GREATER MANCHESTER SMART COMMUNITY DEMONSTRATION PROJECT

Executive Summary

November 2017

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Air source heat pumps are a recognised renewable heat technology, extracting heat from the outside air and pumping it inside to heat indoor spaces, making use of heat exchange as an infinitely renewable energy resource. In addition to producing up to 30% to 50% reductions in CO_2 emissions compared to conventional gas boilers, Heat Pumps also offer high efficiency levels and may lower energy costs for users. They are therefore increasingly being considered a cost-effective option for heating homes, particularly in off-gas areas. However, widespread electrification of heating via heat pumps increases the pressure on the electricity infrastructure network, especially during peak demand times where the network is under the greatest stress. Demand Response (DR) becomes an important mechanism to help maintain the balance of supply and demand during fluctuations in the electricity system. Demand Response is about shifting consumer demand for electricity in real-time, through various methods including financial incentives and behavioural change.

Overview of Demonstration

The Greater Manchester Smart Community Demonstration Project was a collaborative project developed by the Greater Manchester Combined Authority (GMCA) and Japan's New Energy and Industrial Technology Development Organisation ("NEDO"), in collaboration with a range of partners, including three Greater Manchester Housing Associations, Hitachi Ltd, Daikin Industries Ltd, Mizuho Bank, Electricity Northwest and central Government (BEIS) - an example of a multi-national partnership project between government, industry and academia.

The rationale for the project was to develop and deliver a pilot within the social housing sector across Greater Manchester to trial the implementation and use of Air Source Heat Pumps (HP) at scale and test the effectiveness of Demand Response (DR) in the social housing sector. The energy demand shift from one Heat Pump would have negligible impact on the energy system, compared to the impact of aggregating demand shift across multiple properties.

Three Social Housing Arm's Length Management Organisations (ALMOs); Wigan and Leigh Housing (WALH), Northwards Housing (NH) and Six Town Housing (STH) were selected to be involved in this project, based on: the size and quality of their property portfolios, their appetite for innovation and their reputation in having a strong interest in the low carbon agenda.

The demonstration comprised a large scale field trial, replacing old inefficient heating systems in 550 social housing properties across Wigan, Bury and Manchester with a range of cutting-edge electrical and hybrid air-source heat pumps (HPs) and developing an energy aggregation system and ICT platform to control and coordinate the electricity usage of the HPs collectively, reducing electricity usage during peak periods and testing the effectiveness of this reduction as a system to potentially trade in the electricity market. We believe that this project represents the largest field trial of aggregation of demand shift using heat pumps in Europe.

HP performance was measured through the analysis of HP usage data and feedback from the property tenants, who were asked to give their opinions on their experience of their new heating systems and the DR trial through a series of questionnaires and interviews.

A robust business model and evaluation criteria was also developed alongside the field trial, to determine the viability of the commercialisation of the HP technology and electricity aggregation system using data obtained in the trial.

An initial feasibility report was produced in December 2013 and the demonstration phase was implemented between 2014 and 2017.

In addition to the HP installation, WALH also trialled a telecare system in 20 sheltered flats, installing movement sensors and enabling tenants to communicate their health status daily to the shelter manager, via their digital tablets. Further details of the telecare trial are covered in the full technical report.

This demonstration aimed to test real market situations (trading conditions, system cooperation requirements, etc.) to identify cases where electricity aggregation using HPs can be used effectively. Seven scenarios (use cases) were identified. The defined trading partners and purposes of trading are outlined over leaf in Figure 1.

Figure 1: Overview of trading partners and target trades tested

Trading partner	Traded product or trading target	Details of trading target	Trading use case (UC)	Tested in this Project?
Existing aggregator	Demand reduction for ancillary service market	An aggregator (Flexitricity) sells electricity for ancillary service market. The electricity comes from demand reduction made by Electricity Aggregation system.	UC1	Tested using data from demo
Existing aggregator	Surplus absorption for ancillary service market	An aggregator (Flexitricity) sells electricity for ancillary service market. The electricity comes from surplus absorption made by Electricity Aggregation system.	UC2	Tested using data from demo
Distribution Network Operator (DNO)	Demand reduction in abnormal circum-stances	To provide demand reduction by Electricity Aggregation system upon request from electricity distributors in abnormal circumstances.	UC3	Tested using data from demo
National Grid	STOR (Short Term Operation Reserve)	To supply or consume electricity by Electricity Aggregation system according to demand fluctuation.	UC4	Tested using extrapolated data from demo
Electricity retailer	SPOT	A retailor sells electricity for Spot market. The electricity comes from demand reduction made by Electricity Aggregation system in a short time frame.	UC5	Tested using a simula-tor model
Electricity retailer	Load shift due to the increased demand	This service is for load shift due to the increased demand.	UC6	Tested using a simulator model
Electricity retailer	Peak shift and peak cut by tariff	This service is for peak shift and peak cut based on hourly electricity tariff.	UC7	Tested using a simulator model

Each Use Case (UC) is explained in more detail in the full report. In summary, UC1 to UC3 were tested during the demonstration, using actual data obtained in the trial. To conduct a demonstration close to actual trades, it was necessary to meet a variety of conditions stipulated in the trade rules. The minimum trade amount is 200kW (UC1). The key test set for the project was therefore to establish whether 200kW of nega-watts energy demand reduction could be achieved from implementing DR in up to 550 properties. This criteria was successfully met by the project.

UC4 to UC7 were tested using simulation models developed in the demonstration. For UC4, a calculation was undertaken to estimate that 9,000 HPs would be necessary to achieve the minimum trading volume, and this was simulated (extrapolated based on the results of the HPs in the trial). It was not possible to conduct the demonstration by establishing a connection with the actual trading system for UC5-7. However, as these trades represent a viable business opportunity, the demonstration was conducted by way of simulation using an emulator (a mechanical environment simulating the system of the business partner), generating pseudo transactions.

Property Selection and Tenant Participation

Properties were selected for inclusion in the demonstration in each ALMO area based on an assessment of the type and age of the current heating systems, with older and inefficient heating systems prioritised. HP system types were selected based on performance and suitability.

Tenant participation in this demonstration project was voluntary, therefore, for the project to be viable, the uptake project participants was vital. Tenants were contacted via letter, phone and door to door visits by the ALMOs to 'sign up' to the project. Incentives were offered, and participating tenants were provided with free Broadband line and router for two years from the start of the programme, funded by the ALMOs, and were given a free tablet, courtesy of Hitachi, which featured an interactive 'smart communities' web link to provide information on energy saved during the DR trial.

Despite the recruitment incentives, tenant sign up to the project was particularly challenging, with uptake slower than anticipated. Approaches to tenant sign up differed by ALMO, primarily based on the resources available to undertake this activity. The installation targets per ALMO were agreed prior to the installation phase and the final split was adjusted and agreed between the ALMOs as the project progressed, based on tenant sign up rates and suitability of properties.

Actions to accelerate tenant sign up included using a mobile unit provided by Daikin Industries Ltd to show the HP equipment to prospective project participants and a 'demonstration home' installed by Six Town Housing with all project equipment, to show prospective participants around.

Each selected property underwent a pre-installation survey to assess current energy performance and suitability for HP installation. Of the initial properties selected and signed up, 159 were deemed 'not suitable' for a HP installation. Reasons for this were varied and included: no space in the properties for installation works (either HP/ radiators or pipework required); properties not insulated sufficiently (and not able to insulate in scope of project); structure of properties not suitable for a HP (too much external works required i.e. foundation work, asbestos issues, strengthening of beams, wall partitions); and properties containing too much clutter / not hygienically suitable for an installation.

The project worked in close collaboration with Electricity Northwest (ENW), the Distribution Network Operator (DNO) to ensure the project could complete the target number of installations without overloading the local network. Project partners were required to notify and seek approval from ENW in advance of the installations. DNO assessments were undertaken under normal operating conditions. To overcome any delays due to potential requirement for reinforcement of the network, the project partners ensured that the heat pumps operated within the required limits allowed by the DNO for the connection to the grid.

Of the total properties that signed up and were deemed 'suitable properties' at survey stage, 109 did not proceed to installation, the reasons for this were varied, including tenants simply changing their minds, long term health issues of tenants or their relatives not wanting the HP installation to proceed (particularly in the cases of elderly or vulnerable tenants); and tenants not wanting disruption at their properties, for example not wanting to move furniture / flooring to accommodate the installation. Difficulty with access was encountered at all stages of the process; design stage, sign up and installation stages.

In order to improve installation targets and increase the available pipeline of properties, some HPs were installed in void (empty) properties. This meant that installations could be planned and carried out quickly without relying on tenant sign up, or causing any tenant disruption. 103 void installations were carried out in total, providing a strong pipeline for installations, as these could be slotted in with resource availability.

Equipment Installed

The HP types installed in this project are outlined in figure 2. HPs from two manufacturers were installed (Daikin = 540 units and Hitachi = 10 units). By the end of the trial, a total of 550 properties were installed with a HP (307 in WALH; 153 in NH and 90 in STH), of which 543 were also installed with the associated electrical monitoring equipment.

Figure 2: HP installation numbers and types

	Without Buffer Tank				With Buffer Tank			Sub Total
	Electric			Gas Hybrid	Electric		Gas Hybrid	
	LT Split Daikin	LT Split Hitachi	Monobloc Daikin	Hybrid Daikin	LT Split Daikin	Monobloc Daikin	Hybrid Daikin	
WALH	161	8	127	7	3	1	0	**307**
NWH	70	2	27	35	19	0	0	**153**
STH	0	0	15	75	0	0	0	**90**
Sub Total	**231**	**10**	**169**	**117**	**22**	**1**	**0**	**550**
Category Total	**410**			**117**	**23**		**0**	**550**

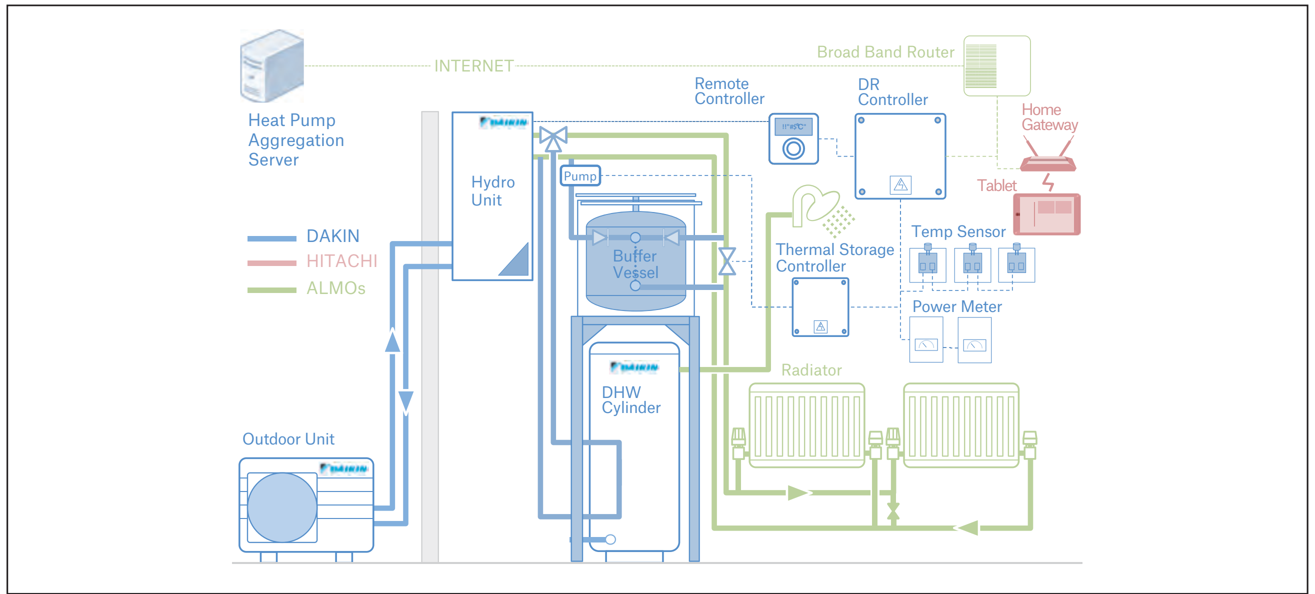
To select the most suitable heat pump for each property, a pre-installation survey (including heat loss calculations) was carried out by the project contractor, Warmer Energy Services, and appropriate HPs selected accordingly.

In this demonstration, two smart electricity meters were installed in each property. A meter, to measure power consumption of the HP and a meter to measure the total consumption amount for the whole house, to enable a comparison with the power consumption of the HP. A Netcomm Home Gateway (HGW) was installed in each property and connected to the broadband router (BBR) to establish a secure connection to transmit data from the meters to the data centre in real time.

A heat pump aggregation system was designed to control the heat pumps in individual properties as groups, to balance the capacity loads of the HPs. The heat pump aggregation system consisted of three components: the heat pump; a DR (Demand Response) controller; and an ICT cloud server system to communicate with the HP systems and operate the DR process.

Figure 3 shows a schematic diagram of a HP system and associated electrical monitoring equipment connections, together with an overview of responsibility of each partner for the components.

Figure 3: Diagram of HP system (with buffer vessel)



HP Data Analysis

Analysis of the data collected from the Heat Pumps was undertaken by Daikin Industries Ltd. Initial analysis looked at the power consumption profiles of the properties to look at trends in the data and establish the appropriate times to undertake the demand response trials. The aggregated HP profiles showed a clear pattern showing two peaks and two valleys in a day.

In this trial, the energy consumption was measured in half hourly 'settlement period' (SP) amounts

Figure 4 below shows the average day profiles observed. The observed peak profiles were used to identify the appropriate timings for the load shedding DR events. These were performed twice a day between 06:30-08.00 and 17.00-18:30 (identified as Key SP 1 and 3 in the graph below), with the period of each DR event varying depending on the use case being tested.

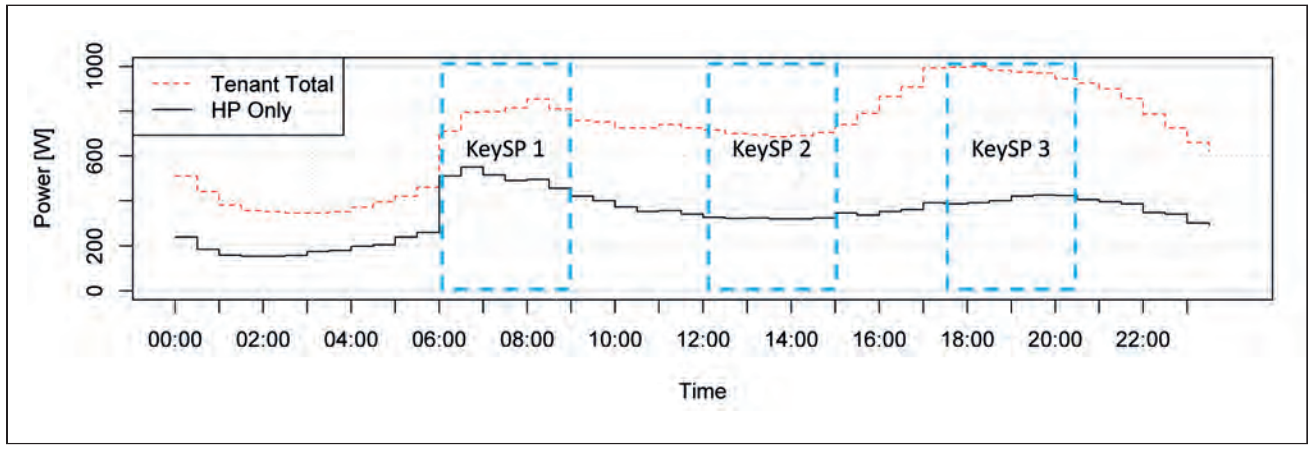
The absorption DR was undertaken during the day time valley observed (Key SP 2).

Analysis of the HP data showed little difference observed between peak power consumption during the week and at weekends. As the external temperature increases, the power consumption decreases in all Key SPs and the hybrid systems showed lower power consumption compared with electric systems. As expected, in the summer time, the values observed were smaller than in winter.

Data from the demonstration trial was extrapolated and tested to produce a simulation model to test the viability of the trading conditions (use cases) in the project. There is a difference in physical configuration and operation policy between the two types of HP system (electric and hybrid) which result in different HP power consumption profiles under the same conditions. Models were developed for each HP type, factoring in HP capacity and using external temperature as model parameter. The HP analysis data showed a clear variation in a day, even with aggregated data which reflect residents' different life patterns and intermittent power demands. The model was developed focusing on Key SPs, because it was difficult to develop one mathematical model considering the day cycle shown in Figure 4.

Data was also recorded for whole house power consumption, to understand the impact of the HP installation on the distribution network. In general, the whole house power was about 2 or 3 times larger than the HP power. As the graph in Figure 4 illustrates, the HP contributes a significant share of the whole house energy, particularly in the morning peak period.

Figure 4: Average day profiles of all data



Demand Response Trial Results

The graph below in Figure 5 shows an example of demand response performed on a group of heat pumps. The chart is drawn at 1-minute data intervals, to accurately observe the response time. The black dashed lines show DR periods, black solid lines show HP power consumption and blue dotted lines show external temperature. It is observed that HP power consumption goes down and up along with DR periods, as a result, so-called bathtub curves can be observed. The depth of the bathtub curves is the DR amount.

Observation of these sharp bathtub curves is one of findings of this project. Because there are multiple DR resources and they may not perform in a synchronized way, it can sometimes be difficult to observe sharp bathtub curves in aggregated DR systems. However, in this trial, the fast response time of the DR events (1 minute being the fastest response time recorded) demonstrates that sharp bathtub curves can be achieved with an aggregated DR system using HPs.

Detailed findings for each use case tested are discussed in the full technical report. In summary, overall, the maximum value of DR amount observed in the trial (load shedding) was 375kW, demonstrating that the overall project target of 200kW DR set by NEDO (use case 1) was achieved. In total, the target DR amount (200kW) was achieved 144 times.

The biggest issue was stability, as the variation of DR amount in this project was significant. It is anticipated that if the volume of participating tenants increases, the deviation will decrease.

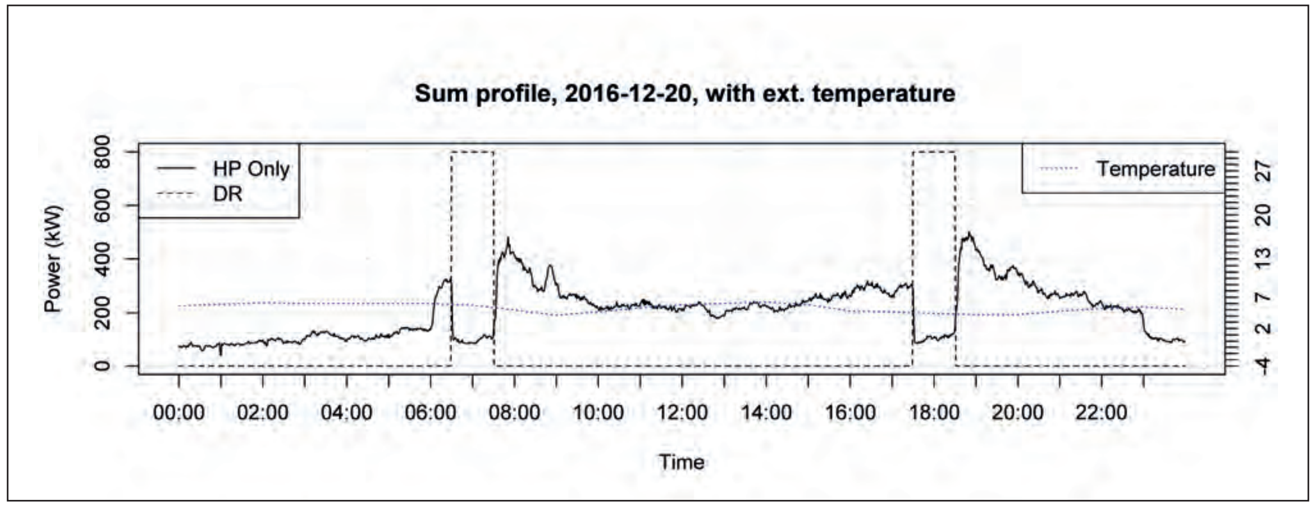
The length of duration of successful DR events was also measured in the trial. Duration is defined as the sum of consecutive successful 'Settlement Period' durations. Across the trial, 189 DR events successfully achieved 60 minutes duration, DR events of 120 mins were only successfully observed in 2 events. This indicates that 1-hour DR is clearly possible and reliable, whereas longer DR periods are thought to be difficult.

An experiment to test a longer term DR period by switching groups of participating tenants was performed. In this method, one group of tenants was controlled into a DR event immediately after another. In this case, the DR event period experienced by each group of tenants remained short, whilst the overall DR event was longer term for the aggregator. In this experiment, whilst the overall DR target was achieved (2 hours duration in total) an issue of instability was observed at the switching time. Firstly, lower power was observed during the very short time in which both groups were in DR at the same time. Secondly, larger power was observed because of reactive operation. This is where the aggregated HP power consumption after a DR event is larger than that before the DR event. This is discussed in the full technical report. To provide stable long-term DR, more precise control methods to avoid overlapping between switching groups and to suppress reactive operation is needed.

The response time was tested for all DR events. In this trial, the response time was measured as the time between the DR start time and the time the HP power reaches the SP average. Overall an average response time of 2.3 minutes was achieved, with a response time of 6 mins or less observed in all 231 DR events. Both load shedding DR and absorption DR showed similar response times. These response times would be more than sufficient to meet the requirements of the STOR (UC4), however were not fast enough response times to meet the target response time of 60 seconds set by Electricity Northwest (UC3), as 1-minute response time was only achieved in 7 of the 231 DR events.

A guideline for DR absorption of 100kW was set in the trial (UC2) and this was observed in 26 SP out of 94, with a response time of 3 mins or less. Whilst a DR event period of 30 minutes was easily achieved, a DR event period of 60 minutes could not be achieved in the absorption trial as there was a wide range of variation in power consumption observed and a limited absorption amount obtained for each property.

Figure 5: Example of a DR result



Opt-Out

The trial was delivered on the basis that all participating tenants 'opted in' to the DR events and to protect tenant comfort, the system automatically opted out from the DR under two 'fail-safe' conditions:

- If the room temperature decreased by 2 degrees from the thermostat temperature set point
- If the room temperature dropped to below 18 degrees

In addition, tenants were notified in advance and given the option to 'opt-out' of each DR event via the 'smart communities' link on their tablet and were also able to override the DR event at any time by operating their HP thermostat.

An analysis of the observed tenant behaviour during the DR events concluded that the ratio of cancellation by users or by a heat pump system was less than 10%, with the highest rate of fail-safe (safety stops) occurring within the first 5 minutes of the DR start time. This is thought to be due to the room temperature falling 2 degrees or more below the set point, or the property temperature being below 18 degrees at the start time of the DR event.

Technical Challenges Encountered

The scope of this demonstration and the technology used was an industry first, therefore obstacles and delays were inevitable. A delay in the development and initial testing of the electrical monitoring equipment (HGW and EDMI meters) meant that this equipment was not installed until 6 months into the Heat Pump (HP) installation schedule. Between January 2015 and September 2015 162 Heat Pumps were installed without the associated electrical monitoring equipment. Subsequently, 6 months after retrofitting this equipment, defects were found. Analysis of these defects identified that they could not be fixed remotely, and the installation was suspended for a further 3 months to modify and retest the equipment. During this time, the HPs continued to be installed independently to meet the timescales of the project.

A programme to remove and replace the defect electrical equipment was carried out concurrently with the continued installation of new HP systems and the retrofitting of equipment into properties with HPs already installed. This created a significant resource impact on the project, pressure to install to tight deadlines and a higher than expected number of 'repeat' visits to properties to complete the installation, in some instances over 20 visits were required to successfully complete the full installation phase. This resulted in 7 properties eventually refusing access to their properties to complete the installations.

Installation of broadband routers (BBR) was an essential component of system. The BBR installation process was time consuming, relying on tenants waiting for long periods for installation. Additionally, the BBR contracts proved to be more expensive than anticipated, as they had to be managed on a commercial basis, as opposed to a domestic tariff.

An example of the number of ad-hoc visits required at each property for is outlined below in figure 6.

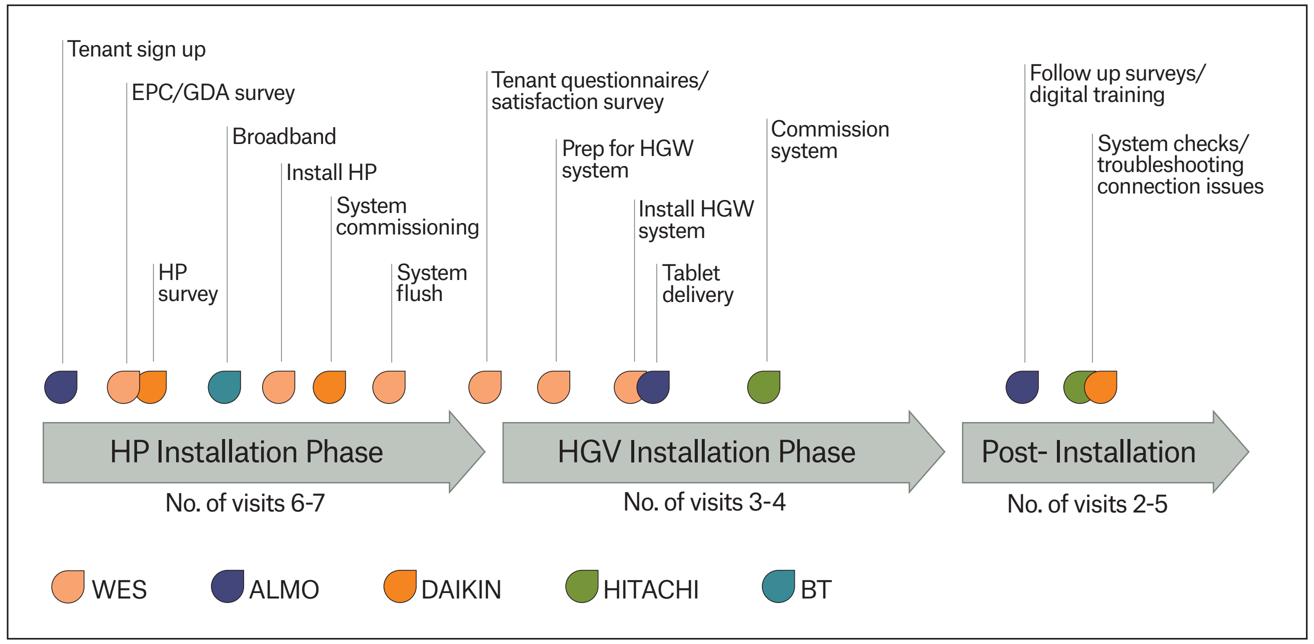
The challenges with equipment defects and tenant access ultimately led to a delay in the full system installation, which resulted in a reduced period for the data collection phase of the project.

A further unforeseen challenge arose in maintaining the connectivity of the equipment components in the properties (the HGW boxes and BBR routers). Despite letters and information leaflets (including FAQs) being sent to tenants asking them not to touch the equipment, labels being added to cables and visits to tenant properties, there was a high number of disconnections on the system. A review found that whilst, in limited instances, these were down to technical faults (with the HGW or cables), the majority were down to 'user' disconnection – tenants simply unplugging the boxes, removing the cables and in several cases changing BBR provider part way through the project, thus losing the established connection.

The result of this was, that despite continued effort by the project partners to maintain connectivity, the project was unable to achieve more than 389 full connections at any one time.

Despite these challenges, the overall project target in terms of reaching 200 kW 'Nega-watts' of energy reduction capability was achieved, which was a significant result for the project and demonstrated that a significant amount of energy can be saved through collective DR across many social housing properties.

Figure 6: An example of the number of tenant visits required to complete an installation



Business Model Development

A key element of the demonstration was the development of a business model to test the viability of the commercialisation of the technology and electricity aggregation system. An innovative HP power consumption model was developed, extrapolating data from the demonstration trial to test the viability of the trading conditions (use cases) and to simulate DR at a larger scale.

The business model was developed through analysis of policy developments and assumptions made on likely future penetration of the HP market in Greater Manchester. It tested the viability of establishing a new company that would control large amounts of HPs collectively by the energy management system to create nega-watt energy demand reduction sufficient for trading in the STOR market (via tier-1 aggregator) and creating a profit. A profit simulation, using the data obtained from the project and taking in consideration likely future costs of equipment identified that it would take 10 years for the company to break even.

The cost estimation for the aggregation business was developed by taking into consideration the investment costs and support service fees for the energy management system (server costs, network costs, software costs etc.) and the investment cost, installation cost and labour costs for the HGW.

The business model, developed in Japan, has used a series of assumptions which would need to be further analysed and tested in the UK, which could alter the payback period.

The HPs installed were all eligible for the Domestic Renewable Heat Incentive (Domestic RHI) scheme, with participating ALMOs able to apply to receive ongoing payments for renewable heat each system produces.

Tenant Feedback

Following the full demonstration phase of the trial, telephone interviews were conducted with 68 of the 550 participants. The results of these interview showed that in general, the majority of tenants (69%), were either 'satisfied' or 'extremely' satisfied with their HP. Those that were not satisfied felt that the system was more difficult to understand and use than their old heating system, some had experienced technical issues following installation and some felt that the cost of their heating had increased compared to their old heating system. Each tenant was provided with information on how to better manage their new heating system, 'energy switching' options to lower tariffs and advice on energy efficiency as part of the trial.

Further analysis of this data and of the tenant demographics and behavioural trends is needed to more fully understand these correlations. Initial analysis indicates that there is an emerging trend between overall satisfaction level and the length of time the system has been installed, indicating that a new system may take time to get used to (Figure 8).

In addition, there was a strong correlation between overall satisfaction ratings and level of understanding of how the system works, demonstrating that it is important for new systems such as HPs to be fully explained to end users.

Figure 7: Reported overall satisfaction level with new heating system

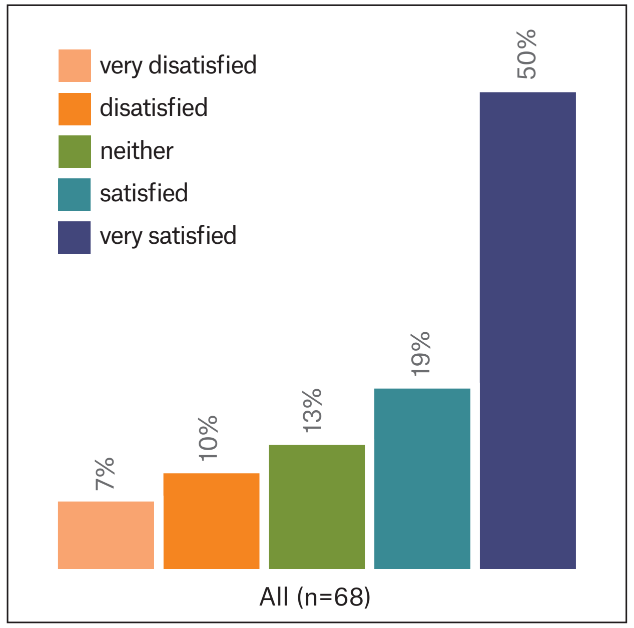


Figure 8: Reported overall satisfaction vs. date of installation

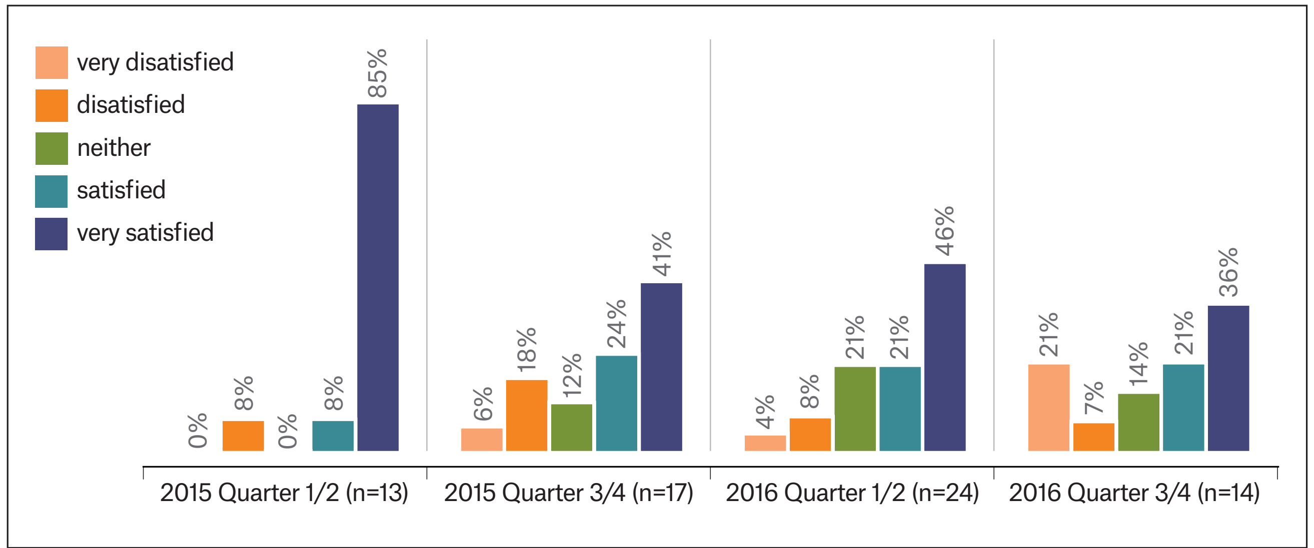
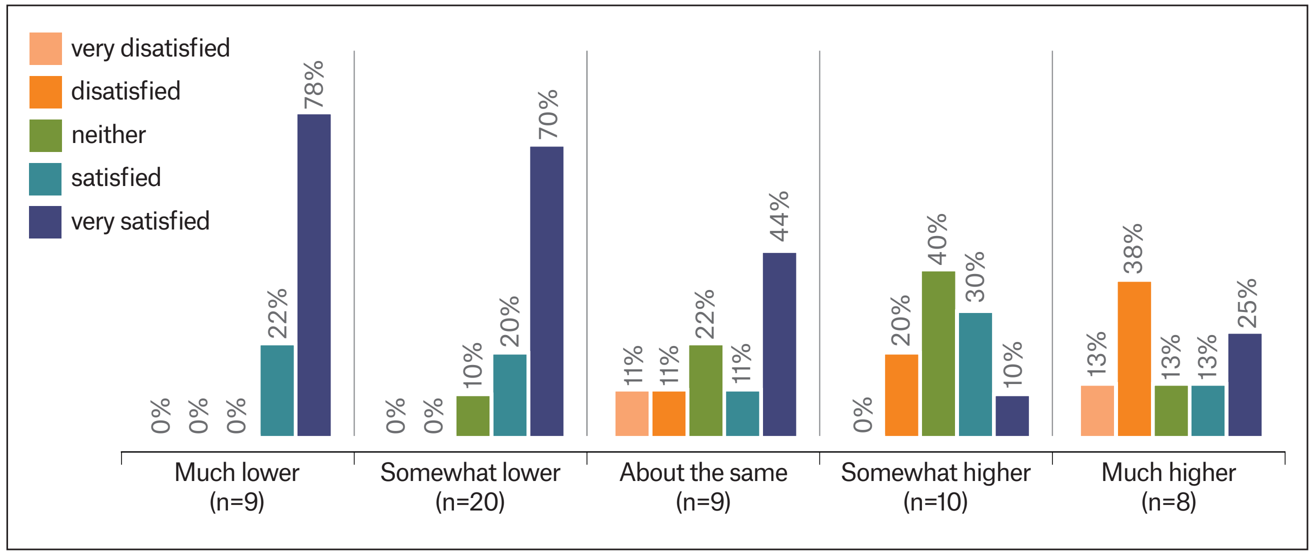


Figure 9: Relationship between reported overall satisfaction (vertical) and perceived change in energy costs (horizontal)



The graph in figure 9 indicates that those interviewees who experience lower costs are more likely to say they are satisfied with their new heating system.

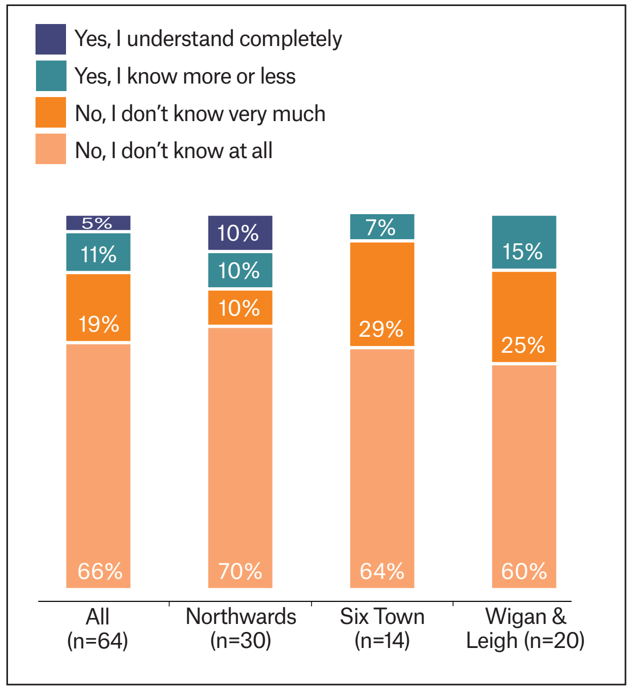
Following the completion of the project, the ALMOs have each followed up with tenants to explore energy costs and to understand why there are some cases where energy bills are perceived to be higher. Initial findings indicate that whilst, in some instances, the electricity bill has increased (for example when replacing a gas boiler) the tenant has not taken into consideration the fact that they no longer receive a gas bill and therefore their overall energy bill is lower. In other instances, there has not yet been enough time to compare 'like for like; energy bills across a whole year and there are some examples where the tenant behaviour and interaction with their new heating system has resulted in higher bills, for example where the room temperature has been set to 26 degrees and windows are left open. Partners are intending to extend the timescale of energy data monitoring, post-trial, to better understand the true impact on residents' energy use over a longer period.

Figure 10 below shows that despite being provided with information, very few respondents understood what a DR event was. Because of this, many interviewees didn't respond to how often they noticed an DR event. Of those that did respond, 71% stated that they had not noticed any DR events taking place with a further 22% 'rarely' noticing. Only one interviewee stated that they took steps to override a DR event.

Over 50% of respondents did not use the digital tablets provided to them, either for general use or to look at the 'smart communities' app. The main reasons given were lack of interest and lack of skills / understanding, this is despite digital inclusion training being offered to all participating tenants.

One of the interesting findings from the project has been that the tablet was not as strong an incentive to participants as expected. This may be linked to many factors, including that technology advancements have moved on significantly since the project development phase (2013) and whereas, a tablet would have been a 'luxury' item at the beginning of the trial, reduction of costs and prevalence in the market now means that anyone who wants one probably already has one.

Figure 10: Interviewees' understanding of what a heating saving event is, split by ALMO



Key Lessons Learned

The complex nature of the project, involving multiple delivery partners, the social housing sector and new innovative techniques has resulted in several lessons that can be passed on for future smart energy projects to learn from. These are discussed in further detail in the full technical report, with summaries outlined below:

- System components need to be fully developed and tested prior to roll out. A small-scale pilot at the start of the installation phase would have identified and managed the risks prior to full implementation rollout. In addition, systems need to be carefully designed to remove 'user' interference by either removing reliance on BBR connectivity (considering alternatives such as 3G connection) or removing the ability for users to disconnect the components of the system.

- An advance pipeline of properties with tenants pre-signed up, surveys complete and DNO consent in place prior to the installation phase commencing would have resulted in a smoother installation programme. Early engagement with the DNO is essential for a project of this scale. Development of a policy change to enable quick assessment of network reinforcement requirements would be required for any future large-scale HP rollout programme,

- Consideration of tenant demographics and suitability of participants to be involved in the trial in addition to a property asset management approach may have increased overall participation in the trial and removed some of the tenant access issues encountered.

- Tenant education on the operation and functionality of their new heating system is important to ensure they fully understand how it operates and how to optimise energy savings. Take up of new technologies should be supported with user friendly interfaces, with appropriate training and a single point of contact to manage issues arising, with better visibility of data to show how efficiently systems are operating i.e. direct access to simple HP energy usage data

- With so many partners involved, project coordination and sharing of information is vital. The establishment of cross-partner operational meetings and a cross-referral system between partners to manage risks helped to streamline resources, and enabled challenges to be identified and dealt with quickly. In addition, a 'contingency fund' set up to cover any additional unforeseen project costs was a helpful addition to the project. The ALMOs each agreed to allocate a proportion of their anticipated RHI payments into a central 'contingency' fund. This central funding was used to: support additional tenant engagement, including digital IT literacy training on tablets; cover unexpected property works to make some of properties suitable for HP installation, such as strengthening beams and to pay for planning application costs.

Conclusion

The project successfully demonstrated that a significant amount of energy can be saved through collective DR across a large number of social housing properties. Each DR activation resulted in accumulated energy demand reduction of between 50kW and 320kW depending primarily on the external temperature during the activation and the number of properties involved in each DR event. This surpassed the expectations of the trial, however could have been even higher if all installed properties had been fully connected.

There is currently little evidence of heat pumps as a large scale retrofit DR solution. This demonstration project enabled the development of further understanding of the challenges these systems present and some solutions to those challenges.

Retrofitting HP installations and associated electrical monitoring systems into existing properties within the social housing sector and activating remote DR control has proved to be a complex operation, with some challenges, particularly in maintaining 'live' connection of the systems to be able collect the data and to perform the DR function on a large number of properties. However, the trial has demonstrated that it is possible to achieve well over 200kW Nega-watts of energy consumption reduction through Demand Response events in less than 400 social housing properties, with an average 'response time' of 2.3 minutes drawing the conclusion that an aggregated group of heat pumps in the social housing sector can be utilized as effective resources for demand response, with very little 'opt-out' experienced by the participating tenants, leading to the conclusion that the overall impact of DR events of 1 hour or less on residents comfort is minimal.

The findings from the business model developed in this demonstration indicate that the development of a commercial venture for DR in the social housing sector does not currently present a strong viable economic return on investment, based on the current limited uptake of HP systems, the market cost of these and the payback period of a commercial venture. Further analysis of the data obtained in this trial and testing of the scenario models developed would give a clearer understanding of the market benefits.

The project has observed a general overall reduction in energy use by the participating residents. This is based on direct feedback from project participants, however the impact of occupant behaviour on energy consumption is a complex area and it has proved difficult to obtain energy use data for the properties for the 12 months preceding the installations. The delay in installation of the systems has also meant that many residents do not yet have a full year of bill data to compare.

The delay to the installation of the equipment meant that the overall timescale for the DR testing phase of the project was shorter than anticipated and an extension of the project timescales to continue DR was not viable due to the funding constraints of NEDO, however following the completion of the project, with the consent of the ALMOs, Hitachi has continued to collect HP operation data to March 2018, enabling a full year of data to be collected for all participating properties.

A positive outcome from this demonstration project has been a greater understanding and knowledge of HP technologies amongst the ALMOs.

To view the full report please visit:
www.greatermanchester-ca.gov.uk/downloads/20005/green_city_region

PROJECT PARTNERS

CONTACT

LCH@greatermanchester-ca.gov.uk
www.gmsmartenergy.co.uk