Department for
Energy Security
& Net Zero

Electrification of Heat Demonstration Project

Heat Pump Optimisation Report

Written by Energy Systems Catapult

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This report has been funded by DESNZ and is issued on their behalf

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Contents

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Glossary

ASHP	Air Source Heat Pump
COP	Coefficient of Performance (Efficiency)
DC	Delivery Contractor
DESNZ	Department for Energy Security and Net Zero
EoH	Electrification of Heat
GSHP	Ground Source Heat Pump
Hybrid	Hybrid system containing a gas boiler and an electric heat pump.
MC	Management Contractor
MMSP	Metering and Monitoring Service Package
RHI	Renewable Heat Incentive
SPF	Seasonal Performance Factor (In-situ efficiency over 1 year)

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1. Executive summary

1.1 Project background

The Electrification of Heat demonstration project (EoH) was funded by the Department for Energy Security and Net Zero (DESNZ) and sought to better understand the feasibility of a large-scale rollout of heat pumps across the UK. To do so, three Delivery Contractors (DCs) have overseen the installation of 742 heat pumps in existing homes within Great Britain, the majority of which were previously heated by gas central heating. These heat pumps are now being monitored to assess their performance in-situ.

The existence of heat pump monitoring has enabled the three DCs to analyse the heat pump performance throughout the project and in some cases optimise the heat pumps to ensure the best possible consumer outcomes are attained.

1.2 About this report

This report introduces the concept of optimising for consumer outcome, incorporating heat pump efficiency as one area where outcomes can be improved. It describes the importance of heat pump monitoring to enable data analysis and optimisation and describes the monitoring system used across the EoH project. It then outlines many of the potential causes of lower efficiency or sub-optimal heat pump operation before outlining the optimisation processes followed and interventions which were made by the DCs.

1.3 Key findings

The key to optimising a heat pumps performance is maximising consumer outcomes (or comfort) whilst minimising electricity consumption (or cost). One way in which this can be done is by maximising efficiency however, it’s important to note that some interventions which increase efficiency may increase electricity consumption or reduce comfort.

In order to understand and then optimise heat pump performance, it is important to monitor the full heating system. This monitoring should include qualitative feedback from consumers as well as quantitative energy and temperature data. Monitoring the system operation allows the consumer or a third-party to identify and investigate low performing systems or periods of operation. It also allows the party to track the impact of any interventions to allow for iterative optimisation.

The most common heat pump optimisation intervention on the EoH project was adjusting the heat pump flow temperature. Other interventions were also made, these include (but are not limited to): advising on zonal control settings, reducing the gap between setback and comfort temperature and adjusting the hot water settings. Where possible, consumers may benefit from making some of these interventions themselves however, some of them may be difficult to achieve without expert involvement.

Monitoring and optimising the performance of heat pumps could prove vital in maximising consumer heating outcomes. This, in turn, would increase consumer confidence in the technology to enable and accelerate large scale rollout of heat pumps. It may also reduce the overall system impacts of a heat pump transition, further assisting the UK move towards a net-zero future.

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Three key recommendations from this report are that:

1. Heating system monitoring should be used to unlock data for consumers and industry.
2. Business models which enable third-party system optimisation should be incentivised and trialled.
3. Heating system installation quality should be made more consistent through business models or redress mechanisms.

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2. Introduction

2.1 Project Introduction

The Electrification of Heat demonstration project (EoH) was funded by the Department for Energy Security and Net Zero (DESNZ) and sought to better understand the feasibility of a large-scale rollout of heat pumps across the UK. It aimed to demonstrate that heat pumps could be installed in a variety of homes and deliver high customer satisfaction across a range of customer groups.

The project team consisted of a Management Contractor (MC) consortium led by ESC and, three Delivery Contractors (DCs). The DCs were responsible for the participant recruitment, home survey, design, and installation of the heat pumps. They also maintained the heat pump monitoring systems to ensure continuous performance data was collected. The MC was responsible for management of the project on behalf of the Department and collation of the data as well as associated analysis and dissemination of project findings. The MC also developed an online service based on EoH data which allows consumers to find out if a heat pump could be a suitable system for their home.

The three DCs were: E.ON (operating in North-East England); OVO Energy (operating in South-East England, excluding London); and Warmworks (operating in South-East Scotland).

In total the project installed 742 heat pump systems in a range of housing types across the UK.

2.2 Project Stages

Figure 2.1 below shows a flow chart of the key project stages. The mass recruitment began in June 2020 and final heat pump system was installed in November 2021. The monitoring stage began upon completion of the first installation (in September 2020) and, for many of the installations ran through until September 2023.

Figure 2.1: Flow chart of key project stages.

During the monitoring stage of the project, the heat pump performance data was regularly reviewed to highlight higher and lower performing systems. Where sub-optimal performance (as defined in the following section) was seen, the DCs aimed to identify the root cause and endeavoured to optimise the heat pump to enable improved heating outcomes.

2.3 Introduction to Optimisation

There are several ways to identify and define optimal performance. One method is focussing on whether the heating outcomes are as desired by the consumer. Most of the DC optimisation activity on the EoH project is consumer led, which often results in aiming to achieve consumer comfort with minimal energy consumption. Following this method may sometimes result in sacrificing heat pump efficiency (or COP) as a heat pump operating pattern which is less efficient may be selected (such as using a lower set-back temperature as discussed in Section 4.2). Ultimately, optimal performance using this strategy may differ significantly based on different consumers, properties, and heating systems.

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The other method to define optimal performance is based solely on heat pump efficiency (which is calculated by dividing heat output by electricity input). Efficiency is generally optimised by making minor tweaks to the control and operation of a system resulting in incremental improvements. Methods to gain these efficiency improvements whilst not interfering with the outcome desired by the consumer include adjusting the “weather compensation” (flow temperature) settings or the domestic hot water temperature (as discussed in Sections 4.1 and 4.6).

In reality, a combination of the two methods to optimise heat pump performance will generally create the best results for the consumer. Efficiency of the HP system can be affected by several things including consumer behaviour, how the system was commissioned or, faults with the equipment itself. Of the three, consumer behaviour is less likely to be factored into design, installation, and handover. Therefore in-situ heat pump optimisation should always be based on achieving the desired consumer outcomes whilst maximising efficiency and reducing energy consumption.

Incrementally improving the efficiency of the heat pump is one way in which energy consumption can be reduced. It should however be noted that in some cases, minimising overall energy use may result in lower efficiency performance or, lower efficiency performance may be a result of consumer preference (such as maintaining a higher internal air temperature - as discussed in Section 4.3). These preferences should be acknowledged by the industry and factored into design, but it may not be possible or necessary to rectify these causes of lower efficiency. Therefore, whilst this report highlights ways in which efficiency gains can and have been made in the EoH project, it also flags where these may negatively impact upon consumer outcomes or overall energy consumption.

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3. Heat Pump Monitoring

3.1 Importance of Monitoring

To enable heat pump optimisation, quantitative monitoring of the heat pump performance is key. This is because the heat pump performance data can be combined with qualitative feedback from consumers to ensure a robust understanding of how the heating system is performing, whether it is delivering the outcome the consumer wants and where opportunities for optimisation may be present.

The monitoring system deployed for EoH installed Heat Pumps was equivalent to that used for the Metering and Monitoring Service Package (MMSP) available under the Domestic Renewable Incentive (RHI). This monitoring system (described in Section 3.2) collected temperature and energy data from all primary components of the heat pump system at 2-minute intervals.

The primary objective of the EoH heat pump monitoring system was to enable the creation and analysis of a heat pump performance dataset [1] and optimisation was a secondary consideration. As such, future heat pump monitoring systems designed to enable heat pump optimisation may deviate from the EoH (and associated RHI) monitoring system designs. Ultimately, a monitoring system designed to enable optimisation of heat pumps for domestic consumers should aim to provide the necessary data to check that the desired heating outcome is being achieved and (if so) whether it is being achieved with minimum electricity consumption.

It should therefore include means to assess the:

- Desired heating outcome,
- Actual heating outcome,
- Reason for gaps in heating outcome,
- Expected electricity consumption,
- Actual electricity consumption,
- Reason for gaps in electricity consumption.

Heat pump efficiency is not ignored by the above criteria as poor efficiency will form one key reason for any difference in actual and expected electricity consumption.

3.2 Monitoring System

The configuration of the monitoring system used for EoH varied for each heat pump type and model however, Figure 3.1 indicates the typical monitoring system configuration used for an ASHP. The monitoring system consisted of a maximum of five electricity meters, one heat meter and one internal temperature sensor. The five electricity meters / sensors recorded the following:

1. The whole heat pump system energy consumed.
2. Back-up heater energy consumed.
3. Circulation pump energy consumed.
4. Position of the control (diverter) valve (to inform hot water or heating mode).
5. Immersion heater energy consumed.

The heat meter present in all systems recorded the heat pump unit heat output (as well as the flow and return temperature). For hybrid systems, there was a second heat meter which recorded the boiler heat output for space heating. For GSHP installations, there were temperature sensors recording the brine (ground loop) temperatures going into and out of the heat pump. All

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installations also had an internal temperature sensor to record room temperature. The external temperatures were collected from the local weather station.

All sensors and meters collected readings at an average of 2-minute intervals.

For more information on the monitoring equipment and configurations, please refer to the Heat Pump Performance Data Analysis Report [2].

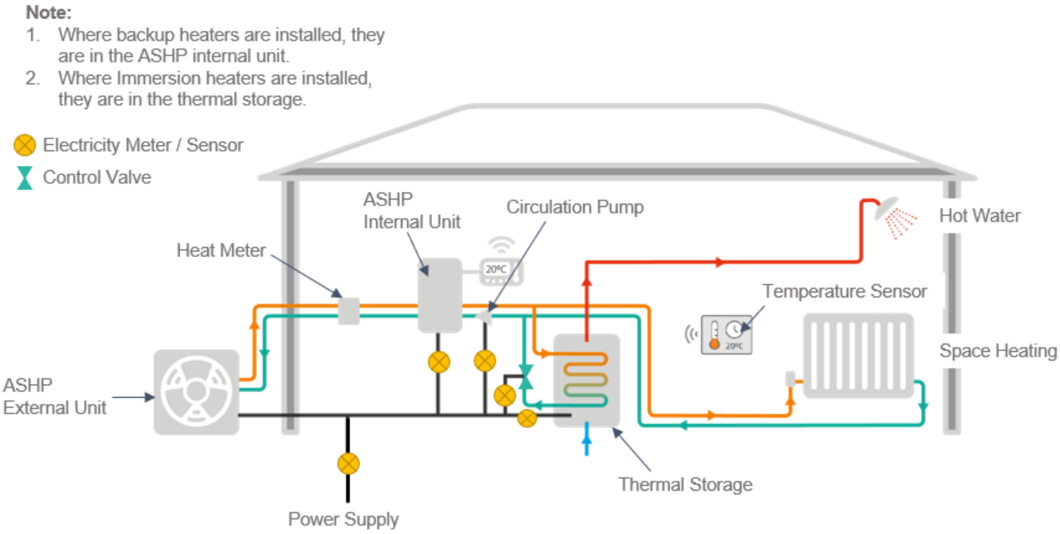

Figure 3.1: Typical arrangement of sensors in ASHP monitoring solution.

3.2.1 System and Transmission Issues

When operating as intended, the heat pump monitoring system forwarded all recorded data from the previous 24-hour period to the project database, once per day. This allowed a short timeframe between any issues or sub-optimal performance arising, being explored and corrective action or optimisation interventions being taken.

When analysing data over shorter time periods to enable heat pump optimisation, intermittent equipment or transmission issues[1] which arise had a more severe impact than when analysing longer time frames (such as at the end of a project). For example, on the EoH project, some equipment issues created erroneous readings indicating unrealistically high or low performance which made it difficult to isolate properties where heat pump optimisation was necessary. As such, it is important that future monitoring systems designed to enable heating system optimisation aim to eradicate these equipment and transmission issues through robust design.

[1] Equipment issues were issues with one sensor or meter which was sending anomalous or no readings. Transmission issues were often connectivity problems, evidenced by no data being received for a period of time.

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4. Causes of Lower Efficiency

As already noted, running a heat pump with an optimal efficiency does not always directly reflect to optimal performance from a consumer perspective. Increasing efficiency does however play a key role in reducing energy consumption so, whilst other factors (such as preferred comfort temperature and operating patterns) must be considered, it is also important to understand the causes of low heat pump efficiency and how to optimise for a higher efficiency.

In most cases, heat pump efficiency can be optimised by changing settings or preferences whilst the heat pump is in-situ. It has been flagged where a lower efficiency may not necessarily result in a higher overall energy consumption (and therefore may not be indicative of sub-optimal performance as far as most consumers will be concerned).

4.1 High Heating Flow Temperature

Heat pumps adapt the heating flow temperature depending on the temperature of the outside air to ensure that the thermal losses of a property can be overcome by the heating system. This is because a higher flow temperature enables the heat emitters to output more energy into a space however, it is more efficient to operate a heat pump with a lower flow temperature. Therefore, optimal performance of a heat pump requires the heat pump to operate with slightly higher flow temperatures when more energy is required to heat up a property or keep it warm (i.e. when it's colder outside), but with lower flow temperatures (achieving efficiency gains) when the outside air temperature is slightly higher. This adaptive flow temperature is controlled along what is known as a "weather compensation curve".

Poor control of weather compensation curve is one of the most common and easily rectified causes of lower efficiency for domestic heat pumps. A weather compensation curve which is set too high will mean the flow temperatures are higher than they need to be. This has a direct impact upon efficiency because heat pumps operate more efficiently when there is a smaller difference between external ambient temperature and flow temperature.

Equally, higher flow temperatures will increase the thermal output of the heat emitters which results in a room heating up more quickly. This will then cause the heat pump to "cycle" on and off more frequently. As heat pump compressors take time to reach peak efficiency, less frequent and longer 'on' cycles result in a higher efficiency.

To enable higher efficiencies and lower energy use, the heat pump weather compensation (flow temperature) curve can be lowered by a small amount. If the home remains warm, the flow temperature may be further adjusted until the heat pump is operating at the lowest flow temperatures while maintaining the ability to keep the home warm. If the heat pump fails to keep the home warm at a lower flow temperature, then the curve may be raised again to ensure that thermal comfort is maintained.

4.2 Low Setback Temperature

A setback temperature is the internal temperature which a heating system maintains as a minimum, even when outside of normal programmed heating use (or when not maintaining comfort temperature). The use of a setback temperature should increase efficiency as it avoids the internal air temperature dropping to very low levels which would result in a heating system working harder, for longer, to get back to the desired comfort temperature. In terms of heat pump efficiency, turning a heat pump off and on rather than using a setback temperature can be considered similar to programming a low setback temperature as both behaviours are likely to

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result in the need to overcome a large temperature variation to warm a home back up to the comfort temperature.

As mentioned above, a large difference between comfort and setback temperature results in the heat pump working harder to get up to temperature. This is because, to get up to the desired comfort temperature quickly, an increase in heat output is required. As mentioned in Section 4.1, the primary method for a heating system to emit more heat into a property is by increasing the flow temperature. Therefore, the heat pump will overshoot it's usual "steady state" flow temperature (as defined by the weather compensation curve) to heat the property up from the setback to the comfort temperature. If the setback temperature is significantly below the comfort temperature, this increase in flow temperature may be greater, or may last for longer, resulting in a lower efficiency.

In certain circumstances, using a low setback temperature may result in a lower overall energy consumption despite a lower efficiency. As a warmer home loses more heat to the environment, keeping the house warm all of the time results in a greater overall heat loss.

Optimising the heat pump therefore requires a balance between maintaining a high efficiency and reducing overall energy consumption whilst maintaining consumer comfort.

For some properties, where it is desirable to maintain comfort temperature for most of the day, it may be worthwhile using a higher setback temperature (at night or during unoccupied periods for example) to ensure high efficiency. Whereas for others, heating may only be required at certain, infrequent times, in these situations, it may still be optimal to operate a low setback temperature despite the efficiency losses that this presents.

The optimal balance will differ depending on the property and the consumer; finding this balance requires frequent communication with the consumer and may require some trial-and-error analysis.

4.3 High Comfort Temperature Setpoint

A higher comfort temperature setpoint results in an increase in heat consumption and generally also results in a decrease in efficiency. This is because some heat pump systems increase the flow temperature based on the internal setpoint. For a 1°C increase in temperature setpoint, the heat pump may increase flow temperature by as much as 5°C resulting in a loss of efficiency.

Consumers comfort is the most important factor related to any heating system operation. Therefore, whilst a system may operate more efficiently at a lower internal air temperature than is desired, optimal control should involve the consumer determining the lowest air temperature which they're comfortable with, even if this is higher and therefore less efficient.

Information relating to how an increase in setpoint temperature will affect heat pump operation should be communicated to a consumer such that they can make a better-informed decision.

4.4 Poorly Balanced Heating System

When commissioning a wet heating system, the engineer needs to balance the pressures, temperatures, and flowrates across the system to give optimal heating outcomes and efficiency. This balancing should be first completed prior to system handover, and in most cases, a balanced system will remain effective despite small changes in heating system operation. It should be noted however that large control changes (such as over-zoning as discussed in Section 4.5) will affect the system balance.

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A basic example of how a balanced system can be driven out of balance is provided below:

Assuming a flow rate of 10l/min through the heat pump is going to two radiators requiring equal output, the pressures should be balanced exactly such that 5l/min goes to each radiator. In addition, the return temperature should be controlled to keep the average temperature across the radiator (and therefore heat output of the radiator) as desired. For example, in the above situation, both radiators could achieve a flow temperature of 45°C and a return of 35°C with a temperature differential of 10°C and average temperature across the radiator of 40°C.

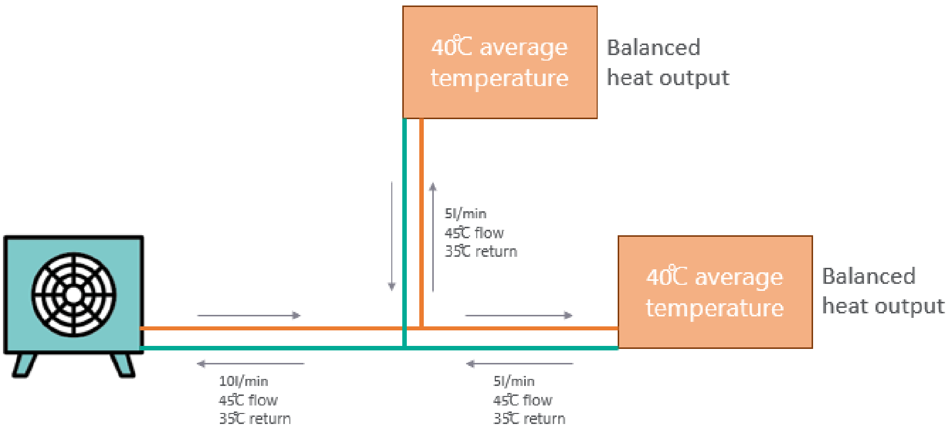

Figure 4.1: A balanced heating system with two equal sized radiators.

If one radiator control valve is then throttled down all of the way, the full 10l/min will go through one of the radiators. The water will then flow through the radiator more quickly which will mean the radiator cannot disperse as much heat per litre of water. The return temperature will therefore increase which will increase the average temperature across the radiator and the overall heat output of the radiator. This will cause the room to heat up more quickly. It will result in a less consistent room temperature and in increased on/off cycling from the heat pump, thus reducing comfort and efficiency.

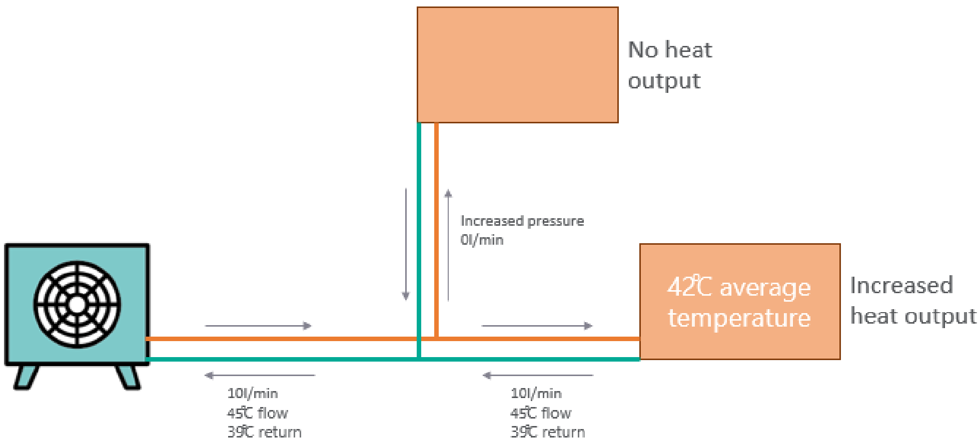

Figure 4.2: The basic heating system shown in Figure 4.1 but now out of balance.

To ensure optimal heat pump operation, it is important to balance the system during commissioning and to revisit the system balancing intermittently throughout operation.

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4.5 Zonal Control or Over-Zoning

A zonal control strategy aims to achieve a different internal comfort temperature in different rooms, spaces, or zones across a home. Zonal control can be achieved using a smart heating control system or simply by turning down radiator valves to reduce heat output from certain radiators.

Setting small temperature variations between each room can result in reduced energy consumption whilst maintaining good efficiencies. Equally, maintaining most of a property at the same temperature whilst not heating one small unoccupied space may not reduce efficiencies significantly and can therefore result in reduced energy consumption.

Setting large temperature variations across much of a home may reduce the heat needed to keep the home at the desired comfort temperature however, it may also reduce energy efficiency of the heat pump which could cause the electricity consumption to increase or remain constant. This is because generally, internal walls are not insulated, so heat is quickly lost from the heated space to any adjacent unheated spaces. This results in a higher heat demand within the heated space which requires an increase in flow temperature and therefore reduces efficiency. In addition, where heat is not rapidly lost to unheated spaces, over-zoning may have a similar effect to oversizing a heat pump resulting in inefficient operation as discussed in Section 4.7. Finally, over reliance on radiator valves for control can cause an imbalanced heating system as discussed in Section 4.4.

Similar to using a low setback temperature, the optimal level of zonal control will differ depending on the property and the consumer and optimisation may require trial-and-error analysis.

Note that this behaviour was also difficult to highlight and optimise through the EoH project data as only one internal air temperature sensor was included.

4.6 High Domestic Hot Water Temperature

Most heat pumps use a hot water tank to heat and store the domestic hot water. Heating the domestic hot water to a higher temperature requires the heat pump to output a higher flow temperature and/or use of an immersion heater. Equally, heating the domestic hot water quickly requires higher flow temperatures or immersion heater use.

As already noted, requiring a higher heat pump flow temperature results in lower efficiency heat pump use. Electrical resistance immersion heaters are also much less efficient than heat pumps, so generally using these results in a decreased overall system efficiency. Finally, storing hot water at a high temperature will generally result in an increase in heat loss from the thermal store, thus requiring increased energy consumption.

These inefficiencies can be overcome by setting the domestic hot water to a lower temperature and (where applicable) using eco modes to heat water more gently.

Similar to internal air temperature setpoint, hot water is a factor of consumer comfort, so gradual adjustments may need to be made to ensure comfort is not negatively affected by reducing hot water temperature. In addition, some households with a higher demand for hot water may benefit from heating their thermal storage to a higher temperature such that they can mix a smaller proportion of their hot water with mains cold water to achieve their desired water temperature. This may help to avoid running out of stored hot water during peak periods of use.

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4.7 Oversized Heat Pump

Oversizing a heat pump at the design stage may cause a significant efficiency loss over the lifetime of the system. Building heat loss calculations used in heating system design are usually very conservative, and engineers are naturally inclined to also be conservative when making estimates to ensure that consumers are not left with an undersized heat pump and therefore left cold in winter. It is correct to be concerned about under sizing but the effect of being overly conservative is often significant oversizing.

This is because, often a designer will make conservative assumptions and then add a margin for error (for example 10%) when performing any calculations. The calculated heat loss will be used to specify the heat pump which is often the “next largest” size. The compound effect (demonstrated in Figure 4.3) results in an oversized heat pump which can generate a heat output which greatly exceeds the building heat loss.

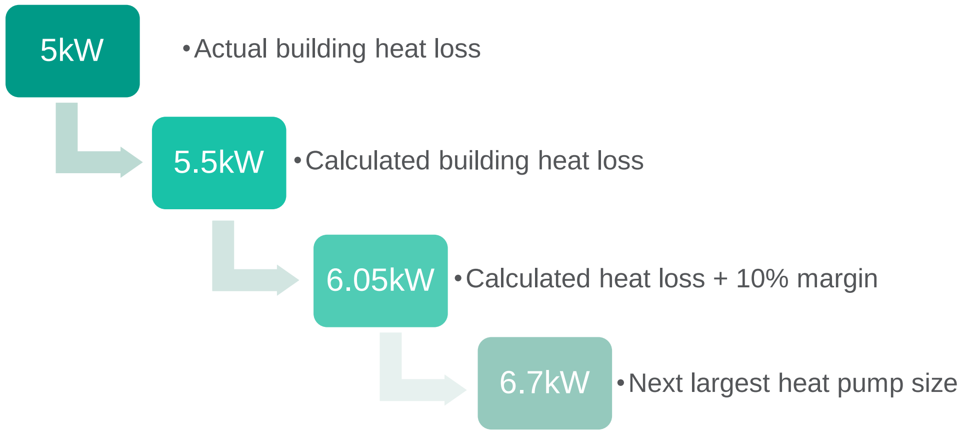

Figure 4.3: An example showing the effect of compounding design margins resulting in a (33%) oversized heat pump selection.

The result of this is that the heat pump will operate below its capable load in, what may be, a less efficient manner. The heat pump will also go through on/off cycles more frequently, meaning it spends more time operating in the less efficient compressor start up period.

The effects of oversizing on the energy system are also significant as oversized heat pumps may result in a higher peak electricity load (due to efficiency losses) and/or an overestimation of home power draw which, when scaled up over many homes, may result in unnecessary upgrades to the network with undue costs incurred by all consumers.

Oversizing is less easily rectified with the heat pump in-situ however, one way in which oversizing can be reduced during the heating design stage is by measuring building heat loss (rather than calculating) in order to decipher a heat pump size. Monitoring heat pumps may also eradicate future oversizing as heat pumps may be sized based on historic heating system operation. These methods produce more accurate results and will reduce the potential risk of compounding design margins.

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4.8 Installation Quality

Inconsistent or poor installation quality also affects overall energy consumption and efficiency. It is important that installations are of a consistent, good quality to ensure consumers are able to realise their heating requirements and with minimal overall energy consumption. Quality Assurance (QA) checks were carried out on 20% of the EoH project installations, and they highlighted some inconsistency in the quality of installation (an example is shown in Figure 4.4). Based on the QA assessors experience these results are similar to those seen across the whole domestic heating industry and are not a factor of the project or the heat pump industry alone.

In most cases, small installation quality issues (such as those shown in Figure 4.4) can be rectified, resulting in improved performance. However, outside of the project environment, consumers cannot be expected to always notice the difference between good and poor-quality installation.

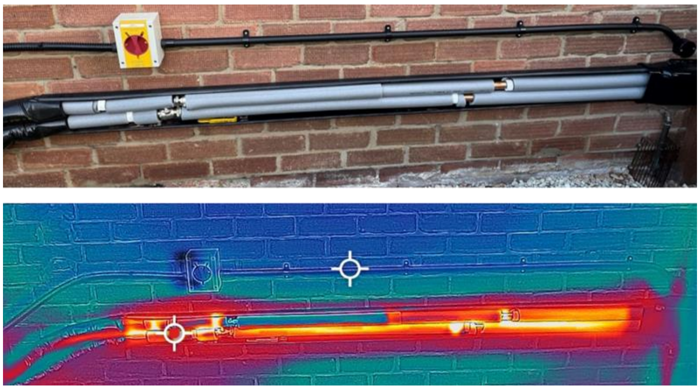

Figure 4.4: An example of poor installation quality which was easily resolved.

The industry therefore needs to ensure good quality installations through a range of potential options, including (but not limited to):

- Business models which encourage good quality installations,
- Business models which include quality assurance activity or,
- Accredited certification bodies which are equipped to redress consistent poor performance.

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5. EoH System Optimisation

5.1 System Identification

Each of the EoH project DCs identified systems to optimise slightly differently, each approach is outlined in the following three subsections.

Generally, the identification of systems to optimise included flagging systems with a lower-than-expected COP (efficiency) or ones which were providing sub-optimal heating outcomes. As mentioned in Section 3, to ensure that optimisation activity was focussed on the heating systems where it was needed, it was necessary for all DCs to check and to ensure that the bulk of the monitoring equipment across the project was sending consistent and accurate data.

5.1.1 Warmworks Approach

Warmworks partnered with Energy Savings Trust to assist with their heat pump optimisation activity. Their initial approach targeted a sample of Vaillant and Mitsubishi ASHPs. Through engineer visits, Warmworks offered the participants common optimisation interventions based on their heat pump settings and behavioural preferences. They also offered additional advice where it was deemed necessary to do so.

Warmworks monitored the initial outcomes of the interventions and continued to monitor the properties to understand seasonal outcomes. Due to positive initial optimisation outcomes as well as the high cost of energy, Warmworks contacted all of their EoH participants in Winter 2022-23 to offer optimisation advice. This communication included a summary of factors which may affect heat pump efficiency, potential steps to improve efficiency and instructions on how to take these steps with certain heat pumps.

5.1.2 E.ON Approach

E.ON's initial optimisation approach targeted Daikin and Vaillant ASHPs. They reviewed the heat pump performance data to identify individual heat pumps with lower performance or efficiency than was expected. They also searched the data for any examples of heat pump control which may cause a sub-optimal performance.

Once they had identified and performed interventions on heat pumps systems, E.ON evaluated the immediate impact of the interventions to understand the immediate success or failure of their optimisation activity. They have continued to monitor each of the heat pumps to better understand the seasonal effect of each intervention. They intend to use data insights alongside their findings on successful heat pump optimisation to offer advice to participants and consumers where interventions may be necessary to optimise their heat pump. They are also working with heat pump manufacturers to understand any additional potential interventions.

Throughout the EoH project, E.ON have adjusted their heat pump optimisation processes. They now work with their customers to further understand the effect of consumer behaviour and preferences (as well as technical factors) on heat pump performance. Upon identification of what may be deemed to be sub-optimal behaviour or heat pump performance, E.ON contact customers in the first instance and work through common resolutions remotely. Where necessary, they then refer to field engineers for further investigation and intervention.

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5.1.3 OVO Approach

OVO used the heat pump performance data to categorise their EoH participants into different groups based on the level and type of intervention which was necessary for them.

Essential

Essential participants formed the majority of the OVO customers, they required only the essential support from OVO to ensure that consumer outcomes and project goals were met. This included ensuring that the monitoring systems remained online and provided accurate data and ensuring that the heating system provided heating and hot water continuously as required.

Enhanced customer care

Participants which required enhanced customer care were those where the data showed behaviours which may indicate participants were struggling with the cost of running their heating system. These behaviours included very low comfort temperatures (below 17°C) or adjusting certain heat pump control features (such as immersion heater legionella cycles). The interventions included discussing methods to achieve electricity use reductions whilst maintaining consumer outcomes and, where necessary, offering energy bill advice and support.

Efficiency gains (all systems SPF <2.5)

Participants which were identified for efficiency gains were those where the data showed that their heat pump was operating with a lower-than-expected efficiency (SPF<2.5). For these customers, checks of the performance data were undertaken to outline potential reasons for the lower efficiency.

The initial performance data checks included assessing whether immersion heater usage was excessive, whether the heat pump was on/off cycling and whether the internal air (comfort) temperature was at very high levels. If these (or other common) behaviours were seen, then advice or optimisation interventions were offered to participants.

5.2 Optimisation Activity

The majority of optimisation interventions undertaken by the DCs involved minor system and control tweaks to improve the system efficiency or reduce the energy consumption. Almost all of the optimisation interventions included reducing the flow temperature (or weather compensation curve) to improve efficiency whilst maintaining comfort.

Other interventions which were commonly recommended included reducing the gap between comfort and setback temperature, adjusting heat zoning plans and adjusting the hot water settings. The hot water setting adjustments most commonly involved switching to eco mode but in some cases also involved reducing the hot water temperature and reducing immersion heater use. In a few cases, rebalancing the whole heating system by adjusting flow temperature was also required.

The initial indications from the data are that all optimisation activity produced immediate positive results however, all of the DCs planned to continue monitoring the properties to see longer term results.

The fact that flow temperature could be so readily adjusted across a range of heat pumps and properties indicates that heat pump installers may be conservative with their initial heat pump set up (to avoid consumers getting cold). Whilst it is correct to try to avoid a reduction in comfort, sub-optimal performance may be the result of being overly conservative. It is important therefore to

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take consumer preferences into account in heat pump commissioning, such that less conservative flow temperatures can be selected.

As noted in the introduction, in a few cases, where QA visits highlighted installation issues with the system, or poor performance could not be rectified by small optimisation interventions, physical system changes were necessary. Some examples include:

- correcting pipework insulation levels,
- installation of buffer tanks,
- installing new valves.

Ultimately, all optimisation activity was property, consumer, and heat pump dependent and therefore generally requires expert involvement. Adjusting the flow temperature however was the most common intervention and, in all cases, provided positive outcomes, it is also something which should be achievable by the average consumer and could benefit them greatly. As such, during handover and annual service visits, consumers should be made aware of how to adjust flow temperature, why they may want to make the adjustment and at what point their optimal flow temperature has been found.

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6. Conclusion

The key to optimising a heat pumps performance is maximising consumer outcomes (or comfort) whilst minimising electricity consumption (or cost). One way in which this can be done is by maximising efficiency however, it's important to note that some interventions which increase efficiency may increase electricity consumption or reduce comfort.

In order to understand and then optimise heat pump performance, it is important to monitor the full heating system. This monitoring should include qualitative feedback from consumers as well as quantitative energy and temperature data. Monitoring the system operation allows the consumer or a third-party to identify and investigate low performing systems or periods of operation. It also allows the party to track the impact of any interventions to allow for iterative optimisation.

The most common heat pump optimisation intervention on the EoH project was adjusting the heat pump flow temperature. Other interventions were also made, these include (but are not limited to): advising on zonal control settings, reducing the gap between setback and comfort temperature and adjusting the hot water settings. Where possible, consumers may benefit from making some of these interventions themselves however, some of them may be difficult to achieve without expert involvement.

Monitoring and optimising the performance of heat pumps could prove vital in maximising consumer heating outcomes. This, in turn, would increase consumer confidence in the technology to enable and accelerate large scale rollout of heat pumps. It may also reduce the overall system impacts of a heat pump transition, further assisting the UK move towards a net-zero future.

6.1 Recommendations

Heating system monitoring should be used to unlock data for consumers and industry.

- Data could prove valuable in enabling a large-scale roll out of heat pumps, enabling heat pump optimisation, and minimising the energy system impact of heat pumps. The collection and use of real-world data could help to minimise oversizing of energy assets (both heat pumps and downstream assets) and could therefore reduce the overall cost of the energy transition.

Business models which enable third-party system optimisation should be incentivised and trialled.

- Enabling system optimisation can offer an immediate benefit to consumers by improving their heating outcomes or reducing their electricity consumption. This will improve consumer outcomes and therefore increase trust in heat pump technologies. Optimisation could also minimise occurrences of inefficient operation offering wider system benefits. Business models such as Heat as a Service could enable this.

Heating system installation quality should be made more consistent through business models or redress mechanisms.

- Low quality design and installation could cause inefficient system operation leading to worse consumer outcomes and increased energy usage. This has a knock-on impact on both consumer confidence in heat pump technology and also on the whole energy system.

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Business models or redress mechanisms which drive high-quality installation should be explored to improve consistency across the industry and ensure better outcomes for all heat pump owners and the energy system as a whole.

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7. References

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