Project Case Study: Total Home Optimisation Management (THOM)

Project theme:

Smart and flexible

Project lead:

GenGame

Partners:

Evergreen Energy Ltd, Chameleon Technology Ltd, TalkTalk, EnAPPsys Ltd, University of Salford (Energy House)

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£762,523

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What were the objectives of the project?

The Total Home Optimisation Management project aimed to:

1. **Increase the uptake of heat pumps** by providing bespoke information to homeowners about the suitability of heat pumps for their specific homes based on data from smart meters and other household data.
2. **Minimise the running costs of heat pumps** in operation by automatically optimising their performance and integrating them with solar photovoltaic (PV) panels, battery storage, time of use (ToU) tariffs, and demand flexibility events.

What activities were funded?

- An algorithm (the 'ivie Thermal Efficiency Score') was developed to represent a home's thermal performance using smart meter data, internal temperature data and trialling the potential of gaining occupancy data from Wi-Fi routers. The Score's accuracy was tested in the Energy House[1] at the University of Salford, retrofitted to three different levels of thermal efficiency.

- Based on the existing Homely heat pump controller, a home energy management system (HEMS) was created to optimise energy assets in the home and reduce energy costs. This included optimised dynamic weather compensation and optimised integration of solar PV, battery storage, and ToU tariffs. The impact of this algorithm on energy costs was then tested in the Energy House under two different weather conditions.
- Small scale field trials were conducted to test the automated optimisation of energy bills in real-world conditions and to understand the potential savings.

Figure 1: The University of Salford's Energy House testing facility

What did the project achieve?:

The project **successfully developed an algorithm** (the 'ivie Thermal Efficiency Score') which **helps homeowners understand whether their home is suitable for installing a heat pump without the need for a survey**. Testing at the Energy House demonstrated that the algorithm was able to identify the thermal performance of a building within best practice accuracy benchmarks. When used in conjunction with a

[1] The Energy House is a replica Victorian solid wall end-terrace house constructed within an environmental chamber.

survey, the Thermal Efficiency Score enables more accurate heat pump sizing, helping to reduce capital costs and improve efficiency in operation.

The Homely Home Energy Management System (HEMS) demonstrated a **22% cost saving on annual energy bills for heat pumps**. This was achieved using optimised dynamic weather compensation and a time-of-use tariff, compared to a counterfactual case that used standard weather compensation and a fixed tariff. This is a notable finding as it demonstrates that **substantial cost savings can be made through smart heat pump optimisation without the need for significant additional capital investment** in batteries or solar panels.

Where solar PV panels and battery were integrated into the home, along with a heat pump and in conjunction with the ToU tariff and dynamic weather compensation, the **integrated and optimised approach resulted in annual space heating savings of 53%**, compared to the fixed tariff and static weather compensation approach.

The project developed an add-on to the HEMS that allowed homeowners to automate their participation in demand flexibility services (DFS)[2]. On average, Homely DFS Assist **reduced peak power demand from heat pumps by 58% (440 W) during flexibility events**. This demonstrates the capability of heat pumps to ease pressure on the grid during peak demand periods and offers potential cost savings to consumers when they participate in flexibility events. No negative impact on customer comfort levels was observed in the trials.

Chameleon Technology Ltd already retails the ‘ivie’ in-home display for real-time energy data. This project has enabled the company to move forward with field trials for the Thermal Efficiency Score with their existing customers to assess heat pump suitability and sizing.

The Homely DFS Assist add-on will be fully rolled out for use in DFS in winter 2024/25 and the dynamic weather compensation and ToU optimisation is being incorporated into the core Homely product (their existing heat pump controller).

[2] The DFS is a program designed to encourage and enable consumers to adjust their electricity usage in response to conditions on the wider grid, particularly during peak demand periods when there may be constraints in transmission capacity or insufficient generation capacity available. The NESO notifies participants of “event” windows when they will be rewarded for reducing their energy demand. The exact nature of these rewards varies depending on the company that the residential customer chooses to register for the scheme through.

Project objective 1: Increase the uptake of heat pumps by providing bespoke information to homeowners about the suitability of heat pumps for their specific homes based on data from smart meters and other household data.

Why is this important?:

It is current practice to assess the thermal performance of a building's fabric (its walls, floors, roof, windows etc.) based on the building's physical characteristics, often determined during an in-person survey from a heating engineer. These **surveys can be costly and time-consuming**. They also rely upon theoretical assumptions of fabric thermal performance, which **could lead to inappropriate heat pump sizing, high costs and poor customer experiences** if incorrect.

What activities were funded?:

- Developing an algorithm to determine a home's thermal performance based on smart meter data, occupancy data and internal temperature (the 'ivie Thermal Efficiency Score').
- Testing the accuracy of this algorithm at the University of Salford Energy House test facility. Modifications to the thermal elements of the Energy House before each phase of testing resulted in the Energy House simulating three dwellings of the same size but with differing thermal performance.
- Testing in 10-20 trial homes to determine if broadband usage could be used to identify home occupancy profiles, which may further improve the thermal performance estimates.

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

- The team **successfully developed an algorithm** based on smart meter data, internal temperature readings and external weather data. The algorithm identified the thermal performance of the Energy House at each stage of thermal retrofit to within best practice accuracy benchmarks, accurately identified the thermal improvements that were being made, and based on these conclusions, identified the home's suitability for a heat pump. This approach **could potentially provide a non-invasive and low-cost method of identifying homes that may be suitable for heat pumps**.
- The trials demonstrated that **the location of temperature sensors in the home can significantly impact the reliability of thermal performance calculations**, especially in homes with less efficient building fabric. Sensors should be placed in locations away from radiators, windows and doors to achieve an accurate assessment.
- **The approach used to identify occupancy profiles through broadband usage was unsuccessful**. This was due to mobile providers implementing a new method to improve data security during the project's timescales, which prevented the project's ability to use broadband data to track occupancy profiles. The project had intended to identify the mobile phones of individual occupants in the home as they connect to the WiFi (via the media access control address, known as the MAC number) to determine occupancy levels and home heating patterns. To improve data security, the mobile providers randomised the ID numbers of broadband devices, which prevented the ability to track occupancy consistently.

Project objective 2: Minimise the running costs of heat pumps in operation by automatically optimising their performance and integrating them with solar photovoltaic (PV) panels, battery storage, time of use (ToU) tariffs, and demand flexibility events.

Why is this important?:

Poor heat pump operation can significantly impact customer bills. **Optimising heat pump performance minimises the costs of running a heat pump.** This is key to increasing the uptake of heat pumps. **Using heat pumps flexibly can also play a significant role in reducing the cost of transitioning to a Net Zero energy system**. This is possible by matching heat pump electricity consumption to periods of high renewable energy output and reducing consumption at periods of low renewable energy output or lack of capacity on the electricity grid.

What activities were funded?

- Developing the Homely HEMS to integrate and optimise heat pump operation with other energy assets in the home (e.g., solar PV and battery storage) using a dynamic time-of-use (ToU) tariff.
- Developing a dynamic weather compensation[3] algorithm for the Homely HEMS.
- Testing the impact of the Homely HEMS on energy costs in the Energy House for both a typical UK winter day and a typical shoulder season (autumn/spring) day.
- Comparing two different approaches to enabling heat pumps to participate in the National Energy System Operator's (NESO) Demand Flexibility Service (DFS) through Homely HEMS:
    - Behaviour-led: The Homely app notified the customer when a flexibility event window had been called, giving them an option of opting in or out for that event. For those that opt in, customers could then choose to manually turn down or turn off their heat pump.
    - Automated control: Customers would sign up for DFS through a certified provider (e.g., their energy supplier), and Homely would automate their participation by automatically creating a new heating schedule for each home each time there was a DFS event (using knowledge of the unique thermal characteristics of each home to maintain comfort levels).

[3] The relationship between external air temperature and flow temperature is set by a weather compensation curve inputted into the air source heat pump (ASHP) controller by an installer or occupant. The compensation curve is a static dataset that illustrates how the output of a heat pump should adjust based on outdoor temperature to maintain desired indoor comfort levels. Whilst yielding improved efficiency, setting the weather compensation curve accurately for a specific home is challenging and is often an iterative process, requiring repeat site visits and often leading to negative customer experiences. Homely aimed to improve on this approach by using HEMS technology to learn the thermal characteristics of a home and then dynamically adjusting the flow temperature to match heat demand.

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

- The Energy House testing firstly validated that weather compensation should be implemented as standard in all heat pumps, reinforcing the existing evidence base on this topic. The study found that even **standard (non-dynamic) weather compensation controls - already available on the market - can reduce annual space heating costs by 16%** compared to fixed flow controls.
- The **dynamic weather compensation** used in the Homely system **reduced energy costs by 10% compared to standard weather compensation control**, and **22% compared to the fixed flow approach**. This was primarily achieved by a lower air source heat pump (ASHP) flow temperature that consequentially increased the heating system COP by 9%. Homely was able to reduce the flow temperature while simultaneously providing more stable internal temperatures. This suggested improved weather compensation control enabled closer alignment between the output of the ASHP and heat demand.
- **Optimisation to a ToU tariff** (as well as dynamic weather compensation) further increased **annual savings to 31%** compared with fixed tariff combined with standard fixed flow **and 19%** with a fixed tariff and static weather compensation controls.
- Additional integration with **PV generation and battery** (in conjunction with the ToU tariff and dynamic weather compensation) **resulted in annual space heating savings of 53%** compared to the fixed tariff and static weather compensation approach.
- For all testing conducted, the Homely system achieved the comfort set point at the same time as the counterfactuals, **demonstrating no impacts on customer comfort levels occurred**.
- An **automated approach to DFS participation led to significantly higher sign-up rates and event participation**, with 98% of those enrolled participating in each event. On average, Homely DFS Assist[4] reduced **peak power demand from heat pumps by 58% (440 W) during DFS events**. This was achieved by gradually pre-heating homes starting up to six hours before the event window, ensuring that there were no comfort implications in providing this flexibility. Whilst this preheating does reduce the coefficient of performance (COP) of the heat pump, incurring a cost of 30p per kWh of flex response, this cost is generally recouped through the payments given to the customer in exchange for the turn-down response they provide.

Summary:

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

The 'ivie Thermal Efficiency Score' approach demonstrates that **it is possible to provide a non-invasive and low-cost method of identifying dwellings that may be suitable for a heat pump**, and of accurately sizing heat pumps based on the calculated thermal performance required. When integrated into the ivie app, this provides a route of identifying and engaging with homeowners who have homes well suited to moving to a heat pump. It also makes it possible to develop the ivie app further to recommend installers

[4] Homely DFS Assist is an add-on to the Homely HEMS that enables customers to automate their participation in DFS events.

and potential finance schemes to homeowners, providing a smooth customer journey for their heat pump installation.

Dynamic weather compensation, optimisation of ToU tariffs, and participation in flexibility services have been demonstrated to provide significant energy bill reductions for customers compared to standard operating practices. This will improve the business case for customers to switch to heat pumps, accelerating deployment, and reducing the potential grid upgrades needed to facilitate this.

What next?

The innovations developed in the project are being implemented in a commercial context by the project partners.

Further work is required to identify the impact of occupancy data on improving thermal performance estimates and methods for sourcing this data in the home.

Where to find out more

Chameleon Technology: Real-Time Data & Smart In-Home Displays

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