Monitoring Air Source Heat Pumps in Domestic Properties

Project partners

National Grid, Affordable Warmth Solution (AWS)

National Energy Action (NEA)

Peaks and Plains Housing Trust

A1 Housing

Acknowledgements

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Executive summary

As a domestic heating technology, air source heat pumps (ASHP) are increasingly being considered a cost effective option for heating homes particularly in off-gas areas. Government targets for carbon dioxide emission reduction and financial incentives and funding mechanisms are all poised to stimulate the take up of air source heat pumps in the UK.

It is widely promoted by manufacturers that heat pumps are a cost effective heating system for properties where mains gas supplies are not available. Through this project, NG-AWS engaged with the Housing Associations involved, and financed the installation of the heating systems in their properties. NG-AWS commissioned National Energy Action (NEA) to conduct this research study on the installations, to further understanding of the effectiveness and acceptability of this technology when deployed in off gas social housing situations.

The project aims as agreed with the funder in 2012 were:

To provide an independent assessment of air sourced heat pumps and their use as a solution to fuel poverty in hard to treat properties.

The focus of this project is the evaluation of the social impact of air source heat pumps in two rural off-gas grid communities.

- Worksop - fitted with Mitsubishi ECOdan units – 10 households evaluated
- Macclesfield – fitted with Husky PWR units – 6 households evaluated.

Within the sample of properties evaluated, 12 properties had previously been heated by electric storage heaters, 2 with solid fuel heating systems, 1 with an oil fired boiler and 1 using an electric boiler.

NEA compared running costs and controllability of the heat pump systems with these previous heating systems, and captured valuable data relating to installation and user experience. The technical efficiency of the two different models of heat pump is not examined in this study – However both have similar published efficiency ratings.

Semi structured interviews were conducted with householders at four points during the process, which started with system installations commissioned in February of 2012, and the monitoring period running until February 2013.

Tenants were generally pleased with the new systems, which provided adequate heating capacity. However several issues were identified.

The project highlighted several benefits to tenants of ASHP heating systems when they were fitted in appropriately insulated off gas properties, correctly specified and supported. The overwhelming majority of tenants (81 %) were happy with their new systems AND would recommend them to others.

Benefits found;

1. increased thermal comfort,
2. lower heating costs,
3. improved controllability of heating
4. Increased automation compared to storage or solid fuel.

The project also highlighted a number of recommendations for future ASHP installations where the social impacts can be improved

1. Appropriate support and training should be provided for residents (appropriate to their ability).
2. Tenants should be adequately supported on choice of (and changing of) their energy tariff.
3. Appropriate specification of systems is required, with appropriate user controls for whole house heating. These controls should include TRVs, and appropriately sited thermostats and programmers.
4. Householders should be involved in decisions of where to site controls and appliances, with housing association backup as the landlord.
5. For future projects - consideration should be given to the deployment of additional monitoring equipment, logging energy use by time, which will provide useful data on ACTUAL patterns and timings of use, but also remove the need for residents to supply utility bills and remove inaccuracies and uncertainty from using estimated utility bills.
6. Consideration should be given to the provision of energy displays / smart meters in conjunction with the rollout of ASHPs and supported by appropriate bespoke training to householders.

Conclusion

Air Source Heat Pumps are a cost effective way of providing affordable warmth in off gas communities - provided the systems are specified correctly by skilled technical staff, and the householder is involved in the decisions affecting them (such as positioning of radiators, buffer tanks and controls).

Further work

This project also helped to tease out more general issues which must be considered before a major roll out of heat pumps in the domestic sector. Specifically this relates to ingrained behaviour linked to long term use of electric storage heating. Tenants choosing to retain their Economy 7 tariff after the installation of the ASHP provided evidence that there is little difference between costs of operating the ASHP on the two main tariff options. NEA recommends more work be conducted to model this across different populations to fully understand the costs. Also, NEA recommends an independent evaluation of modern storage heating – provided as a replacement heating system in properties with older poorly controlled system storage heating. This technology may be more cost effective solution, and may be embraced more by the tenants, allowing them to retain a familiar heating system and energy tariff, and remove the household upheaval caused by installing new radiator based heating system in the properties.

Contents

Glossary

ASHP	Air Source Heat Pump
CoP	Coefficient of Performance (measure of efficiency of a heat pump)
DECC	Department of Energy and Climate Change
ECO	Energy Company Obligation
EST	Energy Saving Trust
LPG	Liquefied Petroleum Gas
NEA	National Energy Action
NG-AWS	National Grid Affordable Warmth Solutions
RdSAP	Reduced Data SAP
RHI	Renewable Heat Incentive
RHPP	Renewable Heat Premium Payment
SAP	Standard Assessment Procedure
TRV	Thermostatic Radiator Valves

Context

The UK government has committed to reduce greenhouse gas emissions by 34% (from 1990 levels) by 2020, and 80% by 2050. The 2009 Renewable Energy Directive set a legally binding target for the UK to achieve 15% (up from 3%) of its energy consumption from renewable sources by 2020[1].

Over 60% of the energy sold to UK consumers is used for heating[2] , most of which is in the form of space and water heating in residential buildings

DECC suggests that there are around 37,000 heat pump units in the UK[3], 28,000 of which are in the domestic sector, but most of these are installed in newly built housing. Government have prioritised the increased deployment of this technology through the UK renewable energy Roadmap[4] , and other key legislation. Another example of this deployment policy is the Code for Sustainable Homes, whereby social housing providers are mandated by Government to be assessed (against this code), which includes energy efficiency standards. Incentives such as the UK Renewable heat premium Payment scheme, Green Deal (and ECO), and Renewable Heat Incentive (RHI), are all poised to encourage the take up of renewable heating in the domestic sector. The RHI provides a payment for each unit of heat produced, with tariff levels varying depending on the type of heat pump and its size. Payments are intended to compensate householders for the increased cost of this technology [compared to traditional fossil fuel heating systems].

A report commissioned by nPower in late 2012 "*Housing Energy index*" [5], found that 50% of social landlords surveyed are considering the installation of renewable technology within their housing stock, and 35% of these landlords are considering heat pumps as that technology for installation into their properties.

Comparing Energy costs using the main domestic energy sources (Electricity, Oil, LPG, and Natural Gas) reveals that natural gas is the cheapest fuel as a domestic heating energy. Heat pumps can provide around 4 times the heat output for energy consumed, when compared to a traditional resistive electric heater, hence their attractiveness for replacing traditional electric heaters in off gas properties.

Heat Pump Installation in the UK

Most heat pumps in the UK are currently installed off the gas grid to replace conventional electrical heaters, oil-fired boilers and Liquid Petroleum Gas (LPG) boilers. Electrical heaters, oil-fired and LPG boilers are more expensive to run and also produce higher carbon emissions than gas boilers.

Some studies have been carried out previously in relation to heat pumps in domestic properties, including the well-recognised Energy Saving Trust (EST) Report "Getting Warmer: a field trial of heat pumps". This report highlights situations where the technology provided benefits to tenants, and how external factors such as the buildings energy performance and tenant behaviour have a big effect on system performance. The report also highlighted that tenants need to be involved in the installation and specification process at an early stage, as well as being supported in selecting an appropriate electricity tariff and supported with operating the new systems controls after installation.

With the predicted increase in prevalence of this technology, catalysed by the incentives provided to property owners, and the need for social landlords to achieve minimum levels of household energy performance[6], it is essential that we "get it right" for the future rollout of this technology.

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[1] The Climate Change Act (2008) requires a 50% reduction in the UK greenhouse gas emissions by the mid-2020s and an 80% reduction by 2050, all from 1990 levels. The EU's Renewable Energy Directive, which requires 15% of energy consumed to come from renewable sources by 2020, up from 3% in 2009.

[2] ONS Publication 12D/291 " Energy consumption in the United Kingdom: 2012" Available at http://www.decc.gov.uk/en/content/cms/statistics/publications/ecuk/ecuk.aspx [accessed 10/06/2013]

[3] Source: AEA heat pump baseline survey information for DECC

[4] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/48128/2167-uk-renewable-energy-roadmap.pdf

[5] Available at http://www.npower.com/Medium-business/social-housing/housing-energy-index/ [Accessed 17/06/2013]

[6] Code for Sustainable Homes and imminent minimum energy performance standards for rented properties through the Energy Act 2011

Background to Heat Pumps

Heat pumps operate on a similar basis to refrigerators and air conditioning units. They move energy from one place to another. Heat pumps capture heat from outside a property, and concentrate it for use inside. The heat is used to raise the temperature of the circulating water in a domestic radiator system.

Heat Pumps work by evaporating and then condensing a refrigerant fluid in a closed loop system. As the fluid evaporates it absorbs heat (called the specific latent heat of evaporation) and then condensed where heat is released (Specific latent Heat of Condensation). In this way, heat pumps capture heat from an external source and provide it to where it is needed (usually the inside of a building). If heat pumps are specified and installed correctly, heat pumps can provide efficient space and water heating. The operating efficiency of a heat pump must be above a certain threshold if it is to offer energy and carbon savings compared to conventional heating systems. Figure 1 provides a diagrammatic representation of the general principle of operation of a heat pump.

A major UK trial[7] commissioned by DECC, demonstrated that appropriate installation is crucial – particularly the size of the heat pump and the selection of heat emitters (e.g. the radiators). Other findings suggested better simpler controls, and a recommendation that further evaluation be undertaken to determine whether best practice is being followed in the communities where units are being installed.

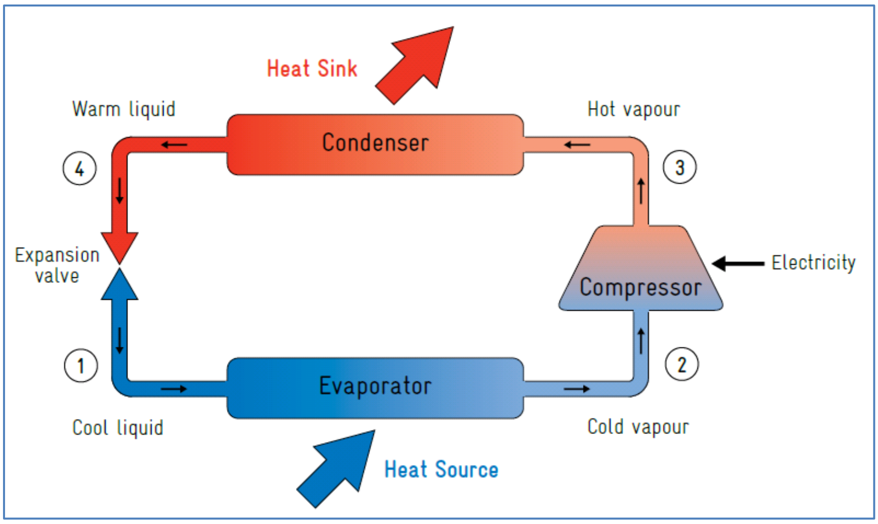


Figure 1

[7] "Getting Warmer: A field trial of heat pumps Available at http://www.energysavingtrust.org.uk/Organisations/Innovation/Field-trials-and-monitoring/Field-trial-reports/Heat-pump-field-trials [accessed 10/06/2013]

Introduction

This report was commissioned by National Grid – Affordable Warmth Solutions (NG-AWS) in 2012, to gain an independent insight into the performance and social acceptability of heat pump technology in a range of housing types who do not have access to mains gas.

The project aim was to perform an independent assessment of air source heat pumps and their use as a solution to fuel poverty in hard to treat properties.

This report will examine what happened in two installation programmes in two separate housing association properties. The installation teams and heat pump units were different for each location, and the study looked at evaluating the tenant experiences in these "typical" projects.

NG-AWS are a Community Interest Company set up to assist homes in the 20% most deprived areas in the National Grid gas distribution network area, offering new gas connections and heating systems to communities and homes not currently connected to the gas distribution network. Other support includes insulation, support & Advice to these households.

NG-AWS operating area is depicted in Figure 2 opposite.

Figure 2

Partners, background and project roles

NG-AWS role involved

- Negotiating project host sites and properties with two social landlords within National Grid's Gas distribution area
- Part funding the measures to be installed
- Assisting with the capture of meter readings and energy usage data in some properties

National Energy Action (NEA) is a national campaigning charity. NEA's mission is to ensure that all households can meet their energy needs for health and comfort at an affordable cost. In addition, NEA campaigns to ensure that the needs of vulnerable energy consumers are central to policy decisions made by national, regional and local governments and the fuel utilities.

To achieve this, NEA undertakes a range of activities including strategic campaigning and lobbying; research into the causes, extent and consequences of fuel poverty; evaluation of programmes designed to address the issue; local demonstration projects; and the development of national qualifications to improve the quality of energy advice provided to vulnerable consumers. These activities enable NEA to shape policy thinking and strategic initiatives.

NEA was asked by NG-AWS to evaluate the installation of heat pumps to inform future activity and funding of this technology through their programmes. The funders and NEA are keen to disseminate best practice findings from this project to a wide audience to inform actions to tackle fuel poverty.

The Landlords involved in this project (A1 Housing and Peaks and Plains Housing Trust) were responsible for the procurement of the installer, specification of systems, coordinating system installation dates between installers and tenants, and educating and supporting tenants on the use of the new heating systems.

The sites agreed between NG-AWS and landlords were:

- 10 Air Source Heat Pumps (ASHP) in 10 hard to treat homes in Elkesley near Worksop, (Nottinghamshire). These properties are owned and managed by A1 housing, and were fitted with Mitsubishi ECOdan heat pump units
- The second site consisted of 6 properties in Macclesfield, (Cheshire). These properties are owned by peaks and Plains Housing Trust, and were fitted with Husky PWR heat pump units

The choice of the different heat pumps was as a result of the landlords preferred suppliers, local installers, and procurement processes. However, the two different installed units were of similar technical performance standards each with a Co-Efficient of performance (CoP) of 4.1 (BS EN-14511).

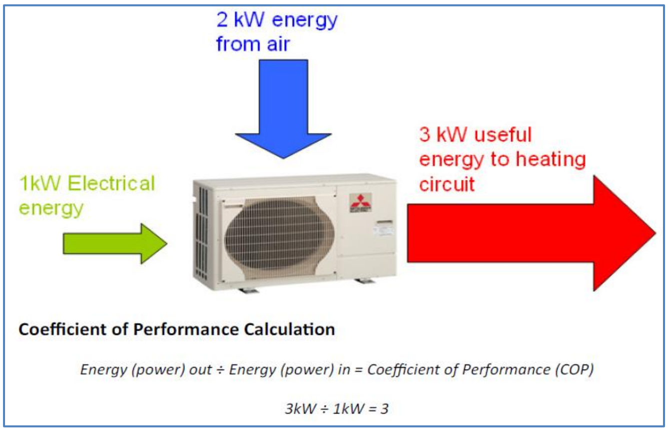


Figure 3

Figure 3 opposite illustrates the basic concept of CoP Verifying the operating efficiency of the heat pump units was outside of the scope of this project, and will not be considered further in this report.

The focus of this project was to monitor and evaluate the financial and social impact of the technology installed; NEA was asked to record the views of the residents over the project commencing in February 2012 until March 2013.

From the start of the project in February 2012, records of historic energy consumption was sought from the residents. Historic energy bills were needed to base line energy use, and to quantify the difference in fuel usage and costs to households before and after the installation of the new heating system. During the project, monthly meter readings were obtained from resident's electricity meters by housing association staff or NG-AWS following the installation of the ASHPs.

SAP assessments were conducted on the properties participating in the evaluation, to determine the thermal characteristics of the properties, and establish estimated heating costs for each property. Automatic Thermal data recording took place in the living areas of all of the properties using Dataloggers, from the heat pump installation date, until March 2013.

Whilst there are essentially two projects, the information, data, and feed-back from residents has been combined into this one report, providing more resilient data from a larger sample. Throughout the report, actual comments made by tenants through interviews and questionnaires are quoted in the following format. NEA comments are provided where relevant.

"Actual comment by tenant"

- NEA comments (where appropriate)

Methodology

Monitoring

This was planned to be conducted in 4 phases:

1. **Initial visit** to speak to residents and gather information about their experience with their existing heating system; their understanding of the system to be installed; and to enable NEA to install thermal data loggers in the properties. These devices will gather temperature and humidity data) over the monitoring period. Visits were carried out during the last week of February 2012.
   NEA conducted Standard Assessment Procedure (SAP) surveys of the properties at this visit. SAP is the Governments method for assessing and comparing the energy and environmental performance of dwellings.

2. **Telephone follow-up** after the installation of the new heating system to gather information of the resident's experience of the installation process. These were carried out, during June/July 2012.

3. **Telephone contacts during the autumn of 2012** to ensure the residents were confident in their ability to heat their homes using the ASHP for the coming winter months. Any reported problems were to be referred back to the respective Housing Association to ensure tenants were able to maintain suitable comfort levels.

4. **A final visit in March 2013** to collect the data loggers and to interview residents about their experience of using the ASHP throughout the monitoring period, and compare experiences with their previous heating system.

5. **EXTRA VISIT** – this visit was not originally planned, but as a result of feedback from some tenants about comfort levels and controllability, NEA visited all properties in February along with NG-AWS and the housing associations.

Evaluation

This was to be comprised of 5 elements:

1. The capture of temperature and humidity levels by automatic thermal and humidity data logging. This was achieved by installing data loggers in the lounge of each property and in some cases a second data-logger in the bedroom.

   Ideally these should have been installed **prior** to the existing heating system being replaced but due to matters beyond the control of the funders and evaluators this was not possible.

2. Degree-day data was obtained for both the monitoring period and the period of historic energy use to enable changes in outside temperature to show energy consumption "normalised" against outside temperature.

3. Meter readings were taken during the initial on site visit, and agreement was reached with the housing associations to read the electricity meter monthly. Historic energy consumption was obtained from previous bills supplied by the tenants [where this was possible].

4. Tenant interviews, along with temperature and humidity data provided details of internal comfort. Energy usage data [from meter readings] allowed comparative heating costs and effectiveness of the ASHP to be compared to those of the previous heating system.

5. Analysis of all comments from tenants during the various questionnaire sessions and other discussions with the residents at each stage of the project would provide details of tenant experiences of both the installation process, in operating the system, and the comfort levels achieved.

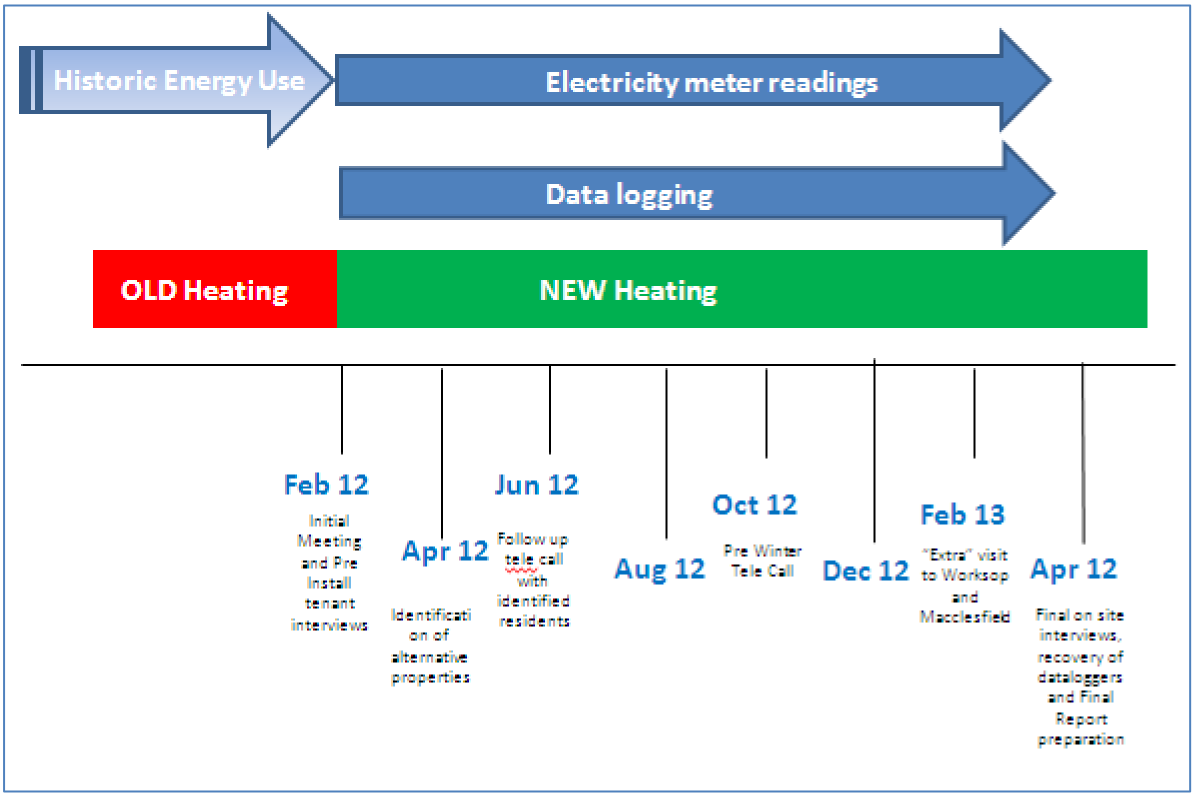


Figure 4

The diagram above (Figure 4) illustrates the timeline of the project, including extra visits in February to view installations and meet housing association staff.

Project Detail

Initial visit

Questionnaires were developed and used during the various tenant interactions to facilitate the semi structured interviews between NEA and the tenant. Interviews were held in February 2012 and March 2013. The questionnaire was used to explore the householder's expectations for the improvements in terms of how they believed the products would impact upon levels of thermal comfort, energy bills and installation process. This questionnaire appears in APPENDIX 1 - Pre-installation questionnaire.

At the initial visit, NEA performed SAP assessments on the properties involved in the trial, and dataloggers were installed in the main living areas. The units deployed were the Tinytag Ultra devices which record temperature and humidity values at regular intervals.

Peaks & Planes Housing Trust – Macclesfield (6)

In March 2012 NEA attended a site meeting with the landlord; Peaks & Planes Housing Trust and NG-AWS, to review the proposal. NEA intended to install, monitoring on that day and perform SAP assessments in the selected sample households. However due to matters beyond the control of the project partners, on the day, there was resistance from 5/6 of the residents to change their heating systems, and the project suffered delays.

NEA installed monitoring and performed SAP assessments on the remaining property (M1) plus one *unoccupied* property (M3) which was undergoing refurbishment, in preparation for a new tenant.

Three further properties were identified later –M2 (Sept 2012), M4 & M5 (Oct 2012), and were included in the monitoring project, bringing the total number of Macclesfield properties involved in the project to 5. Unfortunately, no actual datalogger temperature data was available from any of the properties prior to installation, combination of perceived thermal comfort, historic energy use data, and modelled SAP energy use data would be used to establish comfort and energy use before the new heating systems were installed.

Figure 5 below shows the details of the properties owned by peaks and Plains Housing Trust, taking part in the Macclesfield evaluation.

Property Ref	Type	Beds	Occupancy	Previous heating system	Occupancy change / monitoring potential
Project 2 (Macclesfield area)					
M1	Mid ter. Bungalow	1	1	Electric storage heaters	Monitoring, no change in tenancy
M2	Semi det. Bungalow	1	1	Electric storage heaters	Late installation of ASHP, some monitoring
M3	Semi det. House	3	4	Electric storage heaters	Void property when ASH installed
M4	Semi det. House	3	1	Electric storage heaters	Late installation of ASHP, some monitoring
M5	Semi det. House	3	3	Electric storage heaters	Issues with tenant changing settings

Figure 5

A1 Housing Worksop (10)

Ten properties in the village of Elkesley, near Worksop, (hereinafter referred to as Worksop) were identified for heating system upgrades and inclusion in this project by the landlord A1 Housing. The properties included a mixture of small one bedroomed bungalow; two bedroom bungalow; and three bedroomed houses, as detailed in Figure 6 below. On the 2nd March 2012 pre installation interviews were conducted with the householders, Thermal dataloggers were installed and SAP assessments were conducted on the properties. Unfortunately there were access issues to one three bedroom house (EW4), which precluded involvement in the project. The total number of properties monitored at this location was therefore nine.

Property Ref	Type	Beds	Occupancy	Previous heating system	Occupancy change / monitoring potential
Project 1 (Elkesley, Worksop)					
EW1	Semi det. Bungalow	2	1	Electric storage heaters	New tenant following installation of ASHP
EW2	Semi det. Bungalow	2	1	Electric storage heaters	Monitoring, no change in tenancy
EW3	Semi det. Bungalow	2	1	Electric storage heaters	Monitoring, no change in tenancy
EW5	Semi det. House	3	4	Solid fuel room heater with back-boiler	Monitoring, no change in tenancy
EW6	Mid ter. House	3	3	Oil fired back boiler	Monitoring, no change in tenancy
EW7	Semi det. House	3	2	Solid fuel room heater with back-boiler	Monitoring, no change in tenancy
EW8	End ter. Bungalow	1	1	Electric storage heaters	Monitoring, no change in tenancy
EW9	Mid ter. Bungalow	1	2	Electric boiler and radiators	Monitoring, no change in tenancy
EW10	End ter. Bungalow	1	2	Electric storage heaters	New tenant following installation of ASHP

Figure 6

Several of the tenants were unable to supply historic energy use for a variety of reasons, this will be discussed later.

SAP Modelling

During the initial visits to sample properties, NEA conducted a detailed SAP survey using NHER Plan Assessor software for this analysis. This data enabled the project to compare actual energy consumption with that modelled under SAP. SAP also provided a valuable baseline energy use for properties where historical energy use was not available.

SAP Modelling calculations were made for each property type as exists (with the current heating system) and then remodelled using the ASHP as the heating system.

SAP ratings

Figure 7 below provides comparison of modelled SAP ratings, for the properties before and after ASHP installation. The SAP modelling assumes all cavity walls have been filled and lofts insulated to current standards. NEA verified the presence of loft and cavity wall insulation which is reflected in the SAP ratings.

Property Ref	Type	Beds	Occupancy	Previous heating system	Existing SAP	New SAP With ASHP
M1	Mid ter. Bungalow	1	1	Electric storage heaters	60	61
M2	Semi det. Bungalow	1	1	Electric storage heaters	60	61
M3	Semi det. House	3	4	Electric storage heaters	49	53
M4	Semi det. House	3	1	Electric storage heaters	49	53
M5	Semi det. House	3	3	Electric storage heaters	49	53
EW1	Semi det. Bungalow	2	1	Electric storage heaters	54	59
EW2	Semi det. Bungalow	2	1	Electric storage heaters	54	59
EW3	Semi det. Bungalow	2	1	Electric storage heaters	54	59
EW5	Semi det. House	3	4	Solid fuel room heater	41	40
EW6	Mid ter. House	3	3	Oil fired back boiler	37	40
EW7	Semi det. House	3	2	Solid fuel room heater	41	40
EW8	End ter. Bungalow	1	1	Electric storage heaters	55	60
EW9	Mid ter. Bungalow	1	2	Electric boiler and radiators	35	60
EW10	End ter. Bungalow	1	2	Electric storage heaters	55	60

Figure 7

In all cases apart from where solid fuel was used as the primary heating fuel, the installation of the heat pump technology resulted in a SAP rating improvement. In the houses with solid fuel heating, there was a marginal *decrease* in SAP rating, resulting from the increase in modelled heating *cost* to the householder, when changing from coal to electricity as the primary energy source for heating.

SAP Modelled COST

SAP provides details of this, based on standard occupancy of the properties, and internal temperatures maintained at 21°C in the main living area, and 18°C in the bedrooms.

Figure 8 compares the heating system running costs to householders, before and after ASHP installation based on SAP software modelling. These figures will be used later in the report.

Property Ref	Type	Beds	Occupancy	Previous heating system	Existing Heating Costs £	New Heating Costs (ASHP) £	% Change in Cost
M1	Mid ter. Bungalow	1	1	Electric storage heaters	826	801	3.0
M2	Semi det. Bungalow	1	1	Electric storage heaters	826	801	3.0
M3	Semi det. House	3	4	Electric storage heaters	1321	1249	5.5
M4	Semi det. House	3	1	Electric storage heaters	1321	1249	5.5
M5	Semi det. House	3	3	Electric storage heaters	1321	1249	5.5
EW1	Semi det. Bungalow	2	1	Electric storage heaters	946	887	6.2
EW2	Semi det. Bungalow	2	1	Electric storage heaters	946	887	6.2
EW3	Semi det. Bungalow	2	1	Electric storage heaters	946	887	6.2
EW5	Semi det. House	3	4	Solid fuel room heater	1277	1383	-8.3
EW6	Mid ter. House	3	3	Oil fired back boiler	1966	1383	29.7
EW7	Semi det. House	3	2	Solid fuel room heater	1277	1383	-8.3
EW8	End ter. Bungalow	1	1	Electric storage heaters	801	750	6.4
EW9	Mid ter. Bungalow	1	2	Electric boiler and radiators	1071	750	30.0
EW10	End ter. Bungalow	1	2	Electric storage heaters	801	750	6.4

Figure 8

Scrutinising Figure 8 above, we can see that all electrically heated properties are predicted (through SAP modelling) to benefit from a cost saving of between 3 and 6.4%, with the smaller properties at Worksop benefitting more from the heat pump technology, which is due primarily to the different property designs. SAP considers wall surface areas, building material thermal performance, windows and doors, as well as detailed heating system design and occupancy patterns.

As mentioned above, the exception to the predicted savings being beneficial is where properties were heated using household coal. These households are predicted to increase their heating costs due to the high price of electricity compared to coal (per unit of energy required to adequately heat the property).

The price of coal is volatile; often varying on a monthly basis, so a degree of caution should be exercised when making these comparisons between modelled data. A section later in the report is devoted to discussing this property/ heating type (See the section heading *"Other Housing with Solid Fuel / Oil Heating Systems").*

SAP Modelled CO_2 and Energy

Finally, SAP provides a useful comparison of predicted changes to ENERGY use and associated CO_2 reductions for the households, allowing comparison between "before" and "after" values when changes are made to heating systems and building fabric. Government measurements within the domestic sector and Government funding mechanisms measure carbon savings through the SAP or reduced Data SAP (RdSAP) methodologies. Using this methodology within this project is sensible, when considering the unavailability of reliable energy use data from the households, and other household changes which affect the reliability of the data. Figure 9 below, illustrates the changes to these values in the properties sampled. Energy reduction is around 37% in all cases where electric storage heating is used, and rises significantly to near 60% in houses heated by fossil fuels. The trend is similar for CO_2 changes, where solid fuelled heating systems save around 4 tonnes of CO_2 emissions per year, Oil 3 tonnes and storage heating in small bungalows 1.5 tonnes, when replaced by ASHPs.

Overall the project saved 32 tonnes of carbon over the monitored households (SAP Modelling)

Property Ref	Type	Previous heating system	Existing Energy Use Kwh / annum	New Energy Use Kwh / annum	% Change in ENERGY use Per Annum	CO_2 reduction Tonnes / Annum
M1	Mid ter. Bungalow	Electric storage heaters	9986	6318	36.7	1.5
M2	Semi det. Bungalow	Electric storage heaters	9986	6318	36.7	1.5
M3	Semi det. House	Electric storage heaters	16145	10097	37.5	2.6
M4	Semi det. House	Electric storage heaters	16145	10097	37.5	2.6
M5	Semi det. House	Electric storage heaters	16145	10097	37.5	2.6
EW1	Semi det. Bungalow	Electric storage heaters	11663	7238	37.9	1.9
EW2	Semi det. Bungalow	Electric storage heaters	11663	7238	37.9	1.9
EW3	Semi det. Bungalow	Electric storage heaters	11663	7238	37.9	1.9
EW5	Semi det. House	Solid fuel room heater	27317	11226	58.9	3.9
EW6	Mid ter. House	Oil fired back boiler	26641	11226	57.9	3.1
EW7	Semi det. House	Solid fuel room heater	27317	11226	58.9	3.9
EW8	End ter. Bungalow	Electric storage heaters	9781	6126	37.4	1.5
EW9	Mid ter. Bungalow	Electric boiler and radiators	9345	6126	34.4	1.4
EW10	End ter. Bungalow	Electric storage heaters	9781	6126	37.4	1.5

Figure 9

Household Interviews

Household interviews were held with households immediately prior to the installations taking place around March 2012, and again in March 2013.

Installation Process

During the initial visit, residents were asked to describe their feelings about the installation. Answers received included: Apprehensive, Relieved (from 4 residents due to issues with their existing system), excited, and frustrated (this resident reported that the kitchen had just been refitted). After the installation, satisfaction is depicted in Figure 10 below

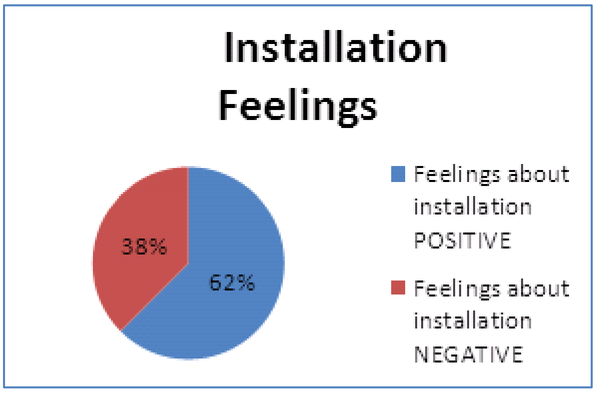


Figure 10

After the installation work had been completed, there were mixed feelings about the installation process, with, 62% positive about the installation, 38% were dissatisfied. Comments included

"The lads that did it (installers) were super – they didn't make any un-necessary mess – they were so good"

"Laminate flooring upstairs was 'jigged' during installation but that was the only downside"

"Had a leak in the system but they came out that day to fix it"

"They cut my carpet, but never explained why; I have tried to get an explanation but never received one"

- *NEA research has discovered that the carpet had been originally fitted after the electric storage heaters and therefore cut around the unit's feet. When the heater was removed the spaces in the carpet were exposed and therefore not related to the ASHP installer.*

Evaluation of the ASHP Units

The evaluation of the success and acceptability of the ASHP units in these communities has been analysed from four main sources.

1. Semi Structured interviews with tenants (see **APPENDIX 1** - Pre-installation questionnaire and **APPENDIX 2** – Post Installation Questionnaire) for further detail.
2. Thermal data collected at 30 minute intervals over the post installation monitoring period.
3. Historical energy data obtained through householder bills
4. Recorded energy consumption (post installation) taken at monthly intervals.

Data from these sources has been cross referenced and compared, to arrive at conclusions as to the success of the project. Data was also processed to determine indicative cost savings to householders as a result of the installation of this new technology.

Thermal comfort

Thermal comfort is extremely important in households, costing the NHS £859 million not including any additional spending by social services, or economic losses through missed work[8]. It contributes to health and wellbeing, improves mental alertness and mental health.

Data was collected from householders through semi structured interviews and automatic logging of temperatures in the main living areas over the post installation monitoring period. In addition, during the interviews, we captured general feelings about comfort levels within households both before and after heating system replacement. The comparisons between the qualitative responses and quantitative data are discussed below.

Householders were questioned about how comfortable they were using their OLD and NEW heating systems; there was a marked improvement in satisfaction levels after the installation of the heat pump, from 40% satisfaction levels to 82% satisfaction.

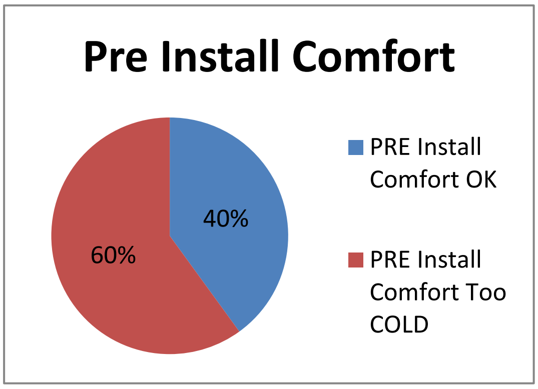


Figure 11

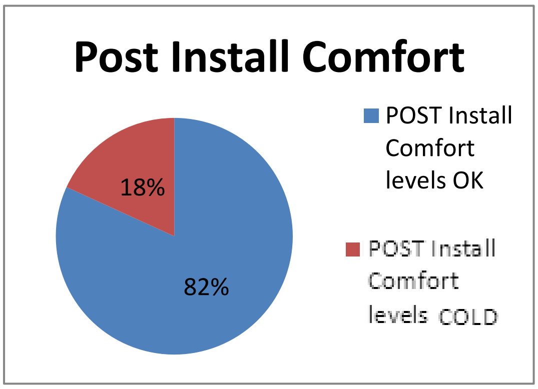


Figure 12

[8] Marmot review available at www.instituteof**health**equity.org [accessed 18/06/2013]

Comments from householders about the old and new systems included;

Old system:

"With the old system you were sweating during the night and freezing come 3 o'clock in the afternoon; it was a nightmare in the winter"

"You could never invite friends round at night unless you gave them blankets and slippers"

"Everywhere was damper; I can't understand why they left it* [electric storage heating] *in so long"

Comments relating to the new system included

"I have not been cold since the system was put in"

"Its 100% better, I wouldn't go back to the old system"

"This room* [Lounge] *is always nice and warm"

Datalogger Data.

To provide information on both temperature and humidity levels within each property data-loggers were installed in the main living area of each property. Initially one data-logger was installed in the lounge but later in the project a second data-logger was installed, usually in a bedroom.

Although data is available for the whole period the data-logger was installed, we selected a short period where there was stability in readings across all sample houses to make a detailed comparison between house types using stable and representative data. This period was taken as a 5 day period from 20th February 2013 to 25th February 2013. This period spans a weekend and may therefore be relevant to those properties EW5, EW7, M3, and M5 with younger families. Figure 13 below shows the average temperature in the houses after ASHPs were installed, over the entire monitoring period.

Property Ref	**Type**	**Beds**	**Occupancy**	**Previous heating system**	**Average Living area temp °Celsius**
M1	Mid ter. Bungalow	1	1	Electric storage heaters	21.8
M2	Semi det. Bungalow	1	1	Electric storage heaters	20.5
M3	Semi det. House	3	4	Electric storage heaters	*Note 1*
M4	Semi det. House	3	1	Electric storage heaters	18.6
M5	Semi det. House	3	3	Electric storage heaters	21.3
EW1	Semi det. Bungalow	2	1	Electric storage heaters	20.6
EW2	Semi det. Bungalow	2	1	Electric storage heaters	18.4
EW3	Semi det. Bungalow	2	1	Electric storage heaters	18.4
EW5	Semi det. House	3	4	Solid fuel room heater	19.8
EW6	Mid ter. House	3	3	Oil fired back boiler	22.6
EW7	Semi det. House	3	2	Solid fuel room heater	18.8
EW8	End ter. Bungalow	1	1	Electric storage heaters	19.2
EW9	Mid ter. Bungalow	1	2	Electric boiler and radiators	19.7
EW10	End ter. Bungalow	1	2	Electric storage heaters	*Note 2*

Note 1 – Datalogger moved & tampered with by tenant
Note 2 – Unreliable Data

Figure 13

Degree-day data

Background

An external temperature of 15.5°C is accepted as the outside temperature below which heating will be required and above which no heating is necessary. Where the outside temperature drops, on average for a day, to 14.4°C this is 1 degree-day. If the outside temperature drops to 13.5°C this is 2 degree-days etc. etc. These degree days are added together for the whole period (usually a month but can be any number of days) to give the total number of degree days for the period.

Different periods (days, months or years) can then be compared using the energy consumption for those periods and the results used to predict energy consumption on a normalised basis taking into account the outside temperature for those different periods.

Where actual readings were available energy consumption and degree-day data was entered into standard spread-sheet software to provide a standard scatter chart from which a performance line and performance line equation was calculated. This analysis can only be performed where sufficient accurate data is available, basically, the more data the more accurate the analysis.

The building performance line is the mathematical line of 'best fit' added to the chart. The equation is that of a straight line (y=Mx+c). The scatter of the points around the performance line can be an indication of a number of conditions.

The quality of the data

Changes in the heating system

Changes in average room temperature

Figure 14 below illustrates the graph produced as a result of Degree Day analysis. Further details about the process of degree day analysis is explained in a summary document[9] produced by the Carbon trust

The most common form of result is a performance line with a positive intersect on the energy consumption axis (the 'y' axis), this provides a non-heating energy load when the degree days are zero and the property is heated to accepted temperatures.

The graph below in Figure 14 depicts the degree day analysis for sample property **EW2**, showing scatter, the straight line equation and the intersect with the y Axis (y=Mx+**c**) where c is the intersect. This value represents the baseline energy use for the property (non-heating load), (80.06Kwh in this example). Degree day data will appear in this report, but graphs will not be included.

[9] "Degree Days for Energy Management available at http://www.carbontrust.com/media/137002/ctg075-degree-days-for-energy-management.pdf [accessed 20/6/13]

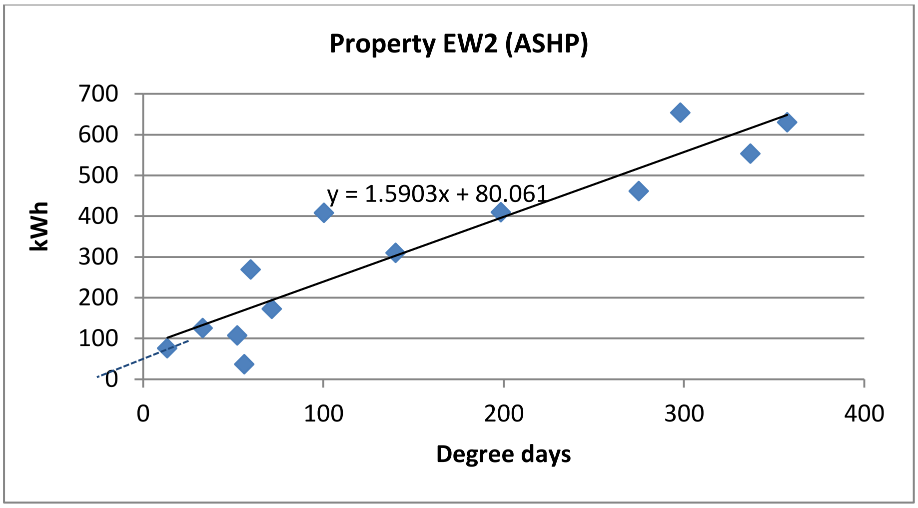


Figure 14

Where there is a negative performance line which intersects the Degree day axis (the x axis), the property may not require heat until a lower outdoor temperature is reached (higher number of degree days), reasons may include other heat gains (adjoining properties or high solar gain) or because the property is particularly well insulated or protected from outside weather conditions.

One property from each property type (with accurate and robust energy data) was selected as a representative property for further analysis; the selection was based on the availability of energy consumption data for a period before the installation (when electric storage heaters were used) for comparison with similar data for the period when the ASHPs were used. As detailed in **APPENDIX 3** – DATA Reliability Comparison Chart, unforeseen circumstances affected several of the sample properties, meaning that they could not be used as representative properties.

The availability of robust data was a major challenge during this project, meaning that each individual property could not be analysed separately. There were many estimated bills, and many bills were not available at all due to changes in energy supplier, changes to tenant, and presence of prepayment meters. The use of incentive payments / gifts and on-site support (for tenants to speak to energy companies re supply of copy bills) should be considered in future projects to improve the level of data obtained by tenants.

Methodology

To be able to use degree-day data for this project, the whole of 2011 and 2012 plus Jan to March 2013 data was downloaded from the Stark web site[10]. This was to enable comparisons to be made between energy usage for the period when the majority of the ASHP were installed (commencing in February 2012) and the corresponding months the previous year. This data is shown in the table (See Appendix 2) and is based on 'East Pennines, Lincoln' for Worksop and 'West Pennines, Manchester' for Macclesfield.

From the information downloaded it should be noted that the main periods of interest are October 2011 to March 2012 compared to October 2012 to March 2013. This information is summarised in Figure 15 below.

	Worksop	**Macclesfield**
2011/12	1,511.7	1,413.5
2012/13	1,946.8	1,883.5
Increase (days) between years	435.1	478.0
Increase (%) between years	28.8%	33.8%

Figure 15

The comparison shown in Figure 15 indicates that Worksop is generally slightly cooler than Macclesfield (higher number of degree-days) and that 2012/13 is much colder, for both regions, than the previous year. However the change in Macclesfield is greater with 478 more degree-days compared to 435 in the Worksop area. The increases in degree-days (signifying therefore colder outside temperatures) between comparison years will have considerable impact on the amount of energy needed to maintain acceptable indoor temperature levels during the period of ASHP operation.

Degree day analysis allows for comparisons between these different periods, by "normalising" the data.

Measured Energy Consumption

Energy consumption was obtained from the two housing associations over the duration of the project. Residents were also asked to provide (where possible) copies of energy bills for the preceding 12 months from which energy consumption of the previous heating system could be determined.

Data reliability varied, due to

- Prevalence of estimated readings on bills.
- Pre-Payment tariffs with no reliable energy usage data.
- Absence of historic data
- Changes in tenancy over the project timeframe.
- Lack of historic energy data / expenditure for solid fuel or oil heated properties.

Where actual readings were available, energy consumption and degree-day data were analysed. The table in **APPENDIX 3** – DATA Reliability Comparison Chart shows the properties where reliable data was available, and which other (similar) properties are represented by this data.

[10] STARK website is available at http://www.degreedaysforfree.co.uk/ [Accessed 18/06/2013]

Results for Main Property Types

2 Bedroom, semi-detached bungalow

Reliable data was available from one properties of this type (EW2). This section is the result of analysis of the following properties, all previously heated using electric storage heaters.

Property Ref	Type	Beds	Occupancy	Baseline BEFORE ASHP Storage Heating Kwh	Baseline AFTER ASHP installation Kwh	Average energy use per degree day BEFORE ASHP Kwh	Average energy use per degree day AFTER ASHP Kwh	Av Winter temp of Living room °C
EW1	Semi det. Bungalow	2	1					
EW2	Semi det. Bungalow	2	1	686	80	4.8	2.1	18.4
EW3	Semi det. Bungalow	2	1					

Figure 16

Degree day analysis was performed on Pre-install energy use data, and again for the period after installation. The temperatures monitored for this property (from Figure 13) suggests that supplementary heating is not carried out within this property. Interrogating the energy use and number of degree days in the locality, we can work out the average energy used per degree day. This is shown above. And illustrates that in terms of ENERGY – the ASHP significantly reduces the energy used to heat the house by 56.2%

Whilst the average internal temperature averaged at 18.4°C, the resident was an active person who was very aware of energy use and adapted her heating regime continually to match her needs. During interview, this resident stated that she manually controlled the system continuously, switching off the system (Via the thermostat) when performing housework or going out of the property, accounting for the lower average temperature. The Maximum and Minimum temperatures achieved are in line with other properties. This resident was unable to control the system via time switch settings, her comment illustrates her frustration.

The controls fitted in these properties consisted of a single controller installed in the lounge or hall, and TRVs fitted only in the bedrooms.

"[I] wouldn't recommend the system as I can't control it or rely on the settings."

"Plug does the programming"

- Plug is A1 Housings technical Surveyor
- The resident is unable to trust the technology, or perform adjustments. She is aware of energy use through her "Smart meter" and will not leave the settings alone – despite them being demonstrated to her [by A1 housing] on several occasions.
- This tenant wants to be in control – and she believes using the On/OFF switch is the way to achieve this.

Looking at a snapshot of the output from the thermal logger [from E2], the manual controlled system can be seen in the first two peaks of Figure 17. The erratic profile shows the manual interventions on the ASHP thermostat, and the systems corresponding response. Other observations show that adequate temperature levels are reached in the early evening of 22nd and 24th February and 20.5°C reached on the 23rd. The resident, when questioned stated she was happy with the level of heat provided by her new system, stating that she was "comfortable".

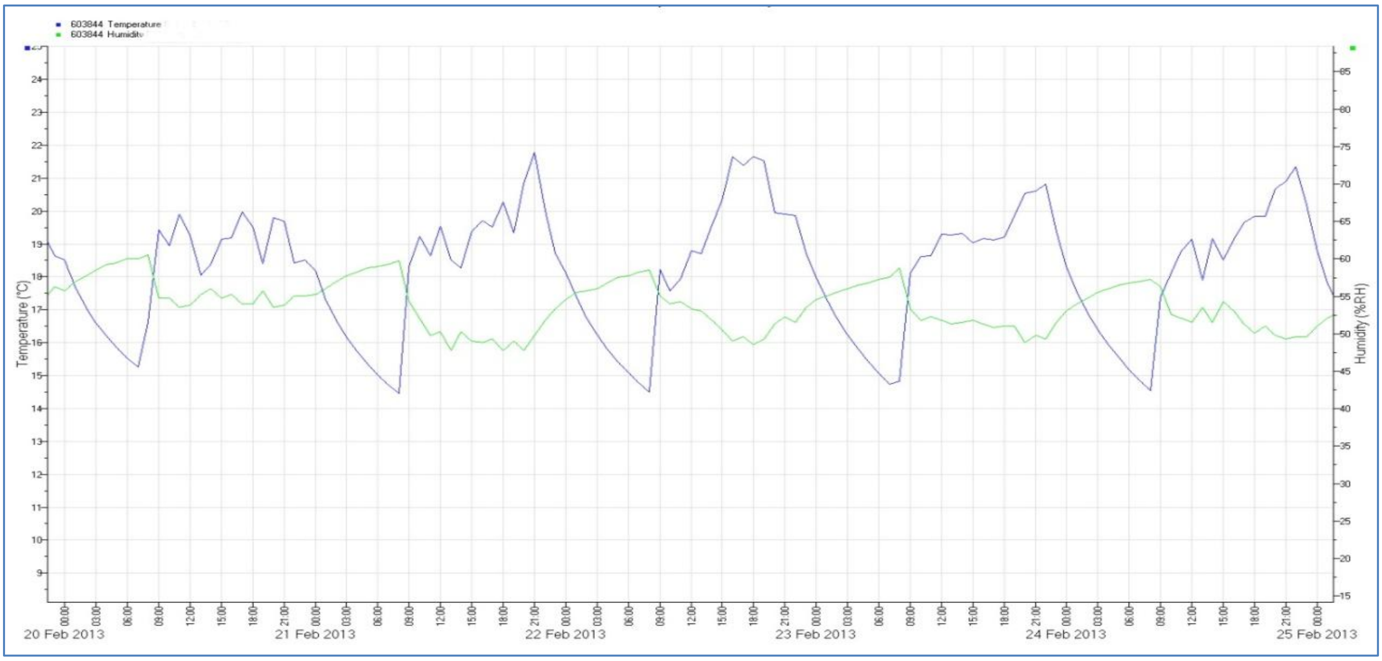


Figure 17

Heating Costs

This analysis used data from **the TWO WINTERS** in the two years (2011-12 and 2012-13).

Whilst it is clear that ENERGY use has reduced for residents in these three properties, it is not so clear whether the COST is lower. Energy cost comparisons are dependent on a wide variety of factors, such as which electricity tariff is in operation, and in the case of dual tariffs (Economy 7) what behaviour pattern exists within the household. Storage heating uses electricity during the night on a lower tariff rate than appliances used during the day, when electricity costs are higher than a standard (single rate) tariff.

Complications arise when simple comparisons are made between two different billing periods, or between two different winters, owing to different heating requirements (caused by varying outside temperatures). In addition to this, energy price rises and differing energy tariffs also distort and complicate simple comparisons. The table in Figure 18 below illustrates this.

Energy use for EW2 is shown for the two recent winters, representing the use of Storage Heating (2011-12) and ASHP (2012-13).

Column 5 shows the ACTUAL bill for that winter. **Column 7** illustrates the "corrected" bill for the ASHP, had the winter of 2011-12 been the same (in terms of temperature) as the 2011-12 winter.

Column 8 shows the saving. Analysing the savings for EW1 and EW3 (part of this representative sample of housing type), the savings were £239.49 (29.8%) and 161.76 (20.7%) respectively.

Column 6 has been included to illustrate the cost which would have resulted from the ASHP period of 2012-13 IF THE TARIFF HAD **NOT** BEEN CHANGED TO A SINGLE RATE (Standard) TARIFF – discussed later in this report.

column	1	2	3	4	5	6	7	8
Property	Metered Period	2011/12 Storage heaters (kWh)	2012/13 ASHP (kWh)	2012/13 ASHP adjusted for degree days (kWh)	2011/12 energy cost (Economy 7 tariff) (£)	2012/13 energy cost (Economy 7 tariff) (£)	2012/13 energy cost (standard tariff) (£)	Energy cost saving Column 7 Over Column 5
EW2	Day	677	2,861	2,221	530.90	448.11	407.64	£123.26 23.2%
	Night	6,161	635	493				
	Total	6,838	3,496	2,714				

Figure 18

- Economy 7 tariff - day 18.72p/kWh, night 6.56p/kWh
- Standard tariff – 15.02p/kWh
- Both tariffs incurred a standing charge of 18.9p per day but are not included in the calculations.

Conclusions

Figure 18 clearly shows that heat pumps provide cost savings to the tenants in the small bungalows of this type (EW1, 2 & 3). These properties had SAP values of 60. Lower SAP values may have an effect on savings and system performance, so caution should be exercised before making direct comparisons with other properties without considering SAP values.

There is further need to engage residents in education, support and bill monitoring to achieve best practice and maximise savings. There is clear evidence within these households that automatic controls are not being fully utilised.

System design and correct whole system specification is essential at the tenant and landlord level. EW1, 2 & 3 were all brand new heating systems (having had electric storage), yet they did not have TRVs in the areas where the thermostat was located. Specification and involvement of residents in the installation process is essential if systems are to support the living habits and needs of the residents. None of these residents know why their systems were being changed. Comments were also received about the wasted water, waiting for hot water to reach the kitchen tap. Whilst this may be an inevitable consequence of plumbing arrangements and available space for tanks etc. the tenant was unaware and "blamed" the ASHP for this inefficiency.

3 bedroom semi-detached house

There were 4 X 3 bedroom semi-detached houses of similar construction and thermal performance in our data sample from the Macclesfield area of the monitoring project. The property used to represent this sample was M4, occupied by one, elderly, lady. Sufficient data was available to allow Degree day analysis to be performed, and there no change to tenancy during the project. **APPENDIX 3** – DATA Reliability Comparison Chart, details the reasons why some properties were unable to be used for data comparison purposes, and therefore influenced the decisions to select the representative properties. The 4 properties were heated by electric storage heaters.

Results of energy ratings

Property Ref	Type	Beds	Occupancy	Baseline BEFORE ASHP Storage Heating Kwh	Baseline AFTER ASHP installation Kwh	Average energy use per degree day BEFORE ASHP Kwh	Average energy use per degree day AFTER ASHP Kwh	Av Winter temp of Living room °C
M4	Semi det. Bungalow	3	1	-119	404	4.2	3.6	18.6
M3	Semi det. Bungalow	3	4					
M5	Semi det. Bungalow	3	3					21.3*
M6	Semi det. Bungalow	3	3					

Figure 19

* 26th February to 9th April 2013 – (due to even later installation)

Degree day analysis performed on the available energy use before and after heat pump installation shows energy use reduced BY DEGREE DAY, by 14.3%.

It is important to note that the negative baseline energy use see (Col 5 in Figure 19) is as a result of under heating the entire house by this single occupant. Many of the storage heaters were switched off in unused rooms. Post installation of ASHP - whole house heating was maintained, resulting in the higher baseline energy use. This is the opposite of what was experienced in the 2 bedroom bungalows studied above in Figure 16.

Reviewing Figure 13, and from tenant interview responses we know that no supplementary heating takes place in the property. We also know from Figure 13 that temperatures in the bedrooms (15.1°C) do not meet current recommended levels (18.0°C). However, the tenant reported that she preferred lower temperatures in her bedroom, and later stated that she was happy with the levels of heating provided by the new system – reflected in the comment from [M4] below

"I have not been cold since the system was put in"

"I now only use my electric fire as a focal point"

- The tenant comment suggests increased room temperatures compared to storage heating
- Tenant regularly used supplementary heating in the evening with the electric storage heating
- The reduction in energy per degree day is less than that achieved on property EW2 - however the average temperature during the winter period was higher indicating a higher level of heating in this house. In addition, the house M4 is larger, requiring a higher heat output requirement from the ASHP.

Considering the thermal data recorded on the datalogger, temperatures in the living room reached 21°C by mid-evening. The tenant was happy with the performance, and stated her preference for a lower temperature. The graph in Figure 20 represents a snapshot of the thermal data used to compare all properties. The “toothed” nature curve in the graph of thermal levels in Figure 20 was not caused by the tenant adjusting system settings [stated in the questions] but it is likely that they are caused by the system thermostat and TRVs. In this property, the minimum temperature recorded was 17.9°C with a maximum of 21.0°C, Average 19.6°C.

The target temperature of 21°C is reached in the living area around 21:00 each evening when the system shuts down for the evening. SAP rating for the properties is 53 (lower than in the previous sample), resulting in higher heat losses and warm up times for these properties. The differences in system design and radiator sizing may contribute to longer warm up times. These properties also had a 3 zone configuration. This will also contribute to different system responses, and introduces variables for comparison.

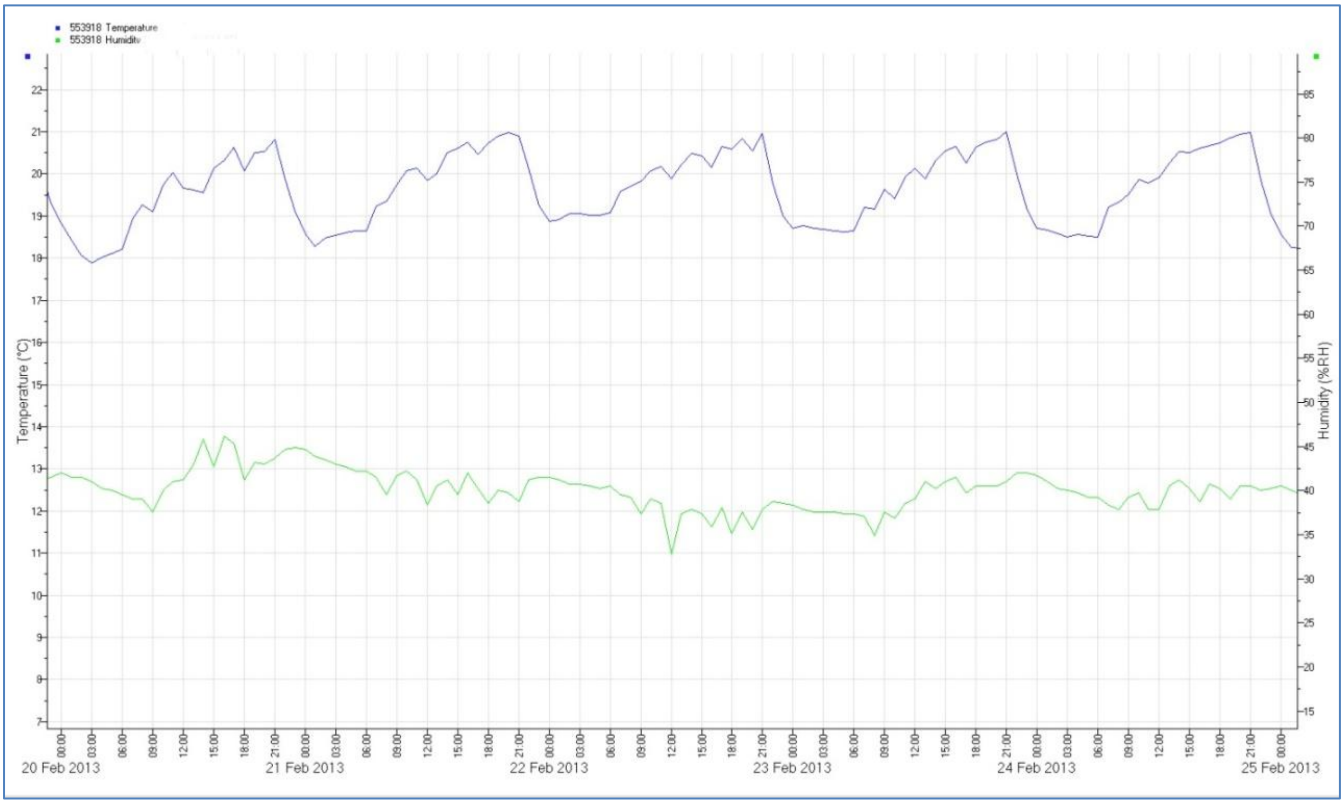


Figure 20

Heating Costs

This analysis used data from **MARCH** only in the two years (2012 and 2013) due to prevalence of estimated energy usage and missing billing periods.

Whilst we can see that ENERGY use has again reduced since the installation of the heat pump, heating cost is very important to tenants – especially in low income households. This tenant was unable to indicate whether there was any saving from the new system, stating that it was "too early to judge". However, the data which was available to NEA allowed for some comparisons to be made.

column	1	2	3	4	5	6	7	8
Property	Metered Period	2011/12 Storage heaters (kWh)	2012/13 ASHP (kWh)	2012/13 ASHP adjusted for degree days (kWh)	2011/12 energy cost (Economy 7 tariff) (£)	2012/13 energy cost (Economy 7 tariff) (£)	2012/13 energy cost (standard tariff) (£)	Energy cost saving Column 7 Over Column 5
M4	Day	1,309	401	299	265	139.10	154.56	£111.34 58.1%
	Night	318	976	730				
	Total	1,627	1,377	1,029				

Figure 21

Energy use for M4 is shown for the two recent winters, representing the use of Storage Heating (2011-12) and ASHP (2012-13).

Column 5 shows the ACTUAL bill for that winter. **Column 7** illustrates the "corrected" bill for the ASHP, had the winter of 2011-12 been the same (in terms of temperature) as the 2011-12 winter.

Column 8 shows the saving.

Column 6 has been included to illustrate the cost which would have resulted from the ASHP period of 2012-13 IF THE TARIFF HAD **NOT** BEEN CHANGED TO A SINGLE RATE (Standard) TARIFF – discussed later in this report.

Conclusions

Figure 18 clearly shows that heat pumps provide cost savings to the tenants in the 3 bedroomed semi-detached properties (representing M3, M4, M5 & M6). The savings are less than those seen in the smaller 2 bedroom properties in the previous sample (EW2).

There was more acceptance of the controls, despite the extra complication of the 3 heating zones.

1 bedroom semi-detached bungalow

Reliable and robust data was available from the single bedroom bungalow **M1** which is also representative of the nearby property M2, and the properties EW8 EW9 and EW10 located in Worksop. All of these properties were of similar SAP values, occupancy and electric storage heating. The representative property M1 was occupied by an active elderly gentleman who supplied regular meter readings during the project.

Property Ref	Type	Beds	Occupancy	Baseline BEFORE ASHP Storage Heating Kwh	Baseline AFTER ASHP installation Kwh	Average energy use per degree day BEFORE ASHP Kwh	Average energy use per degree day AFTER ASHP Kwh	Av Winter temp of Living room °C
M1	Semi det. Bungalow	1	1	0.0	-23	3.8	2.8	21.8
M2	Semi det. Bungalow	1	1					20.5
EW8	End Tce Bungalow	1	1					19.2
EW9	Mid Tce Bungalow	1	2					19.7
EW10	End Tce Bungalow	1	2					N/A

Figure 22

Degree day analysis was again performed on the energy data, which revealed the key points depicted in Figure 22 above. From this data we can see that the energy used per degree day dropped from 3.8Kwh with storage heating, to 2.8Kwh after the installation of the ASHP. This equated to a 26.3% drop in energy used PER DEGREE DAY.

The negative base loading suggests good sheltering from adjoining properties and buildings, resulting in **low heat loss /** some heat gain.

When asked ***"Would you recommend this system to someone else and why?" M1 replied***
"Yes – The control and heat"

- The indicated degree of under-heating may be due to the heat requirement to the single tenant who is active and spends considerable time away from the property, which whilst heated as shown on the data-logger graphs, will not have the same heat losses as an occupied property due to the reduced number of air changes.
- There is very little scatter on the degree day analysis graph suggesting even temperature control throughout the monitoring period.

Looking at the output from the thermal logger, the graph in Figure 23 shows that the property is consistently heated to the accepted level of 21°C in the living room. The erratic nature of the graph is not fully understood, but it is believed to be related to the fact that his room thermostat is located in the bedroom, along with NO Thermostatic Radiator Valve (TRV) on the bedroom radiator. Hence the occupant has set the TRV to 3 in the living room. The resident claims not to alter the settings, only controlling the system through the ON/OFF setting. Key points on graph in Figure 23 - The temperature ranged from 19.8°C to 23.8°C and achieved an average of 21.3°C.

From the in house interview, the resident was extremely happy with the thermal levels achieved with his new system.

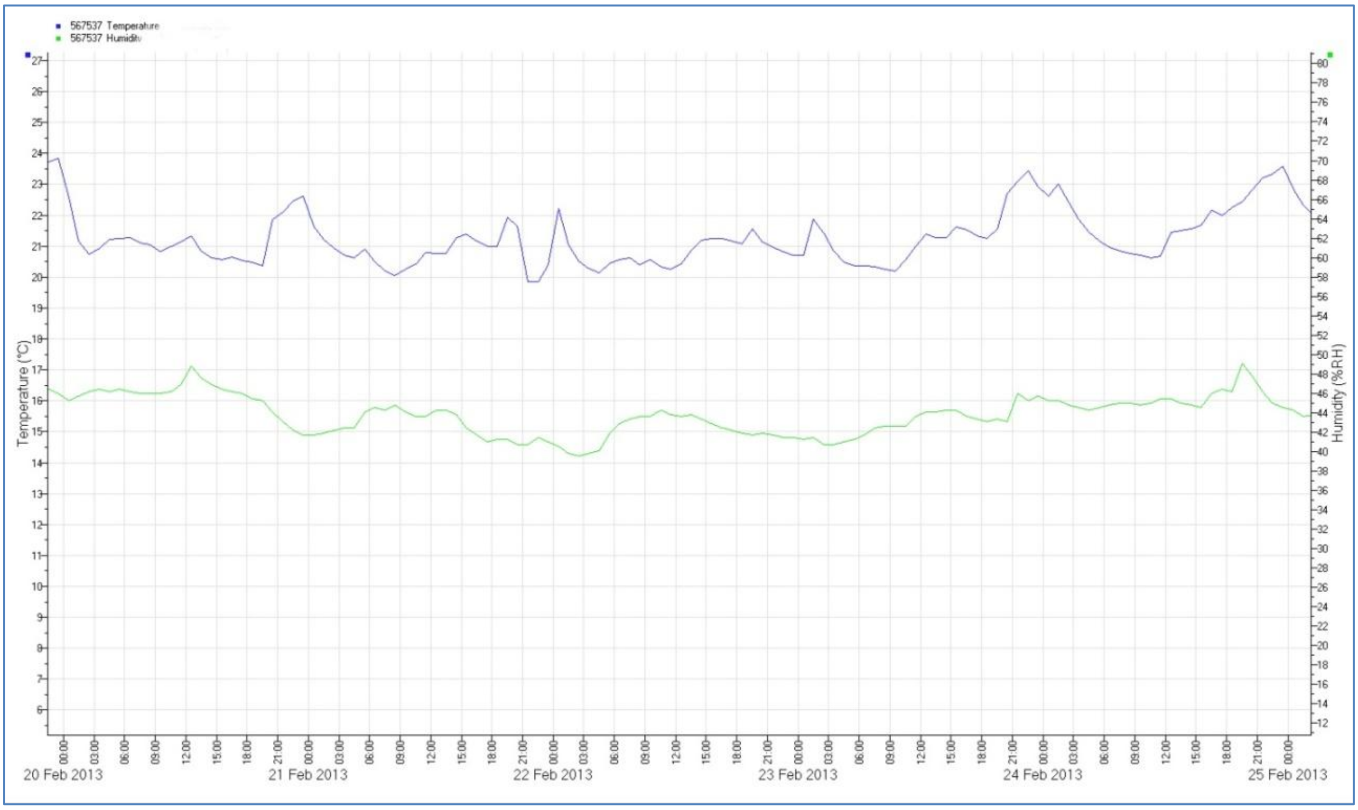


Figure 23

Heating Costs

This analysis used data from **<u>MARCH</u>** only in the two years (2012 and 2013) due to prevalence of estimated energy usage and missing billing periods.

As expected, we have seen an **energy** saving from the use of the heat pump vs. storage heating. It is vital that we understand the cost change from installing heat pump technology, and the effect of changing [or not changing] from the usual dual rate tariff used with storage heating systems. It is often an overlooked point when residents compare the benefits of different systems, that tariff, energy cost increases and outside temperature changes [between comparison periods] is not considered. In this case, [M1] stated that he was paying £10 a week less than he did during the same period the previous year [with storage heating]. It was noted at the time of interview in February that M1 was still purchasing electricity on an ECONOMY7 tariff, which is widely seen as bad practice.

column	1	2	3	4	5	6	7	8
Property	Metered Period	2011/12 Storage heaters (kWh)	2012/13 ASHP (kWh)	2012/13 ASHP adjusted for degree days (kWh)	2011/12 energy cost (Economy 7 tariff) (£)	2012/13 energy cost (Economy 7 tariff) (£)	2012/13 energy cost (standard tariff) (£)	Energy cost saving Column 7 Over Column 5
M1	Day	737	592	443	150.57	93.75	91.32	59.25 39.4%
	Night	192	221	165				
	Total	930	813	608				

Figure 24

Energy use for M1 is shown for the two recent winters, representing the use of Storage Heating (2011-12) and ASHP (2012-13).

Column 5 shows the ACTUAL bill for that winter. **Column 7** illustrates the "corrected" bill for the ASHP, had the winter of 2011-12 been the same (in terms of temperature) as the 2011-12 winters.

Column 8 shows the saving.

Column 6 has been included to illustrate the cost which would have resulted from the ASHP period of 2012-13 IF THE TARIFF HAD **NOT** BEEN CHANGED TO A SINGLE RATE (Standard) TARIFF – in this case, it was noted in February that the resident was still on an inappropriate tariff, and paid this amount. COLUMN 7 is therefore the "predicted" cost in this case.

<u>Conclusions</u>

Figure 24 clearly shows that heat pumps provide cost savings to the tenants in the small single bedroom bungalows of this type (M1, M2, EW8, EW9 & EW10).

In this example, where residents had been long term users of storage heating on a dual rate tariff, it was apparent the energy awareness was high. In this case, the difference in cost between Economy 7 and standard tariff was minimal. This is not generally the case in the other samples.

Other Housing with Solid Fuel / Oil Heating Systems

There were 3 X 3 bedroom houses of similar construction and thermal performance in our data sample from the Worksop area of the project. These properties were heated with fossil fuelled systems as detailed in Figure 25 below.

Property Ref	Type	Beds	Occupancy	Previous heating system	Occupancy change / monitoring potential
EW5	Semi det. House	3	4	Solid fuel room heater with back-boiler	Monitoring, no change in tenancy
EW6	Mid ter. House	3	3	Oil fired back boiler	Monitoring, no change in tenancy
EW7	Semi det. House	3	2	Solid fuel room heater with back-boiler	Monitoring, no change in tenancy

Figure 25

All 3 properties had similar SAP values (and so energy performance). The SAP values vary due to heating fuel costs and CO_2 emissions from the respective heating systems and can be compared in Figure 7.

The lack of historic energy use data meant that direct and robust energy cost comparisons between old and new heating systems could not be performed, nor could we perform degree day analysis with sufficient data where we were confident of its accuracy. None of the residents could quantify either volume or cost of fuel over previous years. **APPENDIX 3** – DATA Reliability Comparison Chart shows this for all sample properties. However, modelled energy consumption, sanity checked by the approximations given through the interview process allows us to draw some conclusions.

Householders with solid fuel all cited the better controllability of their ASHP systems, and the level of automation, however, they did miss their fires as discussed later in the report.

"If I had the choice now I would not have had it done, I do like the coal"

"If there was also an open fire it would have been 110%"

- They did however recognise the benefits
-

"You do have to dust every day with coal fires"

Considering the thermal data recorded on the datalogger [EW5] achieved temperatures in the living room of 25°C by mid-evening, with an average of 20.3 throughout the monitoring period. This may be due to what the tenant was used to with the more intense heat from the solid fuel fire. The heating regime consisted of two "on" periods during the day. The tenant in the other solid fuelled property [EW7] had a lower average temperature, but had the system configured to run continuously (24h a day). Running costs are depicted below and show a higher cost of heating for EW7 (continuous heating regime). It is also worth noting that the SAP values for these properties are 40, compared against the UK average of 51.6[11] there is clear scope to improve the energy ratings (and thereby reduce heating costs) in these properties. It is also worth noting that SAP 40 equates to band E of the ratings (see ***APPENDIX 4** – SAP Bands on Energy performance Certificates* for bands). On survey the loft insulation (reflected in the SAP rating) is only 4" (100mm), whereby the minimum standard as detailed in the current building regulations (Approved Document L1B) is 270mm.

During interviewing, both households reported being "comfortable" in terms of internal house temperature.

[11] Great Britain's housing energy fact file available at https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/48195/3224-great-britains-housing-energy-fact-file-2011.pdf [accessed 27/6/13]

Heating Costs

This analysis used data from **FULL YEARS** to March (2011-12 and 2012-13) but previous system energy costs are modelled and sanity checked.

Whilst ENERGY use is difficult to quantify without accurate costs / quantities of fuel used during the pre-installation period, we must consider modelled energy costs from SAP. Comparing SAP predicted pre installation cost, and actual post installation cost, the results show a significant cost reduction for the tenant. Heating cost is very important to tenants, especially those with lower incomes. When questioned directly, these tenants were unable to indicate whether there was any saving from the new system.

column		1	2	3	4	5	6	7	8
Property		Metered Period	2011/12 Storage heaters (kWh)	2012/13 ASHP (kWh)	2012/13 ASHP adjusted for degree days (kWh)	2011/12 energy cost **SAP MODELLED** (£)	2012/13 energy cost (Economy 7 tariff) (£)	2012/13 energy cost (standard tariff) (£)	Energy cost saving Column 7 Over Column 5
EW5		Day				1277*		540.87	736.13
		Night							
		Total							
EW7		Day				1277*		628.14	648.86
		Night							
		Total							

Figure 26

*Considering Figure 26, using modelled costs for the solid fuel (SAP) we can see that there is a considerable saving in heating costs. For EW5, the modelled costs may be regarded with some confidence as the resident stated (at interview) a solid fuel bill of about £33.00 per week was usual. If we factor in some reduction during summer weeks, the modelled cost seems realistic. EW7 however indicated a fuel spend of around 1.5 bags per week over the year costing £15, so although this was an estimate, the spend also seems realistic.

Looking back at Figure 8 when we used modelled data for "before" and "After" ASHP installation, SAP predicted a cost increase to the tenant. Our findings indicate a saving, despite the relatively low SAP ratings of these properties. Looking at the standard widely recognised "Sutherland Tables"[12] heating a 3 bedroom house with solid fuel and ASHP is £1180 and £1254 respectively, meaning that both SAP and "Sutherland Tables" predict a cost increase for heating a 3 bedroom house by ASHP when compared to Solid Fuel.

EW5 heated the property to a higher level at lower cost. The occupant had a small child and remained at home most days and used a twice daily heating regime.

EW7 heated the house continually to a lower temperature, and worked on a regular basis. Heating costs were higher

In terms of warmth, both residents interviewed indicated they were comfortable with the new system.

[12] Available at http://www.sutherlandtables.co.uk/ [Accessed 28/6/2013]

Conclusions

Indications are that cost savings *can* be made by replacing solid fuel central heating systems with ASHP systems, however, limited data and low sample numbers (2 properties with previous solid fuel systems) this conclusion should be treated with a degree of caution. Tenants tend to *like* solid fuel, even when recognising the issues with dust etc. Both tenants also recognised the benefits and the uniform heating they provide. Whilst there were significant differences in heating costs and system setup between the properties, both achieved cost savings (although didn't realise it). Perhaps this is a feature of the different ways of paying (Cash paid weekly to the "coal man" compared to a payment of a larger sum (longer period) to an energy company for electricity). This was not tested in the project.

The different heating regimes illustrate how system settings (and setup) relate directly to heating costs and thermal comfort. More education is needed to highlight the implications of this. EW7 was not at home for many hours of a day, but believed that leaving the system running 24h a day on a low setting was more cost effective than timing it.

Single House with Electric Boiler

This house EW9 is currently heated by an electric boiler, and radiators.

Property Ref	**Type**	**Beds**	**Occupancy**	**Previous heating system**	**Occupancy change / monitoring potential**
EW9	Mid ter. Bungalow	1	2	Electric boiler and radiators	Monitoring, no change in tenancy

Figure 27

This property has not been grouped in with another representative sample (such as M1 above) as it is a rather special case. Firstly it is the only property heated by electric boiler, and secondly, the resident insists on retaining the Economy 7 tariff he has been purchasing energy through for many years. Unfortunately, EW9 cannot provide **any** data on energy use prior to the heat pump being installed. Figure 28 illustrates the difference in energy COST between Economy 7, and a standard tariff as used in the previous comparisons.

Heating Costs

This analysis used data from **FULL YEARS** to March (2011-12 and 2012-13) but previous system energy costs are modelled.

column	1	2	3	4	5	6	7	8
Property	Metered Period	2011/12 Storage heaters (kWh)	2012/13 ASHP (kWh)	2012/13 ASHP adjusted for degree days (kWh)	2011/12 energy cost (Economy 7 tariff) (£)	2012/13 energy cost (Economy 7 tariff) (£)	2012/13 energy cost (standard tariff) (£)	Energy cost saving Column 7 Over Column 5
EW9	Day				1071	1012	977	
	Night							
	Total							

Figure 28

* No Data Exists for comparison prior to the installation of the heat pump, SAP Modelled data used

"[I am] ***Still on Economy 7 tariff and very happy as I use domestic appliances during night"***

The resident (EW9) refuses to move from an economy 7 tariff as he ensures high energy appliances are used during the cheap (off peak) period. Analysing his (post installation) energy bills reveals an interesting point. It is generally assumed by energy advisors that you should only select an Economy 7 tariff **IF** you heat using storage heating. The careful with energy use, and is not heating his house between 08:00am and 17:00 (as confirmed by the data-logger). Consumer focus (now consumer futures) commissioned a report[13] in 2012 which highlighted that Economy 7 customers are less likely to change supplier / tariff, even when the benefits are highlighted to them. This is the case with EW9.

Detailed examination of data shows that the day time temperature drops on the average day to approximately 18°C which may be adequate; if he chose to maintain a higher temperature throughout the day and therefore using more energy a standard tariff would then provide a cheaper option.

Modelling the meter reading data on a standard tariff reveals only a small difference (£35 a year) in energy costs between the two tariff options.

[13] http://www.consumerfocus.org.uk/files/2012/09/Ipsos-MORI-report-on-Consumer-Experiences-Of-Time-Of-Use-Tariffs.pdf

Conclusion

Conclusions are difficult to draw with example, as there are several special circumstances. More work would be needed with a larger data sample of electric boilers and more representative sample of residents and behaviours to enable robust conclusions to be obtained for cost savings. Using modelled data from SAP (Figure 7) showed a significant benefit to changing the heating system to an ASHP (£1071 - electric Boiler to £750 with ASHP). Actual energy costs for operating the ASHP were verified as £977, but the lack of pre install energy data prevents us from performing direct a comparison.

Tenant Surveys

At two points in the project, formal semi structured surveys were conducted to gauge satisfaction with the new heating systems, and gather information on the comfort and controllability of the new systems.

Data from Survey 1

During the initial visit the residents were asked a number of questions. One asked them to describe their feelings about the forthcoming installation. Answers received included: Apprehensive, Relieved (from 4 residents due to issues with their existing system), excited, and frustrated (the resident reported that the kitchen had just been refitted)

In terms of reliability, only 2 units had failed in the period, and one still has on-going issues. Of the residents who responded to the separate question of whether the ASHP was more reliable than their old system, all respondents replied that the ASHP was more reliable.

The 2 failures were –

- M2 – who had issues with the space occupied by the buffer tank on these systems.
- M5 – has on-going issues between the housing association and system Installer - installer is claiming the tenant is adjusting the factory settings on the unit. NEA was unable to discuss the issues with the tenant who would engage in any conversations with any of the partners.

There were mixed feelings of the installation process its self, 62% were positive about the installation, and 38% were dissatisfied. Of those that were dissatisfied, much of that dissatisfaction was around poorly communicated decisions. For example, holes in the carpet were where storage heaters stood, and not due to the installers. Some other comments were around positioning of controls, and uncontrollability (lack of TRVs) and complex controls. The following comments illustrate the wide spectrum of views.

"The lads that did it (installers) were super – they didn't make any un-necessary mess – they were so good"

"Laminate flooring upstairs was 'jigged' during installation but that was the only downside"

"Had a leak in the system but they came out that day to fix it"

"They cut my carpet, but never explained why; I have tried to get an explanation but never received one"

- NEA research has discovered that the carpet had been originally fitted after the electric storage heaters and therefore cut around the unit's feet. When the heater was removed the void in the carpet was exposed and therefore nothing to do with the ASHP installer.

Comments received around comfort levels before the new systems were installed included.

"With the old system you were sweating during the night and freezing come 3 o'clock in the afternoon; it was a nightmare in the winter"

"You could never invite friends round at night unless you gave them blankets and slippers"

"Everywhere was damper; I can't understand why they left it (electric storage heating) in so long"

Data from Survey 2

Following installation, resident comments included: The control of the systems both in terms of temperature and heating period. In some cases the residents had been told that they should not attempt to adjust the settings provided by the installation engineer. This has led to comments of unsuitable temperature conditions and increased energy bills (or fear of).

Whilst 2/3 of residents questioned had received advice on how to control their system, 50% were unhappy with that advice.

When questioned about running costs, half of the respondents reported that they were aware of the running costs of their new system. However, only 2 people could say whether the system was cheaper or more expensive to run than their old system. Comments received varied, as did the responses which indicate the low understanding of energy management and general rising energy costs. People using solid fuel struggled to give any indication of what they were spending on fuel using the previous system; this makes it difficult to measure the impact of heat pump installations in these houses, without relying on modelled SAP data.

In terms of whether residents would recommend the new ASHP system to other people, 81% of respondents said they would, 19% said they would not. Two responses indicated the extremes of opinion

Physical installation process / general tenant observations

Air source heat pumps have a reputation of being noisy, and historically planning authorities are sceptical about giving planning permission for these units in high density residential areas. With this in mind, the residents were specifically questioned about their feelings about the noise of the outdoor units, and asked about whether they had received comments from neighbours. In all but one case, this was not regarded as a problem. In the one case where the tenant was unhappy with the noise (at night), the neighbours (privately owned house without ASHP) had also complained about excessive noise in the evening.

- This is interesting as this property was in a less densely built area, and the land directly opposite the outdoor unit was open countryside. No conclusions could be drawn from this single situation, but it may be that the residents are used to a quieter location, with lower levels of noise more noticeable in open countryside. There were no walls or trees opposite the unit to reflect sound back to the properties.

Controllability

The specification procurement and commissioning of the heating systems were conducted or arranged by the respective Housing Association. The funder (NG-AWS), and evaluator (NEA) had no part in this process. In the properties at Worksop there was only one zone controller with TRVs fitted only on radiators in the bedroom(s). This appeared to provide issues for the tenants in achieving their required comfort levels.


Hidden heating controller

In addition, in one property (EW6) this was further exacerbated by the position of the wall mounted controller which was installed between the main entrance door and a small window. The red circle shows the position of the controller which would be influenced by its proximity to both door and window. During the site visit it was extremely difficult to check the temperature settings on the controller due to the position of a large fridge/freezer. The tenant reported that they were told to move the fridge/freezer to its current position as the only alternative position was required for the hall radiator to be installed. In addition, the controls for the oil boiler (previous system) are now redundant, and in an appropriate position but this location was not used for the new programmer.

This raises two important questions

- Why the controller was not mounted in a more appropriate position away from the door and window and allowing the fridge/freezer to be moved?
- How was the tenant expected to change the settings on the controller?
- The thermal characteristics of this location – influenced by the draught from the window, and heat from the fridge are not representative of the room in general – resulting in the heat pump not responding to realistic environmental conditions in the house.

  NEA was unable to get a reason for the decision to install the programmer in this position.

"I was told not to touch the controls - they are too technical"

"We were told not to turn radiators off"

"They didn't give us any instructions on how to use the controls, we were told 'we've set it you don't touch it'"

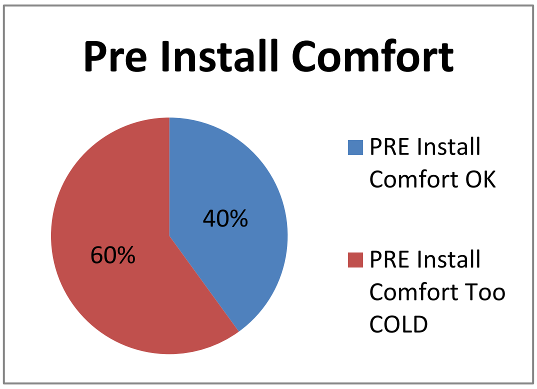
"They should have all of us in the community hall with a mock-up and showed us what was going to happen – there was nothing like that"

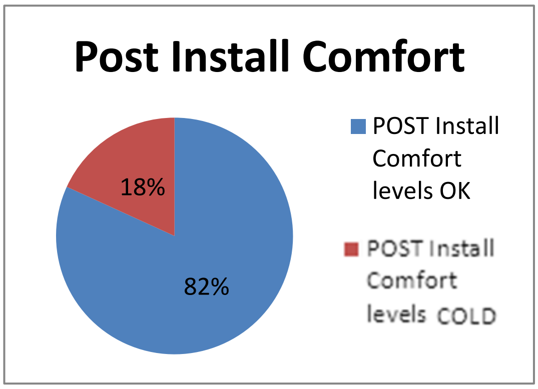
- The controls on the systems installed at the properties in Worksop comprised a single controller located in the hall or lounge and provided control of temperature and the times that heat was required in that single 'zone' Thermostatic radiator valves were only fitted to the bedroom(s) radiators.
- The controls on the systems installed at the properties near Macclesfield comprised two or three (depending on property size) controllers similar to those used at Worksop but these provided independent control of the respective 'zones'
- The majority of the negative comments concerning controllability came from the Worksop tenants;
- One tenant in Worksop did appear to have a greater understanding of the controls (EW2) took a great personal interest in efficiency. (EW3) did acknowledge that this did involve frequent adjustments of the settings.
- Several Worksop residents were less able to understand the controls and relied on visits from A1 housing to make adjustments when needed. This does illustrate the need to install appropriate controls for the target residents, and providing appropriate training.

During the additional visit NEA made to tenants in February 2013, tenants were asked what their programmer was set to, which was then checked by NEA at the time. In some cases the settings the tenant believed to be programmed into the programmer differed significantly from the actual settings. This re-iterates the point made by several evaluation studies that education and tenant support is essential if tenants are to reap maximum benefits from new technology and their controls.

Comfort

When questioned about comfort levels, 81% of the residents were happy with the comfort levels. Respondents to the question earlier in the study, as to whether their comfort levels from their old heating system were adequate, 40% were happy and 60% were unhappy.





"I have not been cold since the system was put in"

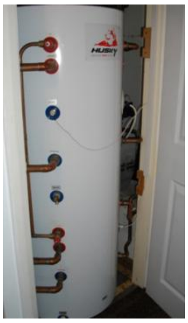
"Its 100% better, I wouldn't go back to the old system"

"This room (Lounge) is always nice and warm"

General Points

As mentioned previously, there were two different units fitted. Macclesfield properties were fitted with Husky PWR units, which necessitated the use of a large buffer tank. In Worksop, Mitsubishi EcoDan units were used, which use a different technology in the motor drives and don't require a buffer tank. The choice of unit / supplier was dependent on local procurement and installer relations, and was outside of the scope of influence of NG-AWS or NEA.

Macclesfield properties were fitted with a system requiring a buffer tank and zone controls to provide suitable temperatures to different zones. Whilst this system provided more control over the temperature settings compared to the system in Worksop (with no buffer tank), the extra space required by the buffer tank did provide problems for at least one resident.



Buffer tank

"I hate the alien in the cupboard"

- Although the issue over buffer tanks was not specifically tested through questioning, for this resident, the buffer tank did cause major problems, and took up the whole of her cupboard space; it was not raised as an issue by other tenants.

One tenant at Worksop noticed a problem with the hot water.

"I have to run a bowl of hot water before it gets warm, it didn't happen before. My water is metered so I am paying for that water. It is annoying that I have to go through a whole bowl of water, the water is then really hot but it wastes so much, it's easier to just boil a kettle"

- The position of the hot water tank has been moved to a position further away from the kitchen sink. This *may* have been the only technical solution – but this was not communicated to the tenant. NEA could not obtain design reasons from the installation company.

We received several comments on the general price of energy and keeping homes warm and comfortable, whilst not related to heat pumps, this comment gives a flavour of the comments received.

"If the bills go any higher I will have to forfeit my car"

- Comment about energy prices in general.

Finally, two of the sample properties involved in the study had solid fuel heating systems including an enclosed room heater (Glass fronted fire). These residents had very little awareness of how much money it cost them to heat their houses with this system, but generally liked the system.

The tenants recognised the benefits of their ASHP system, remembered the disadvantages of the solid fuel systems, but liked the heat and focal point of that solid fuelled fire.

Room heater [EW7]

"If I had the choice now I would not have had it done, I do like the coal"

"If there was also an open fire it would have been 110%"

"It's the same price but I was getting a hot house (with coal) but now only a warm house - Although warm enough"

"You do have to dust every day with coal fires"

Conclusions and Recommendations

Conclusions

The amount of data gathered during this project for the fourteen properties is extensive and provides a great deal of scope for comparison and interpretation. Data availability and integrity caused problems and limited the use of some properties in the analysis. This included tenant changes, estimated bills, and availability of historical energy usage.

Grouping similar property types and occupancy allowed robust data to be used as representative of other households, allowing strong conclusions to be drawn.

81% of the study participants would recommend the system to others.82% of respondents were comfortable in their new environment compared to only 40% with the previous heating system.

Findings

- Tenants' perception of running costs is based on monetary value. Energy price increases during the period of the project combined with much colder weather compared to the previous winter confuse the tenant regarding any perceived benefit of the change to an ASHP.
- Through degree day analysis, measured energy use (kWh), and increased comfort levels do show reduced energy consumption over storage heaters.
- The comfort levels provided by the ASHP were generally seen as a great improvement over that provided by the electric storage heaters.
- Understanding of systems and controls were not fully understood and resulted in unintentional over and under heating, or tenants resorting to "manually control" their systems.
- The housing association provided intensive support to configure systems at the request of tenants, but failed to coach them on adjusting their systems themselves for the future.
- Many tenants did not understand the implication (or sometimes the existence) that different electric tariffs would have on the change from electric storage heaters.
- Some tenants chose to remain on Economy 7, retaining previous behaviour developed through years of living with storage heating supplied by an economy 7 tariff.
- Households retaining Economy 7 (as their electricity) tariff had relatively similar electricity costs to that which would have resulted if they changed to a [recommended] single tariff.
- Tenants generally did not understand why the new systems were being installed, what the benefits should be, and had not been involved in any decisions as to where controls would be installed, where buffer tanks were to be placed, or why some radiators did not have Thermostatic Radiator Valves fitted.

Recommendations

- Based on the conclusions in this report NEA recommends the continued roll out of ASHP as an alternative to older electric storage heaters and other off-gas heating systems. However to ensure the best use is made of the technology and maintaining acceptable comfort levels other additional recommendations must apply.

- NEA recommends that future rollout includes:
    - More training on the use of controls systems
    - The specification and installation of easy to understand appropriate controls
    - More support should be provided by expert energy advisors on the individual circumstances relating to the selection / transfer to an appropriate energy tariff when building and heating systems are changed
    - Involve tenants from the outset – in the decisions to install the systems, and involve them in the specification and design where it affects their living environment.

- NEA also recommends that more research be undertaken to better understand the change from electric storage heaters (or other off-gas heating systems) to ASHP systems in different housing and resident types and occupancy patterns.
- Projects should start with monitoring a minimum of one winter period before new systems are installed.
- Projects should consider utilising automatic energy logging equipment, increasing data confidence and detail.
- Systems should be specified and installed using rigorous standards. Some properties had very few Thermostatic Radiator Valves fitted, and those that did, were in different locations in different properties.
- Perform an evaluation project to compare ASHP technology with MODERN automated storage heating replacements.

APPENDIX 1 - Pre-installation questionnaire

Introduction: the main aims of this stage of the process are to build a good relationship with the householder, to begin the collection of fuel bill information and to gauge initial thoughts/feelings so we can compare them later in the process.

PART 1: ABOUT THE PROPERTY

INTERVIEWER CHECK. Is the respondent head of household?	Yes	1	No	2

1a. Property type		1b. Tenure		1c. Household detail **(write number)**	
Detached……………………….	1	Owner-occupier………	1	Total number in household:	n
Semi-detached……………….	2	Privately rented…………..	2	Number of adults (16-59):	n
Terrace………………………….	3			Number of children (<16):	n
Bungalow……………………….	4			Number aged 60 or over:	n
Flat/maisonette……………...	5				

2. Property Age					
Pre 1919	1	Late 1940s- early 1960s	3	1990-onwards	5
1919-1945	2	Mid 1960s – Mid 1980s	4	Other (Please specify below)	6

3a. Number of Floors		3b. Bathrooms, Kitchens and utility rooms	
One……………………….	1	Number of Bathrooms including: en-suites (write number)	n
Two……………….	2	Number of baths (write number)	n
Three………………………….	3	Mains Shower (write number)	n
Four……………………….	4	Electric Shower (write number)	n
Five	5	Kitchen with utility room (tick)	
		Kitchen only (tick)	

4. Property location			
Urban…………………………..	1	Rural……………………….	3
Suburban……………………….	2	Remote rural…………….	4

5. Access to mains gas?	Yes……….	1	No……………….	2

6. What insulation measures have been installed?

Loft Insulation……………………………………	1	Cavity wall insulation…………..		3
Draught proofing …………………..….	2	Other (specify)..		4

7. Alongside information about the heat pump, have you been given further advice on?

General Energy Advice……………………………………	1	Budgeting for fuel…………..		3
Low energy light bulbs …………………..….	2	Other (specify)..		4

PART 2: MONITORING YOUR CHANGE IN ENERGY CONSUMPTION

We would like to be able to monitor how the air source heat pump affects your energy consumption and fuel bills. It would be useful if you could share with us the following information:

8. Who is your fuel suppler?

……………………………………………………………….................

9. Do you know what tariff you are on (specify)?

……………………………………………………………….................

10. What is your energy customer number/account number?

....

11. IF have bills, please take copies.

If not, what is your current estimated expenditure – please specify if annual, monthly, quarterly (if quarterly, check if winter quarter etc)

……………………………………………………………………………

12. Can I take a meter reading today?

......DATE: ....READING:.........................

12a. Are you happy to help provide us with future information? (monthly meter readings, telephone questions and visits). ***Please go through meter reading log book with them.***

....

PART 3: Previous Heating System

13. Before the air source heat pump was installed how was your home heated?

Oil………………………………….	1	Electric storage heaters………….	3
Electric convector heaters …………………..…	2	Other (specify)..	4
Solid Fuel ………………..	5		

14. Approximately how old was the previous system?

1 to 3 years………….…………	1	9 to 12 years…………….……	3	17 to 20 years ……………..	5
4 to 8 years………………………	2	13 to 16 years……………..…	4	More than 20 years……….	6

15. What controls were in place for the previous heating system?

Thermostat …………………………………………	1	Thermostatic radiator valves (space)	3
Programmer / timer……………………………….	2	Other (specify)…	4

PART 4: UNDERSTANDING AND EXPECTATION

16. On a scale of 1 – 10, 1 meaning 'I don't know anything' and 10 meaning 'I know everything,' how much do you know about the system that is about to be installed?

…………………………………………………………

17. How would you describe your feelings about the forthcoming installation?

Excited **Relieved** **Unsure**

Apprehensive **Laid back** **Confident**

Frustrated **Disappointed** **Passive**

Other……………………………………………………

18. Is there a particular piece of information you would like at this stage?

…………………………………………………………

PART 5: ABOUT THE RESPONDENT

19. Sex		**19b.**	
Male…………………………….	1	16-35…………………………..	1
Female………………………..	2	36-59…………………………..	2
		60-84…………………………..	3
		85+……………………………..	4

20. Employment status (Please remember to state occupation in the box provided)

Work full-time………………………………………..	1	Retired………………………………………………	6
Work part-time…………………………………….	2	Full-time carer……………………………….…..	7
Not working on health/disability grounds…	3	Full-time education…………………………….	8

Full time parent/guardian..........................	4	Unemployed..		9
Other (specify)	5	**B.** Specify occupation:		

21. Which of the following benefits do you receive?

(Please ☑ all that apply)

	Yes	No	Don’t Know
Pension Credit			
Council Tax Benefit			
Housing Benefit			
Income Support			
Income Based Job Seekers Allowance			

Other please state here:

....

APPENDIX 2 – Post Installation Questionnaire

National Grid, Affordable Warmth Solutions / A1 Housing properties Elkesley, Nottinghamshire

ASHP follow up survey post installation

Name ……………………………………………………………..

Address ……………………………………………………………….

Telephone ………………………………………………………………..

How long has the ASHP been installed? ……………… months

OLD SYSTEM

1. What heating system did you have? Storage heaters / solid fuel

   Other ……………………………………..
2. How warm did you feel with your old system? Comfortable / Too cold / Too warm

   Comments …………………………………………………………………………………..

3. When did you have your heating on? Twice daily / Evenings / All Day / 24hrs

   Comments ………………………………………………………………………………………….

NEW SYSTEM

4. Where is the heat pump located? ……………………………………………….
5. Is it attached to the wall? Y / N
6. Did anyone provide you with instructions on how to use your ASHP system Y / N

   If Yes, who …………………………………………….
7. How satisfied were you with the instruction? …….
   (1 = very satisfied, 2 = satisfied, 3 = neither, 4 = dissatisfied, 5 = very dissatisfied)
8. If not satisfied, why or how could they be changed? …………………………………………………
9. Did the installer set the timer on your new system? Y / N
10. Were you given a contact person for further support? Y / N
11. Do you know how to change the time settings? Y / N

    If yes, have you changed the settings? Y / N
12. Do you think the new system's controls could be improved? Y / N

    If Yes, how …………………………………………………………………………………
13. To date as your new system broken down? Y / N
14. Do you think the new system is more reliable than your old one? Y / N

    If Yes, why and how ………………………………………………………………………………………
15. Do you find your new system noisy? Y / N

If Yes, details ……………………………………………………………………………………………………….

16. Have your neighbours commented or complained about the noise? Y / N

If Yes, details ………………………………………………………………………………………………………..

17. Have you been given further advice on?
    - General energy advice Y / N
    - Budgeting for fuel Y / N
    - Supplier/tariff switching Y / N

18. Have you switched supplier / tariff Y / N

19. Who is your current fuel supplier? …………………………………………………

20. Do you know what tariff you or on? ………………………………………………….

21. Would you have liked help to switch supplier / tariff? Y / N

22. When the system was installed, how satisfied or dissatisfied were you with each of the following? (1 = very satisfied, 2 = satisfied, 3 = neither, 4 = dissatisfied, 5 = very dissatisfied)
    - Making arrangements for the installation …….
    - The manner and presentation of the installer(s) …….
    - The tidiness of the completed installation ……..
    - Being kept informed about the progress of the work …….
    - The installation overall …….

23. How satisfied or dissatisfied are you with the cost of running your ASHP …….. (1 = very satisfied, 2 = satisfied, 3 = neither, 4 = dissatisfied, 5 = very dissatisfied)

24. How satisfied are you with the following?
    - The heat levels the system can provide …….
    - Ease of using the system …….
    - Amount of control you have over the system …….
    - The cost of running the system …….
    - The overall reliability of the system …….

25. How satisfied or dissatisfied are you overall with your ASHP? ……..

Comments expressed on satisfaction ………………………………………………………………………

26. Would you recommend this system to someone else? ……..

Why? …………………………………………………………………….

……

27. Do you wish to make any other comments not covered by the questions asked? Y / N

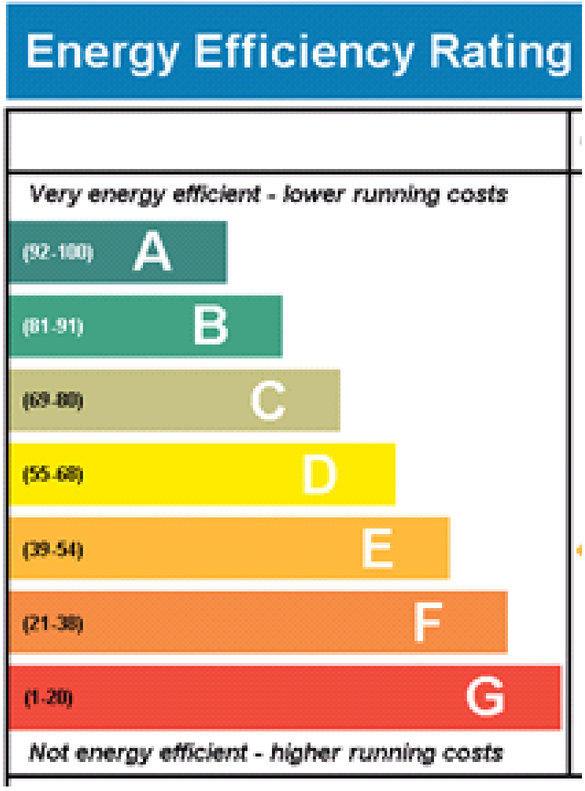
(Use space below to record any comments)

APPENDIX 3 – DATA Reliability Comparison Chart

Table below summarising the issues experienced with data / robust monitoring

Property	Data used	ASHP not installed	Tennant Changed	Late start	Limited data	Not storage heaters	Portable heater used
EW1	✓		✓	✓			✓
EW2	✓						
EW3	✓				✓		
EW4		✓					
EW5					✓	✓	
EW6					✓	✓	
EW7					✓	✓	
EW8					✓		✓
EW9	✓				✓	✓	
EW10			✓	✓	✓		
M1	✓						
M2				✓			
M3			✓	✓	✓		
M4	✓			✓			
M5				✓	✓		
M6		✓					

APPENDIX 4 – SAP Bands on Energy performance Certificates



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