rb&m research

In-Situ Heat Pump Performance

Analysis of Ofgem Data 2017–2022

September 2024

An independent report funded by:

rb&m

RECC RENEWABLE ENERGY CONSUMER CODE

GSHPA GROUND SOURCE HEAT PUMP ASSOCIATION

Department for Energy Security & Net Zero

rb&m

Contents

Glossary

ASHP	Air Source Heat Pump
COP	Coefficient of Performance
DESNZ	Department for Energy Security and Net Zero
DRHI	Domestic Renewable Heat Incentive
EoH	Electrification of Heat
GSHP	Ground Source Heat Pump
MCS	Microgeneration Certification Scheme
NDRHI	Non-Domestic Renewable Heat Incentive
RHI	Renewable Heat Incentive
RHPP	Renewable Heat Premium Payment scheme
SCOP	Seasonal Coefficient of Performance
SEPEMO	SEasonal PErformance factor and MOnitoring (for heat pump systems in the building sector project)
SPF	Seasonal Performance Factor

Introduction and executive summary

About this report

This report presents the results of an analysis of heat pump in-situ performance versus the 'as designed' performance. It draws on Ofgem data on heat pump installations that are subject to metering for payment under the Renewable Heat Incentive (RHI). That metering provides data on both electricity consumption by, and heat generation from, the heat pump systems, thus enabling an analysis of the actual in-situ efficiencies of more than 1700 installations of air-source and ground-source heat pumps.

The data analysed covers installations between 2017 and the end of 2022 in Great Britain, that is from October 2017 when important changes to the MCS Microgeneration Installation Standard for Heat Pumps (3005) were made compulsory.

The report builds on a similar exercise carried out in 2019 using a previous dataset provided by Ofgem when a methodology was developed to process the data, calculate the in-situ efficiencies and compare those results with the installer performance forecasts. The current exercise, with a larger dataset, examines results over time and by region and against the results of the RHPP field trials published in 2017 and the 2024 results of the Electrification of Heat Demonstration Project.

The work necessary for this paper was funded by the Department for Energy Security and Net Zero (DESNZ), the Renewable Energy Consumer Code (RECC) and the Ground Source Heat Pump Association (GSHPA).

The report was researched and written by **rb&m** Managing Partner Colin Meek with invaluable support from Excel Specialist Jamie Newman. The report was edited by **rb&m** Managing Partner Sue Bloomfield.

Executive summary

The UK Government plans to boost heat pump installation rates from 30,000 per year to 600,000 by 2028 as a key element in the drive to Net Zero. Information about the in-situ performance of heat pumps is critical to understanding the contribution they can make to that drive to Net Zero and in predicting how domestic and commercial consumers are likely to respond to the market as it develops.

Previous work

Field trials carried out prior to 2017 suggested that the performance claimed for such systems was not always matched by the in-situ performance achieved, and that some systems had very low in-situ efficiencies. To explore this further, a dataset was obtained in 2019 from the UK's Office of Gas and Electricity Markets (Ofgem) for installations that were subject to metering of both electricity consumption and heat generation. The analysis of data from nearly 600 installs yielded both positive and negative results: more than half of the ground source and a quarter of the air source heat pumps achieved Seasonal Performance Factors (SPFs) of at least 3.0, but there was a significant gap between the installer performance forecasts and in-situ performance achieved. Also, a large proportion performed below the benchmark SPF of 2.5. At the time, a design efficiency of 2.5 was set by Ofgem as the minimum allowable for Renewable Heat Incentive (RHI) eligibility. The report concluded that these information asymmetries could damage consumer confidence in heat pumps and could limit market growth.

The data

To add to the pool of knowledge on in-situ performance, this paper updates that analysis using a more recent dataset provided to DESNZ by Ofgem. It includes analysis of performance information on 1700 installations with a sample of nearly 300 GSHPs, providing important additional information on GSHP performance and on the relative performance of both GSHPs and ASHPs.

The findings

Table 1 gives the median and average in-situ SPFs and the design Seasonal Coefficient of Performance (SCOPs) for the whole ASHP and GSHP samples and for the installations carried out in 2022 only (the most recent calendar year for which adequate data is available).

After outliers were removed, no installation was found to be performing with an efficiency of less than 1.0.

Table 1

	Median Actual Efficiency – SPF [IQR]	Mean Actual Efficiency – SPF [95% CI]	Median Consumer Forecast Efficiency – SCOP [IQR]	Mean Consumer Forecast Efficiency – SCOP [95% CI]
System Boundary	Ofgem Specified (Note 1)	Ofgem Specified (Note 1)	Note 2	Note 2
ASHP				
(1431 installs):	**2.69** [2.26, 3.07]	**2.65** [2.61, 2.68]	3.59 [3.41, 3.86]	3.61 [3.59, 3.63]
GSHP				
(286 installs):	**3.26** [2.83, 3.64]	**3.24** [3.16, 3.32]	3.93 [3.59, 4.29]	3.95 [3.90, 4.00]
ASHP				
(2022 only – 435 installs):	**2.74** [2.26, 3.11]	**2.67** [2.61, 2.73]	3.67 [3.46, 3.92]	3.71 [3.68, 3.74]
GSHP				
(2022 only – 116 installs):	**3.34** [2.88, 3.79]	**3.31** [3.18, 3.43]	3.99 [3.73, 4.43]	4.06 [3.97, 4.14]

Note 1: See – System Boundaries, Page 3 and Appendix 1.

Note 2: See - Comparing 'as-designed'with 'in-situ' performance, Page 3

System Boundaries

The SPF metric is used to express the efficiency of a heat pump over a full year and is the ratio of electricity consumed in relation to the heat energy generated. The SPF efficiency outcome depends on the system components included or excluded from the measurement 'boundary'. System boundaries normally follow definitions set out by the SEPEMO project (see Appendix 1). It is important to note here that the Ofgem instructions for the metering used for the Metering for Payment installations reflected the SEPEMO boundary H4. However, the Ofgem metering instructions did not explicitly instruct installers to follow the SEPEMO boundary H4 and, as a result, the metering arrangements in some installations may not replicate that SEPEMO boundary exactly. For more detail, see Appendix 1.

Comparing 'as-designed' with 'in-situ' performance

It is normal practice when comparing heat pump performance to specify the SEPEMO boundary being used and compare like for like. For example, a performance forecast based on the H2 boundary should be compared to the in-situ performance based on H2 metering. However, it is also important to compare the *actual consum-*

er experience with the *consumer system performance forecast* provided. The consumer performance forecast methodology used in the UK since October 2017 has been based on the H2 boundary but presented to the consumer by installers as a forecast of system performance. This report therefore compares the actual in-situ performance experienced by the consumer (Ofgem specified boundary in Table 1) with the forecast system performance provided prior to the installation (the consumer forecast efficiency in Table 1).

Results summary

Overall, there is some important evidence of heat pumps performing well:

- the average GSHP SPF has improved significantly since 2017 from just over 3.0 to 3.31 in 2022;
- more than 16% of GSHPs and nearly 6% of ASHPs had in-situ efficiencies that were at or above their design Seasonal Coefficient of Performance (SCOP);
- exactly one third (33%) of GSHPs and 8% of ASHPs were performing at SPF 3.5 or above;
- 67% of all GSHPs and nearly 30% of all ASHPs performed at SPF 3.0 or above; and
- after outliers were removed, no installation was found to be performing with an efficiency of less than 1.0.

Those and other positive results, however, are tempered by findings showing that:

- a disappointing proportion of installations – ASHPs in particular – are performing with low or very low SPFs (for example, there are more ASHPs in this study with in-situ SPFs between 2.0 and 2.5 than between 3.0 and 3.5);
- a significant performance gap between the design SCOPs and the in-situ efficiencies remains for both ASHPs and GSHPs and the gap appears to be widening for ASHPs;
- the average ASHP SPF has not improved since 2017 remaining close to 2.7; and
- at the same time and over the same period, average design SCOPs for ASHPs have jumped from 3.25 (for the earliest cohort of installations included in the previous study) to 3.71 in 2022.

Background and context

Heat pumps are seen as a critical tool in the decarbonisation of domestic heating.

The actual performance achieved by such systems is critical both in delivering carbon savings and in attracting commercial and domestic users to install low-carbon alternatives to fossil fuel generators. Yet prior to the Electrification of Heat Demonstration Project published at the time of writing (April 2024), research on in-situ heat pump performance dated back to the RHPP field trial which took place from 2013 to 2015 with results made available in 2017[1].

2021 Analysis of Ofgem Data

In 2019, the author sought to update knowledge of in-situ heat pump performance through analysis of a large dataset obtained from UK's Ofgem. The dataset, provided under the *Environmental Information Regulations 2004*, contained anonymised information for domestic heat pump installations that were subject to compulsory metering as a condition of eligibility for the Renewable Heat Incentive (RHI) under the 'metering for payment' scheme.

The dataset included both the quarterly heat generation and the heat pump systems' electricity consumption values for ASHPs and GSHPs, thus making it possible to calculate measured heat pump efficiency (the SPF, a measure of the ratio of heat output to electricity input). The dataset also included the installer's consumer design efficiency forecast in the form of a compulsory MCS performance estimate making it possible to compare the calculated in-situ efficiency with the design efficiency.

That dataset provided viable data for at least one whole year for nearly 600 installations. However, while the dataset included information on monitored installations from 2016 to 2019, only a relatively small number were actually installed after October 2017 when a revised MCS standard for heat pumps, MIS 3005, became compulso-

[1] Lowe, R., Summerfield A., Oikonomou E., Love J., Biddulph P., Gleeson C., Chiu L., Wingfield J. (2017) *Final Report On Analysis Of Heat Pump Data From The Renewable Heat Premium Payment (RHPP) Scheme Issued : March 2017*

ry. That revised standard mandated installers to provide design efficiencies using a modified SCOP measure – a product metric[2].

The data was obtained in late 2019, the process used for the analysis was designed through 2020 and a final report was published by RECC in early 2021[3], and was presented at the Sustainable Ecological Engineering and Design for Society (SEEDS) International Conference in 2022. This paper refers to that original study as the *2021 Analysis of Ofgem Data*.

The heat pump efficiencies reported in the *2021 Analysis of Ofgem Data* for the whole ASHP and GHSP samples were:

- ASHP mean SPF: 2.71 (510)
- GSHP mean SPF: 3.07 (88)

RHPP field trial results

The results from that *2021 Analysis of Ofgem Data* were broadly consistent with the results from the RHPP field trial reported in 2017 although efficiencies reported in *2021 Analysis of Ofgem Data* were higher than the RHPP field trial results for both the H2 and H4 SEPEMO boundaries. The RHPP results are set out in Table 2 below.

The SEPEMO system boundary issue is covered in Appendix 1.

[2] MCS (2017) *MIS 3005 requirements for mcs contractors undertaking the supply, design, installation, set to work, commissioning and handover of microgeneration heat pump systems*. Available at: https://mcscertified.com/standards-tools-library/

[3] Meek, C. (2021) *Heat pumps and UK's decarbonisation: lessons from an Ofgem dataset of more than 2,000 domestic installations. Spring 2021*. Available at: https://www.recc.org.uk/pdf/performance-data-research-focused.pdf

Table 2: RHPP field trial results reported in 2017

	Median Efficiency – SPF [IQR]	Mean Efficiency - SPF [95% CI]	Median Efficiency – SPF [IQR]	Mean Efficiency - SPF [95% CI]
System Boundary	H2	H2	H4	H4
ASHP				
(292 Installs)	**2.65** [2.33, 2.95]	**2.64** [2.60, 2.70]	**2.44** [2.15, 2.67]	**2.41** [2.37, 2.46]
GSHP				
(92 Installs)	**2.81** [2.63, 3.14]	**2.93** [2.80, 3.06]	**2.71** [2.48, 3.02]	**2.77** [2.66, 2.89]

Electrification of Heat Demonstration Project 2024

As this report was being written, the preliminary and full results from a more recent field trial, the Electrification of Heat Demonstration Project (referred to as the 'EoH study' herein) became available[4].

Results for ASHPs in the EoH study are set out in Table 3 below. These also show an improvement compared with the H2 and H4 SEPEMO system boundary results from the RHPP field trial set out above.

Table 3: EoH study results reported April 2024

	Median Efficiency – SPF [IQR]	Mean Efficiency - SPF [95% CI]	Median Efficiency – SPF [IQR]	Mean Efficiency - SPF [95% CI]
System Boundary	H2	H2	H4	H4
ASHP				
(428 Installs)	**2.93** [2.67, 3.19]	**2.95** [2.90, 2.99]	**2.78** [2.55, 3.05]	**2.81** [2.76, 2.85]
Hybrid Sample				
(94 Installs)	**2.68** [2.30, 3.03]	**2.73** [2.58, 2.87]	**2.50** [2.10, 2.84]	**2.50** [2.37, 2.64]

The EoH study does include results for a small sample of GSHP installations, but the research team recommends that the figures should not be used as a reference for mean or median SPFs.

The current study

To add to the pool of knowledge on in-situ performance, this paper updates *2021 Analysis of Ofgem Data* using a more recent and larger dataset provided to DESNZ by Ofgem. It includes analysis of performance information

4 Energy Systems Catapult. (2024) Electrification of Heat Demonstration Project, Heat Pump Performance Data Analysis Report. April 2024.

on 1700 installations with a sample of nearly 300 GSHPs and therefore provides important additional information on GSHP performance and the relative performance of both GSHPs and ASHPs.

The results provide performance information from heat pump systems subject to metering for payment installed since the revised MCS standard MIS 3005 became compulsory in October 2017 and subsequent installations up to the end of 2022.

As well as adding further intelligence to the results from the RHPP field trial, the Electrification of Heat Demonstration project and the *2021 Analysis of Ofgem Data*, the current analysis also provides two unique perspectives:

- compared to the dataset provided by Ofgem in 2019, the new dataset is much larger and has allowed analysis by annual cohort of installations providing information on trends in performance since the MCS standard for heat pumps was changed in 2017 and ending in 2022.
- limited geographical information has also made it possible to allocate installations to location to provide performance information by GB country and English region.

The dataset and data cleaning

The dataset provided by Ofgem for this project included electricity consumption and heat generation information for more than 3000 installations.

The installations included in the dataset are sub-set of those eligible for the Domestic RHI (DRHI) and are all subject to the rules for 'metering for payment' including compulsory metering as a condition of RHI eligibility. The dataset included the following information for each installation:

- heat generation in kWh or MWh;
- electricity consumption in kWh or MWh;
- the heat generation and electricity consumption values are provided for each heat meter and each electricity meter used for each installation separately;
- the period of time each data point covers (usually quarterly);
- unique but anonymised identifiers for each installation;
- the installer's design SCOP provided at the time of the install (that predicted COP is essential for the calculation used to assign the RHI); and
- the town in Great Britain where the installation took place.

Sample choice, data cleaning and identification of outliers

Strict sample and quality criteria were applied to ensure data integrity and practice consistent with that used for the *2021 Analysis of Ofgem Data*. The same criteria were applied to both ASHP and GSHP technologies in the dataset. Installations were excluded if they were identified as 'cancelled' or 'rejected' by Ofgem and, additionally, only those installations that met the following criteria were included in the final Excel pivot table analysis:

- installations where the first meter readings were recorded *after* version 5 of the MCS Heat Pumps Installation Standard became compulsory (in late October 2017); and,

- those where at least one whole year of contiguous clean data could be identified.

The method ensured that electricity consumption and heat generation for at least one year related to exactly the same specific period of time. Erroneous and anomalous meter readings were identified using conditional formatting and conditional analysis. Once 'cleaned' and filtered according to the above criteria, the spreadsheet was subject to an independent process of verification to assess the alignment of the consumption and generation data for all installations. A small number of data anomalies were then resolved thus ensuring perfect alignment.

Efficiency calculations were possible only after the final Excel pivot table stage and installations with extremely high or extremely low results (<1.5 and >5) were examined individually and removed where appropriate before a Tukey outlier analysis was deployed to the ASHP and GSHP samples separately.

The final ASHP sample includes 1431 installations and the GSHP sample includes 286.

Statistical significance

Some of the results provided in this report compare the in-situ heat pump performance with the 'as-designed' forecast performance. That performance gap in all samples was tested for statistical significance using paired, two-tail t-tests with a critical value of 0.05. Statistical significance was present for all main samples and sub-samples apart from the sample of 17 GSHP installations for Wales where the statistical significance of the small performance gap was slightly lower than 95%.

The regional sample with the fewest installs (10 GSHPs in London) had a p-value of 0.0425 which still indicates statistical significance. The performance gap for the largest samples all indicated extremely high significance: (>99.9%).

Results

1 Performance

Summary of findings

Overall, there is some important and positive evidence of heat pumps performing well and close to or above their design SCOPs:

- Exactly one third (33%) of GSHPs and 8% of ASHPs in the study were performing at SPF 3.5 or above.
- Nearly 30% of all ASHPs and 67% of all GSHPs performed at SPF 3.0 or above.
- 15% of all GSHPs performed at SPF 4.0 or above.
- Although the vast majority of in-situ SPFs were found to be lower than the design SCOPs, nearly 6% of ASHPs and more than 16% of GSHPs had actual efficiencies that were above.
- The average GSHP SPF has improved significantly since 2017 from just over 3.0 to 3.31 in 2022.
- The gap between the design SCOPs and the SPFs are lower in some areas than in others. For example, the gap is smallest in the South West and the South East for GSHPs and in Wales, the South East and East Midlands for ASHPs.

Those positive results, however, are tempered by findings showing that a large gap remains between average design SCOPs and average in-situ SPFs and that this gap is particularly wide for the most recent cohort of ASHPs. Correlation between design SCOPs and actual efficiency is weak. Of further concern is the proportion of installations performing with low and very low SPFs. Those issues are described in more detail below.

Average SPFs

Table 4 gives the median and mean efficiency for the overall ASHP and GSHP samples.

The results are given with relevant interquartile ranges (IQR) and confidence intervals (CI) with a significance value of 95%.

Table 4

	Median Actual Efficiency – SPF [IQR]	Mean Actual Efficiency – SPF [95% CI]	Median Consumer Forecast Efficiency – SCOP [IQR]	Mean Consumer Forecast Efficiency – SCOP [95% CI]
System Boundary	Ofgem Specified (Note 1)	Ofgem Specified (Note 1)	Note 2	Note 2
ASHP				
(1431 installs):	**2.69** [2.26, 3.07]	**2.65** [2.61, 2.68]	3.59 [3.41, 3.86]	3.61 [3.59, 3.63]
GSHP				
(286 installs):	**3.26** [2.83, 3.64]	**3.24** [3.16, 3.32]	3.93 [3.59, 4.29]	3.95 [3.90, 4.00]

Note 1: See – System Boundaries, Page 3 and Appendix 1.

Note 2: See - Comparing 'as-designed'with 'in-situ' performance, Page 3

Figure 1

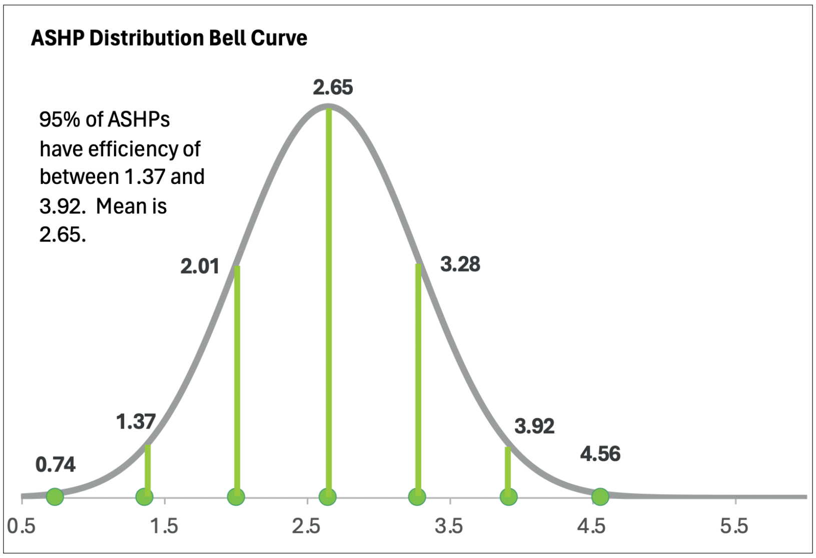
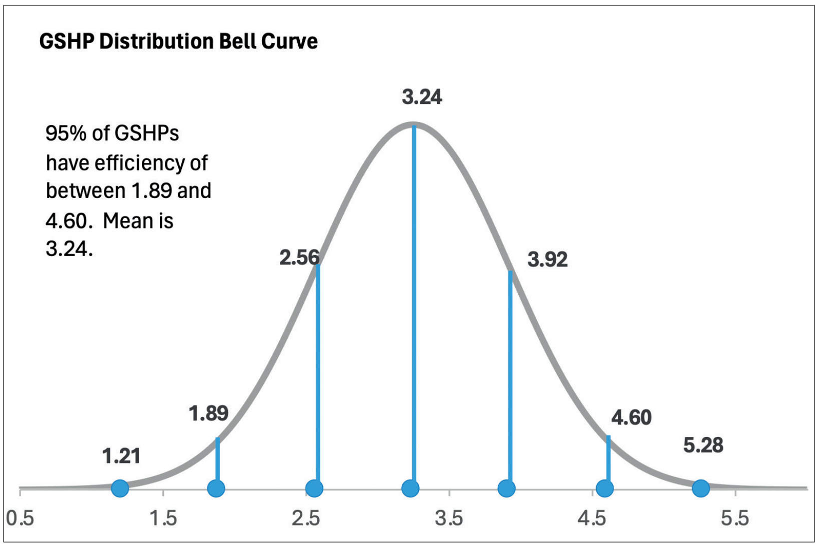


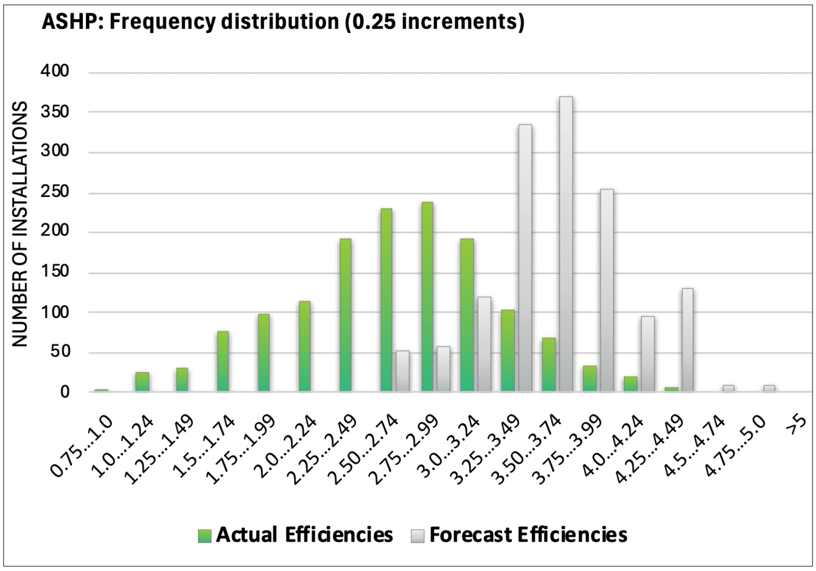
Figure 2



Performance Distribution Bell Curves

Figures 1 and 2 are 'normal' or probability distributions for the overall ASHP and GSHP samples. They include the mean and the standard deviations from the mean. Because the curves indicate probability, they are symmetric about the mean and calculated using the standard deviation. Around 68% of the installations are within one standard deviation from the mean and 95% within two. These projections imply that efficiency of less than 1.0 is possible, however, the data shows that, after outliers were removed, no installation was found to be performing with an efficiency of less than 1.0.

2 Frequency distribution



Figures 3 to 4 plot the frequency distribution of the whole ASHP and GSHP samples in 0.25 SPF increments. The in-situ SPFs are compared to the installer forecast SCOPs.

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Figure 3: Frequency of ASHP SPFs and installer forecast SPFs. Sample size: 1431.

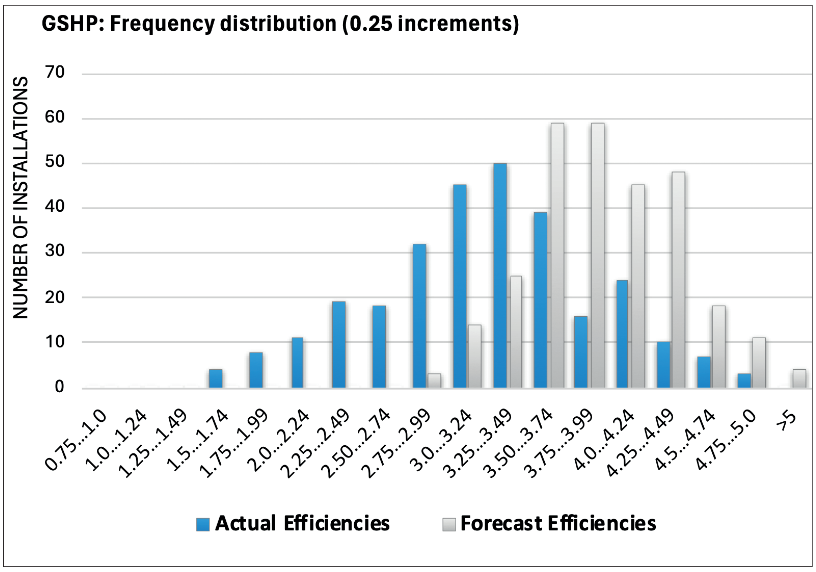

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Figure 4: Frequency of GSHP SPFs and installer forecast SPFs. Sample size: 286.

3 Actual versus forecast efficiency

As explained in the Background and Context, since October 2017 MCS Certified installers have used the SCOP metric as a tool for forecasting efficiencies in formal MCS Performance Estimates provided to consumers. The *2021 Analysis of Ofgem Data* found that there was a gap between the calculated efficiencies and the installer forecasts. This new analysis explores that issue in more detail for both technologies.

Correlation and commentary

Almost no correlation could be found between the installer efficiency forecasts and the actual measured efficiencies in the *2021 Analysis of Ofgem Data* in any of the samples analysed. In this 2024 analysis, the Pearson correlation ***r*** value for ASHPs was 0.225 and for GSHPs it was 0.228 and therefore correlation is weak for both samples.

The ASHP results for specific performance benchmarks are of particular concern:

Table 5

	Whole ASHP Sample	Whole GSHP Sample
% of installations with SPF < 2.5	38%	14%
% of installations with SPF < 2.8	58%	23%
% of installations with SPF > 3.5	8%	33%

Other findings are of equal importance:

- There are more ASHPs where the actual performance is between SPF 2.0 and 2.49 (just over 300) than there are where the performance is between 3.0 and 3.49 (just under 300).
- 547 (38%) ASHPs have in-situ SPFs of less than 2.5 while all installer forecasts were above 2.5.

The scatter plots below (Figures 5 and 6) include the whole ASHP and GSHP samples in the 2024 Analysis.

Please note that, at the time the installations were carried out, installations were only eligible for the RHI incentive scheme if the installer design SCOP was at least 2.5. This explains why all installer design SCOPs are above 2.5.

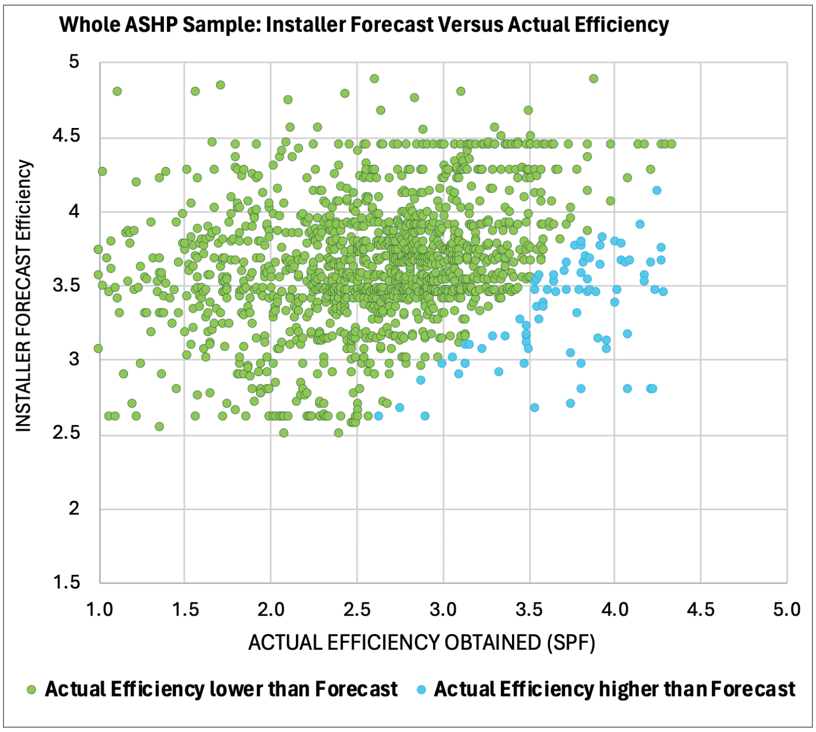

Figure 5: The actual efficiencies were found to be lower than the installers' forecasts for 94% of the ASHP installations (green markers). The blue markers indicate those installations that performed better than the installer forecast. Sample size: 1431.

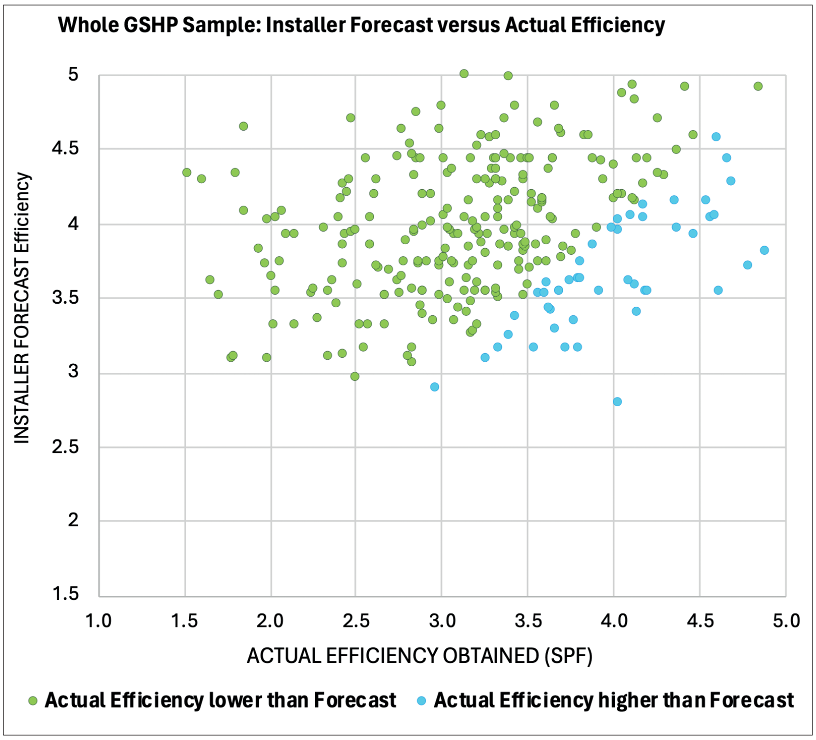

Figure 6: The actual efficiencies were found to be lower than the installers' forecasts for 83% of the GSHP installations (green markers). The blue markers indicate those installations that performed better than the installer forecast. Sample size: 286.

Figures 7 and 8 below give further visualisations for the 2022 cohort only illustrating the gap between the in-situ efficiencies and the design SCOPs. The installations are ordered by design SCOP (grey, starting far left) and the corresponding actual SPFs shown for ASHPs (green in Fig 7) and GSHPs (blue in Fig 8). These visualisations show that:

- Very few design SCOPs are realistic and a large proportion overestimate likely performance significantly; and,
- While this paper shows that very high efficiencies are sometimes achieved, the most optimistic efficiency estimates are rarely actually achieved in-situ.

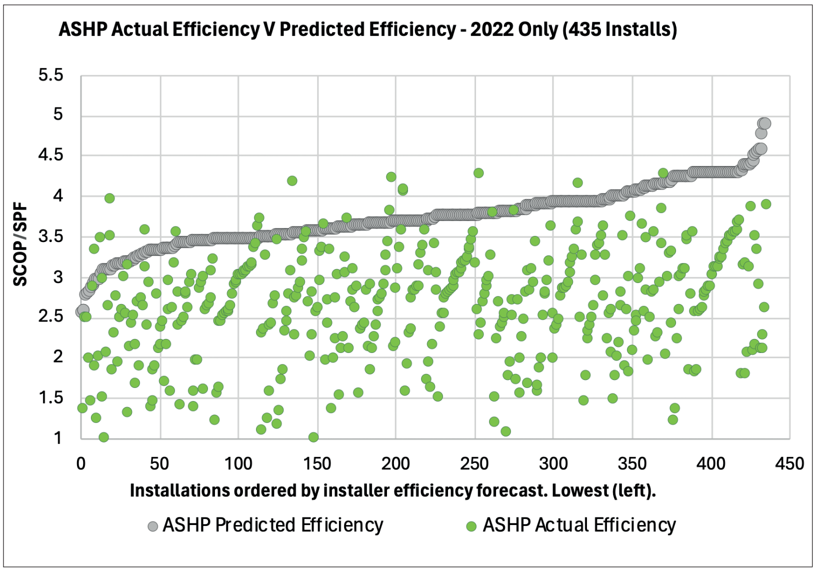

Figure 7: Sample 435

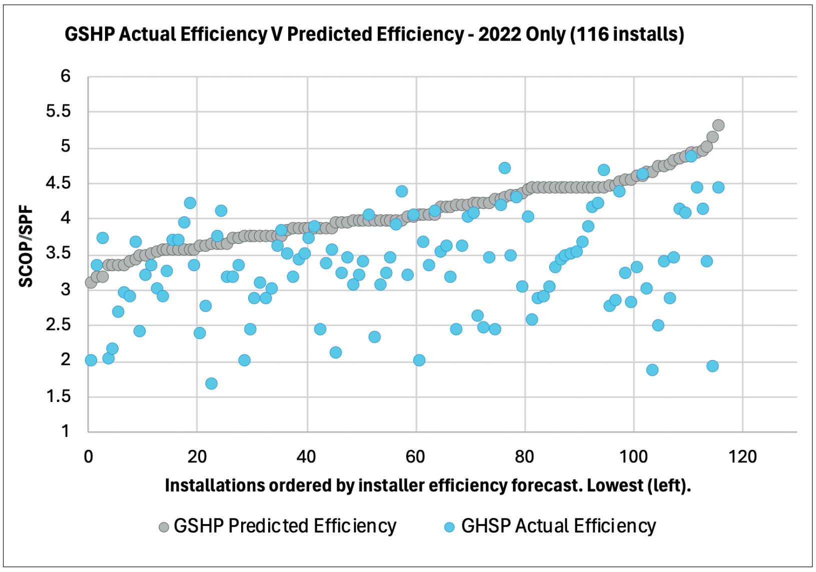

Figure 8: Sample 116

4 Performance by installation year

The installations were allocated to installation year co-horts according to their first meter readings and both the average design SCOPs and in-situ SPFs determined for each cohort. Results for 2022 only (the most recent available) are shown in Table 6.

Table 6

	Median Actual Efficiency – SPF [IQR]	Mean Actual Efficiency – SPF [95% CI]	Median Consumer Forecast Efficiency – SCOP [IQR]	Mean Consumer Forecast Efficiency – SCOP [95% CI]
ASHP				
(2022 only – 435 installs):	**2.74** [2.26, 3.11]	**2.67** [2.61, 2.73]	3.67 [3.46, 3.92]	3.71 [3.68, 3.74]
GSHP				
(2022 only – 116 installs):	**3.34** [2.88, 3.79]	**3.31** [3.18, 3.43]	3.99 [3.73, 4.43]	4.06 [3.97, 4.14]

The results for all the annual cohorts are given in Figure 9.

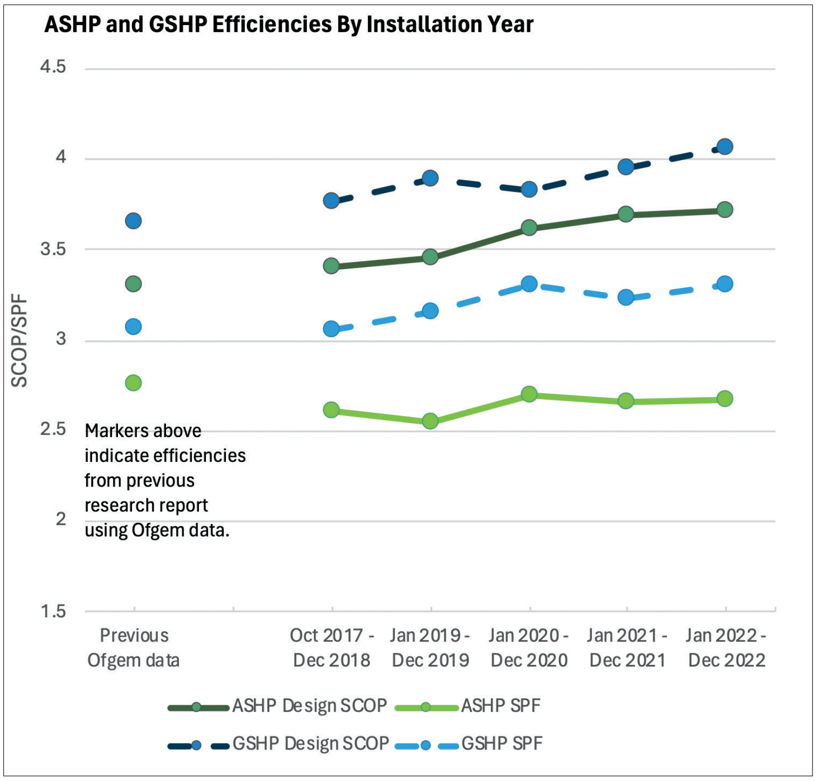

Figure 9 shows the design SCOPs and in-situ SPFs for each group of installations installed during the periods indicated for the *x* axis. The markers on the left give the results for the 2021 Analysis of Ofgem Data and this new analysis of Ofgem data starts in October 2017 when the MCS Heat Pumps installer standard was changed. The first cohort therefore represents those installations carried out from late October 2017 to 2018. The subsequent cohorts relate to calendar years.

The trends show that average GSHP in-situ SPF has improved from about 3.0 for the whole GSHP sample in the *2021 Analysis of Ofgem Data* to 3.31 in 2022 for this study. GSHP design SCOPs have also climbed from about 3.7 to above 4. However, the 'gap' between the design SCOP and the actual efficiency for GSHPs has remained roughly stable since October 2017. In contrast, the average ASHP in-situ SPF has not improved (compared to the *2021 Analysis of Ofgem Data*), but the ASHP design SCOPs have risen from about 3.3 in the 2021 study to 3.71 in 2022. The 'performance gap' for ASHPs has therefore widened.

Figures 10 and 11 plot the performance gaps for each technology for each installation cohort.

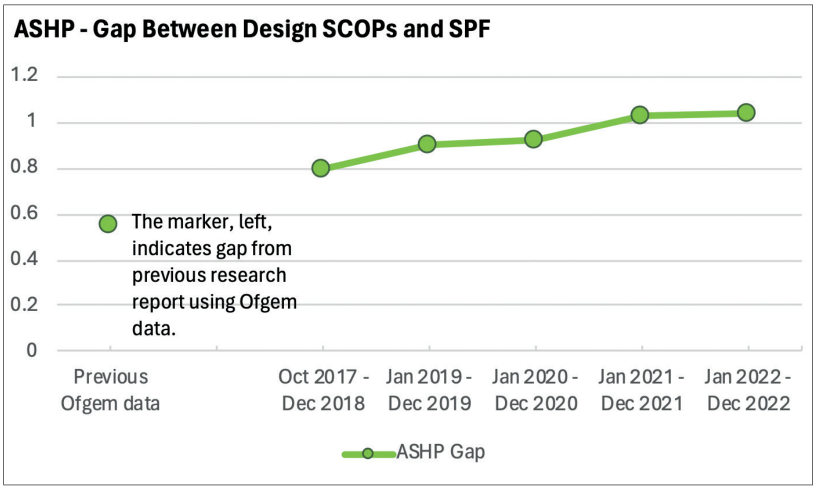

Figure 10: Annual Gap ASHP

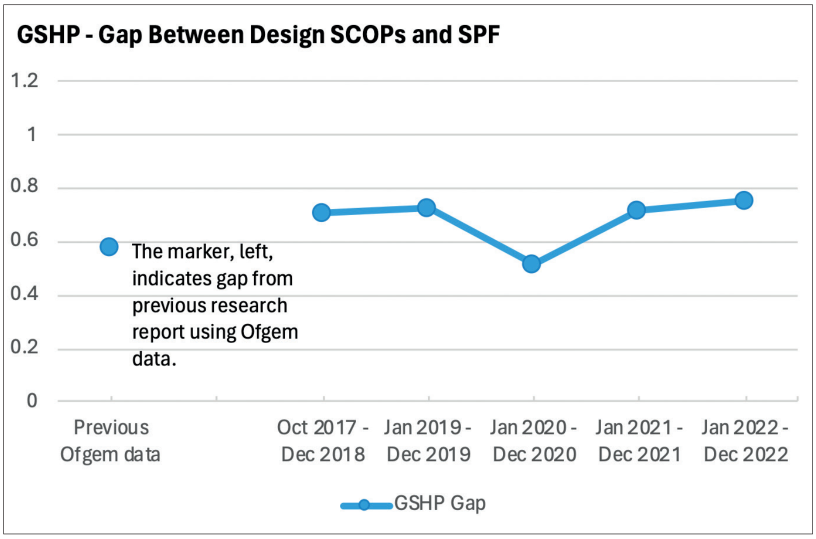

Figure 11: Annual Gap GSHP

5 Performance by GB country and English region

The Ofgem dataset included limited geographical information, but it was possible to allocate each installation to a GB Country/Region. The average ASHP sample size for each country/region was 130 and the average GSHP sample size was 26. Whilst there is obvious correlation between the ASHP and GSHP results, the GSHP results for individual regions/countries should be treated with caution due to the small sample sizes. The results are given in Figures 12 and 13.

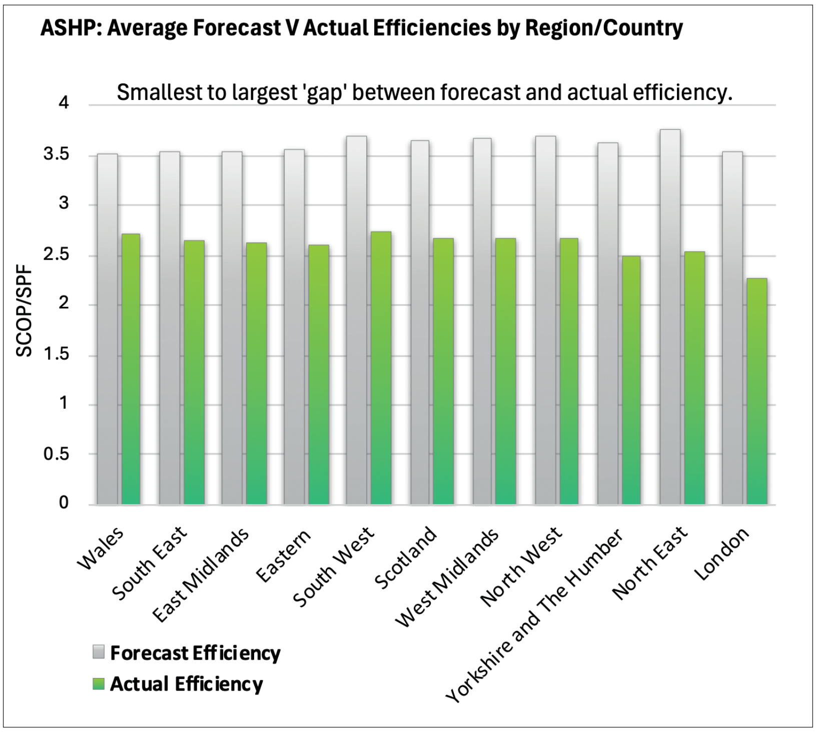

Figure 12: The results for GB Country/Regions are ordered from left to right according to the gap between average design SCOP and in-situ SPF. The average sample size for ASHPs was 130 and the region with the smallest sample was London with 33. The performance 'gap' was statistically significant for all regions/countries.

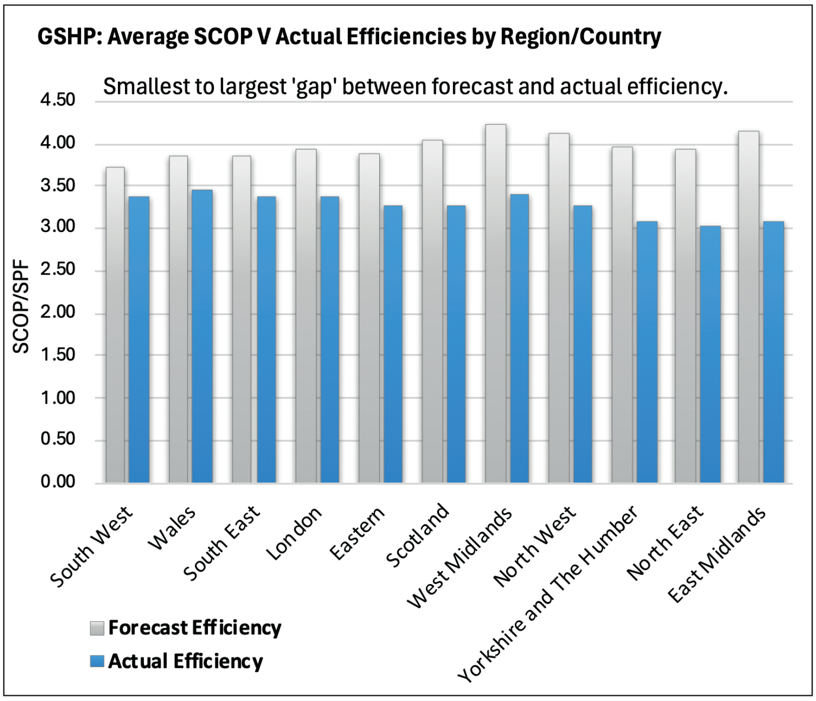

Figure 13: The results for GB Country/Regions are ordered from left to right according to the gap between average design SCOP and in-situ SPF. The average sample size for GSHPs was 26 and the region with the smallest sample was London with 10. Note: The small performance 'gap' for Wales (17 installs) was not statistically significant. Statistical significance was shown for all other regions/countries.

Wales and the South East are among the three areas with the smallest gaps for both ASHPs and GSHPs. Average in-situ efficiency for ASHPs is highest in the South West and lowest in Yorkshire and the Humber, the North East and London. The sample size for London (33) was well below the average (130).

GSHP in-situ efficiency was highest in Wales at nearly 3.5. The Performance gap was widest in the North East and East Midlands. Sample sizes for GSHPs were low. The average was 26 and there were 11 and 10 installations in London and the North East respectively.

Limitations, discussion and conclusion

Limitations

This analysis is restricted to data from heat pump installations that are subject to metering for payment under the Renewable Heat Incentive (RHI). These homes were specifically chosen to be metered because they are unusual. For example, they have either bi-valent heating with a boiler or other heating device providing a portion of the heat demand or they are in second homes which are likely have unusual heating patterns.

The dataset is not derived from full system monitoring (as used for Electrification of Heat research) and it does not include information about the system design, internal dwelling temperatures, the heating flow temperatures, the DHW system or heat consumption. Further, the data does not include information on whether another heat source was present and if so, how much it was contributing and cannot be used to determine how these systems were being used which is particularly relevant for second homes.

Given the above, it is impossible to know if the performance assessed is representative of installations under the RHI or more generally.

The rules used by Ofgem to regulate the RHI incentive scheme included strict obligations on installers for the metering that had to be put in place for systems subject to 'metering for payment'[5]. Those rules specified a metering boundary that is closest to the SEPEMO H4, but did not explicitly refer to H4. The efficiency results in this paper are therefore not labelled as defined by a specific SEPEMO boundary. Appendix 1 describes the issues related to SEPEMO boundaries in more detail.

Discussion

The results in this paper are qualified by the limitations set out above; but those limitations need to be put in context.

[5] Ofgem (2021) *Essential Guide to Metering*. Available at: https://www.ofgem.gov.uk/sites/default/files/docs/2021/04/easy_guide_to_heat_pumps_final_2021_0.pdf (Accessed: March 2023)

- Firstly, it is important to note that meter readings for the installations subject to Ofgem monitoring and obtained for this study are likely to offer a reliable summary of heat pump electricity consumption and heat generation. Installers had obligations to install metering equipment correctly and consumers have strict obligations under the RHI to provide accurate information. The system used by Ofgem to obtain the data seeks to prevent unit errors, meter reading errors and reporting errors. The methodology used for this research also removed the anomalous values that were present and strict criteria ensured that only the installations where at least one whole year of contiguous clean data could be identified were included.
- Secondly, although the analysis in this paper is based on secondary data, the whole sample includes efficiency calculations for 1700 heat pumps and this study can be directly compared to the 2021 Analysis of Ofgem Data that included results for nearly 600 heat pumps in all samples. Results from the annual cohorts can be compared over time.
- Thirdly, whilst we cannot assume the results from the Ofgem data analysis are representative of the wider market, this is in line with previous field trial studies.
- Lastly, it is notable that, despite their differences in terms of data source, the research results from the Ofgem data and from the field trials tell a remarkably similar story.

Conclusion

The analysis of a large sample of heat pump systems installed in the five years from late-2017 to 2022 has shown that a significant proportion of heat pumps do perform well. A notable result is that one in three of all 286 GSHPs in the study perform with SPFs over 3.5. The other positive findings are described on page 11.

However, the results also demonstrate that a large percentage of design SCOPs are not realistic and results for ASHPs are of particular concern.

While there is some evidence that SPFs have improved since the RHPP field trial finished in 2015, there is no evidence from this study that the performance of ASHPs installed under the RHI and subject to metering for payment has improved since 2017.

The average design SCOP (or perfomance estimate) for ASHPs has increased. In 2022 the gap between average design SCOP and average in-situ performance had grown to 1.04.

Furthermore, and irrespective of the performance gap, it is of continuing concern that a significant proportion of installations perform with low and very low SPFs. One striking finding summarises the issue: this study found more ASHPs performing at between SPF 2.0 and 2.5 than between 3.0 and 3.5. This paper confirms that:

- acute information asymmetries continue to exist in the market for domestic heat pumps; and
- while some installations perform well, a significant proportion of heat pumps perform with low or very low efficiency.

Whilst the evidence in this paper is based on data from a sub-set of installations, the findings are also reflected in the field trial research.

These findings support the conclusion from recent policy research that much more emphasis should be placed on the routine measurement of 'real-world' outcomes[6]. It is argued that the heat pump roll out could be accelerated through reliable performance measurement and the creation of a database of in-situ outcomes and case studies. We would add that the consumer detriment related to poor and very poor heat pump performance should not be underestimated and that this should be investigated as part of intensive research using installation case studies in different areas and different housing types.

The findings from this paper also support the conclusion set out in the Electrification of Heat Demonstration Project that a review should be carried out (including further research into the current methods for calculating building heat loss, designing heating systems and estimating efficiencies) to "evaluate how and why designs consistently produce unrealistic estimates for many consumers"[7]. It is our view that the review should also:

- evaluate industry marketing claims about performance with a focus on claims that

[6] Carmichael, R., (2022) *Accelerating the transition to heat pumps: measuring real-world performance and enabling peer-to-peer learning. An Energy Futures Lab Briefing Paper*. Imperial College London. Available at: https://www.imperial.ac.uk/energy-futures-lab/reports/briefing-papers/paper-10/ (Accessed: 10 November 2020)

[7] Energy Systems Catapult. (2024) *Electrification of Heat Demonstration Project, Heat Pump Performance Data Analysis Report*. April 2024.

confuse product performance with likely system performance;

- evaluate how consumer information about heat pumps can be improved with a focus on heat pump performance; and
- involve a broad spectrum of stakeholders and certainly consumer representatives.

Appendix 1

SEPEMO boundaries

It is difficult to compare and evaluate heat pump efficiencies without defining the system boundaries that apply. The SEPEMO boundaries developed initially by SP Technical Research Institute in Sweden[8] are now used as the standard established methodology (in Europe at least). Of critical importance is that the boundary set in the EU methodology is SCOPnet[9] which is equivalent to the SPFH2.

According to the European Commission the calculation of renewable energy supplied should depend on the heat pump alone and should not include parts of the heat distribution system[10]. It is therefore argued that SCOPnet is a laboratory forecast of product efficiency, not an estimate of in-situ performance and that SPFH4 is the most appropriate boundary for heat pump design[11].

Of key relevance to this discussion is the provision of consumer performance information in the UK that is calculated using the SCOP metric: an estimate of product efficiency that may overestimate in-situ performance[12].

SEPEMO boundaries and the RHI

The rules relating to the Non-Domestic RHI (NDRHI) instructed heat pump installers to define the metering deployed using the SEPEMO boundaries. Under those NDRHI rules, installers were required to tell Ofgem what

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8 Gleeson, C.P. 2014. *Understanding the field performance of domestic heat pumps: an analysis of recent residential heat pump field trials and training needs*. PhD thesis University College London Bartlett School of Graduate Studies, Energy Institute

9 Lowe, R., Summerfield A., Oikonomou E., Love J., Biddulph P., Gleeson C., Chiu L., Wingfield J. (2017) *Final Report On Analysis Of Heat Pump Data From The Renewable Heat Premium Payment (RHPP) Scheme Issued: March 2017*

10 European Commission (2013a) establishing the guidelines for Member States on calculating renewable energy from heat pumps from different heat pump technologies pursuant to Article 5 of Directive 2009/28/EC of the European Parliament and of the Council. European Union. Available at: https://eur-lex.europa.eu/legal-content/GA/TXT/?uri=CELEX%3A32013D0114 (Accessed: 9 January 2021)

11 Dunbabin, P. and Green, R. (2013) *Detailed analysis from the second phase of the Energy Saving Trust's heat pump field trial*. Available at: https://www.gov.uk/government/publications/analysis-from-the-first-phase-of-the-energy-saving-trust-s-heat-pump-field-trial

12 MCS (2020) *Domestic Heat Pumps : A Best Practice Guide*. Available at: https://mcscertified.com/standards-tools-library/

components were included within the measurement of electricity consumption and heat output to enable Ofgem to determine the SEPEMO Boundary[13].

The Ofgem rules relating to the Metering for Payment used a different approach. The instructions to installers stated that "all electrical input to the system that may influence the heat output" (including circulation pumps) should be metered.[14] Whilst the boundary specified by Ofgem therefore reflects SEPEMO H4 most closely, the Ofgem metering instructions did not explicitly refer to a specific SEPEMO boundary. As a result, the metering arrangements used for some of the installations included in this report may not replicate the SEPEMO H4 boundary exactly. ■

[13] Ofgem (2021) *Essential Guide to Metering*. Available at: https://www.ofgem.gov.uk/sites/default/files/docs/2021/04/easy_guide_to_heat_pumps_final_2021_0.pdf (Accessed: March 2023)

[14] Ofgem (2018) *Domestic Renewable Heat Incentive Essential Guide to Metering*, Version 3.0.