Project case study: Right Sizing Heat Pumps

Project theme: Improving the survey and design process

Project lead: Hoare Lea

Partners: City Science, PurrMetrix, Places for People

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What were the objectives of the project?

Correctly sizing a heat pump is essential to ensure the heat pump is appropriate for a property's heat loss at the design temperature. Oversized heat pumps can increase the upfront costs of the installation, and due to lower operational efficiencies, they can also incur higher running costs. Evidence from the MEASURED project in Heat Pump Ready Stream 2 showed that BS12831 surveys will overestimate heat loss 60% of the time. Installers will often add a margin above estimated heat loss so the Right Sizing Heat Pumps project believed 60% would be a conservative estimate of how many homes have oversized heat pumps. The Right Sizing Heat Pump project demonstrates that using measured energy consumption with heat loss data can mitigate this risk. The Right Sizing Heat Pumps project had the following objectives:

1. To help **reduce consumers' upfront and ongoing running costs** by accurately sizing heat pumps using measured data.
2. To develop a tool that can **support installers and consumers by using measured data** combined with advanced algorithms to allow the selection of specific models of heat pumps in the design process that are accurately sized to the individual dwelling.

What activities were funded?

To achieve the above objectives, the following activities were funded through the project:

- Live trial deployment of temperature sensors in 30 homes.
- The Energy House in Salford was used to carry out a controlled experiment where the algorithm's output from data recovered at the house could be compared with known heat transfer data.
- Developing the heat pump sizing algorithm.
- User research on what consumers and industry professionals need from such a tool.

- Developing a data collection package and platform and early market testing on pricing.

What did the project achieve?

The Right Sizing Heat Pumps project has successfully developed a tool capable of sizing heat pumps – using measured temperature sensors and smart meter data – that are consistently 15-20% smaller than sizing through the MCS calculator. MCS is a standards organisation that certifies low-carbon products and installations. Its Heat Load Calculator is a widely used online tool to help MCS-certified low-carbon heat installers complete heat load calculations in accordance with relevant standards. Throughout this project, Hoare Lea and its project partners have been working on the development of both a static and a dynamic modelling tool that uses in-home wireless temperature sensing, external weather conditions and smart meter data to determine the heat loss characteristics of a residential property and also calculate the Heat Transfer Coefficient (HTC)

A successful trial of 30 homes, alongside testing at the Energy House in Salford, was conducted to test the viability and accuracy of in-home temperature sensors in feeding data into software being developed to train dynamic algorithms. This data was then used in a bespoke testing package and platform, which was also developed. The data from the trial homes has provided confidence in the methodology and the robustness of the algorithms used in the tool by suggesting consistently smaller heat pumps than the MCS calculator tool. The software development activities have created a tool that uses house-specific data to accurately size heat pumps for individual properties. This can reduce costs and support customers and installers by enabling a consistent and accurate method of selecting an appropriately sized heat pump for a home from a product database within the tool. The project is currently exploring commercialisation options with potential partners.

Project objective 1: To help reduce consumers' upfront and ongoing running costs by accurately sizing heat pumps using measured data

Why is this important?

It is essential that a heat pump can be sized appropriately for the home and that its output can match the heat loss from the property at the design temperature. An undersized heat pump will struggle to provide enough heat for the property and may struggle to achieve the internal design temperature or desired internal comfort levels. Equally, an oversized heat pump, which is the more likely scenario, will be more expensive to install and operate as it will work at sub-optimal efficiencies. This will be especially apparent in milder weather (spring and autumn), where the heat pump might experience cycling (turning on and off repeatedly) as it struggles to modulate down far enough to provide for the reduced heat demand required in milder weather.

Given the potential impacts of mis-sizing a heat pump, it is critical to ensure it is sized correctly in the design phase. Hoare Lea suggests that a property's heat loss can be determined with more accuracy than the standard visual survey approach; by using measured data from internal temperature sensors and smart meters combined with weather data, the algorithms developed can provide house-specific insights into thermal performance. The standard visual survey approach relies on numerous assumptions and worst-case backstops. Using a combination of measured data and advanced algorithms can save consumers upfront installation costs and lower ongoing running costs.

What activities were funded?

A substantial portion of the activities required to create the proposed tool involved highly technical software development processes. However, alongside the software development required for the tool, the following activities were also undertaken:

- Creating data pipelines from smart meter data, weather data, and temperature sensors.
- Creating algorithms to determine optimal heat pump size for a given property by simulating future energy usage.
- Testing and data analysis of the algorithm’s outputs, including data validation testing at the Energy House.
- Validation testing of the algorithm across a range of climate conditions, data collection periods and properties.

What were the project findings and did the project achieve this objective?

Accurately sizing a heat pump to match a property’s heat loss is a central component of every heat pump installation. The Right Sizing Heat Pumps project has demonstrated that its tool can consistently size heat pumps 15-20% smaller than those sized through the incumbent MCS calculator. This results from actual measured data replacing the assumptions used in the MCS sizing calculator. Using measured data in place of assumed data through conventional survey methods does, however, require a longer data collection period. The results from the project suggest that a sizing tool based on a steady-state approach can achieve good accuracy with 3 weeks' worth of data, and a dynamic model can achieve this with 10 days' worth of data.

To avoid an installer attending the site, it falls on the homeowner to install the internal temperature sensors. However, user research has found that a segment of the homeowner market is happy to self-install test kits for better clarity on heat pump sizing.

To investigate this market, Hoare Lea worked with an installer to ship tests directly to a small number of their customer homes (5). Homeowners were given access to a web account and shipped a simple test kit, which included 4 temperature sensors and a gateway for delivering real-time data. Data collection setup involved clear guidelines on location and notes on where sensors were to be located.

It takes less than 30 minutes to install, and homeowners can validate that data is returning in real time. The equipment then has built-in alerts to highlight data outages during the test period. In all 5 homes tested using this method, the data passed the project's basic quality checks, and homeowners required little or no support to set up.

In the future, features can be built in to allow consumers to quality assure tests using photos of sensors in situ and to highlight quality issues with data, for example, extremely rapid changes in temperature suggesting irradiance or detected movement of the sensor.

Not all homes where tests were supplied had smart meters, but for those that did, the consumer was also invited to share smart meter data. This additional step added around 15 minutes of set-up time.

Since the project can now provide evidence that using measured data can lead to a smaller heat pump, leading to lower consumer costs, this can serve as an added incentive for homeowners to install the sensor kit themselves. Because measured tests are currently not MCS-compliant, homeowners who volunteered to install the kit themselves were not advised to base their heat pump design upon the measured heat loss. The motivation for most was to compare a measurement to existing advice and design proposals to give more confidence in those proposals. Moreover, enabling consumers to install the test kit themselves may help empower them and bring them along on the heat pump customer journey differently from a conventional installer site visit. Although this was not tested within the project's scope, it could present an interesting area for future research.

The project found it challenging to gain permissions required to access smart meter data from homes. Consumers can be resistant to downloading mobile applications to grant permissions, which is often the approach used by smart meter data owners. It was highlighted that the delay between permission being granted and access to the data being achieved was a barrier. For instance, if the data could be accessed within one hour of the permission being granted, installers could accelerate the customer journey and improve the customer experience.

Project objective 2: Develop a tool that can support installers and consumers by using measured data combined with advanced algorithms

Why is this important?

Heat pump installers are required to be expert equipment installers and property surveyors in the current customer journey, which is not a requirement placed on boiler installers. However, by using measured data to accurately size a heat pump, the installer is released from the survey aspect of the customer journey and can avoid a site visit in the first instance. This means their time and expertise can be better placed installing heat pumps, saving time and costs, which could be passed on to the customer.

Using a tool that takes measured data (from sensors and smart meters) and feeds this through building-physics algorithms can allow installers to calculate a property's heat loss to a previously unachievable level of accuracy compared with more traditional survey-based methods. It also provides a level of consistency and standardisation to the heat pump survey and design process that is impossible through traditional methods. This supports installers by saving them time and costs associated with site visits, allows senior engineers to focus on installations rather than surveys, and supports customers by adding confidence to the customer journey through a data-led standardised approach.

Existing steady-state calculation approaches do not account for thermal inertia (the energy stored in buildings) and do not accurately estimate heat loss when temperatures are not constant. Additionally, existing approaches to calculating heat loss only determine a single value when, in reality, the physics of the situation is more complicated. A more detailed thermal assessment that leverages building-physics algorithms fed by property-specific data can better predict future performance. These techniques could also enable rapid (once the data has been collected) low-cost tests that can be applied quite early in the customer journey to establish commitment, supporting both installers and customers.

What activities were funded?

The following activities were funded under the programme to meet the above objective:

- Deploying internal temperature sensors in 30 trial homes.
- Developing the heat pump sizing algorithm.
- User research on consumers' and industry professionals' needs from such a tool.
- Dataset training with Energy Plus dataset.
- Testing the tool at the Energy House 2.0.
- Developing the data collection package and platform and early market testing on pricing.
- Alpha and beta phase developments of the AI algorithm.
- New features for the data collection platform and hardware to deliver a testing package suitable for installers or homeowners.

What were the project findings and did the project achieve this objective?

The user needs assessment research carried out through this project found that many installers and property owners are very interested in the developments in data-led technologies that can support the customer journey in heat pump deployment. The research found that they are frustrated with the inaccuracy of current approaches, and they would benefit from a reliable tool that could improve accuracy.

The validation testing results have demonstrated that an AI-based 'dynamic' approach thermally assessed a property with a predictive error of 9%, compared to 16% for a steady-state approach. Both these approaches improve on the survey-based approach, but the dynamic approach offers increased accuracy to installers and customers for heat pump sizing. Additionally, the development process of the algorithms found that the amount of data required to size a heat pump depended on the number of degree hours in the data collection period. It was found that a minimum of 2,000 degree hours with sections of at least 12-hours of continuous data at a time was needed for the highest accuracy, which is generally easy to achieve across the heating season (i.e. the winter)

It was also found that a sizing tool can reasonably estimate heat loss whenever the internal/external temperature differential exceeds 5 degrees and the primary heating system is in use. This allows for extended data collection periods, typically from the start of October to April, instead of only the coldest winter months. This allows installers to collect more data and support more consumers during the heating season. The ability for installers to offer a data-led tool with a proven, increased accuracy over survey-based methods is also important for consistent and standardised survey and design methodologies. This can then be used to help increase consumer confidence and reduce drop-offs within the customer journey.

One of the key discoveries from this project was that current regulatory barriers limit the commercialisation of innovations such as the Right Sizing Heat Pump tool. In the UK, most domestic heat pumps are installed through grant schemes such as the Boiler Upgrade Scheme (BUS) or Home Energy Scotland grant, which are required to adhere to MCS standards. Whilst this enhances consumer protection, the installer must also attend the site and carry out a BS EN 12831 calculation to size the heat pump. This project has demonstrated that increased accuracy of a property's heat loss can be obtained from measured data. However, this remote assessment using measured data does not conform to current MCS standards or BS EN 12831. Work is currently underway, led by the University of Sheffield, Hoare Lea, Purrmetix and City Science, with other Heat Pump Ready projects and industry stakeholders, to produce a technical memorandum with CIBSE. This will provide an evidenced methodology and recommendations for changes/updates to these regulations in order to support the use of innovative tools that leverage measured data in the sizing of domestic heat pumps.

Summary:

What impact could this have on accelerating the heat pump rollout?

The Right Sizing Heat Pumps project has proven that using measured data alongside technology that leverages advanced algorithms can increase the accuracy of heat pump sizing. The results of this project could encourage more homeowners to invest in heat pumps by making them more affordable, both in terms of upfront and running costs. Based on the project's anecdotal research, a heat pump represents about 50% of the installation cost and reducing its size could save about 20% of the cost of the heat pump. So, the capital cost savings are about 10% of the total cost. While this is relatively small, having the ability to test the size of the emitters could also bring significant cost savings. Further, this tool would give homeowners greater trust in the sizing process through a data-led consistent methodology. Additionally, by saving installers time (by eliminating the initial survey and MCS calculation), they will be able to utilise their engineers more effectively by deploying them on installations rather than surveys. The work has also demonstrated that the technology can retrieve measured data over more of the year than just the coldest winter months. By retrieving measured data over the 'shoulder seasons', installers will be able to collect more data and support more customers in installing heat pumps using this tool.

What next?

Following the successful development of the initial tool, the next steps will be continued trialling of the tool over a larger group of properties. City Science also plans to use the tool in upcoming projects (see: City Science - investment-grade-proposals) to determine the heat loss characteristics of residential properties before and after retrofits to validate improvements. The use of the tool in this real-world application will also further support the development and commercialisation of the tool. Hoare Lea, alongside the University of Sheffield, Purrmetrix and City Science, is leading on writing a CIBSE technical memorandum (TM), which will present an evidence approach to the methodology to ensure the dynamic HTC methodology can be used and still qualify for the BUS grant and be compliant with MCS standards. This would help enable further commercialisation of the technology and support its wider adoption in the sector.

Where to find out more

More information on the Right Sizing Heat Pumps project can be found on the City Science website, where a case study of the project is presented, and on the Heat Pump Ready website:

https://www.heatpumpready.org.uk - right-sizing-heat-pumps

https://cityscience.com/case-study/smeter/

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