The Carbon Baseline of Merthyr Valley Homes:

2 - Homes

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1 Background and Introduction

This research note is the second in the series that estimates the carbon baseline of Merthyr Valley Homes (MVH), a community mutual housing association, with a Head office based in the Gellideg area of the town and homes located all across the Merthyr Tydfil County Borough. The prior report addressed the greenhouse gas emissions (GHG) associated with operational activities – including, for example, following electricity and gas consumption at MVH office locations (Scope 1 and 2), along the MVH supply chain (part of Scope 3), and consequent on MVH employees wage-based consumption[1].

Here we provide a baseline estimate of the greenhouse gas emissions arising from the energy footprint of the MVH owned and operated housing and building stock – some 4,000 properties rented to tenants.

This report is part of a larger project supported by Cardiff University and the ESRC Impact Acceleration Account entitled *Low Carbon Community, Low Carbon Economy: Building Re-localised, Sustainable and Prosperous Communities*. This project aims to help communities (including 'institutional communities' like MVH) understand and improve their socio-economic and environmental baselines, impacts and opportunities when facing our challenging future[2]. Our previous reports have estimated the economic Impact of MVH[3] and the carbon footprint of Treherbert, In the Rhondda Valleys[4].

The emissions covered in this report constitute:

> *"emissions from leased assets, investments, and franchises that are excluded from the company's organisational boundary but that the company partially or wholly owns or controls"*[5].

1 See https://orca.cardiff.ac.uk/id/eprint/155963/
2 More information on this project is available from the current author.
3 https://orca.cardiff.ac.uk/id/eprint/154428/
4 https://orca.cardiff.ac.uk/id/eprint/150091/
5 See https://www.local.gov.uk/climate-change-reporting-guidance-local-authorities for an explainer.

Whilst owned homes are considered 'inside' the organisational boundary, the reality is that the bulk of associated GHGs are not under the direct control of the social landlord, with the purchase of heating and power a tenant's responsibility. Emissions from socially rented homes are thus typically thus assessed in Scope 3[6].

The reporting of individual elements of Scope 3 emissions is not mandatory, but the understanding of individual elements is very important for climate strategy and carbon management. Typically, well over half of a UK public sector organisations' GHGs arisings will be in Scope 3. In the MVH case emissions from tenants' homes are an extremely important element of the carbon baseline:

- They are likely to be significant in scale,
- As the homeowner, MVH has the largest impact on the reduction of home GHGs via its management of homes, investments in retrofit insulation or home renewables systems, and through behavioural interventions with members and tenants,
- GHG emissions are a good indication of the exposure of tenants to increasing energy costs, now and over the longer term.

Note that MVH homes also require continual maintenance and upgrade, and emissions associated with this are not insignificant. These emissions – averaging around 300kg per home per annum – are assessed in our first report, and largely arise in the MVH supply chain.

With the above in mind, the next section explains our approach to estimating GHG emissions associated with heating and power in MVH housing stock.

[6] https://www.insidehousing.co.uk/insight/insight/explainer-how-to-measure-a-social-landlords-carbon-footprint-71623

2 Methodology & Data

2.1 Our Data Sources

Our analysis is based on a 100% census of MVH owned homes in 2021-22, overwhelmingly in Merthyr Tydfil but with properties to the south (e.g. in Aberfan and Bedlinog) and north (in the rural hamlet of Pontsticill). The database is largely complete, with 4,060 records – each a home – and variables covering:

- Address including postcode,
- Building archetype (house, bungalow, maisonette, flat etc.),
- Construction method,
- Number of bedrooms,
- Year of construction (in bands),
- Fuel type,
- EPC and SAP ratings.

These data provide an excellent basis for understanding the energy use within buildings. However, an extensive literature review suggests there is limited information available from other sources that tells us how buildings perform as variables (such as number of bedrooms, or year or method of construction) influence the use of energy for power and heating (via electricity, gas or other means). What information does exist is often not in a UK context[7], based on cases with limited application to Merthyr[8], or lacking relevance for MVH's exclusively social-renting households[9].

There is however a high quality and relatively up-to-date estimate of energy use for small areas in the UK – down to full 7-digit postcode level. This dataset, produced by the UK Government Departments for Energy Security, and for Net Zero, and Business, Energy & Industrial Strategy, also distinguishes energy use between electricity and gas.

[7] See for example Goldstein, B., Gounaridis, D., & Newell, J. P. (2020). The carbon footprint of household energy use in the United States. *Proceedings of the National Academy of Sciences*, *117*(32), 19122-19130.
[8] Elsharkawy, H., & Rutherford, P. (2015). Retrofitting social housing in the UK: Home energy use and performance in a pre-Community Energy Saving Programme (CESP). *Energy and Buildings*, *88*, 25-33.
[9] For example papers that look across all socio economic groups; Druckman, A., & Jackson, T. (2008). Household energy consumption in the UK: A highly geographically and socio-economically disaggregated model. *Energy policy*, *36*(8), 3177-3192.

These data[10] are compiled from information provided by electricity and gas supply companies for each of their meters, with these meters then allocated to residential and non-residential customers. With the exception of mistakes, misallocations cases where results would be disclosive[11], this is then theoretically a full census of household gas and energy use in the UK.

2.2 Data Manipulation

To link the MVH and energy consumption datasets, and to assess resultant greenhouse gas emissions, the following steps are undertaken:

- Individual MVH properties are connected to the sub-national energy estimate for the relevant 7-digit postcode[12]. We apply the UK Gov mean energy use estimate for that postcode (for both gas and electricity) to each MVH house within that postcode.
- Estimated gas consumption in kWh for each property, based on the average for that 7-digit postcode, is converted to greenhouse gas emissions (in kilogrammes of CO2e) using UK Government GHG Conversion Factors for 2021. and the same process undertaken for electricity[13].
- An additional estimate is undertaken for electricity using the regional generation mix for electricity[14], rather than the UK average. This adds around 60% to estimates of GHG from electricity due to south Wales' fossil fuel heavy mix.
- Estimates are thus made for GHG emissions for each MVH property from electricity and gas, and by aggregate in total for heating and power, on both a UK-grid average and south Wales-grid average basis.

Following this analysis, we have a robust estimate of emissions from MVH homes, both individually and in total. There are however some weaknesses and limitations of which readers should be aware.

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10 Available from https://www.gov.uk/government/publications/postcode-level-domestic-gas-and-electricity-consumption-about-the-data/postcode-level-domestic-electricity-consumption-notes
11 Full methodology is available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1131522/subnational-methodology-and-guidance-booklet-2023.pdf
12 Using XLOOKUP in Excel.
13 See https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2021
14 For 2019 average; unpublished analysis available from the current author

- Each estimate is based on the mean energy use across a postcode. This will provide a fully accurate estimate of aggregate MVH housing emissions only where MVH own all properties within that 7-digit code. Where there are, for example, private homes in the same 7-digit code that are substantively different in archetype, size or power sources, the MVH estimate will be somewhat biased,
- The postcode matching does not provide 100%. coverage Although Gas meters have excellent linkage[15], matching is less good for electricity meters[16]. Thus, where data are missing, energy use is estimated by averaging energy use for the postcodes alphanumerically above and below the missing records,
- A small number of properties (less than 20) which are not on mains gas (LPG, full electricity and air source heat pump) require bespoke estimation.

With these caveats in mind, the following Section provides estimates of GHGs arising from the power and heating used in MVH homes in 2021.

[15] 4032 of 4060 properties, or 99.3%
[16] 3442 of 4060 properties or 84.8%

3 Results: The Greenhouse Gas Emissions of MVH Homes

3.1 Aggregate MVH Homes Carbon Baseline

We estimate that in 2021 greenhouse gas emissions from MVH homes totalled 8,915 tonnes from gas use[17], and 4,070 tonnes of 'actual' emissions from electricity supply (factoring in the carbon-intense south-Wales grid), but 2,484 tonnes of emissions on the UK-grid average measure.

Total actual emissions from homes heating and power were therefore around 13,000 tonnes, but with a total for carbon reporting and comparison purposes of 11,400 tonnes (Figure 1).

Figure 1 Merthyr Valley Homes Scope 1 & 2 Greenhouse Gas Emissions (2021-22)

(tonnes CO2e)	**Total CO2e (t)**	**Average CO2e per home (t)**
GHG Gas	8,915	2.20
GHG Electricity UK	*2,484*	*0.61*
GHG Electricity south Wales	*4,070*	*1.00*
Total GHG UK Grid Basis	11,399	2.81
Total GHG south Wales Grid Basis	12,985	3.20

As the Figure also shows, the per-home emissions of GHGs totals 3.2 tonnes on a south Wales basis, and 2.81 tonnes on a UK-grid basis. In both cases, emissions from gas (largely heating) are significantly greater than from electricity.

Note that undertaking a parallel analysis for all Cardiff postcodes suggests that gas use in MVH homes is 11% lower, and electricity use 8% lower, than the 'CF all residential properties' average. Average emissions from MVH homes in 2021 will thus be roughly 9-10% lower than the CF average.

The comprehensive MVH database allows an assessment of energy use by house type, efficiency rating and other variables. Note in the following sections, in the interests of readability and comparability we use ***only UK-grid average electricity results*** to inform the GHG analysis.

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17 Including a very small amount from LPG

3.2 The Influence of Property Characteristics

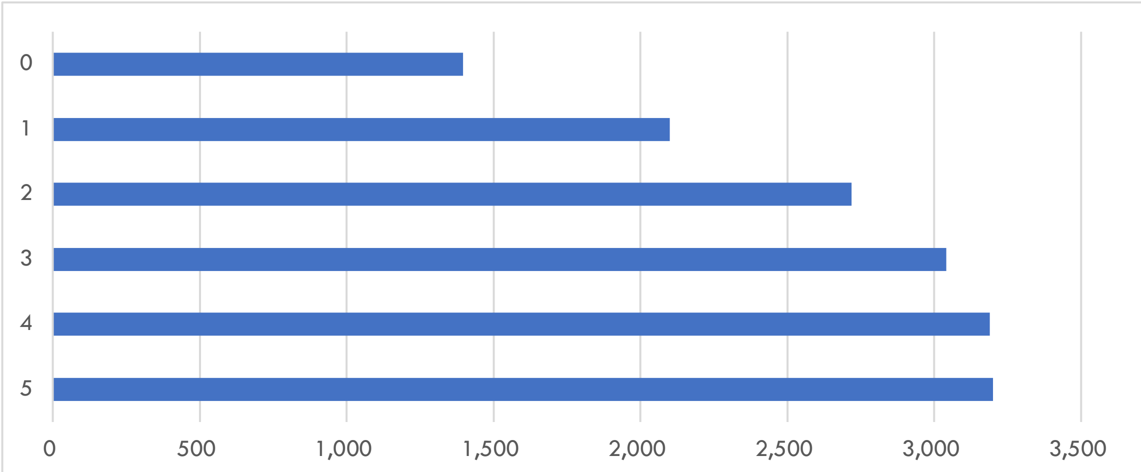
Our analysis suggests, unsurprisingly, that home characteristics will influence the level of energy use and GHG emissions. A number of these variables are inter-related[18] which should be remembered when examining individual results.

3.2.1 Bedrooms

Number of bedrooms has a significant impact on GHG emissions from homes, with a linear and positive relationship. Properties with zero bedrooms (bedsits etc.) emit the least; 1.4 tonnes of CO2e on average, but with 5-bedroom homes at 3.2 tonnes (albeit with only 12 of these under ownership). Note that without detail on household size we can make no assessment about the level of *per person* emissions in different property sizes.

Figure 2 GHG Emissions and Number of Bedrooms (kg CO2e)

(kg CO2e)	TOTAL GHG_UK_BASIS	GHG_Gas	GHG_Electricity_UK	Count
0	1,397	999	397	29
1	2,100	1,630	470	511
2	2,718	2,134	584	1,340
3	3,041	2,379	663	2,075
4	3,189	2,471	718	90
5	3,199	2,415	784	12
Total	2,808	2,196	612	4,057



[18] For example flats might on average be more recently built than houses – and of course will have on average fewer bedrooms.

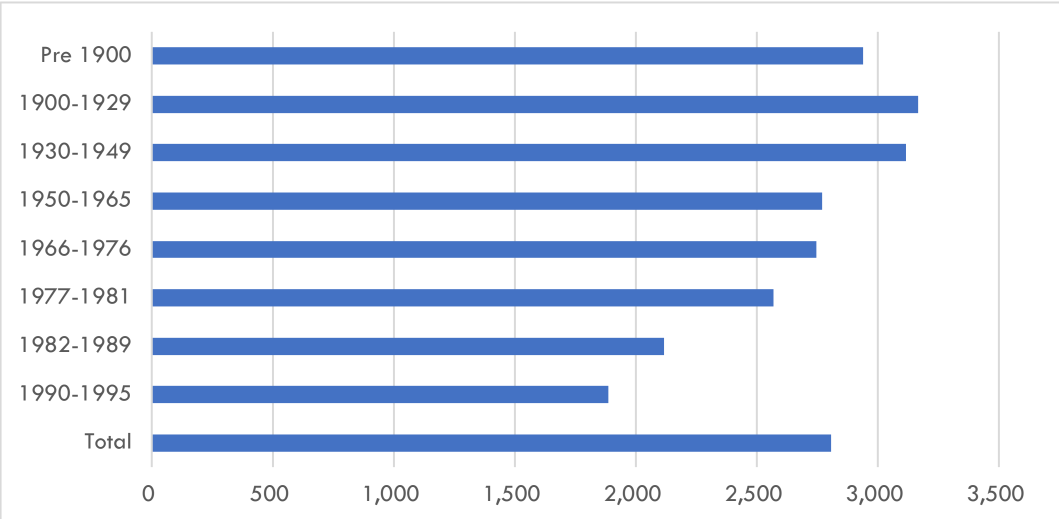
3.2.2 Year of Construction

There was a strong relationship between year of construction and greenhouse gas emissions. Pre-1950 houses reported energy use leading to emissions of 3 tonnes or more, whereas for homes built between 1950 and 1976 (two-thirds of MVH stock) the average was around 2.75 tonnes.

More recent (post-1981) homes were estimated to have GHGs at around 2 tonnes in 2021 but these comprise a very small proportion of MVH stock.

Figure 3 GHG Emissions and Year of Construction

(kg CO2e)	TOTAL_GHG_UK_BASIS	GHG_Gas	GHG_Electricity_UK	Count
Pre 1900	2,939	2,353	586	22
1900-1929	3,167	2,475	692	220
1930-1949	3,115	2,420	696	630
1950-1965	2,769	2,168	601	1,697
1966-1976	2,747	2,153	594	1,050
1977-1981	2,568	2,019	549	344
1982-1989	2,117	1,764	353	29
1990-1995	1,886	1,408	478	26
Total	2,808	2,196	612	3,996

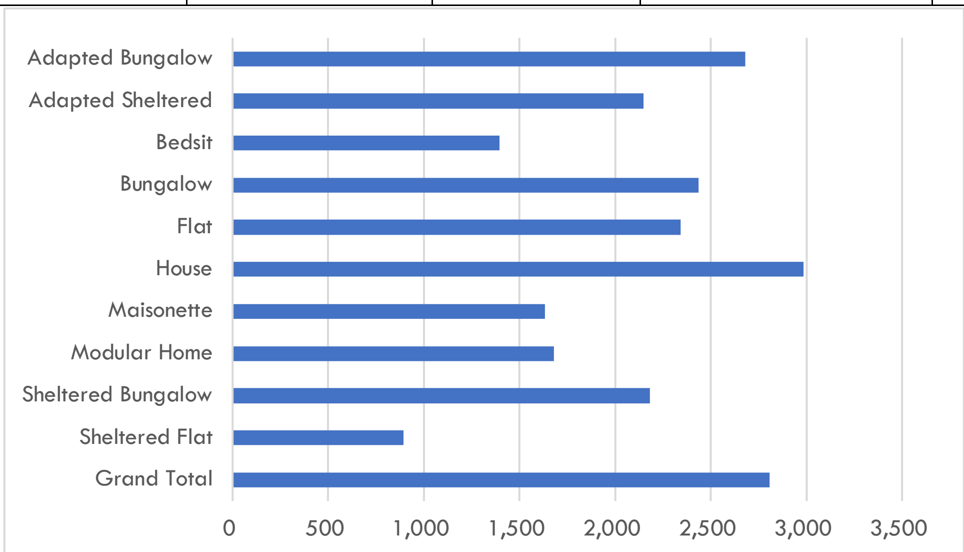


3.2.3 Archetype

There were, unsurprisingly large differences in GHG emissions with Houses (75% of all homes) the worst performing (but of course, likely the largest number of residents). The two modular homes had estimated GHG emissions of 1.68 tonnes per annum, 1.3 tonnes (or 44%) lower than the average for an MVH house.

Figure 4 GHG Emissions and Archetype

(kg CO2e)	TOTAL_GHG_UK_BASIS	GHG_Gas	GHG_Electricity_UK	Count
Adapted Bungalow	2,679	2,107	572	46
Adapted Sheltered	2,149	1,565	584	2
Bedsit	1,397	999	397	29
Bungalow	2,437	1,943	494	208
Flat	2,341	1,819	523	268
House	2,984	2,337	647	3212
Maisonette	1,632	1,244	389	83
Modular Home	1,680	1,274	406	2
Sheltered Bungalow	2,183	1,688	495	143
Grand Total	893	584	310	66



3.2.4 Location

The database allows an examination of GHG emissions per property across different places. Clearly these emissions are driven largely by property characteristics, not the location of the home; moreover, the address field may not be filled consistently, hence there may be some difficultly in analysis.

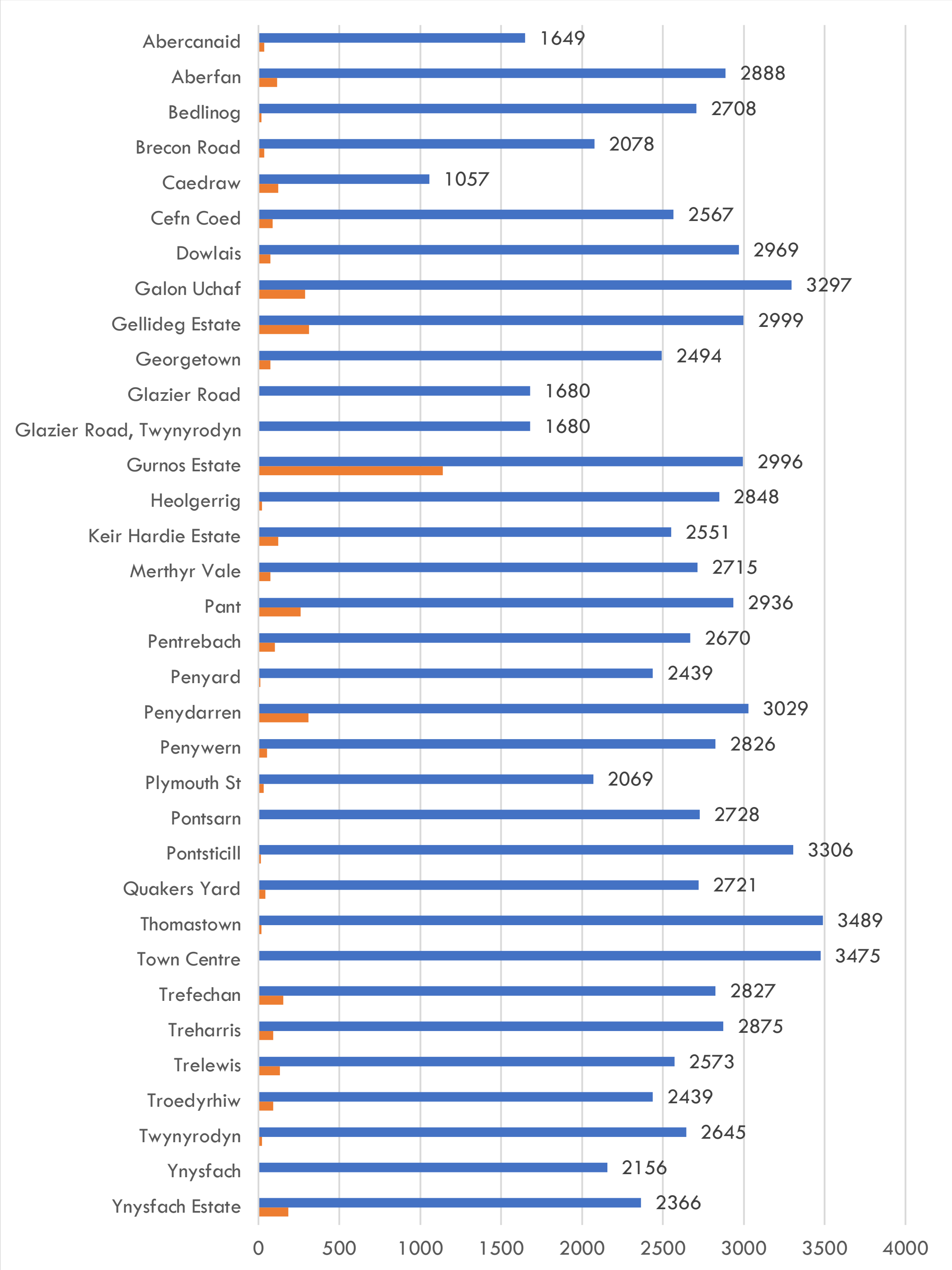
Nonetheless, the data does allow both an indication of where large property 'blocks' are performing better or worse. In areas where MVH has a very small number of properties, these data may will identify the energy/GHG profile of those specific properties for attention.

Figure 4 reveals that the worst-performing large block of properties is at Galon Uchaf, with an average of 3.3 tonnes of GHG emissions per home. Gellideg, Gurnos, Pant and Penydarren show no significant difference, all around 3 tonnes per homes.

Ynysfach estate, with almost 200 homes, showed relatively low emissions per property at under 2.4 tonnes per home in 2021.

Meanwhile, the 17 3-bed houses at Thomastown and the five 3-beds houses in the town centre had very high energy use, this leading to around 3.5 tonnes of CO2e emitted in the reference year; however, these may be artificial results if these properties share postcodes with non-MVH residential properties with higher energy use.

Figure 5 - Average GHG Emissions Across Places



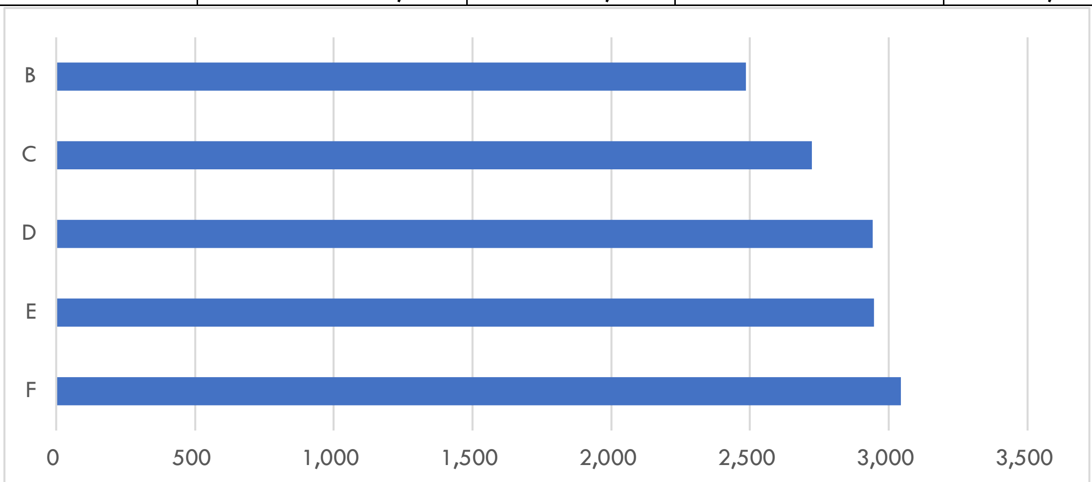
3.2.5 Energy Efficiency Ratings

EPC rating was related to GHG emissions, but this was most notable at the most efficient end of the scale, with EPC C properties at 2.7 tonnes (over half the MVH stock), and EPC B properties (of which MVH has 47 homes) at 2.5 tonnes.

This analysis suggests[19] that if ***all*** MVH properties were to achieve EPC B, in the absence of any other interventions, emissions from homes would reduce from by 11,400 tonnes to 10,070 tonnes – a reduction of 12%.

Figure 6 – Greenhouse Gas Emissions and EPC Rating

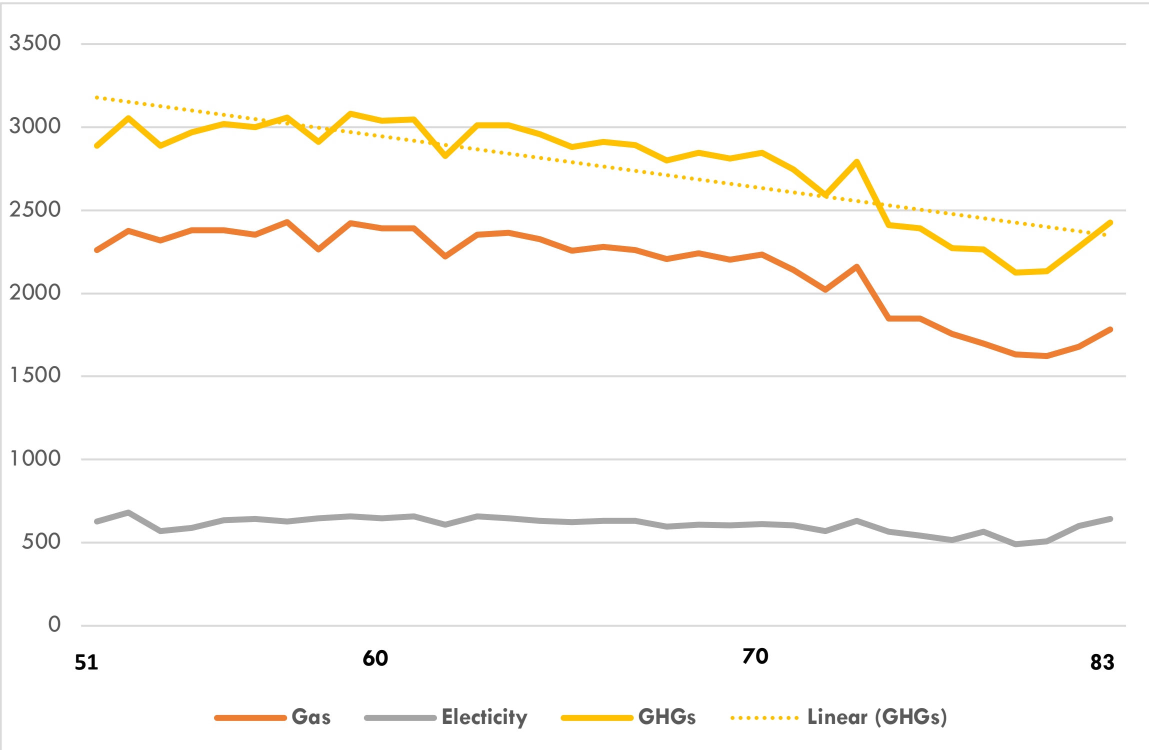
(kg CO2e)	GHG_UK_BASIS	GHG_Gas	GHG_Electricity_UK	Count
B	2,486	1,847	639	47
C	2,723	2,126	597	2,325
D	2,941	2,306	635	1,571
E	2,947	2,335	612	89
F	3,043	2,412	632	6
Grand Total	2,808	2,196	612	4,038



[19] Broadly, and with some unknowns.

Meanwhile SAP rating (with 99.5% of MVH properties rated) also showed a relationship with GHG emissions; unsurprisingly this arose through gas rather than electricity use. Mirroring the results for EPCs, it was mostly at the higher end of energy efficiencies that the relationship emerged; only for SAP ratings of 72 and higher was there a significant relationship between SAP and GHGs. In the absence of other interventions, SAP improvements between 50 and 70 may thus have limited impacts on GHG emissions[20].

Figure 7 Greenhouse Gas Emissions and SAP Rating[21]



The 900 MVH worst SAP-rated homes generated on average an estimated 2.97 tonnes of GHG in 2021, compared to around 2.54 tonnes for the 900 best-rated. Moving a home from the lowest to highest performing segment would, all other things remaining equal, thus save around 14.5% of GHG emissions from that property.

[20] Clearly there are complex interrelationships here with property archetype etc. that we do not consider.

[21] Observations are truncated at the top and bottom of the distribution due to low numbers of observations. The relevant linear regression equations is y = -25.935x + 3204 with an R^2 of 0.71.

3.3 Notable Results

There are several results worth noting from the above.

- Firstly, the results are largely intuitive, with larger houses and more recent builds showing lower energy use than older properties. The methodology seems therefore to function as intended – with the caveat thus there may be errors where 7-digit postcode areas contain a higher number of non-MVH owned, and differently specified, properties.

- Whilst houses, and larger houses, perform worst in terms of average GHG emissions, these properties will likely to be home to larger households. If data on number of residents per property were available, it would be possible to judge the per-person energy (and GHG) efficiency of larger and smaller households.

- Significant energy improvements appear to occur in houses built after 1949, then after 1981.

- Whilst it is difficult to be definitive, improvements in EPC or SAP rating seem to have only a marginal impact on energy use unless the improvement is to the highest levels – EPC C and (especially) B; and SAP ratings higher than 72. Thus moving all relevant MVH stock from EPC E to EPC D would have zero (apparent) impact on emissions.

- Even in the *best* case, physical improvements to existing stock can only have a marginal impact on GHG emissions – perhaps 10-15% savings. Thus, the decarbonisation of the grid (especially in south Wales), and of heating remains of paramount importance.

4 Conclusion

4.1 The Overall Carbon Baseline of Merthyr Valley Homes

The two reports in this series have sought to holistically estimate the greenhouse gas emissions associated with MVH activities. Our first report covered direct (Scope 1) and electricity supply-related (Scope 2) emissions, and those arising from the MVH supply chain, and associated with homes-maintenance (both part of Scope 3). We also estimated the GHGs associated with wages paid to MVH employees as they consequently consume goods and services, although this is clearly outside the MVH operational boundary[22].

Here we have turned our attention to the GHGs emitted as tenants heat and power MVH's 4000+ owned homes. This analysis suggests that in 2021, the overall GHG baseline for all operations, and including wage effects, was 15,244 tonnes of CO2-equivalents[23].

Figure 8 - The Carbon Baseline of Merthyr Valley Homes

	CO2e(t)	%
Fuel Burn, Electricity & Gas	225	1.5%
Supply Chain	1,329	8.7%
Housing Repair & Maintenance	1,134	7.4%
Employee Wages	1,157	7.6%
Homes' Heating and Power	11,399	74.8%
Total	**15,244**	100.0%

As Figure 8 shows, three quarters of this carbon is consequent on the heating and lighting of MVH homes, with the bulk of this homes element (70-80%) then related to mains gas use. Clearly, then, the decarbonisation of heating remains by far the most important issue in addressing the climate footprint of MVH.

Note that the postcode-level energy consumption emissions are available for each year back to 2015 and for 2013. Should they continue to be published they thus, together with UK Government GHG conversion factors for gas and electricity, offer a medium term and consistent trend estimate for emissions from homes that is relevant for MVH decarbonisation.

22 See earlier report for detail.
23 Or 16,885 tonnes if we were to use the 'south Wales grid' basis.

4.2 The Implications of Our Analysis

Following our operational and homes analyses, some broad themes and implications can be drawn – albeit needing further deliberation and setting within institutional and policy contexts. These might be grouped as following:

Home Type Matters, Place Matters – Our analysis has shown that GHG emissions vary significantly between different estates owned by MVH, driven by when and what types of homes were built where. This level of detail is operationally useful; for example, over 100 houses in Galon Uchaf (the worst performing estate) – suffering from damp and mould as well as poor energy performance – have already been targeted for efficiency (and liveability) interventions by MVH as part of the optimised retrofit programme. This report will guide further investigations into where effort might be best placed to make further improvements.

Go big (on homes) or go home – This (effective) Census of MVH homes would suggest that incremental improvements to home energy efficiency in the middle of the distribution will likely have a minimal-to-zero impact on energy and climate performance. It appears only worth moving homes to EPC A/B or a high SAP (72+). This would suggest that piecemeal interventions undertaken 'as and when' might would be less favoured than whole-house, systematic interventions that then might require careful scheduling (e.g., requiring decanting or being ready to apply significant resource between tenants).

Building type is significant, new builds matter – At the time of this analysis, MVH had only two homes built to radically different standards – Beattie Passivhaus modular[24]. These homes provided an energy performance significantly better than other self-contained properties (i.e., homes and bungalows). New build therefore provides a significant opportunity to reduce emissions per-home (and per-tenant) but raising significant issues around appropriate methods; realising the potential for modular construction and local sourcing[25]; finance; and (where land is scarce) the balance between new development and the costs of demolition – including, indeed, the consequent carbon footprint of that demolition.

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[24] See https://www.youtube.com/watch?v=zyBECg5AsgU and https://www.beattiepassive.com/what-we-do/modular-housing/

[25] See https://www.unitedwelsh.com/blog/first-phase-of-new-homes-in-llanbradach-complete/ and https://www.gov.wales/sites/default/files/publications/2021-07/trees-timber-task-force-recommendations.pdf for the Timber Industrial Strategy

Maintenance matters – In even the 'best' case, the bulk of MVH stock will be around and lived in for decades. The finding (in our first report) that home maintenance activities accounted for around 300kg of CO_2e per annum per home is therefore stark. Approaches to managing and maintaining both existing and new homes should be carbon-efficient – as should procurement approaches – and look to support the generation of low carbon products and supply chains.

Heat solutions are key – This analysis reinforces the (already well understood) lesson that decarbonising heat is the most pressing and difficult 'homes' issue: without this, efficiency interventions will (by definition) not be enough to achieve net zero for established homes[26]. It is critical for the wellbeing and financial health of tenants as well as the climate, to change the source of heat from mains gas. The majority view is settling on the electrification of heat as the most likely solution (despite the UK Government requiring new boiler installs to be Hydrogen-ready), with fewer analysts suggesting hydrogen boilers will play a domestic role at scale[27]. This is in part because where 'green' hydrogen is available, it has many important alternative uses where green electricity is of less use (for example in making low-carbon steel or providing off-grid energy). The best current thinking would suggest access to heat pumps and to relevant installation technology is key – but alongside an understanding of how such devices function both within the fabric of (especially) ex-council houses, and accounting for behaviours and engagement of occupiers (here socially-renting tenants).

The Grid matters most – As this and our earlier reports have suggested, MVH and its tenants sit in the heart of what is (by UK standards) a very high carbon grid – and moreover one where renewables installations have been, in recent years, woeful[28]. It is incumbent on MVH to make all efforts to improve its performance on direct and supply-chain GHG efficiency, and to work with suppliers and tenants to reduce its emissions from the heating and powering of its housing stock. All this effort will, however, be significantly compromised if National Grid, UK and Welsh Governments and other stakeholders fail to ensure the supply low-carbon, affordable and reliable grid electricity – and with immediate urgency.

26 We do not have enough excellent homes to be sure, but probably nowhere near enough.
27 See https://www.theguardian.com/environment/2022/sep/27/hydrogen-is-unsuitable-for-home-heating-review-concludes and https://www.nesta.org.uk/sustainable-future/#our-thinking
28 https://www.gov.wales/energy-generation-wales-2021