFI, increase loft insulation, thin EWI, double glazing and improved doors, dMEV	£25,300
Scenario 2 – Scenario 1 + programmable TRVs, draught proofing	£1,400 (£26,700)
Scenario 3 – Scenario 1 + 2 + ASHP, thermal store, controls and pipe insulation, MVHR	£18,400 (£45,100)

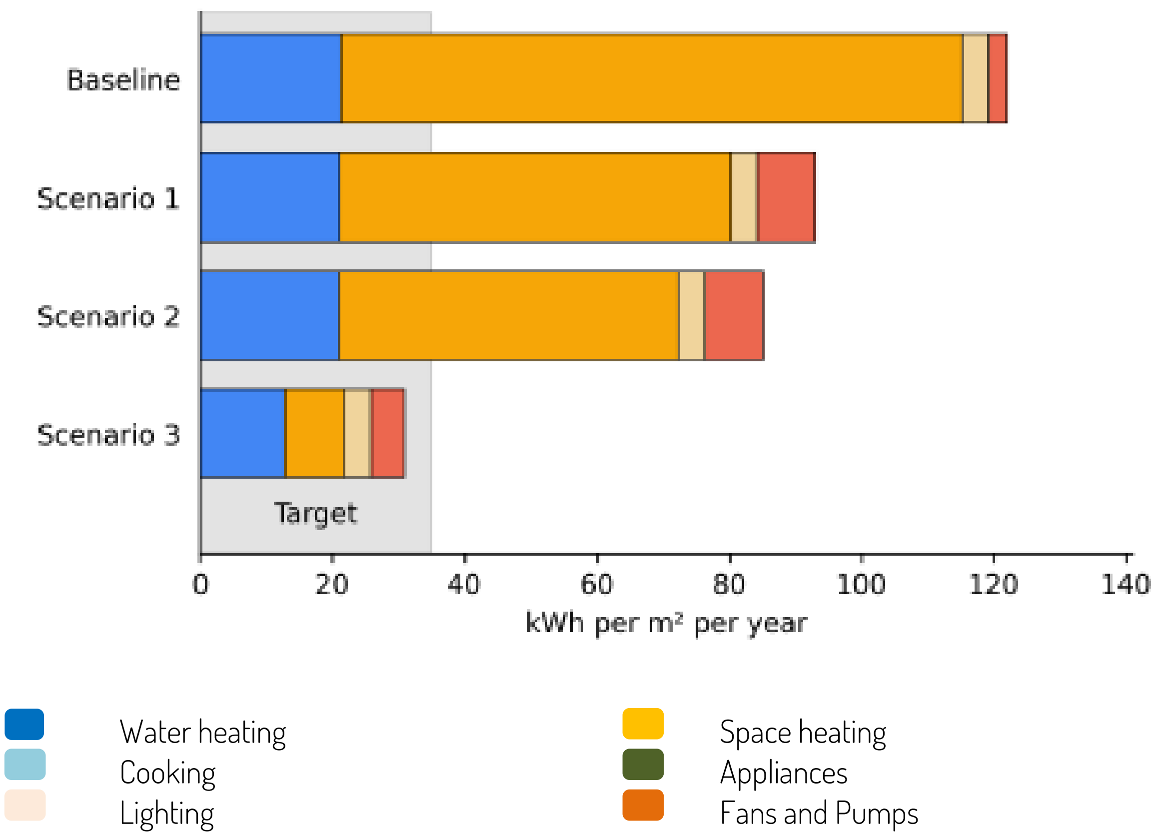
The current heating demand for the property was the highest of all the properties we surveyed at 162.2 kWh/m^2. However, through improvement, the property had the potential to achieve a heat demand of 67.6 kWh/ m^2 in line with the other solid wall properties considered on this project (the terraces). This reflects the heating demand based on a standard occupancy as modelled in SAP. In five of eight cases, the heating demand when modelled based on actual occupancy and heating patterns was actually lower. While generally this was a difference of less than 20%, in this case the heating demand based on actual occupancy was only 54% of that based on standard occupancy patterns. While it is widely accepted that SAP can overestimate heating patterns this does suggest some underheating in these properties as can be observed in the Chart 1 below.

Chart 1 – variation in heating demand – standard occupancy and heating patterns vs. actual



The heat load for this property was mid-range for those properties surveyed at 8.6kW but showed the potential for improvement to 3.7kW

The EUI performance can be found below. The target shown is the LETI new build target:



When based on customer information about occupancy, heating patters and appliances then this property has the joint lowest EUI at around 130 kWh/m^2/year. Additionally, it has the potential to achieve the joint lowest EUI after improvement of around 35 kWh/m^2/year, well below the LETI retrofit target. However, in this case it is based on the customer's occupancy, heating and unregulated energy patterns which appear to be relatively low. Consequently, the property has the lowest predicted baseline carbon emissions at 1255 kgCO_2e/year. When a standard figure for unregulated energy is used (2,200 kWh year) then this property has a significantly higher EUI in its current condition (219 kWh/m2/year) and can only reach a modelled 56 kWh/m2/year, just above the LETI retrofit target.

<u>ASHP cost and practical considerations</u>

The cost of installing the heat pump was comparable with other archetypes at £14,700. Though this was more than £1k higher than all other properties apart from the terrace properties.

Practical considerations that came up included:

- Fabric improvements should be made to improve performance
- Four radiators may need to be increased size to deal with the properties heat loss

<u>Optimum ASHP approach and impact on fuel bills</u>

Using the carbon coop tool, we were able to model a range retrofit scenarios using the properties existing fabric standards as a baseline. This also allowed us to consider the impact of heating type of fuel bills for each of these retrofit scenarios.

In the case of this bungalow, a rise in annual fuel bills of 15% with the current fabric standard was predicted where an ASHP is installed to replace to gas boiler. This was the lowest of all properties apart from the Easiform archetypes. Should the property fabric be improved in line with what has proposed based on consumer preference and the practical realities of the property in question, then an ASHP is shown to show no additional cost in fuel bills at today's prices compared to a gas boiler. However, the predicted cost of the proposed improvement measures at £45k may well be a barrier to many householders in this archetype achieving an ASHP bill comparable to that of gas. Similarly, to other archetypes, while a NSH is predicted to have 26% higher fuel bill costs than an ASHP with the property in its current condition, should someone spend £45k on thermal improvements then it switched round and the ASHP is predicted to be 4% more expensive in terms of fuel bills than NSHs.

The quote for an ASHP installation recommended fabric improvements before installing an ASHP including:

- Solid wall insulation
- Improved double glazing
- Party wall insulation

1930- 1960s bay window, cavity walled semi-detached house

Summary of findings

We looked at two 1930- 1960s cavity walled semi-detached properties with bay windows. Property 1 had previously had cavity wall insulation removed due to damp issues associated with poor installation. It also had a room in the roof. Property 2 already had Solar PV installed, as well as cavity wall insulation. It also has a converted basement.

The retrofit measures that were considered appropriate for each terrace based on the practical realities of the properties and consumer preference were as follows:

Semi-detached – Property 1:

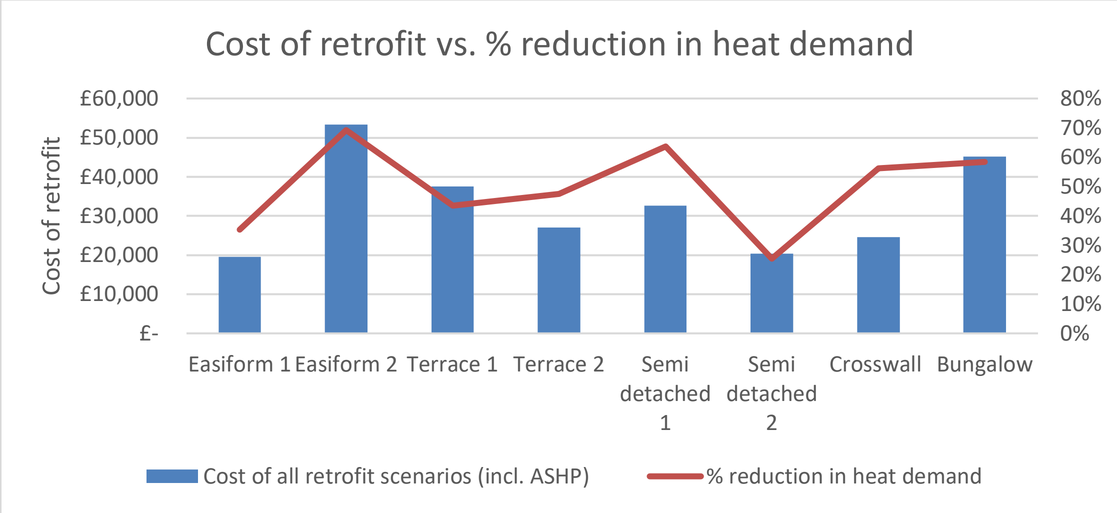
Improvements	Cost (cumulative)
Scenario 1 – Flat roof and suspended floor insulation, draughtproofing, dMEV	£8,700
Scenario 2 – Scenario 1 + CWI, advanced draughtproofing, dMEV, programable TRVs	£5,580 (£14,280)
Scenario 3 – Scenario 1 + 2 + ASHP, MVHR, Thermal Store, pipes insulated	£18,400 (£32,680)

Semi-detached – Property 2:

Improvements	Cost (cumulative)
Scenario 1 – Loft insulation, secondary glazing, insulated door, flat roof insulation, draught proofing, advanced central heating controls	£4,510
Scenario 2 – Scenario 1 + Floor insulation, bay window insulation and some external wall sections, draught proofing, dMEV	£2,690 (£7,200)
Scenario 3 – Scenario 1 + 2 + advanced airtightness, ASHP, pipe insulation, advanced controls to hot water store	£13,150 (£20,350)

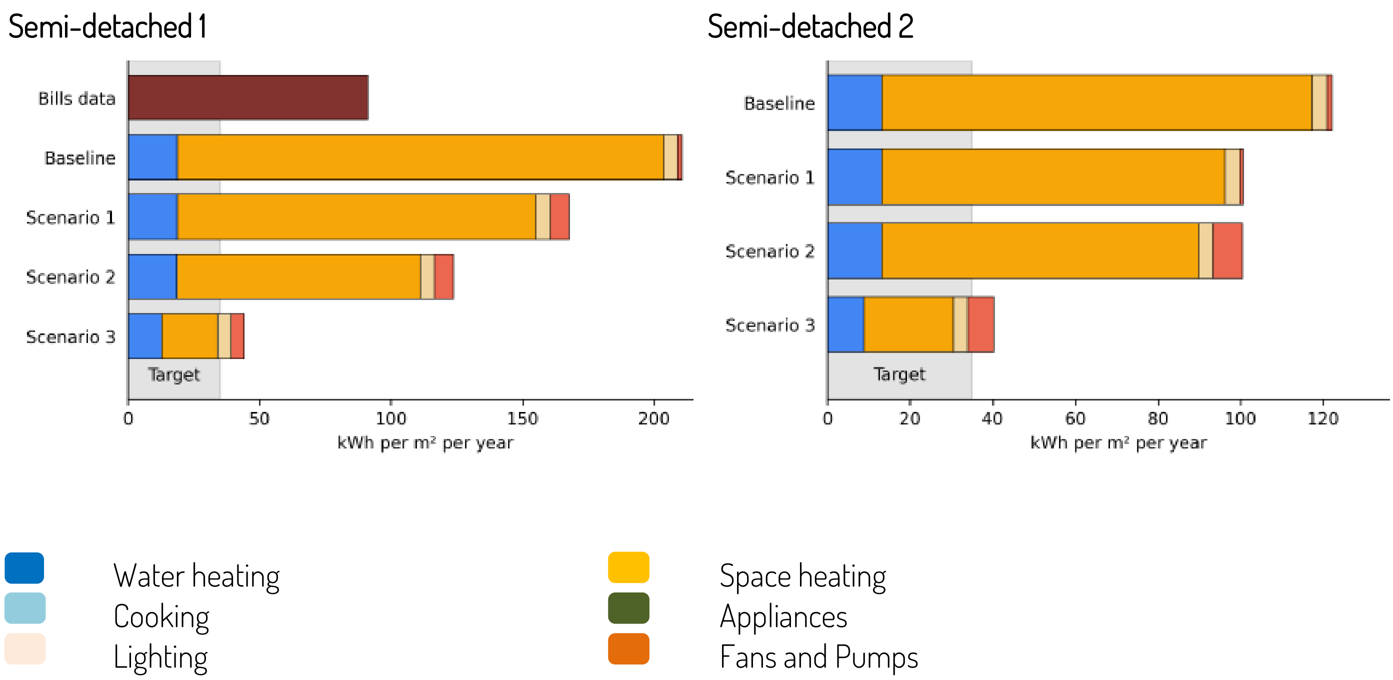
The current heating demand for both properties varied from 168.6 kWh/m^2 for property 1, and 112.4 kWh/m^2 for Property 2, most likely reflecting the lack of cavity wall insulation in Property 1. However, the fabric improvement measures proposed for both properties were modelled to reduce the heating demand to 61.4 kWh/ m^2 for Property 1, and 83.8 kWh/ m^2 for Property 2. In the case of Property 2, this is the highest post improvement heat demand for all properties. However, the package of improvements is also the 2nd lowest cost for this property at £20,350 for the most extensive retrofit scenario. Chart 2 below shows the correlation between heat demand and retrofit spend (notably, the crosswall property shows the most cost-effective reduction in heat demand which is considered further in the relevant section of this report).

Chart 2 – cost of retrofit vs. reduction in heating demand



The post retrofit improvement heat load also remains at high 8.4 kW for Property 2, vs. 4.4kW for Property 1.

The EUI performance for each of the semi-detached properties before and after improvement can be found below. The target shown is the LETI new build target:



Both properties are able to reach below the LETI retrofit target for EUI. Notably, in both cases the amount of energy associated with fans and pumps increases with the introduction of mechanical extract ventilation. Water heating remains relatively constant with the biggest improvements on space heating.

In property 1 an attempt was made to consider the EUI based on bills data. This comes out significantly lower than as predicted through modelling. This warrants further investigation, though where the target is set on modelled data then so long as the approach to assessment is consistent then this finding does not undermine the value of EUI as a target for driving energy efficiency improvements. When a standard figure for unregulated energy is used (2,200 kWh year) then both properties are shown to achieve an EUI of 38-42 kWh/m2/year, below the LETI retrofit target.

ASHP cost and practical considerations

The cost of installing the heat pump for both properties was comparable to other archetypes at between £13,100 and £13,500. Notably, property 2 required a 11.2kW heat pump (vs. 8.5kW for property 1) due to the increased heat load. The cost differential for this was only £400 though.

Practical considerations that came up in these properties included:

- Planning permission may be required
- Fabric improvements should be made to improve performance
- Radiators may need to be increased size to deal with the properties heat loss (3 each in property 1 & 2)

Optimum ASHP approach and impact on fuel bills

Using the carbon coop tool, we were able to model a range of retrofit scenarios using the properties existing fabric standards as a baseline. In the case of these semi-detached properties, a rise in annual fuel bills of 26%-34% in the properties with their current fabric standards was predicted where an ASHP is installed to replace to gas boiler. At an average of 30%, only the terraces saw a greater increase in bills for replacing a gas boiler with an ASHP at 32%.

Should the property fabric be improved in line with what has been possible based on consumer preference and the practical realities of the properties in question, then an ASHP is shown to only cost 8-11% more than a gas boiler in annual fuel bills at today's prices.

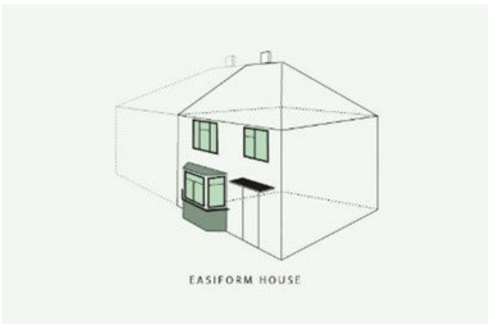
With the properties at the current fabric standard, then an ASHP is modelled to produce a fuel bill 26-42% lower than a NSH. Once improved, then the bills for NSH and ASHPs are modelled to be comparable (0-4% variance).

Both quotes for ASHP installations recommended fabric improvements before installing an ASHP including:

- Floor insulation
- Double glazing

Easiform

Summary of findings



We looked at two Easiform properties. First built in 1919, there are reported to be 85,000 Easiform properties in the country with most built between 1946 and 1970[7]. The properties are built with cast- n-situ concrete.

The perception around these, and other system 'non-traditional' build properties of this era is they will perform poorly on energy efficiency terms. However, the findings from this report are counter to that. The two properties we considered showed the lowest expected increase in bills for replacing a gas boiler with an ASHP, as well as some of the lowest heating demand figures (before and after retrofit improvements).

[7] Laing Easiform Cast-in-Situ House - Non-Standard House Construction - Information & Resource Centre (nonstandardhouse.com)

Notably property 1 already had significant improvements carried out, including CWI and EWI. But this was not the case for property 2, which still had relatively low heating demand. Both properties had double glazing.

The retrofit measures that were considered appropriate for each terrace based on the practical realities of the properties and consumer preference were as follows. The improvements are mapped out in scenarios that progressively improve the performance of the property. A fabric first approach was taken wherever possible:

Easiform Property 1:

Improvements	Cost (cumulative)
Scenario 1 – loft insulation, extractor fan, insulate hot water pipes	£1,150
Scenario 2 – Scenario 1 + insulated HW cylinder, ASHP	£11,550 (£13,100)
Scenario 3 – Scenario 1 + 2 + advanced airtightness, MVHR	£6,500 (£19,600)

Easiform Property 2:

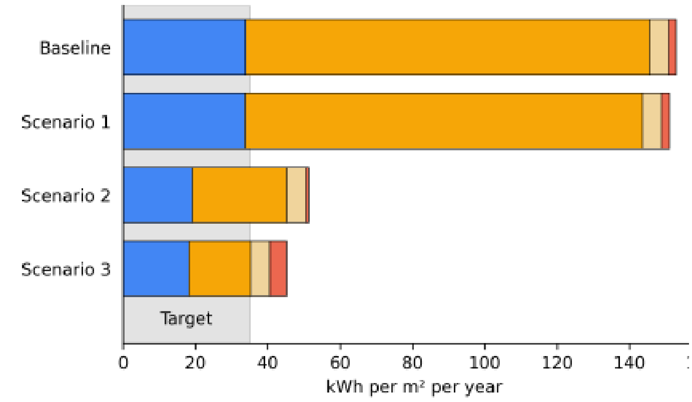
Improvements	Cost (cumulative)
Scenario 1 – Loft insulation, 'hard to treat' CWI, draught proofing, dMEV	£6,800
Scenario 2 – Scenario 1 + insulated doors, triple glazed windows, EWI, advanced airtightness, MVHR	£32,300 (£39,100)
Scenario 3 – Scenario 1 + 2 + ASHP, advanced airtightness, all primary hot pipes insulated, advanced HW controls	£14,200 (£53,300)

Property 1 had the lowest proposed cost of improvements of all properties considered but also managed to achieve the third lowest post improvement heat loss. However, CWI and EWI were already installed for this property which adds £23k of projected costs to improving the second property which had not yet had this done. Prices included in this report are only guide prices and it may be these costs could be significantly lower in practice.

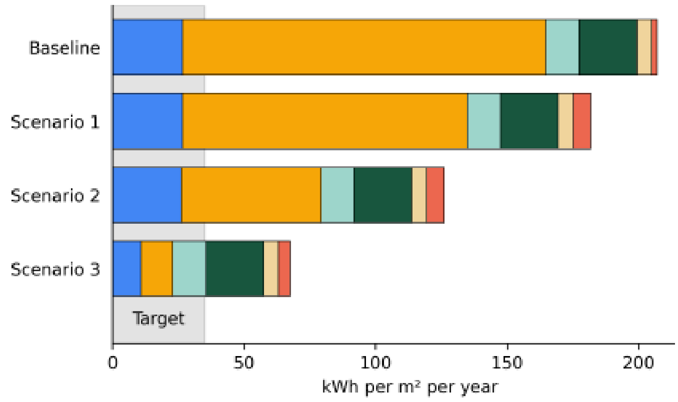
The current heating demand for both properties varied from 78.7 kWh/m^2 for Property 1, and 130 kWh/m^2 for Property 2, reflecting the fact that Property 1 has CWI and EWI. The fabric improvement measures proposed for both properties reduce the heating demand to 50.9 kWh/ m^2 for Property 1, and to 40 kWh/ m^2 for property 2, which is the second lowest heating demand achieved post improvement. This may well be down to the inclusion of very advanced airtightness and MVHR in the retrofit scenarios for this property – modelling showed this to reduce space heating demand by 8-10 kWh/m^2 which is very significant when you get to this level of efficiency. In both cases the heat load can be reduced to very low levels for an existing property, at 4.5kW for Property 1, 2.7 kW for Property 2. Property 2 represents the lowest possible heat load for any property apart from the crosswall, though this set against £53,300 of retrofit costs (including the costs of MVHR).

The EUI performance for each of the Easiform properties before and after improvement can be found below. The target shown is the LETI new build target:

Easiform 1



Easiform 2



Water heating
Cooking
Lighting

Space heating
Appliances
Fans and Pumps

Property 1 is able to reach below the LETI retrofit target for EUI. Property 2 remains above this even after extensive retrofit and despite very low water and space heating demand. From the chart above this can be seen to be due significant cooking, appliance and fan and pumps use. This captures the complexity of EUI when it comes to unregulated energy and householder behaviour. In the case of this report, not all householders provided complete data, and this makes comparison more difficult. However, when a standard figure for unregulated energy is used (2,200 kWh year) then both properties are shown to achieve an EUI of 49-62 kWh/m2/year.

ASHP cost and practical considerations

The cost of installing the heat pump for both properties was comparable to other archetypes at £12.9k for an 8.5kW heat pump.

Practical considerations that came up in these properties included:

- Planning permission may be required
- Fabric improvements should be made to improve performance – floor insulation and improved double glazing

Optimum ASHP approach and impact on fuel bills

In the case of these Easiform properties, a rise in annual fuel bills of 13%-14% in the properties with their current fabric standards was predicted where an ASHP is installed to replace to gas boiler. This was the lowest of all the archetypes.

Should the property fabric be improved in line with what has been possible based on consumer preference and the practical realities of the properties in question, then an ASHP is shown to only cost 4-6% more than a gas boiler in annual fuel bills at today's prices.

In the case of NSH, an ASHP is shown to have predicted fuel bills that are 8-16% lower at current fabric standards. Once the properties are improved, then an ASHP is modelled to have fuel bills 15-26% than with NSH. As with all other properties this comparison was carried out using SAP bill cost figures[8] which are both out of date but also makes the presumption that with the progression of smart meters and time-of-use tariffs that the current significant price decrease for night-time 'off-peak' energy will remain.

Both quotes for ASHP installations recommended fabric improvements before installing an ASHP including:

- Increased floor insulation
- Improved double glazing

Crosswall/rationalised construction terraces with flat roofs

Summary of findings

Cross-wall construction is a form of construction in which two load bearing walls provide the support bridging components such as floors, roofs and beams. External wall panels (including with tile hung finishes) are used to 'fill in' the front and rear façade where there are no window or door openings.

For the purpose of this project, we are considering crosswall properties generally built 1950-1980 as local authority housing stock as per the picture below. We were only able to identify one crosswall property to survey as part of the programme.

Figure 2 – Crosswall property

Much like Easiform properties, these properties are anecdotally known to be hard to heat and to perform badly in energy efficiency terms as built. Due to the complexity of the wall structure, these properties often have complicated junctions where thermal bridges play a significant part in the success (or otherwise) of insulation improvements. This property had had an upgraded and well insulated flat roof installed but the house was draughty, and it was noted that windows are not easily sealed to the walls. It is thought that whilst draught-proofing can be undertaken, it is likely that for a properly adequate resolution, the windows and doors would need to be replaced and installed to a high standard.

[8] 0.21 daytime and £0.08 per unit night-time was used for NSH fuel bill costs - space heating energy use is 80% low tariff and 20% high tariff, and water heating is 100% low tariff. Stanadard (non-Economy 7) unit = £0.1944. Electric standing charge = £97

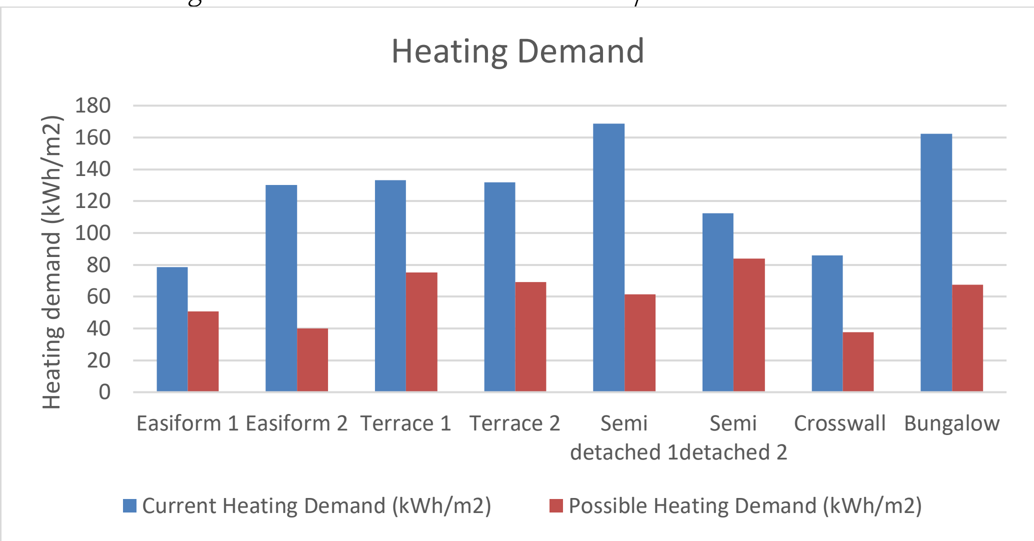
As modelled through SAP, however, this property performed remarkably well – it was the only property that post improvement showed price parity between a gas boiler and an ASHP (in terms of annual fuel bills) as well as showing the second lowest baseline heating demand at 86.1 kWh/m2. This exemplifies the widely discussed performance gap with SAP as well the difference in quality of living experience for householders – a draughty property will feel colder than it is in practice and be less comfortable in the winter months.

The retrofit measures that were considered appropriate for this crosswall property based on the practical realities of the properties and consumer preference were as follows:

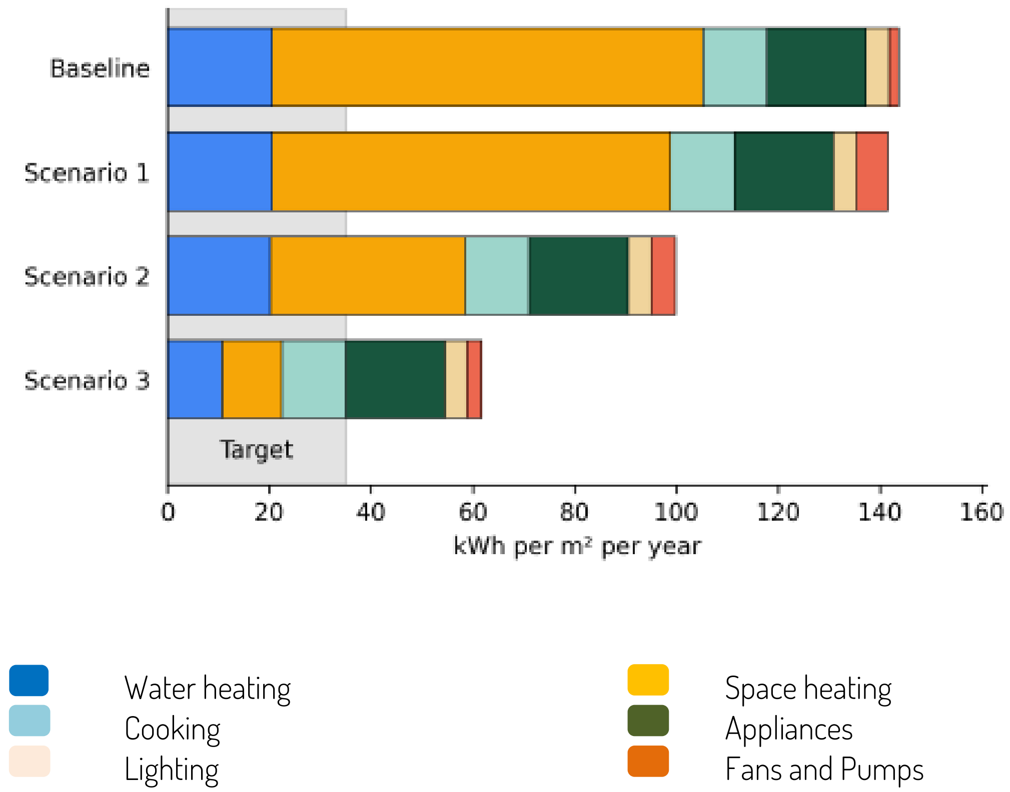
Improvements	Cost (cumulative)
Scenario 1 – Double glazed patio door, advanced draughtproofing, dMEV, primary hot water pipes insulated	£1,930
Scenario 2 – Scenario 1 + EWI, IWI, double glazed windows, insulted door, advanced airtightness, MEV	£11,200 (£13,130)
Scenario 3 – Scenario 1 + 2 + ASHP, hot water tank	£11,500 (£24,630)

As well as having the second lowest theoretical heating demand of 86.1 kWh/m^2, through improvement, the property had the potential to achieve a heat demand of 37.7 kWh/ m^2 - the lowest of all the properties surveyed as can be seen in the chart below.

Chart 3 – heating demand before and after retrofit improvements



The heat load for this property was similarly modelled as low at 3.8kW and showed the potential for improvement to an impressive 2.2kW. The EUI performance be found below. The target shown is the LETI new build target:



Despite having a low space and water heating requirement, this property does not meet the LETI retrofit target. Much like the second Easiform property, this is due to the energy associated with cooking, lighting, appliances, fans and pumps based on consumer behaviour reported by the customer (though the figure based on a fixed volume of unregulated energy (2,200 kWh year) was very similar at 63 kWh/m2/year.

<u>ASHP cost and practical considerations</u>

The cost of installing the heat pump was comparable with other archetypes at £12,880 for an 8.5kW ASHP.

Practical considerations that came up included:

- Fabric improvements should be made to improve performance – walls
- Double glazing should be improved

<u>Optimum ASHP approach and impact on fuel bills</u>

Using the carbon coop tool, we were able to model a range retrofit scenarios using the properties existing fabric standards as a baseline.

In the case of this crosswall property, a rise in annual fuel bills of 18% with the current fabric standard was predicted where an ASHP is installed to replace to gas boiler. Should the property fabric be improved in line with what has proposed based on consumer preference and the practical realities of the property in question, then an ASHP is shown to add only 5% additional cost in fuel bills at today's prices compared to a gas boiler. Notably, the cost of achieving this improvement was predicted to be only £13.1k before the costs of the ASHP and hot water tank.

An ASHP was predicted to give 3% cheaper fuel bills than a NSH pre-improvement, and 16% more expensive post improvement. Give the significantly cheaper install costs for modern high heat retention night storage heaters, this requires further exploration.

The quote for an ASHP installation recommended fabric improvements before installing an ASHP including:

- Wall insulation
- Improved double glazing

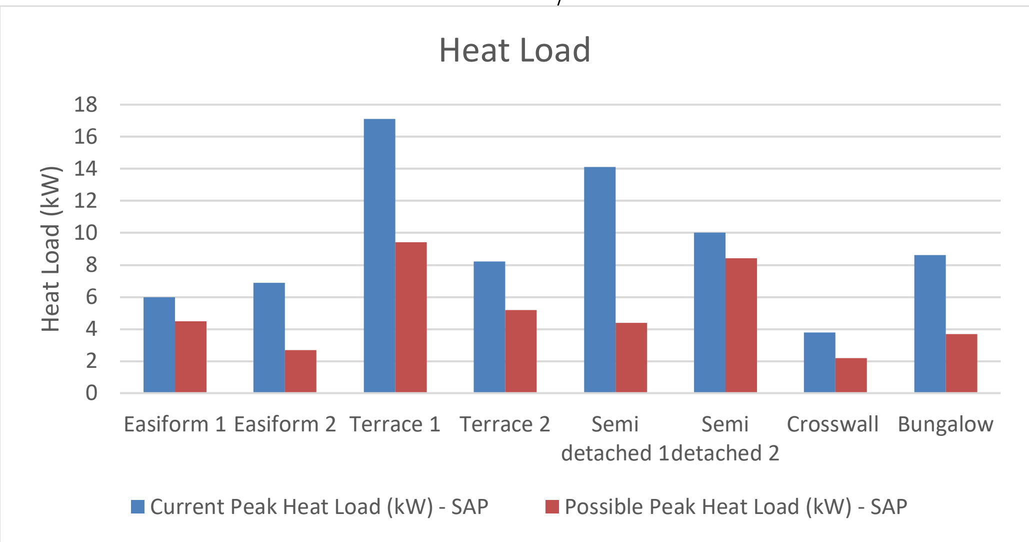
Retrofit scenarios and impact on ASHP viability

Using the carbon Coop tool, we were able to model performance with a heat pump for a range of different retrofit scenarios. This helps to provide advice to customers considering ASHP at different stages of the retrofit journey as well as assess the overall optimum approach to installing a heat pump. This section considers these findings across all 5 archetypes explored in this project.

Heat Load

Heat load is important in sizing the appropriate heat pump. The chart below shows how heat load varied significantly across the properties surveyed as a function of size and fabric performance. This resulted in a dramatic difference in cost and approach to heat pump installation between the two terrace properties and shows the importance of property specific advice.

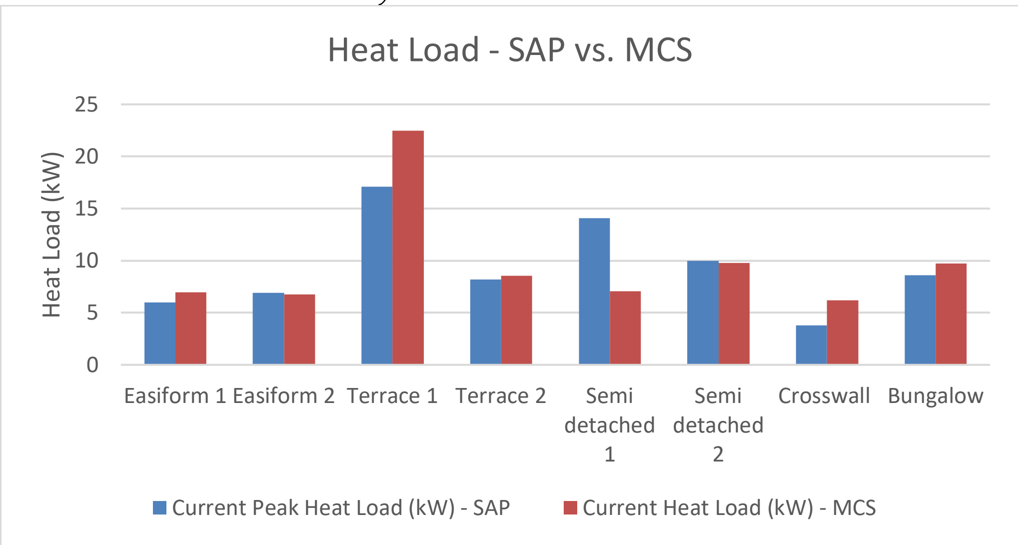
Chart 4 – Heat Load before and after retrofit improvements



The ability to reduce heat load through retrofit improvements shows the importance of heat pump sizing relative to retrofit plans. In all cases for this project, the ASHP size proposed now based on current performance standards was likely to be oversized once properties had reached the end of their retrofit journey – an average reduction in heat load of 44% was shown to be possible across all properties with 69% achievable in the second Easiform which included MVHR and associated airtightness works in its improvement plan.

It was also notable to see the difference between the modelled heat load through SAP vs. the heat load generated through the MCS heat loss survey. Assuming this is not down to human error, this will be an important consideration when giving customers initial advice around heat pump approach. If not handled properly this could lead to inconsistency of messaging and confusion. It is understood that Carbon Coop are looking at building this functionality into their tool which will be welcome.

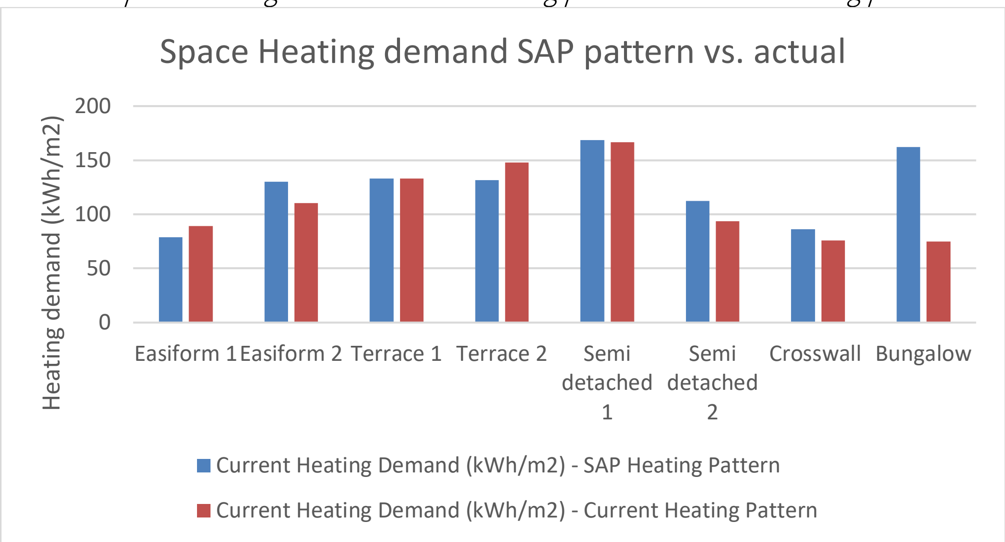
Chart 5– Heat Load – MCS survey vs. SAP



Space heating demand

The Carbon Coop tool considered both the space heating demand for standard occupancy and heating patters (as generally used in rdSAP) and actually householder occupancy and heating patterns. The average variance was 9% but there was no distinguishable pattern and it ranged between -54% to + 14%.

Chart 6– Space Heating Demand – SAP heating pattern vs. actual heating pattern



Heating bills

Carbon Coop carried out modelling of likely energy bills with different heating sources. This can be observed in Chart 7 below. In all cases ASHP proved significantly cheaper than direct electric heating. However, in all cases ASHP proved more expensive based on current prices in SAP for heating bills when compared with an efficient gas boiler. The average precited bill increase was 23% - see Chart 8. Surprisingly, the lowest predicted increase was in the Easiform properties.

Chart 7– Heating bill comparison for baseline property.

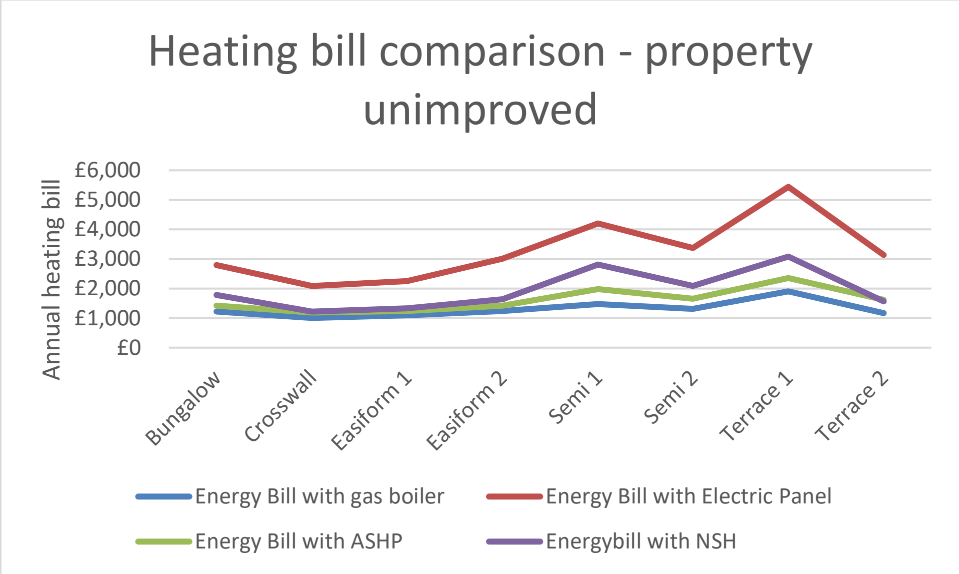
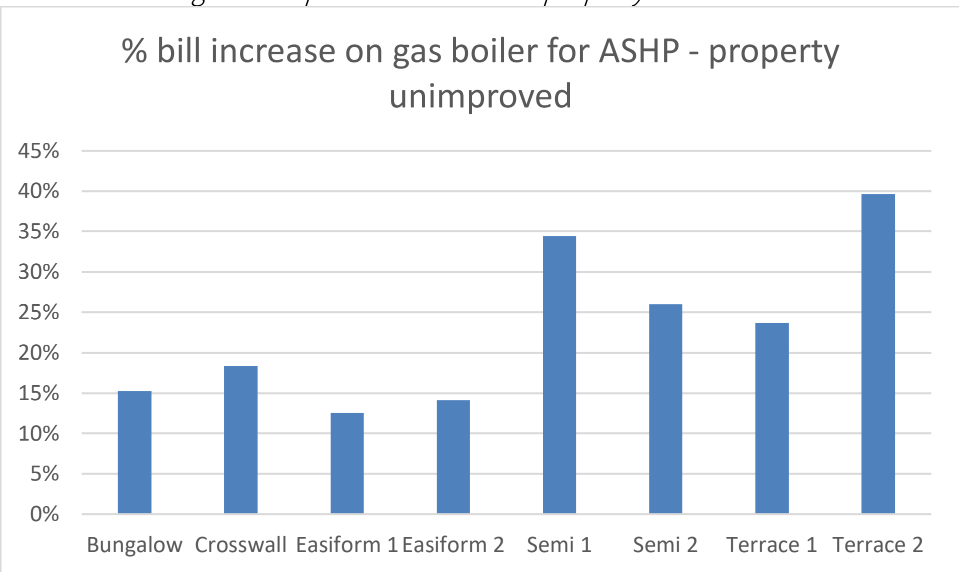


Chart 8 – Heating bill comparison for baseline property - % increase for ASHP over gas boiler



Once the properties have been improved, then a lower heating bill increase is expected. This is expected to be only an average 8% increase (at current SAP prices) between a gas boiler and an ASHP. Again, surprisingly, the system build properties performed best in the improved scenario when compared with the other archetypes (with exception of the bungalow). Notably, NSH were modelled to produce lower fuel bills than ASHPs in all cases once the properties had been improved. See charts 9&10 below. This comparison was carried out using SAP bill cost figures[9] which are both out of date but also makes the presumption that with the progression of smart meters and time-of-use tariffs that the current significant price decrease for night-time 'off-peak' energy will remain.

[9] 0.21 daytime and £0.08 per unit night-time was used for NSH fuel bill costs - space heating energy use is 80% low tariff and 20% high tariff, and water heating is 100% low tariff. Stanadard (non-Economy 7) unit = £0.1944. Electric standing charge = £97

Chart 9– Heating bill comparison for improved property.

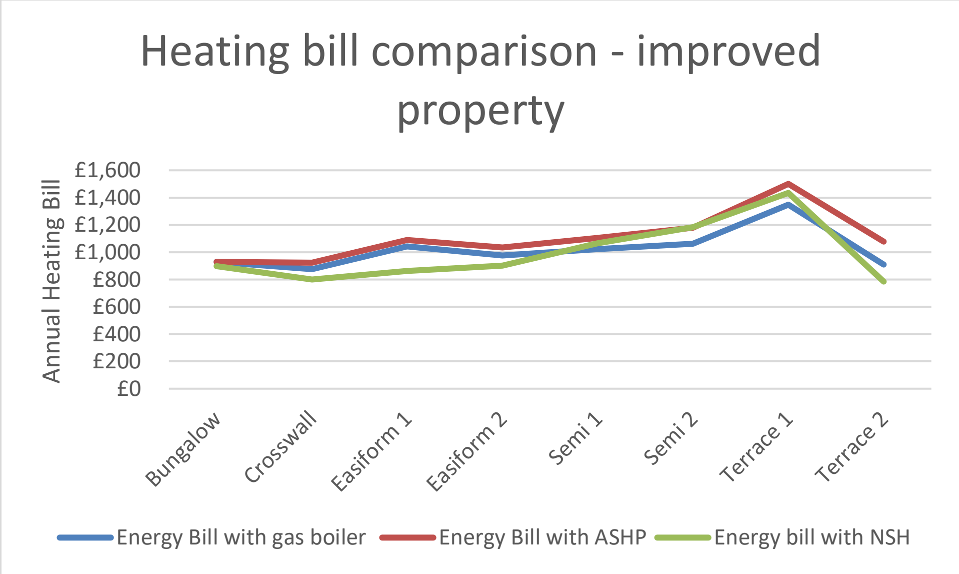


Chart 10 – Heating bill comparison for improved property - % increase for ASHP over gas boiler

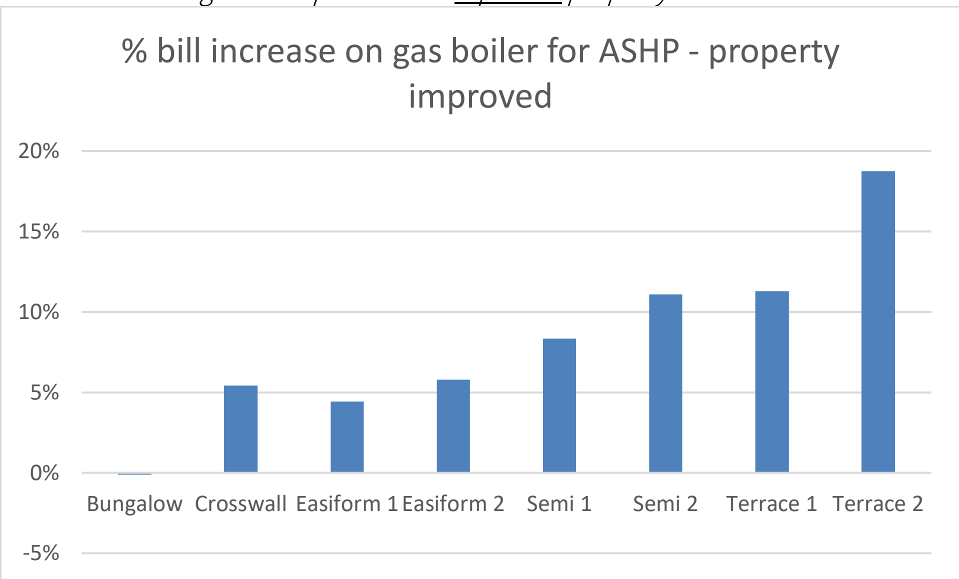
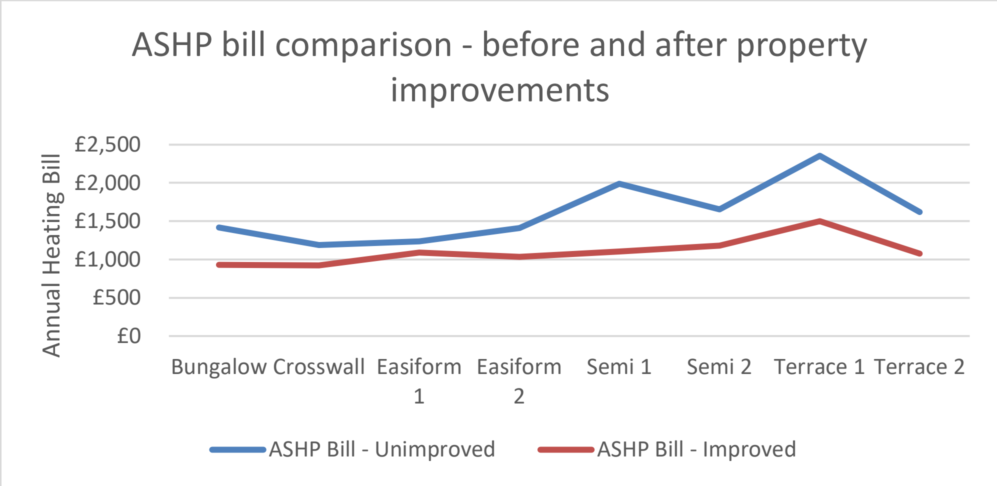


Chart 11 shows the proposed improvements to the fabric of the property help to reduce future heating bills, with the biggest gains being made in the terrace and semidetached houses. This report has been complied during the largest increase in living expenses in 40+ years in the UK. OFGEM has predicted that the current energy cap price of £1971 is set to climb to £3540 in October 2022. As such, the SAP energy unit cost prices used are significantly lower than the prices being experienced now in reality. While prices are expected to drop from their current peak, wholesale energy prices are predicted to remain high, and significantly above pre-pandemic levels (by organisations such as Cornwall Insight) for the next eight years at least.

This is an important consideration when giving advice to fuel poor households in particular (with National Energy Action projecting this could be 1 in 3 UK households in this position with predicted fuel bill increases this year). Customers will need to be supported understand potential impacts on fuel bills as part of the decarbonisation of domestic heat.

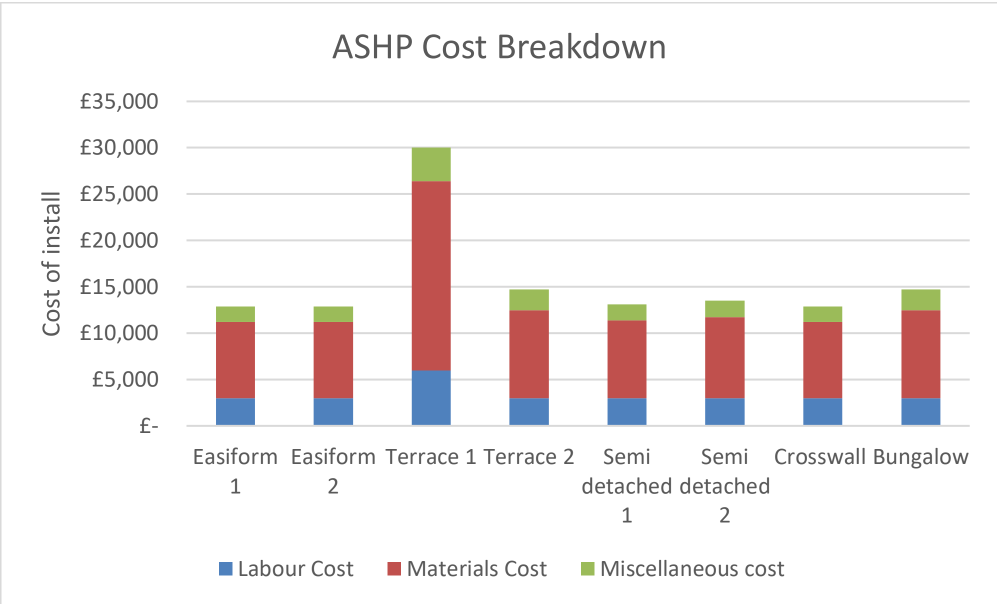
However, in terms of this comparison between fuel bill costs for a gas boiler vs. an ASHP, the January 2022 SAP unit rates used, still slightly favour gas. It is possible that the October 2022 price cap might tip the balance against gas a bit further, a trend that would be increased should some of the non-commodity costs (e.g., green tariffs) be removed from electricity unit costs.

Chart 11– ASHP bill comparison before and after property improvement



<u>Breakdown of installation costs</u>

Chart 12 – Breakdown of installation costs

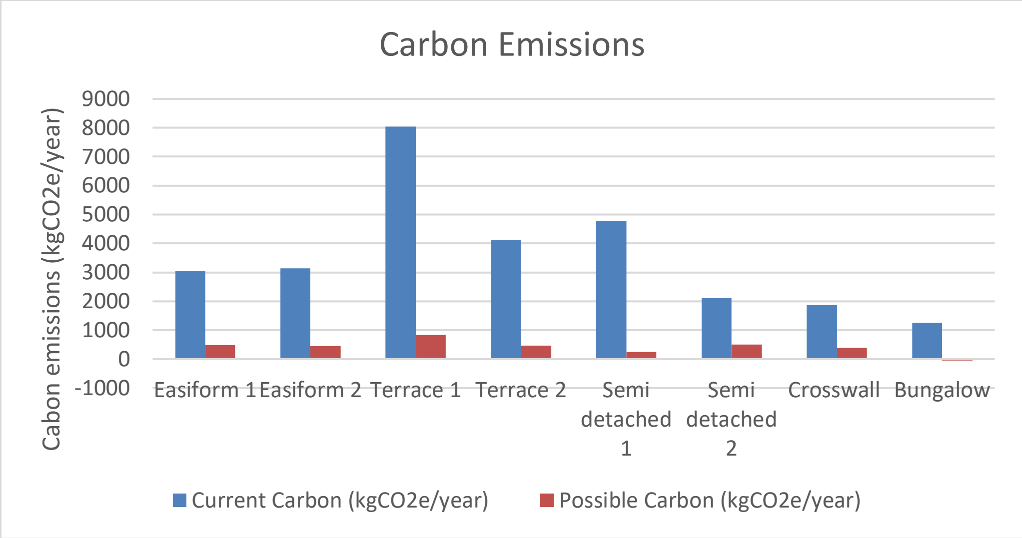


On average materials made up 65% of costs and labour 22%.

<u>Carbon Emissions</u>

All properties showed potential for significant carbon savings, even based on current grid carbon factors. The bungalow in particular is shown to achieve operational net zero carbon.

Chart 13 – Carbon emissions – before and after improvement



Opportunities for heat pumps in Plymouth

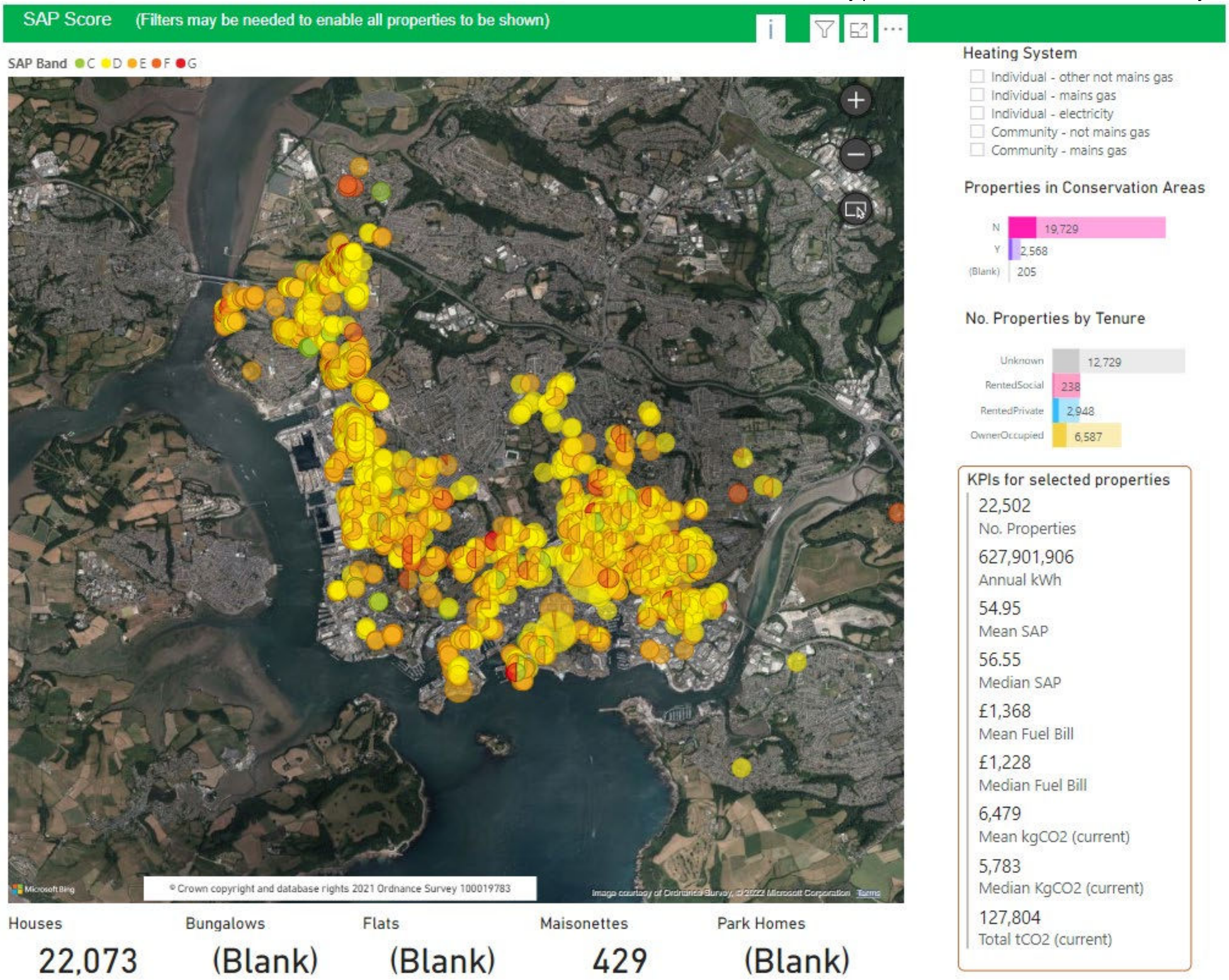
The initial expectation was the analysis form this project would be used to produce an online tool for people living in these archetypes to better understand if a heat pump is a viable option for their home and if so, what measures might be required or suggested to support installation. However, a key learning through this project is the amount of variance between even quite specific archetypes. Given the low sample size for this project, it was felt that any online tool created based on the data could be misleading as it would not be property specific enough.

Instead, Plymouth City Council and PEC have decided to create online case studies on installing a heat pump in each of these archetypes (which have been submitted in draft along with this report) as well as purchase the Parity Projects Plan online advice tool, an example of this can be found in the Cosy Homes Oxfordshire project: https://app.cosyhomesoxfordshire.org/ . This allows you to build property specific plans based on EPC data which we feel will give customers far better property specific advice alongside the case studies for each archetype.

Plymouth Energy Community and Plymouth City Council now possess extensive housing and energy data that we have purchased from Parity Projects. Parity Projects utilises advanced data science, intuitive software and in-depth analysis to help its clients deliver energy efficiency retrofit programmes efficiently, and effectively. Parity works with local authorities and community energy groups to develop cost-effective retrofit programmes to provide a data driven foundation to plan and meet their goals. This data builds on the RdSAP data that sits behind an EPC as well as filling in the gaps with data analysis where EPC data is not available.

For each archetype we have set search criteria and parameters for Plymouth to identify the number and location of the homes. We have included screen captures from Parity's Pathways software searching for each archetype in Plymouth below. The plan is to use this data to work with Plymouth City Council to build a targeted approach to domestic retrofit.

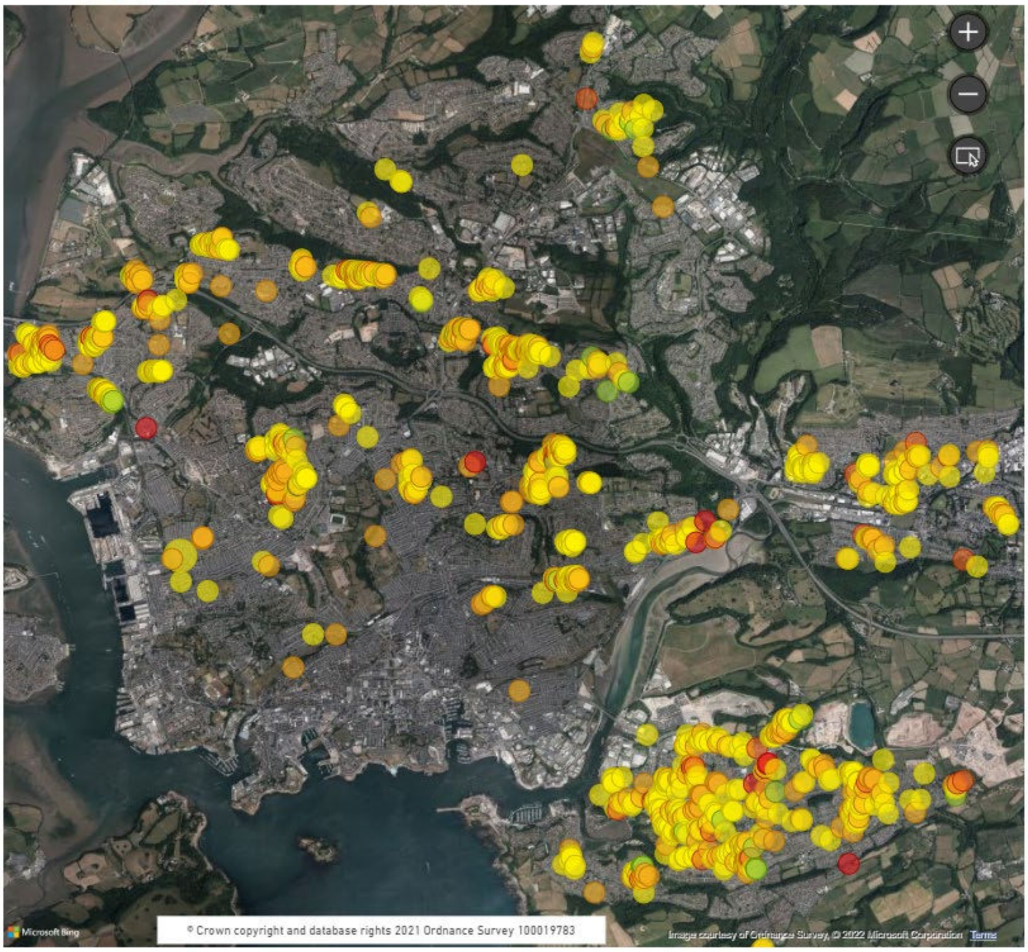
Pre--1900 to 1929 – Victorian Terraced home (these numbers include all types of Victorian terraces in Plymouth).



1930-1949 – Bungalows

SAP Score (Filters may be needed to enable all properties to be shown)

SAP Band ● C ● D ● E ● F ● G

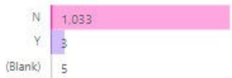


Houses	Bungalows	Flats	Maisonettes	Park Homes
(Blank)	1,041	(Blank)	(Blank)	(Blank)

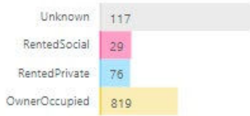
Heating System

- ☐ Individual - other not mains gas
- ☐ Individual - mains gas
- ☐ Individual - electricity
- ☐ Community - not mains gas
- ☐ Community - mains gas

Properties in Conservation Areas



No. Properties by Tenure



KPIs for selected properties

1,041
No. Properties

20,084,231
Annual kWh

55.64
Mean SAP

57.74
Median SAP

£1,029
Mean Fuel Bill

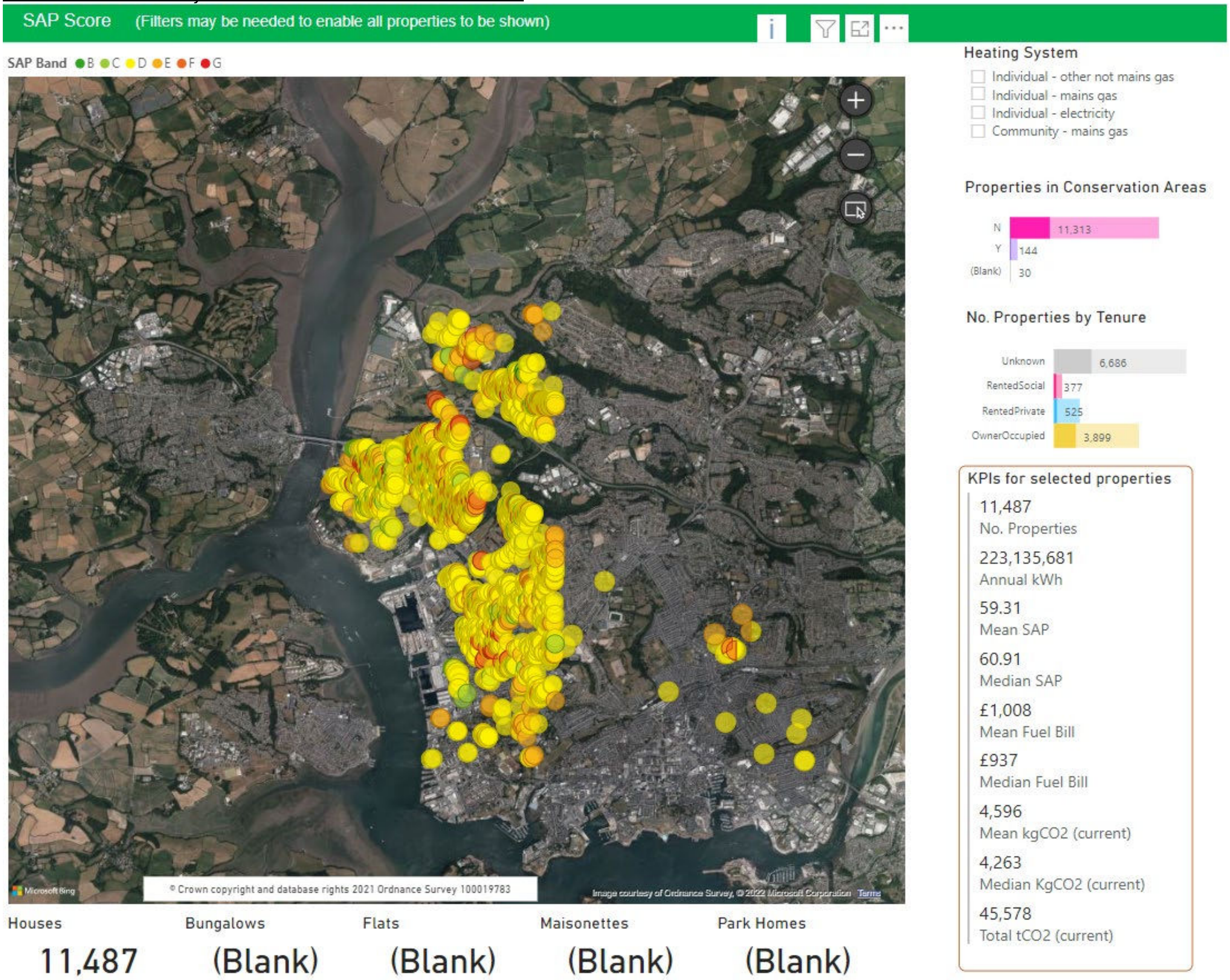
£944
Median Fuel Bill

4,663
Mean kgCO2 (current)

4,305
Median KgCO2 (current)

4,064
Total tCO2 (current)

<u>1930 – 1966 Cavity wall, Semi-detached houses</u>



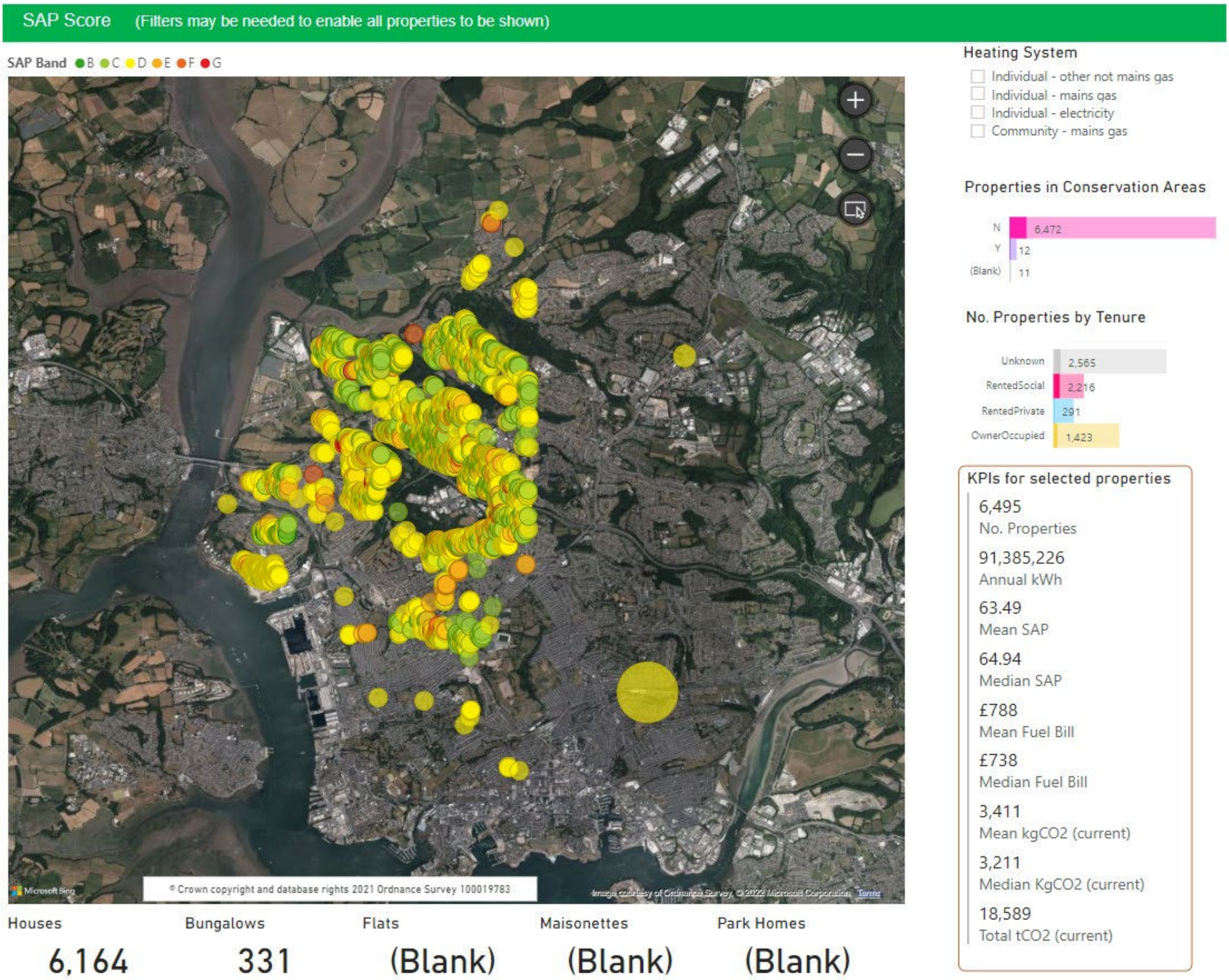
1930-1982 – System Built Walls

This includes the following system build types as we were not able to separate out the data by each system build type further.

<u>Easiform</u>

Crosswall

Cornish Units



Next steps

The learning from this project will support PEC and Plymouth City Council with domestic low carbon retrofit across the city. This will include the launch of the Sustainable Warmth programme and support practical recruitment of householders to receive funded low carbon improvements.

This project provides a more robust understanding of heat pump roll out for Devon and SW of England by rounding out the learnings from the rural heat pump project undertaken by the SW Net Zero Energy Hub. In addition, it will support work in the development of an approach to the local decarbonisation of heat, with discussions well advanced with local partners on how best to build on this work.