Programme Area: Distributed Energy

Project: Micro DE

Title: Findings From Field Trial Occupant Interviews

Abstract:

Please note this report was produced in 2010/2011 and its contents may be out of date. This deliverable is number 2 of 7 in Work Package 3. It summarises the findings of two rounds of interviews carried out on participants of the 18 home field trial carried out as part of Work Package 2. First round interviews were carried out prior to the 2010/11 heating season, second round interviews after the heating season. The findings from these interview have been included in report D3.7 : Final project report together with outputs from other deliverables within Work Package 3.

Context:

The project was a scoping and feasibility study to identify opportunities for micro-generation storage and control technology development at an individual dwelling level in the UK. The study investigated the potential for reducing energy consumption and CO2 emissions through Distributed Energy (DE) technologies. This was achieved through the development of a segmented model of the UK housing stock supplemented with detailed, real-time supply and demand energy-usage gathered from field trials of micro distributed generation and storage technology in conjunction with building control systems. The outputs of this project now feed into the Smart Systems and Heat programme.

WP3.2.1 Findings from the field trial occupant interviews

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Executive Summary

This report is one of seven reports presenting the findings and recommendations from the ETI Micro Distributed Energy project, a scoping and feasibility study to determine the opportunity for Distributed Energy (DE) technology development. The report deals specifically with the potential contribution of building Energy Services Management (ESM) systems in the residential setting.

The following report outlines the findings from a series of interviews conducted with the occupants of eighteen field trial homes. Each field trial home had at least one of the following technologies installed: Photovoltaic (PV) panels, Solar Thermal Hot Water (STHW) systems, Biomass boilers, Air Source Heat Pumps or Ground Source Heat Pumps (GSHP).

The findings indicate that the key investment drivers for early adopters of Micro DE technologies were:

- saving money on energy bills,
- reducing their carbon footprint and impact on climate change,
- reducing their reliance on oil and gas (concerns over rising prices and future supplies).

The findings suggest that financial incentives such as feed in tariffs and the Green Deal are likely to be important future drivers. Financial incentives are likely to make PV panels in particular more attractive to consumers.

Occupants with STHW and PV systems tended not to interact with these technologies other than to look at the digital displays. Many noted that there was little or nothing to adjust on these systems and that they would like more detailed and user friendly feedback. Many had not adjusted anything on their controls since the systems were first installed and set up. Some noted that because interaction with the systems was so rare it was easy to forget how to use the controls. Thus occupant behaviour appears to have little effect on the performance of these technologies. However, for many occupants these technologies did influence their behaviour. Participants reported altering their behaviour, and the times at which they carry out certain tasks, to make maximum use of the electricity and hot water generated by the PV and STHW systems.

It was observed that in several households, occupants were trying to use their ASHPs GSHPs and Biomass boilers as they had their previous conventional boilers. They tended to have their systems timed to come on at certain times and only to be on for relatively short periods of time. These households tended to describe the systems as being slow to bring the house up to the desired temperature and sometimes unable to reach these temperatures. Conversely, participants who ran their heat pumps either continuously or for larger proportions of the day tended to describe the systems as providing a stable temperature over time and being quick to react to temperature changes. Occupants with heat pumps tended only to interact with their central heating programmers and thermostats rather than to adjust anything on the heat pumps themselves.

The findings showed that occupants with Biomass boilers and GSHPs were least happy overall with their systems and rated the performance of these systems lower than the other technologies looked at in this

study. Biomass boilers were described as the least easy to control. Many of those with a Biomass boiler felt that they were still learning how to live with their system and use it most efficiently and effectively. This technology seemed to require the most trial and error and had the greatest learning curve. Several participants noted that these systems required a great deal of attention, cleaning, interaction and maintenance. Participants were required to interact with this system much more than the other systems, and the system's performance was reliant on this interaction (i.e. cleaning it out and refuelling).

The findings indicate that the key factors that influence the performance of these technologies are:

- the quality of the installation
- the information provided to the occupant at the point of installation
- the occupants' level of understanding over how to use their system efficiently and effectively.

The way a micro DE technology is installed, its orientation and location, the length and position any pipe work, and how it is set up has a big influence on how the system will perform. Several participants noted that their installers did not appear to be fully informed about the systems they were installing. The findings indicate that occupants very rarely adjust anything on their micro DE controls (where they have them). This means that the systems are left to run exactly as they were set up when installed. It is therefore vital that the systems are installed and set up to work as efficiently as possible.

The quality and quantity of the information and advice provided with these systems varied a great deal in the field trial. A few of the participants did not receive any kind of manufacturer's manual with their systems, and others were given no information or advice from the installers. It is important that occupants are given good clear information about how the system works and how to use it efficiently. Without this information many people will struggle to understand how to use their technologies efficiently and get the most out of them. This information can be passed on by the installers of new systems, although the findings of this field trial suggest that in many cases this is not happening.

Occupants' levels of understanding of how the technologies worked and how to control them varied a great deal. However, it was noted (even by the participants themselves) that there is a big difference between understanding how to get the systems to do what the occupants want them to do and how to use these technologies efficiently and get the most out of them. Without this deeper level of understanding many occupants were failing to use the technologies as they had been designed to be used. This can lead to underperforming systems and dissatisfied occupants.

With the exception of Biomass boilers very few, if any, of the participants had had their technologies serviced or professionally maintained. Without this, any deficiencies in the set-up of the technologies are unlikely to be identified and rectified, meaning that a particular technology can be underperforming for years without the occupant or anyone else knowing. Occupants are calling for more user-friendly information on how to get the most out of their DE technologies, when to service them, and to whom to go for servicing.

Contents

1 Introduction

As part of the ETI Micro Domestic Energy (DE) project, data is being collected from eighteen field trial homes. Micro DE technologies were installed in these homes, before the start of the field trial, by the owner occupiers or the housing associations who own the properties. Several of the properties have more than one type of technology installed. In total the field trial is monitoring five Photovoltaic (PV) systems, 12 Solar Thermal Hot Water (STHW) systems, five Biomass boilers (Biomass), four Air Source Heat Pumps (ASHP), and four Ground Source Heat Pumps (GSHP). Appendix A shows which technologies are installed in each of the field trial homes and which homes are owned by the occupiers and which are Social Housing homes.

As well as collecting physical data via monitoring equipment such as internal and external temperature, $C0_2$ levels, energy used and energy generated, etc, a series of interviews are also being conducted with the occupants of the field trial homes. Information is being collected on:

- demographics and occupancy patterns
- occupant comfort and control
- perception of the environmental conditions
- typical energy use behaviours
- perception of the micro DE technologies installed
- feedback on participation in the field trial study and the recruitment process.

A copy of the full interview schedule for the first-round of interviews can be found in Appendix B and the schedule for the second-round interviews can be found in Appendix C. Where possible the first-round interviews were conducted at the occupants' homes by trained BRE interviewers. Conducting the interviews at the homes allowed the occupants to show or physically demonstrate to the interviewer any problems, issues or things they particularly like about their DE systems or other aspects of their homes. The first-round interviews typically took place within one month of the installation of the monitoring equipment at each home. The interviews were conducted between July 2010 and February 2011. Findings from the first-round interviews alone can be found in the 'Interim report based on the findings from the first round occupant interviews' sent to the ETI on the 3rd of March 2010.

The second-round interviews were conducted over the telephone in February and March 2011. Only those participants who had their first-round interview before the heating season received the full second-round interview (a total of 10 households). However, a series of brief telephone interviews was conducted with specific households to identify exactly what make and model of DE technology they had and/or to try to find explanations for anomalies in the physical monitoring data. The full second-round interview was intended to ascertain whether anything had changed in terms of occupancy patterns, the structure of the

building, insulation levels, the perceived environmental conditions, etc since the first interview. The interviews also focused on occupants' perception and rating of their DE systems over the heating period.

This report pulls together the findings from all the occupant interviews. As well as providing detailed occupant feedback on the DE systems themselves, the report also explores exactly how the occupants heat their homes, and how their perception of temperature is related to the physical monitoring data for each property. It also looks at occupants' energy use behaviours and how they try to save energy in their homes. Finally the report looks at occupants' feedback regarding participation in the field trial itself and makes recommendations for future field trials.

The findings are often clustered and broken down by the type of micro DE technology namely; Air Source Heat Pumps (ASHP), Ground Source Heat Pumps (GSHP), Biomass boilers (Biomass), Photovoltaic panels (PV) and Solar Thermal Hot Water (STHW). In addition, findings are also given for individual households. The properties are referenced by the house id number (e.g. House 002). The use of the house id numbers also ensures that the findings are anonymised, and household confidentiality is maintained, for readers outside the partner organisation. Table 1 on the following page provides more detailed information about each of the field trial properties and the occupants who live there.

The occupants of house 002 withdrew from the field trial a few months into the monitoring period and after their first-round interview. The occupants were concerned that the wireless monitoring equipment was making their children ill. The occupants of house 010 withdrew from the field trial just before their first interview because they had been incorrectly told by a plumber that the monitoring equipment was affecting the performance of their malfunctioning heat pump. These participants also felt that participation was more time-consuming than they expected.

House ID	Social housing (SH) or owner occupied	Number of adults	Number of children	Age and sex M - Adult male F- Adult female B – Boy,G - Girl	The approximate number of days the house is occupied during the day by at least 1 occupant	Free time spent at home, adults (1= Majority spent at home 5= Majority spent away)	Frequency of visitors	Employment status of adults (SAHP = stay at home parent)
000	OO	2	0	M – 52, F- 52	3-4	2	Once a fortnight	2 x FT employed
001	OO	2	2	M, F, B-9, G-11	6-7	2-winter, 3-summer	Once a fortnight	2 x FT employed
002	OO	2	3	M, F B-12, B14, G-9	6-7	2- winter, 4-summer	Once a month	1 x FT employed 1 x SAHP
003	OO	2	0	M-65+, F-65+	7	2-winter, 4-summer	At least 5 times a week	1 x PT employed 2 x Retired
004	OO	2	3	M-65+, F-65+	7	2-winter, 3-summer	Once a week	2 x Retired
005	OO	3	2	M-18,M,F G-14,G-14	6-7	3	Once a fortnight	2 x FT employed 1 x Unemployed
006	OO	2	3	M, F, G-7, G-9, B-11	5-7	3	Once a week	1 x FT , 1 x PT 1x SAHP
007	OO	1	0	F-60+	3-5	3-4	More than once a week	1 x retired
008	SH	2	0	M-61, F-60	7	3	Once a fortnight	2 x retired
009	SH	1	0	F-72	7 but out ½ of each day either morn or afternoon	3	Twice a week	1 x retired + PT voluntary work
011	SH	2	1	M, F, G-14	7	1	At least once a week	2 x retired
013	OO	2	0	M-71 F-68	7 (but go for a walk everyday)	3	Once a week	2 x retired
017	OO	2	2	M-40+, F-40+ G-13, G-10	1-2	3	Once a month	1 x FT employed 1 x PT employed
018	OO	2	2	M-43, F-38, G-8, B-6	2-4	3	Once a fortnight	1 x FT employed 1 x PT employed
019	SH	2	2	M-37, F-33 S-4, S-6	5-7	3	Once a fortnight	2 x FT employed
020	OO	2	0	M-72, F-66	7	1	Once a year	2 x Retired
022	SH	3	0	F-62, M-67, M-33	7	F-1, M-3,M-4	Once a fortnight	2 x Retired 1 x FT employed
023	SH	2	1	M-60, F47, G-17	7	1	Once a week	1 x FT employed 1 x Disabled

Table 1. Participant profiles and occupancy patterns for each of the field trial homes
Note - the occupants of house 002 pulled out of the field trial after their first interview. The occupants of house 021 were not available to be interviewed

2 Findings

2.1 Heating

Perceived versus recorded temperature

Participants were asked to rate the general temperature of the house during the coldest months of the year on the following five point scale:

1 - Uncomfortably cold

2 - Comfortably cool

3 - Comfortable

4 - Comfortably warm

5 - Uncomfortably hot

The average monitored temperature for each house between September 2010 and February 2011 was also calculated. For some houses, data was not available for this whole period and so an average was taken from the available data. None of the participants rated their homes as generally uncomfortably cold or uncomfortably hot, although some said that their homes could be uncomfortably cold at times.

As can be seen in Figure 1 below, the temperatures described by participants as 'comfortably cool' ranged from 11.1°c to 18.2°c. The occupant whose house was on average only heated to 11.1°c acknowledged that anyone else would describe the temperature as uncomfortably cold. This occupant generally only heated the room they were occupying and preferred to add layers of clothing rather than put the heating on. The temperatures described by participants as 'comfortable' ranged from 17.3°c to 18.9°c. Several participants noted that they tried to dress appropriately for the conditions and would put a jumper on rather than turning the heating up. The temperatures described as 'comfortably warm' ranged from 18.6°C to 22.2°C.

A significant correlation was found between occupants' rating of the temperatures and the average measured temperatures ($r=0.725$, $p=0.001$). No significant differences were found between social housing tenants and owner occupiers in terms of the measured average temperature recorded or their perception of the temperature in the properties.

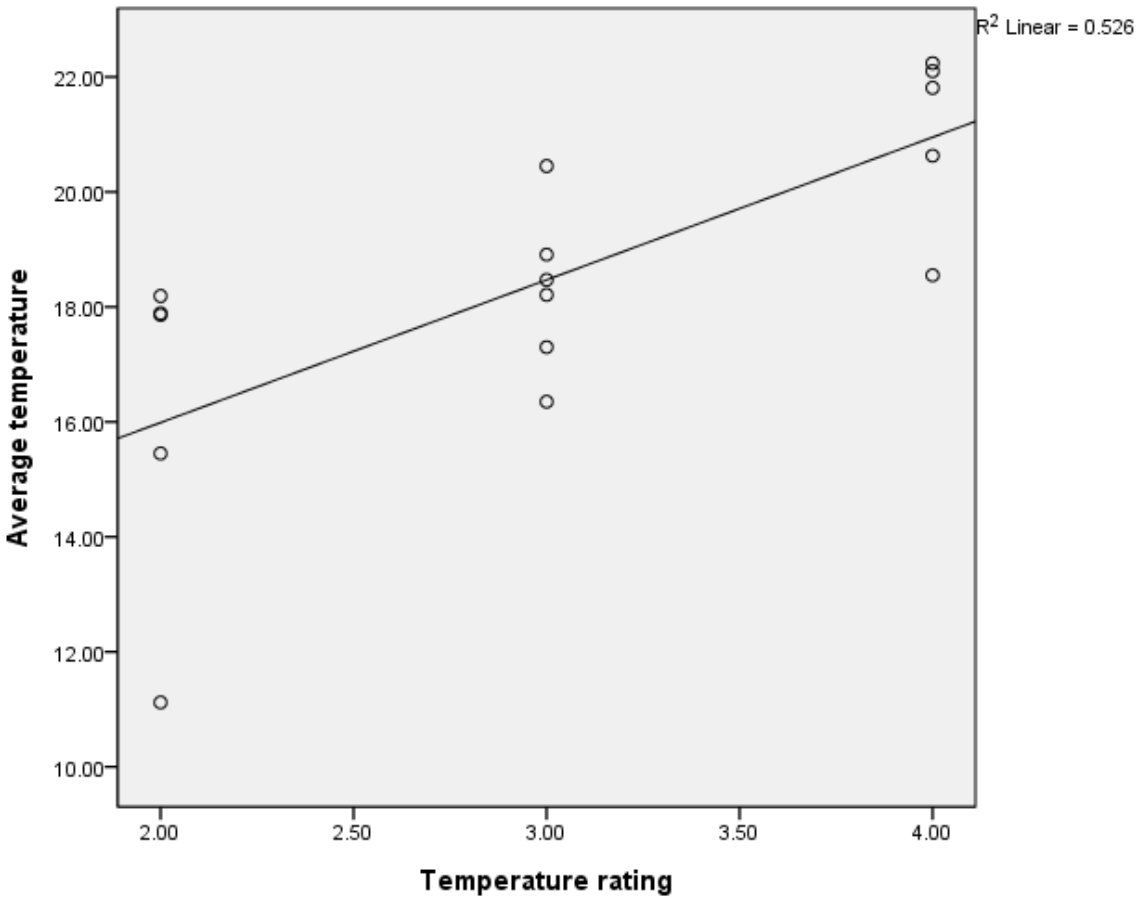

Figure 1. Correlation between the average recorded temperatures and occupants' temperature rating

How do occupants heat their homes?

In the vast majority of the field trial homes, just one of the adults took responsibility for controlling the heating and hot water. In some homes the other occupants in the house had very little understanding of how to adjust or control the heating systems. In eight of the eighteen homes the adult male was responsible and in nine homes the adult female was responsible (although in two homes there was only one occupant). In the final home (011) nobody touched the heating controls; they were left at the same settings all year round. The thermostat was set to 23°C, and the ASHP was left to run constantly.

The participants were asked how they typically heated their homes over the coldest months of the year. Eight of the homes were heated exclusively by the central heating system. However, nine of the homes were heated by other heating devices in addition to the central heating system. Often these heating devices were used to supplement the central heating, as the central heating alone could not provide sufficient heat for some areas of the house. In other cases the additional heating devices were used to heat certain rooms when the occupants did not want to heat the whole house using the central heating. Some occupants said that they used either the central heating or the other devices depending on which part of the house they were trying to heat. One household (007) was generally heated by a wood burning stove and/or a gas fire rather than by the central heating, which was only put on when visitors came to stay.

The additional heating devices frequently used were:

- Wood burning stoves (four homes, some properties had up to three)
- Open wood burning fires (three homes)
- Separate electric under floor heating systems (three homes)
- Electric fires and portable electric heaters (three homes)
- LPG heater (one home)
- Electric oil filled radiator (one home)
- AGA (one home)
- Halogen heater (one home)

In six of the eighteen homes the central heating was left permanently on during the heating season and the temperature was moderated by a thermostat, or in some homes by multiple thermostats. In some homes the thermostats were set to lower temperatures at night or for the first floor of the properties. In eight of the homes the central heating was programmed to come on at particular times of the day. In four properties the central heating was manually turned on and off as required. Some of the occupants turned the heating systems on and off by raising or lowering the desired temperature on the thermostat. In seven homes the whole house was heated, in eight homes unoccupied rooms were heated to a lower temperature than the rest of the house and in three homes unoccupied rooms were not heated at all.

Interviewees were asked how they typically heated their homes during the shoulder months (i.e. spring and autumn). In five of the eighteen homes the occupants did not adjust the temperature or the times the central heating came on. These settings stayed the same throughout the heating season. In six of the homes the occupants set their central heating systems to come on less often and/or for shorter periods of time. In four of the homes the occupants used a combination of their central heating and their additional heating devices, tending to rely more on their additional devices to heat certain rooms rather than putting the central heating on to heat the whole house. In three of the homes the occupants relied almost exclusively on their additional heating devices in the shoulder months only putting the central heating on during the coldest months of the year.

2.2 Energy use behaviours

Low energy lighting

Over 70% of respondents estimated that over three quarters of the electric lights in their house had low energy bulbs. However, the estimated percentage ranged from just 5% (two bulbs in the whole house) to 100%. The lights that were least likely to have low energy bulbs were fluorescent lights in kitchens and ceiling spot lights (typically with halogen bulbs).

Participants were asked why they did not have low energy bulbs in some lights. Nine of the eighteen participants reported that they had not used low energy bulbs in some lights because they were not aware of any low energy replacement bulbs on the market for some of the light fittings. Many participants also reported that they would only replace their existing bulbs with low energy equivalents when they

stopped working. Some participants did not like the light emitted by the low energy equivalent bulbs. The colour and quality of the light was described as “horrible” and not as warm as their current tungsten or incandescent bulbs. Participants who had low energy LED bulbs instead of halogen bulbs described the light emitted as inconsistent, having a blue tinge, and being dimmer than the halogen equivalents. These bulbs were also described as relatively expensive. Finally several participants also mentioned that low energy bulbs were comparatively slow to respond and reach full brightness.

Energy saving behaviours

Interviewees were asked how often the occupants of their house turned the lights off in unoccupied rooms/areas. As can be seen in Figure 2 below, 50% of the participants said that they turned the lights off every time and 50% said that they often turned lights off in unoccupied rooms. Several of the participants with children did acknowledge that their children turned the lights off less frequently. Participants also pointed out the following exceptions.

- Energy saver lights in the kitchen were often left on because they take so long to warm up
- A light was left on in the hall from dusk until they went to bed
- Some lights were left on all day for ambient light in dim areas on dull days
- Four lights were left on timers when the house was unoccupied for security reasons
- One sitting room table lamp was left on during the evening
- Only a fluorescent light in kitchen and a lamp in the lounge were left on in unoccupied rooms.

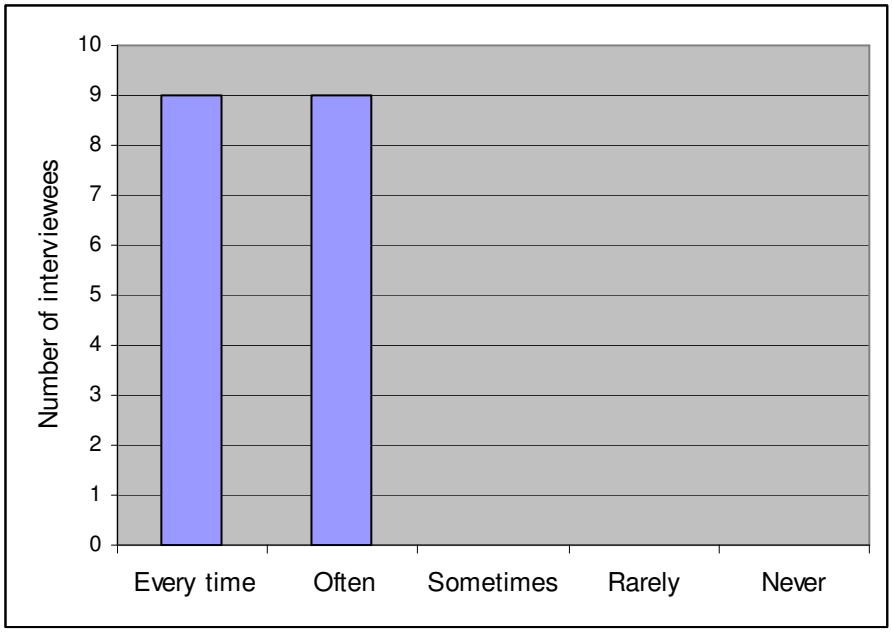

Figure 2. Frequency with which occupants turn lights off in unoccupied areas/rooms

Interviewees were also asked how often they turned the plug sockets off at the wall for items that would otherwise use some electricity. As can be seen from Figure 3, far fewer of the participants said that they often or always turned plug sockets off. The distribution was much more spread. Participants were much more conscious of turning lights out than of turning devices off rather than leaving them on standby. Several participants said that they did not turn devices off that had in built clocks such as microwaves and cookers as it took too much time to reset the clocks each time they were turned back on, and some products would not work again until the clock was set.

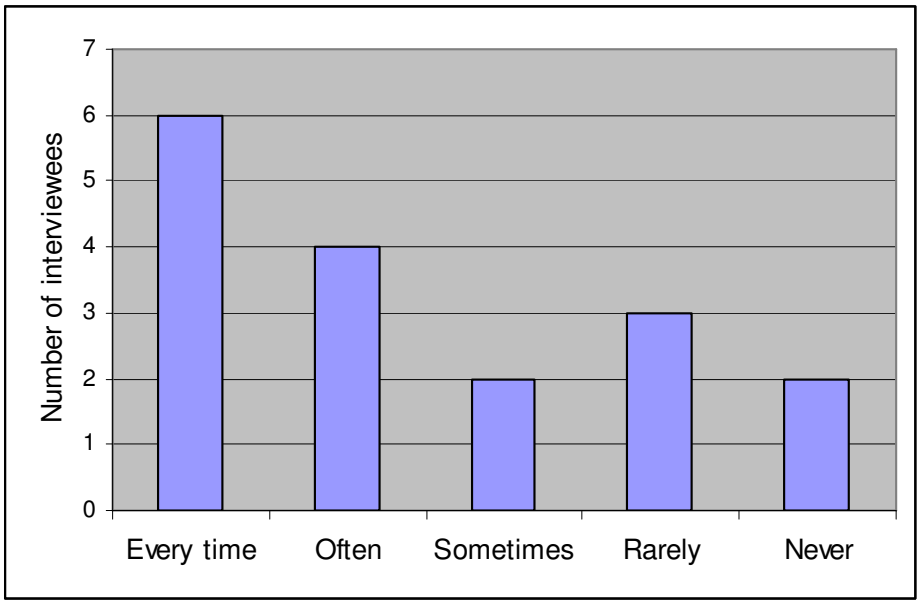

Figure 3. Frequency with which occupants turn plug sockets off at the wall.

Participants were asked to what extent they and the other occupants of the house thought about the environmental impacts of their domestic energy use and what impact this had on the way they used energy in the home. The vast majority of the participants said that they tried to use as little energy as possible to do what they needed to do in the house and to stay comfortable. Most said that they tried to minimise wasted energy wherever possible and only to use energy when necessary.

Specific examples of how participants tried to minimise energy use concerned washing (clothes and dishes), lighting and heating. Examples include:

Heating –

- Not heating the house during the day whenever possible
- Drawing curtains in the evenings to keep the heat in
- Leaving the hot water in the bath / sink to heat room
- Not heating the house unnecessarily.

Washing –

- Using eco wash on the washing machine
- Hanging washing out to dry whenever possible. The tumble drier is not the default way of drying clothes

- Only using the dishwasher once a day
- Using a larger washing machine to halve the number of weakly loads
- Washing up rather than using the dishwasher for small loads.

Lighting –

- Turning of lights in all unoccupied rooms
- Reducing the number of lights on in occupied rooms
- Turning off lights when not needed.

Several participants with solar technologies said that they tried as much as possible to carry out tasks that require hot water or electricity when their renewable technologies were able to provide sufficient power or heat. For example, those with PV systems tried to use the washing machine, dishwashers and other electric appliances when the sun was shining and the panels were providing sufficient energy. Several participants who had STHW systems had hot feed washing machines, and so were able to take advantage of the free hot water. These participants also reported having showers and baths in the evening where possible to use the hot water generated by the STHW system, rather than by their central heating system.

Five of the participants indicated that it had little effect on how they used energy and behaved at home. Two of the five participants said that the environmental impacts of their domestic energy use had influenced their decision to refurbish their houses and to install micro DE technologies, but not necessarily how they behaved and used energy in the home. One noted that they had installed the micro DE technologies so that they did not have to worry about how much energy they used.

Participants with children said that they were trying to educate their children about energy use and their effect on climate change. Most acknowledged that their children were less careful about their energy use behaviour; however some were finding that the children were starting to switch unused lighting and appliances off. One participant found that smart meters were very useful way of demonstrating energy use and the impact their behaviour could have.

2.3 Feedback on Micro DE systems

Overall happiness with the DE technologies installed.

Participants were asked ‘Overall, on a scale of 1-5 how happy are you with your DE technology / technologies’ (1= Very unhappy – 5= Very happy). This question was asked in both the first and second occupant interviews. No significant differences were found between each participant’s first and second rating. None of the differences exceeded one scale point. Participants’ ratings at the first and second interviews were averaged. Participants with ASHPs were found to be happiest with their systems (average rating 4.8). On average participants were least happy with their Biomass boilers (average rating of 3.3) and GSHPs (average rating 3.6). Figure 4 below shows the average rating for each of the technology types.

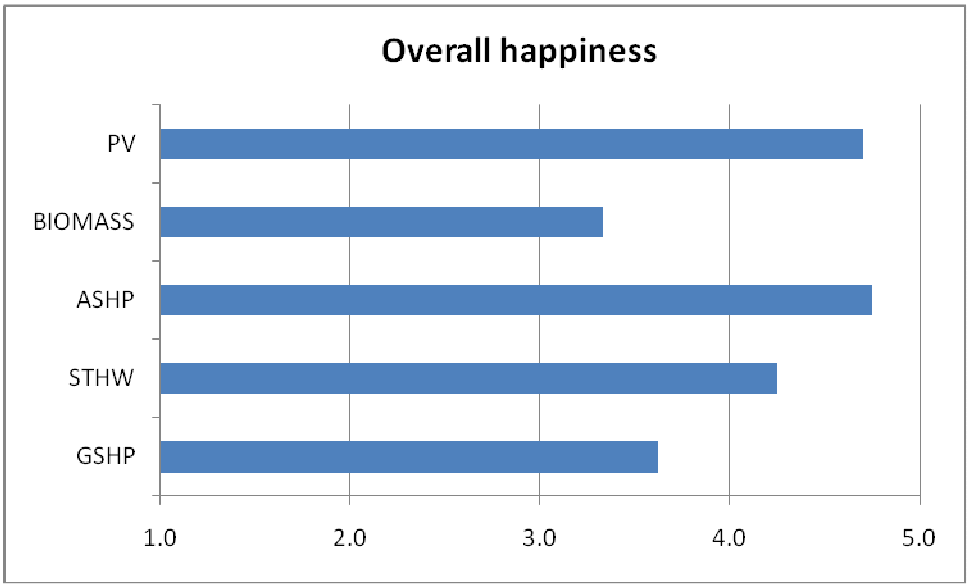

Figure 4. Average 'happiness' rating for each of the technology types

Rating the current performance of the DE technologies

Participants were asked 'Overall, on a scale of 1-5 how would you rate the current performance of your DE technology / technologies' (1= Very poor – 5= Very good). This question was asked in both the first and second occupant interviews. No significant differences were found between each participant's first and second rating. None of the differences exceeded one scale point. Participants' ratings at the first and second interviews were averaged. As with the overall happiness scale above, GSHPs and Biomass boilers were rated lowest by participants in terms of the performance of these systems. GSHPs were by far the lowest rated by participants with an average rating of just 3.3 out of 5. Figure 5 below shows the average performance rating for each of the technology types.

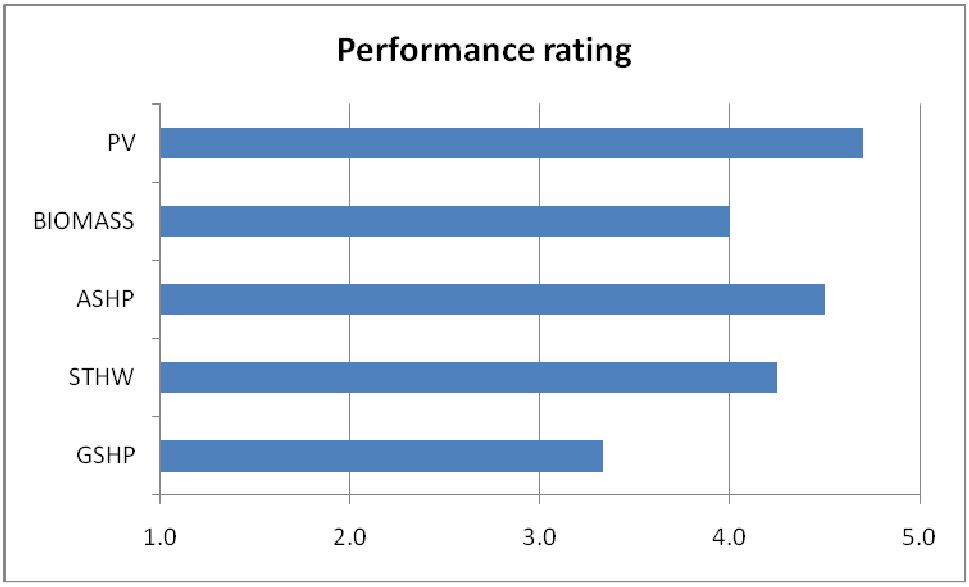

Figure 5. Average performance rating for each of the technology types

Many participants with STHW systems accepted that these systems could not provide all their hot water all year round and so their rating was based on what participants felt was achievable. One said 'you can't expect miracles with solar thermal in the UK'.

House 022 reported that the performance of their GSHP was satisfactory when the external temperature was above 0^0C, but when the external temperature dropped below freezing the system was no longer able to generate the desired internal temperature. A few of the other participants who had GSHPs reported that the systems were very slow to bring the house up to the desired temperature.

What, if anything, do occupants think is particularly good about their DE technology?

STHW and PV

Participants liked the fact that these technologies made use of 'free' solar energy and therefore reduced their reliance on fossil fuels. They liked the fact that these systems save money and energy. Many participants were pleased that these systems required very little input from occupants. Participants described the systems as 'running themselves'. Several participants liked the fact that their STHW systems alone could provide all the hot water needed for the whole household in the summer. The interviewee from house 000 noted in their second interview that they were pleasantly surprised by the performance of their STHW system. Even in the first few months of 2011 the system was often able to provide the majority of their hot water needs as well as feeding their buffer tank. Similarly, the interviewee from house 006 was also pleasantly surprised that her STHW system was still providing some heat even over the winter and on cloudy days during the spring.

PV

The interviewee from house 004 noted that one of his PV panels had been attached to a roof joist. He felt that this was a more secure and better way of installing the panels rather than securing them to other less structural parts of the roof.

ASHP

As with the STHW and PV systems, participants with ASHPs liked the fact that the systems required very little input or interaction. The interviewee from house 009 said 'It just works' and the occupants of house 020 said 'the system automatically controls itself'.

The occupants of house 020 felt that the system provided consistent heat and was quick to react to requested temperature changes. The occupants of house 023 also noted that the ASHP generally provided a stable temperature over time. However, they reported that the system was slow to bring the house up to temperature (see observations and recommendations section later in the report).

Biomass

The interviewee from house 003 was pleased that his Biomass boiler was separate from the house but still worked with the existing heating system. This meant that the installation did not require any major changes in the house. He also liked the way that the pellets were supplied and pumped / blown in to his hopper unit.

GSHP

The occupants of house 013 particularly liked the fact that the system could be installed in an outhouse rather than in the house. They were pleased that heat was always available and could be switched on or off instantly. The occupants of house 017 reported that their system was cheap to run.

What, if anything, do occupants think is particularly bad about their DE technology?

STHW

The interviewee from house 001 noted that the insulation used on the pipework was very inefficient, leading to a 3°C temperature drop between the solar manifold and the cylinder. In house 005 the interviewee reported that some pipes were laid too close to the edge of the roof and were not sufficiently insulated, which caused them to freeze in the winter. The interviewee from house 006 felt that there needed to be more feedback from the STHW system, as they could not tell what level of performance they were currently achieving and so whether the system was working optimally or not.

Biomass

The interviewee from house 018 reported that his Biomass boiler required a great deal of maintenance and attention. He felt that it was expensive to run as it had to be on all the time, whether heat was required in the house or not. He was also disappointed that the system could not feed heating and hot water to the house simultaneously.

The interviewee from house 003 found that regularly cleaning out the Biomass boiler required a certain amount of physical activity. He expressed concerns about his ability to do this in the future as he becomes older and loses mobility. He was also concerned about the amount of fumes and dust that he was inhaling every time he had to clean out the boiler. He suggested that future Biomass boilers should be easier to clean out and should require less frequent attention. His final concern was about the quality of the pellets and where they had come from, particularly the carbon miles associated with their transportation.

The participants of house 008 installed a Biomass boiler between the first and second occupant interview. They fitted a wood pellet boiler with a hopper that automatically fed the boiler. However, in their garage they could only fit a small hopper, which was not large enough to accept blown pellets, which therefore has to be fed manually into the hopper. This is time-consuming and requires considerable physical effort. The interviewee would have preferred to have the pellets blown into the hopper.

ASHP

Occupants in house 009 reported that the pump installed in their hall cupboard made a whirring noise, which they found disturbing. In the second interview they noted that the system also makes a humming sound for a minute or two when switched on. Participants from house 011 reported a similar sound when the system first comes on which lasts for a few minutes. The occupants of house 023 considered that the position and orientation of their ASHP was particularly bad. In its current position the ASHP blows cold air across the patio and the rear of building and in through the kitchen window and back door if they are open. This is particularly problematic in this household, as the kitchen window is left permanently open to allow their cats in and out. The kitchen window has become so cold on occasions that it has become frosted on the inside. Occupants suggest that the ASHP should be orientated to blow cold air down the garden, rather than across the back of the house.

GSHP

Some of the systems installed in social housing properties did not have individual thermostatic radiator valves (TRVs), which made it hard for the occupants to control the temperature in individual rooms (e.g. house 013). Occupants would like to be able to reduce the temperature in rooms that are unoccupied, and increase the temperature in occupied rooms that are currently cooler than the rest of the house. They feel that this would allow them to use their heat pump more efficiently. Some participants report that the systems are slow to bring the houses up to temperature. The interviewee from house 013 reported in

interview one that the system takes at least an hour to raise the temperature by one degree. In their second-round interview (March 2011) they also reported that their system was struggling to bring the house up to the desired temperature (23°C) over the winter period. The occupants of house 022 also reported that the system was often not generating the required temperature during cold winter spells.

How do occupants feel that the performance could be improved?

STHW

Participants in houses 001 and 005 suggested that the performance of their STHW system could be improved if the insulation on the pipework was improved. They also suggested that on future installations the length of pipework from the tubes on the roof to where the water was stored should be minimised. The interviewee from house 001 would also like to alter the delta T temperature on his system; however, his current controller will not allow him to do this. The interviewee from house 005 felt, with hindsight, that he could have harnessed more heat by installing additional panels on different parts of the roof.

The interviewee from house 002 suggested adding more solar thermal tubes to provide more hot water. Occupants of house 003 felt that the whole STHW system needed to be replaced as it was not working properly. In house 006 they felt that turning the current panels to face further south would improve performance. The interviewee at house 007 was concerned that hard water might begin to clog up the current system and reduce performance.

PV

The interviewee from house 004 thought the efficiency of future PV panels could be improved further. He noted that his new PV panel was more efficient than his old one. In particular, the new panel was found to make better use of very high light levels. He noted that the performance of the panels decreases as the panels get hot. He suggested it would be useful to have some way of cooling the panels to prevent the drop in performance at peak times.

GSHP

The interviewee from house 017 felt that he may need to adjust the 'heat curve' to improve efficiency. He has already had to do this once soon after installation, as his energy bills were extremely high. The system was trying to draw more heat from the ground than was needed. The interviewee from house 022 suggested that they may need a larger capacity system and more lagging on the external pipes.

Biomass

The interviewee from house 000 felt that the performance of his system could be improved if the insulation of the pipework in his boiler room was increased.

What would occupants change about their current system if they could?

Biomass

The interviewee from house 018 thought that the Biomass boiler may have been undersized for his house and suggested that a larger capacity system may be better suited to the size of the property.

STHW

The occupants of house 006 would like a display unit, located in a sensible place, providing useful information on the amount of heat generated and the equivalent energy / money saved. The occupant of house 007 would like to have a switchable system where two or three panels are working in shoulder

months, and only one or two in the summer. This would extend the proportion of the year when the occupant could get all their hot water from the STHW system.

The interviewee from house 019 felt that the setup of their STHW system could be improved. They feel that it is not currently set up in optimum way meaning the immersion heater comes on more often than necessary. Some of the occupants have showers in the morning, which uses the hot water. The immersion heater then automatically heats the hot water even though it is not needed again until later in the day. The solar thermal system would heat the water later that morning, but the water has already been heated by this time by the immersion heater. The interviewee would like to optimise the setup so that the immersion heater does not automatically start in the mornings after occupants have taken showers.

GSHP

The occupants of house 013 said that they would have TRVs installed on the radiators so that they could get a better temperature balance across the house. They would like to use the excess heat from the other rooms in the house to heat the lounge, which is always comparatively cold. The occupants of house 022 are so dissatisfied with their current system that they would like to 'rip it out and fit gas central heating' if they could.

ASHP

The occupants of house 023 have asked the housing association if a deflector could be installed to redirect the cold air down the garden rather than across the back of the house. They have also asked if a cat flap could be installed in the back door so that they do not have to leave the back window open.

2.4 Occupant control over the micro DE systems

How easy are the micro DE systems to control?

Participants were asked 'On a scale of 1-5 how easy to control do you find your DE technology?' The scale ran from 1-Very difficult to 5-Very easy. This question was asked in both the first and second occupant interviews. No significant differences were found between each participant's first and second rating. None of the differences exceeded one scale point. The vast majority of participants described the technologies as easy or very easy to control. Figure 6 shows the average ratings for each of the technology types. The majority of participants noted that their systems had very little to control and that they very rarely adjusted anything on their systems. Many had not touched the controls since the systems were first installed and set up. The participants said 'we don't control it we just leave it be', 'it just takes care of itself', 'the system controls itself, no input required', 'it just works', 'nothing has gone wrong so not had to interact with them' . The solar systems (STHW and PV) in particular were perceived as requiring no input or interaction. Participants reported that there was very little they could control or alter on these systems.

Some participants noted that while the systems require very little control or occupant interaction some did take time to set up properly when first installed. Others noted that because interaction with the systems was so rare (particularly STHW and PV) it was easy to forget how to use the controls. Some of the participants from social housing properties were told by the housing associations/council not to touch or adjust anything (particularly with the STHW systems).

As can been seen from Figure 6 below, Biomass boilers were described as the least easy to control. However, this was based on a comparatively small sample of participants. Many of those with Biomass boilers felt that they were still learning how to live with their system and use it most efficiently and

effectively. This system seemed to require the most amount of trial and error and required the greatest learning curve. Participants were required to interact with this system the most, and the system's performance was reliant on this interaction (i.e. cleaning it out and refuelling).

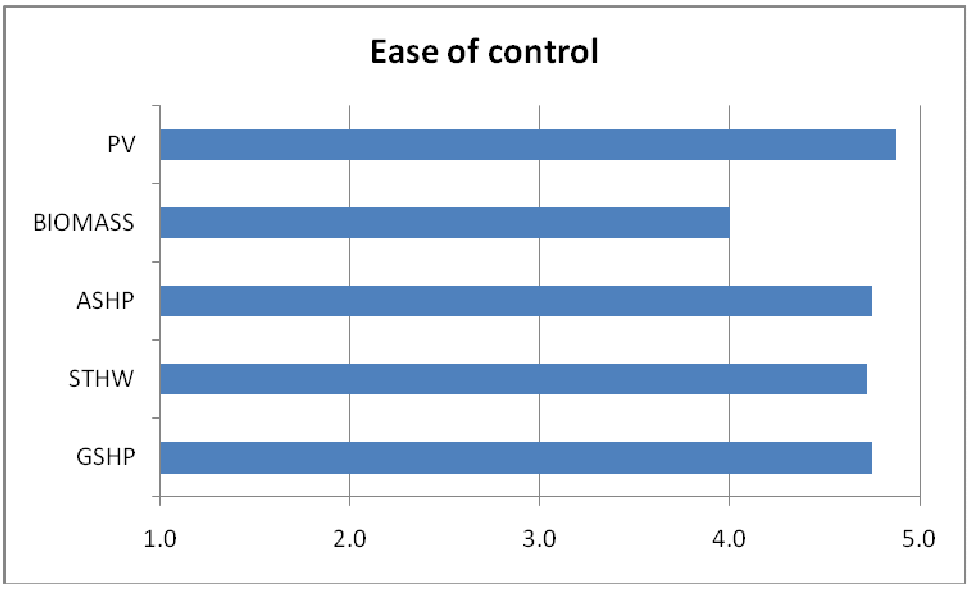

Figure 6. Average ease of control rating for each of the technology types

Occupants' level of understanding of how to control the DE systems.

Next participants were asked 'On a scale of 1-5 how well do you understand how to control your systems from 1- Not at all to 5-Completely?' This question was asked in both the first and second occupant interviews. No significant differences were found between each participant's first and second rating. None of the differences exceeded one scale point. Participants' ratings at the first and second interviews were averaged. As can be seen in Figure 7 below, the average rating for each technology was between 3.5 and 4. The level of understanding was largely dependent on the participants themselves and their level of interest and technical knowledge. The scores for the majority of products ranged from 1 or 2 up to 5. However, the scores for the air source and ground source heat pumps did not fall below 3, suggesting that those participants with these products feel that they have a fairly good understanding of how to control these systems. Further questioning later in the interview indicated that participants with heat pumps were generally referring to their central heating controls rather than to any controls associated directly with the heat pumps.

Participants noted that the level of understanding dramatically differed between different members of the household. In the second round of interviews the female occupant of House 20 said that she was able to use the control panel because she was computer literate, but noted that her husband was not able to operate the system. Often there was just one member of the household who interacted with and understood the systems. Figure 7 shows the average scores for the occupants who best understood the system.

Several participants pointed out that there was a big difference between understanding how to control the systems' day to day activity and understanding how to deal with the systems if they went wrong or behaved in an unexpected way. The findings shown in Figure 7 below show the average level of

understanding of how to control the systems' day to day running. Most participants said that they would not understand the systems well enough to diagnose or fix a problem. Recent BRE research suggests that end users' level of understanding over how their appliances and controls work is often overestimated. Occupants generally understand the controls well enough to make the systems do what they need them to do. However, they often do not control and use the systems in the most efficient or effective ways, or understand the full functionality of the system.

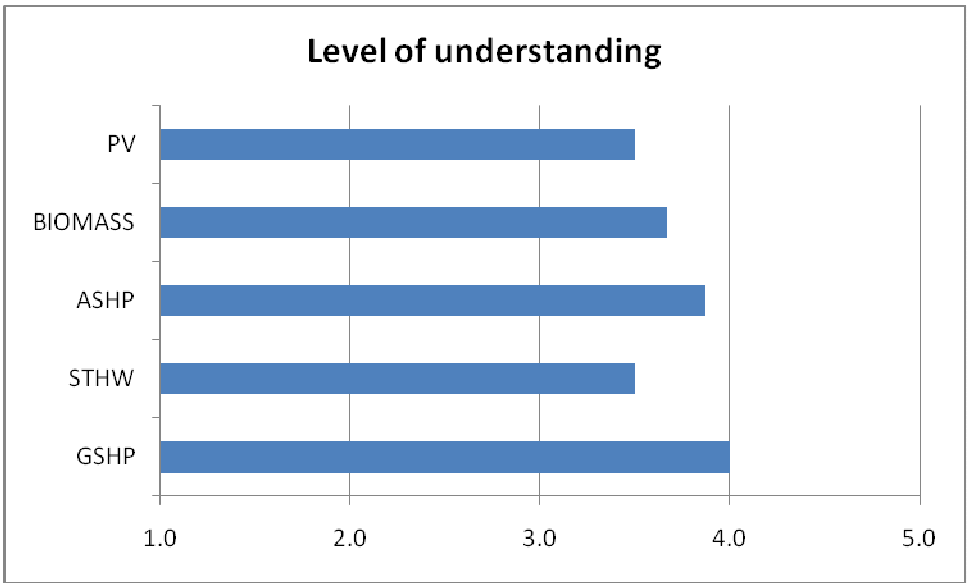

Figure 7. Average level of understanding of each of the technology types

How often do occupants look at any display readouts from their DE technologies?

Participants were asked how often they look at any display readouts from their DE technologies. Those with Biomass boilers tended to look at the digital displays once a week or once a fortnight when they were cleaning out and refuelling the boiler. Those with PV said that they tended to look every day, particularly on sunny days.

For those participants who had STHW systems, the frequency of checking the displays varied a great deal between households. It ranged from everyday to never; however, the majority said that they looked at the display at least once a day during the spring, summer and autumn when the system was fully operational. Those who do look every day tend to look at the end of the day, or before anyone has a shower, to check that there is sufficient hot water. Some controllers provided detailed information regarding the temperature of the water at different points in the system; however, others were reported to provide very little information. One household found the display unit hard to interpret and not intuitive to use, and so they tended to just listen to the pump to understand if and how the system was working.

All the participants with ASHPs said that they looked at the displays everyday; however, they were generally referring to the central heating thermostats and programmers, rather than to any displays associated with the ASHP itself. The same result was found for GSHPs; participants looked at their thermostats / programmers everyday but not at any displays on the GSHP itself. The one exception was the interviewee from house 017 who said that in addition to looking at the thermostats every day, he went out every day when the heat pump was first installed to look at the displays on the heat pump itself.

However, once the heat curve had been adjusted to improve the efficiency and optimise performance he now only checks once a month.

How often do occupants interact with the controls for their DE technology?

Participants were asked how often they interacted with the controls for their DE technologies. Those with Biomass boilers tended to interact with the controls rarely or never. The only exceptions reported were when the system has to be reset if it has run out of fuel, or restarted if there is an error. Some participants reported in the second-round interviews that they had increased the output temperature of their Biomass systems during the coldest periods of the winter (2010/2011). Some said that they were still learning how to use their boilers in the optimal way, and so were making minor adjustments to try to improve the performance (e.g. house 008). However, once they have got the system working as they want it to, they do not envisage making adjustments often. The participants who have PV systems said that they never interact with the controls.

The vast majority of participants who have STHW systems said that they very rarely or never interacted with the controls. Some of the social housing tenants were told by their councils/housing associations not to touch or interact with their STHW systems. Those who do regularly interact said that they only ever switch between the different temperature displays rather than adjusting the system in any way. In house 005 the interviewee checks how much water is in the tank every day. If the top of the tank is over 35°C, then he can use the hot water. An overall check of the system and the water pressure is done once a month or less. Other occupants (e.g. house 000 and 006) said that they switch where any excess hot water is sent to depending on the season. For example at house 000 the occupants send any excess hot water to their swimming pool in the summer and autumn but to a second water tank in the winter when the swimming pool is not used.

As with looking at the displays, participants with heat pumps said that they interacted with their thermostats, programmers, central heating controls almost every day (depending on the external temperatures). The participants interacted with the heat pumps themselves very rarely or never. Several participants manually turn the heat pumps off and on by adjusting the desired temperature on their thermostat (e.g. house 009)

The occupants of house 020 noted that the controls for their ASHP and central heating would be difficult to use for people in their 70s or 80s. They liked the fact that almost everything had been preset for them. The occupants were able to switch between five preset programs. Other more detail control was available to the end user; however, the occupants predominantly just use two of the preset programs.

Future control interfaces will need to be carefully designed as there are big differences between different consumer groups in terms of what they look for in a controller. Some want to have a fine level of control over exactly how and when their system operates, while others want the systems to be preset and not to have to interact with them at all.

What do occupants adjust most often when they interact with the controls?

Those with Biomass boilers said that other than cleaning it out, refuelling it and reset / restarting the system when it has run out of fuel, they adjusted nothing on the system. Those with PV panels also said that they did not adjust anything; many reported that there was nothing to adjust.

The majority of participants who have STHW systems also said that they did not adjust anything on their systems. However, four of the participants had adjusted (or attempted to adjust) the hot water temperature and/or the temperature at which the system stops sending hot water to the tank. The interviewee from house 005 increased the top temperature achieved before the collector switched off from 51°C to 60°C to prevent legionella growth and to provide more hot water. However, he noted in the second interview that he makes adjustments to the system very rarely. The interviewee from house 006 tried unsuccessfully to adjust the temperature at which the system would switch over to the next hot water tank. The interviewee from house 019 adjusted the hot water temperatures to control when the immersion heater would come on. The interviewee from house 000 raised the upper limit temperature of the buffer tank to 90°C to prevent the STHW stalling. This was done so that the solar fluid does not spoil, stagnate or turn to jelly.

Once again, participants with ASHPs and GSHPs only reported adjusting their thermostats or programmers to adjust either the temperature or the times the heating went on and off. None of the participants reported regularly adjusting anything on the actual air source or ground source heat pumps.

How could the control systems be improved?

The interviewee from house 000 noted that his Biomass boiler system should have been designed so that the pump turned off when the fuel ran out. This feature had to be retrofitted. The interviewee from house 018 felt that the controls for their Biomass system could be more intuitive, and that they would like more control over the system.

The most frequently suggested improvement to the control interfaces of STHW systems focussed on feedback. Several participants called for more feedback on the system outputs, when the system is working, how much hot water it is contributing and equivalent financial savings. Some of the control displays were described as not intuitive, very hard to interpret, and not telling the occupants everything they wanted to know. Participants felt that it was very difficult to monitor how well the STHW systems were performing, and that this information should be provided on the control panel/digital display.

The participants from house 019 found their GSHP control difficult to use and not intuitive. They found that they had to drill down through lots of menus to find what they were looking for and it was not clear which menu key actions would fall under. They called for a more intuitive control/display system where key functions and actions are not buried deep in submenus. Participants who did not have TRVs on their radiators called for these to be installed to increase the level of control they have over the temperatures in individual rooms.

What user information is provided with the Micro DE technologies?

The majority of participants reported receiving a brief practical demonstration from the installer and copies of the manufacturers' manuals for their systems. Most did not feel that they had received adequate information or training and were left to work out how to use the system for themselves. As has been noted earlier, many participants had left their system as it was original set to run and not adjusted anything.

The participants from houses 001 and 006 reported that their installers gave them no additional information, advice on how to use the systems or a demonstration of how the system worked. The installers of the Biomass system in house 018 were unable to give any kind of practical demonstration as they were unfamiliar with the Swedish system that they had been asked to install.

Several participants noted that their installers did not appear to be fully informed about the systems they were installing (e.g. the first PV system installed in house 004). However, others reported that their installers were very helpful and knowledgeable and that the practical demonstrations were very useful. The installer of the STHW in house 005 showed the occupants how the system worked, recommended temperature settings, and advised how to use it effectively. In addition, the company (Eco2Solar) provided a simple 'user guide' to the system as well as the manufacturer's manual. The installer of the GSHP in house 017 wrote down a simple guide for common tasks which the occupants found very useful.

Some of the manuals provided with the systems were described as "intimidating" (house 003) and "impossible to follow" (house 022). Other participants had never looked at their manuals and felt that they did not need them. This was found to be the case for many of the solar systems which were described as "plug and play" (house 019). A few of the participants, mostly with PV systems, did not receive any kind of manufacturer manual with their systems.

The interviewee from house 003 said that he panics that his Biomass boiler will go wrong and he would not know how to deal with it or what to do next. He said he would get the original installers back if anything did go wrong with his biomass boiler or STHW system. He expressed concern that if the installer went out of business he would not know what to do. He suggested there should be businesses set up to offer training, support, servicing and maintenance for micro DE technologies. He felt that there should be more firms that can maintain existing systems and provide technical support and user training. Users need to secure a long-term relationship with supplier, possibly through a service contract. It was suggested that there should be a website showing who provides these services and for which products.

It is important that occupants are given good clear information about how the system works and how to use it efficiently. This information can be passed on by the installers of new systems, although the findings of this field trial suggest that for many occupants this is not happening. However, it is important to consider how this information can be passed on to the next occupants of a property. The occupants of house 023 moved into a property that already had an ASHP installed. Initially they were just provided with a technical manual for the system and no demonstration or induction. Having never experienced a heat pump before, and not knowing anything about them, the occupants assumed that it was just like a conventional boiler. They struggled to control the system and reported being "completely flummoxed" by the technical manual. After a couple of weeks they had to ask an onsite heating engineer for help. He was able to explain how the system worked and demonstrate how to use it. However, he had to reset the controls completely. The participants report that they had been unnecessarily using the immersion heater to heat their hot water before this brief demonstration and explanation. A short time later they were given a full induction and a user guide by the housing association. However, this information may not have been passed on if the property had been privately rented or privately owned.

The effect of micro DE technologies on energy usage and bills

Many of the participants had only recently installed their DE systems, and so were unable to quantify the impact as they had not had any energy bills since the installation. Some were still learning how to use their systems and adjust them to optimise their performance so again could not say. Others felt that their energy bill had been lowered but could not say by how much. Participants with STHW systems all report a definite reduction in gas or oil usage over the summer, although they were often not able to quantify what these saving amounted to. However, some participants were able to quantify the energy generated, energy saved or impact on energy bill:

House 000 (Biomass and STHW)
The interviewee expected their winter fuel costs to be approximately a third of what they were before the installation of DE technology. In their second interview in March 2011, they estimated that their winter fuel cost had been less than half the cost of oil.

House 001 (STHW)
The interviewee reported in the second-round interview that the feedback he had received showed that his solar thermal system was providing 30% of his hot water and producing sufficient electricity to power the STHW pump.

House 003 (Biomass and STHW)
The interviewee notes that while the wood pellets are cheaper than the oil they replace, the savings will not be sufficient to pay back the installation costs in their lifetimes.

House 004 (PV and STHW)
The interviewee estimates that 1000kwh of gas has been saved by the STHW system alone. At the time of the interview they were exporting more electricity from the PV system than they were using. They are receiving more money from the feed-in tariffs than they are paying out for electricity.

House 007 (STHW and PV)
The occupant reports that her total energy costs are now less the £20 a month.

House 011 (ASHP and STHW)
The occupant reports that her energy bills have more than halved since the introduction of these technologies. She believes she saved over £500 on her 2010 energy bills and estimates she is using less energy, thanks to the micro DE technologies and improved insulation.

House 013 (GSHP)
The occupant has recently received an electricity bill that compares current usage with last year's. The bill shows that electricity use in January 2011 was less than half that of January 2010.

House 018 (PV, STHW and Biomass)
The interviewee notes that the PV system has had the most noticeable impact. Overall, the PV system is generating more electricity (2,300kwh) than the family is actually using. Much of this electricity is exported to the grid as the family are often not there to use the energy when it is generated. However, they are currently only needing to import 1,200 – 1700kw per day from the grid.

House 020 (ASHP)
The interviewee estimated in their second interview that they had been saving approximately £5 a day during the coldest parts of the winter and about £3 day in February. They estimated the amount of money spent on heating the house had halved this winter compared with the last (before ASHP installation). They estimated that the ASHP was not just saving them money but that they were using less energy.

House 022 (GSHP)
The occupants have recently had their electric storage heaters replaced with a GSHP. Unfortunately, the system has not always been able to provide them with the heat they require, and so they are supplementing the heating with a portable gas heater. They have found the GSHP is cheaper to run than the old storage heaters, but, the cost to run the portable gas heater negates any savings made.

The effects that DE technologies have on how occupants use energy in their home

Many of the participants with PV and STHW reported altering their behaviour, and the times at which they carry out certain tasks, to make maximum use of the electricity and hot water generated by the PV and STHW systems. For example, participants report taking showers or baths in the evening rather than in the mornings whenever practical. Several participants have hot water feed washing machines which they try only to put on when there is sufficient hot water generated by their STHW systems. In house 005 they have an electric shower and a shower fed by the STHW system. Whenever possible they will avoid using the electric shower. In house 004 the occupants try to use the water heated by STHW system whenever possible. When there is insufficient hot water they only heat enough hot water to complete the task that they are doing, often by using the kettle rather than heating the hot water cylinder from the boiler.

Others with PV try to use electric devices such as dishwashers and washing machines when the PV system is providing sufficient electricity. In house 018 they try to charge their laptops during the day with electricity generated by the PV, and use them on their batteries at night. In house 008 they leave the hot water in the bath or sink to supplement the heat to the room / house on colder days.

An extreme example is the occupant of house 007 (PV and STHW) who said that her life was controlled by the level and direction of the sunlight. Whenever possible she only uses hot water heated by the sun. She moves around the house during the day occupying the rooms heated by the sun at different times and her dishwasher and washing machine are only used when the sun is shining.

However, there are a few examples where the introduction of DE technologies may be leading to behaviours that result in greater energy use. For example, two of the Social Housing properties included in this field trial have replaced electric storage heaters with heat pumps. The participants report 'you can heat the house whenever you want'. They report staying up later as there is now heat available in the evening which was not the case with the storage heaters as they had always run out by early evening. One participant said that before they had their ASHP installed they could not afford to put the immersion heater on for hot water so they would save the dishes till the end of the day and then boil the kettle for the hot water to wash them. However, they report they no longer do this because they can afford to put the immersion heater on whenever they like. Other participants reported using energy without feeling guilty since the installation of the DE systems. One participant's reason for installing the technologies was so that they would not have to worry so much about how they were using energy.

Participants living in social housing properties where electric storage heaters have been replaced with heat pumps generally report they are warmer, more comfortable and happier since the installation of the heat pumps. The interviewee from house 011 said, "The ASHP has made staying at home a comfortable experience. We are happy to have a warm and comfortable home"

Drivers to investment in DE technologies

Participants were asked why they had decided to install the technologies they had in their home.

Reasons for investing in Biomass boilers included:

- There was the space for the Biomass boiler, and the old oil powered boiler was at the end of its life. The rising price of oil and LPG put them off investing in another oil fired boiler (000)
- Using a wood chip boiler would mean that they could grow their own material to feed the boiler (000)

- Biomass seemed the most appropriate heating system for the house (003). The house was not well insulated enough for a GSHP to work effectively and they felt that it would have been prohibitively expensive to insulate and lay underfloor heating.
- To reduce their carbon footprint (018)

Reasons for investing in STHW included:

- STHW is cheap to run and meant that the Biomass boiler did not need to be run over the summer for hot water (000)
- Suited property and was affordable (001)
- Achievable and affordable. To set an example for others. To test the equipment and installation before encouraging others take it up. To reduce the household carbon footprint and become more ecological. Saving money was a consideration but to a much lesser degree (005)
- Installed to save energy and because it was the most practical technology for the building. Also to lessen their reliance on natural resources and protect themselves against rising oil and gas prices (006)
- To save money (018)

Reasons for investing in PV included:

- Political statement – installed wind turbine and PV panels on listed property to show that it could be done and that planners would allow it. Also installed to reduce personal impact on climate change (007)
- The first set was installed primarily to save money. Secondly, to save energy and reduce their reliance on fossil fuels because of a perceived threat to energy security. Thirdly, to lessen their impact on climate change (004)
- A second set of PV panels was added because the first set did not qualify for the FIT scheme as they were installed too long ago. The second set was added to secure financial gain from the feed-in tariffs (004)
- To be more self reliant and sustainable, less dependent on the grid and oil. Also wanted to be a pioneer and understand better how these technologies can work and perform (008)
- Installed PV because he wanted to reduce their carbon footprint and save money but also because he was interested in PV as a “gadget / boys toy” (018)

Reasons for choosing ASHP or GSHPs included:

- Housing association offered the option of either oil powered or ASHP. They chose the ASHP because it was cheaper to run than having oil and more environmentally friendly. They said comfort was a big driver and they felt that they would be more comfortable with the ASHP (009)
- Comfort was the primary driver. Keen to try the new technology because they had electric storage heaters before and these did not generate sufficient heat and therefore the house was often cold (011)

- MacMillan Cancer Support wrote to the council to ask for an upgrade of heating. Housing association suggested AS heat pump and occupants agreed (020)
- GSHP installed to reduce energy bills and save money in the long run. House built to be a home for life, and so the GSHP was a long-term investment. Recommended by their grounds man and a person in the village who had one (017).
- GSHP (plus STHW and PV) added to help them reach code level 5 for their new build property (019).

The key recurring drivers tended to be:

- Saving money on energy bills
- Reducing personal carbon footprint and impact on climate change
- Reducing reliance on oil and gas (concerns over raising prices and possible future supplies)

Interestingly, the interviewee from house 008 reported that he had initially thought a GSHP would have been more expensive to install than Biomass boiler. However, since recently installing the wood pellet boiler he now feels GSHP may have been easier to install and because of the additional work needed to install the wood pellet boiler it worked out just as expensive to install as the GSHP would have cost.

Barriers to investment in other DE technologies

Of those participants who said that they would invest in other DE technologies, 60% said that they would invest in PV panels and 40% said that they would invest in a heat pump of some kind. They were then asked what had stopped them investing in these technologies and what were the barriers to investment. The vast majority said that the payback time before the introduction of the new feed-in tariffs had meant that PV was not financially the best option. These participants all felt that the introduction of new feed-in tariffs and the future 'Green Deal' had made PV a much more attractive option. Other reasons for not investing in PV to this point included lack of useable space on the roof, aesthetic appearance on the roof, and the cost of PV. Those with STHW and a micro DE heat source were attracted to PV as this would enable them to be more self sufficient.

Those who had considered or were considering heat pumps listed the following reasons for not investing thus far:

- House was too big and not suitably insulated for an ASHP,
- The noise generated by ASHP units,
- They felt that a GSHP would not be as carbon efficient as a Biomass boiler.
- Understood that heat pumps were not good for short burst of heating but better for keeping a house at a more constant temperature over the whole day. Therefore felt that this type of system would be less appropriate for people who are out at work all day.

Observations and Recommendations

Through visiting the houses and conducting the interviews, we have observed several ways in which the performance of the systems may be improved and the comfort of the occupants increased. This section highlights some potential interventions.

It was observed that in several households, occupants were trying to use their ASHPs GSHPs and Biomass boilers as they had their previous conventional boilers. They tended to have their systems timed to come on at certain times and only on for relatively short periods of times. These households (e.g. 013, 018, 022 and 023) tended to describe the systems as being slow to bring the house up to the desired temperature and sometimes unable to reach the desired temperature. It is suggested that these systems may be more efficiently run if they were on constantly (perhaps at a slightly lower temperature) or at least on for longer periods of time. Those participants who ran their heat pumps either continuously or for larger proportions of the day tended to describe the systems as providing a very stable temperature over time and being quick to react to temperature changes (e.g. house 020). Interestingly, in their second-round interview the interviewee from house 013 said that they were aware that some people with GSHPs run them constantly, however, they believe this is a 'waste of money'. They manually turned the system on when they felt that they needed heat. It should be noted that these participants also complained that their system took too long to heat their house and often struggled to reach the desired temperature of 23°C.

It is also recommended that:

- TRVs should be fitted in the houses with heat pumps that do not currently have them
- The insulation on the STHW system pipework of houses 001 and 005 should be improved (if this has not already been done by the occupants)
- A deflector and a cat flap should be installed for house 023
- PassivSystems experts should look at the control system for the STHW system in house 019 to see if the interaction between the STHW system and the immersion heater could be set up differently.

Very few participants mentioned any kinds of servicing and maintenance of their systems. Those with Biomass boilers tended to be more aware of the need for good servicing and maintenance. The interviewee from house 005 felt that more information was needed on:

- when the system should be serviced
- approximately how much the occupant should expect to pay for a service
- how to recognise if it breaks down or is not working properly
- what to do if it breaks down
- how the system works and what occupants need to do to keep it working efficiently and effectively.

The interviewee was referring to STHW systems; however the above is true of all the Micro DE systems looked at in this study.

2.5 Participating in the field trial

Why did participants choose to take part in this project?

The vast majority of participants said that they had chosen to take part because they were interested in the findings from the monitoring, and particularly in understanding how well their technologies were performing. They were interested to see if the systems were performing as well as they could, or whether improvements could be made to optimise performance. Some were interested in how they could use their systems more efficiently. Many also felt that the research was important and worthwhile, and so were happy to take part to support the research. For many this outweighed the potential intrusion of the monitoring. Some were happy to support the organisations that put them forward for the project, as these organisations had either paid for or installed their systems (e.g. housing associations or installers). They saw it as 'returning the favour'. A few participants were keen to take part as they had a professional interest in the findings, as their work related to micro DE technologies in some way.

For future research of this kind, it will be important to tell potential participants that they will get detailed feedback on the performance of their systems as this is likely to encourage more people to take part. It will be vital to deliver on this promise of feedback and to ensure that any additional work associated with this feedback is costed from the outset. This will help to ensure that the participants are satisfied and feel they are getting something out of it.

Reservations about taking part in the study

Before agreeing to participate and to the installation of the monitoring equipment, many of the participants reported that they had been concerned about the monitoring aspect of the field trial. Several were concerned that the monitoring might be "like big brother" and one was even concerned he could end up on the internet video clip site 'YouTube'. The term 'big brother' was frequently used by participants; however, these concerns had all been put to rest before the installation of the monitoring equipment.

Some were concerned that the wireless monitoring equipment could cause problems in their homes. Others were concerned about any potential damage or mess created during the installation of the monitoring equipment. Others were concerned about the potential cost of the electricity used to power the monitoring equipment.

Once the monitoring equipment had been installed and the monitoring had begun, the vast majority of participants did not have any concerns or reservations about participating in the study. However, a few participants reported initial problems with the installation of the monitoring equipment that meant the installers had needed to return to the property. One household was slightly concerned about how the house would be left at the end of the study once the monitoring equipment was removed. They expressed reservation about whether the house would be put back exactly as it was.

Feedback on the installations of monitoring equipment

For future field trials it is very important that the installations are conducted sensitively and that any equipment and wiring is as discreet as possible. Participants suggested that installers should aim to minimise the amount of visible wiring. Several respondents mentioned the use of coloured wiring; they much prefer white wiring to grey. One participant felt that more wireless monitoring solutions should be used on future projects. Some of the monitoring equipment was described as ugly.

Some participants felt that the presence of a representative from PassivSystems was unnecessary, especially if they were not actually involved in the installation itself. However, most said that they were happy with the final installations, the way in which they were done and how quickly the equipment was installed.

Aspects of participation that may put other people off taking part

Almost all the participants felt that the installation of monitoring equipment would put some people off participating in similar future research. Participants felt that some people would find the installation and subsequent monitoring intrusive, invasive and 'like big brother'. Both the installation and the monitoring itself were identified as 'intrusive'. One participant suggested some people might not like installers to have access into their bedrooms and for these rooms to be monitored.

The appearance of the equipment was also raised as a potential issue. One participant suggested that house-proud people may be put off by the amount of monitoring equipment on the walls, while another suggested the amount of wiring would put people off. One participant suggested that concerns over the potential implications for people's home insurance might put them off.

Several participants thought that the time commitment required and the need to be at the property for the surveys, installations, and interviews might put busy people off taking part, particularly if they needed to take time off work to be available.

For future field trials, researchers will need to be very careful how they describe the monitoring aspects of the trial to potential participants. One respondent said, "The use of the term 'monitor' suggested people will be watching you". They suggested the term 'monitoring' should be replaced by an alternative term.

When designing future trials every effort should be made to minimise the time commitments required from participants.

Did participants receive adequate information about the project?

Most of the participants said that they felt that they had received adequate information about the project and their involvement throughout their participation in the field trial. Many commented that they liked the face to face contact they had received at the start of the project. They found the project representative to be very knowledgeable and able to answer all their questions. They felt that there had been a clear explanation of what was going to happen and what they would be required to do. Only one participant felt that the face to face introduction to the project was unnecessary. This participant suggested a telephone call would have sufficed for them as they are extremely busy people.

One participant reported that the big gap in time between agreeing to take part and the installation of the monitoring equipment meant that it was hard to remember exactly what they agreed to participate in and what they would be required to do. Another participant reported that they were slow to realise the number of partners involved. For future field trials it will be important to outline very clearly exactly who is in the partnership and who will have access to the data.

Participants noted that for similar future trials it will be important to ensure that those communicating with potential participants at the start of the project have good technical knowledge to reassure potential participants and be able to answer any technical questions they may have. It will be a challenge in a

larger-scale field trial to ensure that all those meeting the participants have a good technical knowledge and a very clear understanding of the field trial and exactly what participation will entail.

In addition, it must be ensured in future trials that any participants joining the trial after the monitoring has begun (i.e. moving into a house that is already being monitored as part of the research) must be fully informed and give consent to participate before moving in.

Feedback on the householder agreement

Participants generally found the householder agreement clear and easy to understand. None of the participants interviewed reported any particular issues with the document. However, many could not remember exactly what was in the householder agreement, as they had read it and signed it long before the monitoring equipment had been installed and their first interview had been conducted. This delay meant that some participants had forgotten about the occupant interviews by the time they were scheduled. One participant suggested that the requirement to participate in occupant interviews should have been highlighted more clearly in the householder agreement and during the recruitment process, as they had overlooked / forgotten about this aspect of participation. Some participants found it very helpful to have someone take them through the document face to face and answer any questions they had. One participant noted that the insurance advice was particularly useful.

For similar trials in the future it will be important to minimise the amount of time between recruitment and the installation of the monitoring equipment/start of the field trial. If possible, it would be beneficial for some potential participants to be taken through the householder agreement face to face.

Overall, how did the participants find the recruitment process?

Almost all the participants were happy with the recruitment process. Some noted that it was quite time-consuming, but felt that it was thorough and they completely understood what was happening. One participant described the recruitment process as very good, and noted that everything was done at the occupants' convenience. Another said that they had felt fully informed throughout the field trial and that the people they had dealt with had been very professional.

As noted above, the majority of participants liked the face to face contact they had at the start of the project. They reported that the face to face explanation of the field trial and exactly what it would entail was very important. They generally felt that everything was explained clearly, and that as long as this happens for participants on future trials there should not be any problems. It may be impractical on a larger trial to have recruiters visiting all potential participants in person to explain what the field trial would entail. However, the findings from this study strongly suggest this would be preferred by the vast majority of participants.

General feedback on participation in the field trial

Generally the participants reported that they felt fully informed and were happy with the level of communication. Several noted that the installation process and the occupant interviews were rather time-consuming. Some had to take time off work to be available to let installers or surveyors in. It was suggested that that for future trials the researchers need to try to minimise the amount of participants' time required.

Receiving feedback on the performance of their systems and houses in general was an absolute key driver for participation in the study for the majority of participants. Some reported that they would have liked

more frequent and more meaningful feedback on the results of the monitoring throughout the field trial. One participant said he would like to see graphs that plotted the data daily from the monitoring equipment. Receiving feedback and information from the monitoring was seen as a key benefit of participating in the field trial. Participants suggested that the benefits of taking part in the study should be clearly outlined to potential participants, and that the more people get out of it the more likely they are to take part.

In the second round of interviews conducted in February and March 2011, participants were asked how they had found participating in the field trail overall. Generally, the findings echoed the feedback from the first interviews. The majority of occupants had found participating interesting and a good experience. The interviewee from house 001 described taking part as a "painless experience". However, a few of the participants were slightly frustrated at the lack of feedback they had received regarding the performance of their DE systems. The interviewee from house 006 said, "We haven't learnt anything yet". The housing associations responsible for some of the field trial homes were also very keen to receive feedback. They were keen to use this information to inform decisions regarding future installs. Those who had received feedback were very interested in the findings and grateful for the feedback. They found the information very informative, and it helped them to better understand their technologies.

The interviewee from house 004 praised the PassivSystems employees that he had encountered and noted that any issues had been dealt with promptly. It was suggested that similar future field trials could be improved if energy meters were installed in the properties. This would ensure that participants would not be inconvenienced by having to supply records of their energy bills, and more consistent information could be gathered. Several interviewees were very keen that the results of the study should be widely disseminated and made accessible to as many people as possible. They believe that information about these renewable technologies should be shared with all households, so that more people become aware of the environmental and financial benefits.

3 Summary, conclusion and recommendations

Heating

A significant correlation was found between occupants' rating of the internal temperatures in their homes and the average measured temperatures. The average temperatures ranged from 11.1°C – 22.2°C. None of the participants described the temperature as uncomfortably cold or hot suggesting that occupant comfort at home can be achieved over a broad range of temperatures. Many participants said that they tried to dress appropriately for the conditions and would put a jumper on rather than turn the heating up.

The occupants of nine of the eighteen field trial homes said that they used other heating devices in addition to their central heating during the heating season. Often these heating devices were used to supplement the central heating, as the central heating alone could not provide sufficient heat for some areas of the house. In other cases the additional heating devices were used to heat certain rooms when the occupants did not want to heat the whole house using the central heating. This is worth noting for future trials, since monitoring the use of a central heating system alone will not provide all the information on how occupants heat their homes and how much energy is used to do this.

The way that the central heating was controlled varied a great deal between the field trial homes. In eight of the homes the central heating was programmed to come on at particular times of the day. In six homes the central heating was left permanently on during the heating season and the temperature was moderated by a thermostat, or in some homes by multiple thermostats. In four properties the central heating was manually turned on and off as required. The way that the central heating was controlled was largely dependent on typical occupancy patterns and the type of heating system. Those who were regularly out during the day tended to have their heating programmed to come on at certain times. Those with heat pumps or Biomass boilers were more likely to have their heating on constantly.

Energy use in the field trial homes

Over two thirds of participants estimated that over three quarters of the electric lights in their house had low energy bulbs. However, the estimated percentage ranged from just 5 % (2 bulbs in the whole house) to 100%. Reasons given for not having all low energy bulbs included participants not being aware of any low energy replacements for some of the light fittings, only replacing their existing bulbs with low energy equivalents when they stopped working, and disliking the light emitted by the low energy equivalent bulbs.

Participants were much more conscious of turning the lights off in unoccupied rooms than of turning devices off that would otherwise be on standby. Several participants said that they did not turn off devices that had inbuilt clocks, such as microwaves and cookers. It took too much time to reset the clocks each time they were turned back on, and some products would not work again until the clock was set.

Many of the participants with PV and STHW reported altering their behaviour, and the times at which they carry out certain tasks, to make maximum use of the electricity and hot water generated.

Occupant feedback on the Micro DE technologies

The vast majority of participants described the technologies as easy or very easy to control, although many noted that their systems had very little or nothing to control and that they very rarely adjusted anything on their systems. Many had not touched the controls since the systems were first installed and set up. Some noted that because interaction with the systems was so rare (particularly STHW and PV) it was easy to forget how to use the controls. Some of the participants from social housing properties were told by the housing associations/council not to touch or adjust anything (particularly with the STHW systems). Participants' only interaction tended to be with their central heating controls/programmers and occasionally checking the readouts from the DE systems displays. Almost all the participants felt that their Micro DE technologies had saved them energy and money on their energy bills. However, many could not quantify what this saving was.

The level of understanding over how the systems worked was largely dependent on the participants themselves and their level of interest and technical knowledge. Participants noted that the level of understanding differed dramatically between different members of the household. Several participants also pointed out that there was a big difference between understanding how to control the systems' day to day activity and understanding how to deal with the systems if they went wrong or behaved in an unexpected way.

Future control interfaces will need to be carefully designed as there are big differences between different consumer groups in terms of what they look for in a controller. Some want to have a fine level of control over exactly how and when their system operates, while others want the systems to be preset and not to have to interact with them at all.

The quality and quantity of the information and advice provided with these systems varied a great deal. A few of the participants did not receive any kind of manufacturer's manual with their systems, and others were given no information or advice from the installers. Several participants noted that their installers did not appear to be fully up to speed and informed about the systems they were installing. It is important that occupants are given good clear information about how the system works and how to use it efficiently. This information can be passed on by the installers of new systems, although the findings of this field trial suggest that in many cases this is not happening. However, it is also important to consider how this information can be passed on to future occupants of a property.

Very few participants were aware of the servicing and maintenance needs of their systems. Those with Biomass boilers tended to be more aware of the need for good servicing and maintenance. However, participants felt more information was needed on:

- when the system should be serviced,
- approximately how much the occupant should expect to pay for a service,
- how to recognise if it breaks down or is not working properly,
- what to do if it breaks down,
- how the system works and what occupants need to do to keep it working efficiently and effectively.

The findings showed that occupants with Biomass boilers and GSHPs were the least happy overall with their systems and rated the performance of these systems lower than the other technologies looked at in this study. Biomass boilers were described as the least easy to control. Many of those with a Biomass boiler felt that they were still learning how to live with their system and use it most efficiently and effectively. This technology seemed to require the most amount of trial and error and had the greatest learning curve.

For the field trial participants, the key drivers to investment in micro DE technologies were: saving money on energy bills, reducing personal carbon footprint and impact on climate change, and reducing their reliance on oil and gas (having concerns over rising prices and possible future supplies). Of those participants who said that they would invest in other DE technologies if they had the money and time, 60% said that they would invest in PV panels. The vast majority said they had not previously invested in PV because the payback time before the introduction of the new feed in tariffs had meant PV was not financially the best option. These participants all felt that the introduction of new feed in tariffs and the future 'Green Deal' had made PV a much more attractive option.

STHW and PV

Many participants liked the fact that the majority of these systems required very little input or interaction and essentially ran themselves. Several occupants felt that the pipework for their STHW systems was too long and not sufficiently insulated. It was suggested that on future insulations, the pipework from the tubes on the roof to the water tank should be well insulated and the length should be minimised.

Biomass

Occupants with biomass boilers liked the fact the systems could be installed away from the house and that they did not require any major alterations to the existing central heating systems. However, several noted that these systems required a great deal of attention, cleaning, interaction and maintenance. Participants were required to interact with this system much more than the other systems, and the system's performance was reliant on this interaction (i.e. cleaning it out and refuelling). Some were disappointed that the systems could not provide heating and hot water simultaneously.

ASHP

Occupants with ASHPs generally felt that these heat pumps provided consistent and stable heat when the systems were on. However, many reported that they were slow to bring the house temperature up if they were off for any length of time. The cold air released by the system was found to be an issue if the unit was orientated badly. Participants generally felt that they had a fairly good understanding of how to control these systems; however, when talking about controlling the system the participants were generally referring to the central heating thermostats and programmers rather than to the ASHP itself.

GSHP

Occupants with GSHPs reported that they were cheap to run, and they liked the fact heat was instantly available. However, some occupants reported that the systems were not capable of generating the required internal temperature during particularly cold winter periods. Some were using supplementary heating, and others were so dissatisfied with the performance that they said they would like to rip it out and replace it with a gas-fired boiler. As with the ASHPs, the GSHPs were reported to be slow to heat the homes if they were turned off for any length of time. The lack of TRVs provided with some installations made it difficult for the occupants to control the temperature in individual rooms. Occupants noted that these systems need to be carefully set up to work efficiently.

It was observed that in several households, occupants were trying to use their ASHPs, GSHPs and Biomass boilers as they had their previous conventional boilers. They tended to have their systems timed to come on at certain times and only to be on for relatively short periods of time. These households tended to describe the systems as being slow to bring the house up to the desired temperature and sometimes unable to reach these temperatures. It is suggested that these systems may be more efficiently run if they were on constantly (perhaps at a slightly lower temperature) or at least on for longer periods of time. Those participants who ran their heat pumps either continuously or for larger proportions of the day tended to describe the systems as providing a very stable temperature over time and being quick to react to temperature changes.

Lessons learnt for future trials

The vast majority of participants said that they had chosen to take part in the field trial because they were interested in the findings from the monitoring, and particularly in understanding specifically how well their technologies were performing. Receiving feedback on the performance of their systems and houses in general was an absolute key driver for participation in the study for the majority of participants, and is very likely to continue to be a key driver for similar future trials. Participants suggested that the benefits of taking part in the study should be clearly outlined to potential participants, and that the more people get out of it the more likely they are to take part. However, if this kind of feedback is offered, the work associated with its delivery, level of detail and frequency must be carefully considered and costed.

Before agreeing to participate, many of the participants reported that they had been concerned about the monitoring aspect of the field trial. Several were concerned that the monitoring might be “like big brother”. Participants felt that some people would find the installation and subsequent monitoring intrusive and invasive. For future field trials researchers will need to be very careful how they describe the monitoring aspects of the trial to potential participants. One respondent said, “The use of the term ‘monitor’ suggested people will be watching you”. They suggested that the term ‘monitoring’ should be replaced by an alternative term.

The appearance of the monitoring equipment was also raised as a potential issue for similar future trials. Some of the equipment was described as ugly. For future field trials it is very important that the installations are conducted sensitively and that any equipment and wiring is as discreet as possible. Participants suggested that installers should aim to minimise the amount of visible wiring. Several respondents mentioned the use of coloured wiring; they generally prefer white to grey. Others were concerned about any potential damage or mess created during the installation of the monitoring equipment or the removal of the equipment at the end of the trial.

Several participants thought that the time commitment required and the need to be at the property for the surveys, installations, and some interviews might put busy people off taking part, particularly if they needed to take time off work to be available. When designing future trials every effort should be made to minimise the time commitments required from participants.

Many commented that they liked the face to face contact they had received at the start of the project. They particularly found it very helpful to have someone take them through the house holder agreement face to face and answer any questions they had. They found the project representative to be very knowledgeable and able to answer all their questions, and felt that there had been a clear explanation of what was going to happen and what they would be required to do. If possible, it would be beneficial for potential participants of future trials to be taken through the householder agreement face to face.

Participants noted that for similar future trials it will be important to ensure that those communicating with potential participants at the start of the project have good technical knowledge to reassure people and be able to answer any technical questions they may have. However, it will be a challenge for a larger scale field trial to ensure that all those meeting the participants have a good technical knowledge and a very clear understanding of the field trial and exactly what participation will entail. It may be that other forms of direct communication need to be considered such as telephone calls.

Participants generally found that the householder agreement used for this trial was clear and easy to understand. None of the participants interviewed reported any particular issues with the document. However, many could not remember exactly what was in the householder agreement, as they had read it and signed it long before the monitoring equipment had been installed and their first interview had been conducted. For similar trials in the future it will be important to minimise the amount of time between recruitment and the installation of the monitoring equipment/start of the field trial. In addition, it must be ensured in future trials that any participants joining the trial after the monitoring has begun (i.e. moving into a house that is already being monitored as part of the research) must be fully informed and give consent to participate before moving in.

Several interviewees were very keen that the results of the study should be widely disseminated and made accessible to as many people as possible. They believe that information about these renewable technologies should be shared with all households, so that more people become aware of the environmental and financial benefits.

Appendix A – The technologies installed in each field trial home

House ID number	Owner occupier (OO) or Social Housing (SH)	Micro DE technologies installed and being monitored				
		PV	STHW	Biomass	ASHP	GSHP
000	OO		✓	✓		
001	OO		✓			
002	OO		✓			
003	OO		✓	✓		
004	OO	✓	✓			
005	OO		✓			
006	OO		✓			
007	OO	✓	✓			
008	OO	✓	✓	✓		
009	SH				✓	
011	SH		✓		✓	
013	SH					✓
017	OO					✓
018	OO	✓	✓	✓		
019	OO	✓	✓			✓
020	SH				✓	
021	SH		✓	✓		
022	SH					✓
023	SH				✓	
Total	OO=**12**, SH=**7**	**5**	**13**	**5**	**4**	**4**

Note - the occupants of house 002 pulled out of the field trial after their first interview. The occupants expressed concerns that the wireless monitoring equipment was making their children ill.

Appendix B – Interview 1 full schedule.

Data collection point 1 – Interview schedule

Introduction

- The main purpose of the interview is to understand how you use your house and the systems / appliances installed in it. We are also interested in how comfortable you find the conditions

- The interview will take between 60 and 90 minutes. There are no right or wrong answers to these questions. Please be as honest as possible, your answers will not be judged by anyone. We are interested in <u>your</u> experiences and behaviours.

- If there are any questions you feel uncomfortable answering just let me know and we will move on to another question.

- All the information you give will be entirely confidential. All notes and recordings will be securely stored and destroyed at the end of the research. Your answers will only be used for the purposes of this research project and will only be made available to the project partners. Any reported findings will be anonymised.

- The project partners are: PassivSystems, EDF energy, UCL, BRE and the client is ETI

Basic Demographic information

I'd like to start by asking you some questions about yourself and the other people who live in the property.

Questions	**Answers recorded here**
1. How long have you lived in this house?	
2. Please can you confirm what renewable technologies you have installed in this house?	
3. Did you live in this house prior to the instillation of the renewable technology / technologies?	
4. Including you, how many adults (aged 18 and over) live in the house?	

5. How many children (under 18) live in the house?	
6. What is the age and sex of the people living in the house?	

Section 1. Occupancy patterns

The next set of questions is about the house and how it is occupied. These questions will help us to understand typically who is in the house and when the house is occupied. This information will help us to interpret and understand the physical monitoring data we are collecting.

Questions	**Answers recorded here**
1. Do you have anyone who lives in the house for part of the year and elsewhere for the rest of the year? (E.g. children who live elsewhere during university or school term times or people who work away for periods of time?) • If so when is the house occupied by this person / these people?	
2. On average, how often do you have guests visiting the house but <u>not</u> staying overnight? (Once a week, once a fortnight, once a month, once a quarter, once every 6 months, once a year)	
3. On average, how often do you have guests staying one or more nights at the house? (Once a week, once a fortnight, once a month, once a quarter, once every 6 months, once a year.)	
4. Over a typical week, when is the house occupied and by whom? Do you have a regular pattern? • Probe regarding normal working hours, school times etc	

5. Do you and the other occupants partake in any <u>regular</u> activities that bring additional people to the house or mean you spend time away from the house (eg regular group meetings at the house, or clubs / society meetings elsewhere). • If so, typically, when do these activities take place?	
6. Over the next 12 months do you have any planned holidays or extended periods when the house will not be occupied? • If so when will these periods be and how long will you be away from the house for? (if you prefer you can contact us after any periods spent away from the house)	
7. Do you have any planned periods when there will be people coming to visit, e.g. Christmas or family members coming for holidays? • If so when will these periods be and how long?	
8. Where do people spend most of their time when at home?	
9. Why do occupants particularly like spending time in these areas?	

10. Generally, do the occupants of this house tend to spend their free/spare time in the house or away from the house? <u>Rate on scale of 1-5.</u> 1= Majority of free time spent in the house 5= Majority of free time spent away from the house • If there is a marked difference between the occupant rate for each occupant	

Section 2. Environmental conditions in the house
The next set of questions is about how comfortable you find the conditions in your house and how easy it is to control the temperature, lighting, ventilation etc.

Temperature

Questions	**Answers recorded here**
1. Generally, how would you describe the temperature in the house during the coldest months of year? 1 Uncomfortably cold, 2 comfortably cool, 3 comfortable, 4 comfortably warm, 5 uncomfortably hot.	
2. Generally, how would you describe the temperature in the house during the hottest months of year? 1 Uncomfortably cold, 2 comfortably cool, 3 comfortable, 4 comfortably warm, 5 uncomfortably hot.	
3. Generally, how stable do you find the temperature in the house? 1=Very unstable – 5=Very stable	
4. Generally, how easy is it to control the temperature in the house and get the	

temperature to a comfortable level? 1=Very difficult to control – 5 Very easy to control	
5. Are there any particular issues with the temperature or temperature control in any specific rooms or areas of the house? • Are there any particular hotspots / cold spots in the house?	

Lighting

Questions	**Answers recorded here**
6. Generally, on a scale of 1-5 how would you describe the amount of daylight entering the house? 1= very little – 5= a great deal	
7. Are there any areas of the house where you need to have the electric lights on during daylight hours?	
8. Do you feel that you have adequate control over the level of electric light? • Do you use dimmer switches or dimmer lamps / up lighters in any areas?	
9. Are there any particular issues with the lighting or lighting control in any specific rooms or areas of the house?	
10. What proportion of the electric lighting in the house has low energy bulbs?	

11. Why do you not use low energy bulbs in some lights? (not aware of this type of low energy bulb, low energy bulbs of this type are too expensive etc…?)	

Ventilation and air quality

Questions	**Answers recorded here**
12. Overall, how would you describe the ventilation and air quality in the house? (1=very poor – 5 =very good)	
13. How do you control the ventilation in the house? • Do you feel you have enough control?	
14. Do you tend to open windows in the heating season as well as the summer months to ventilate the house?	
15. Do you use any electric fans or de-humidifiers to improve the ventilation and air quality in the house? • If so where do you use them?	
16. Have you experienced problems with mould or condensation in any parts of the house? • If so where?	
17. Are there any particular issues with the ventilation or ventilation control in any specific rooms or areas of the house?	

Section 3. Typical energy use and behaviour

In this section I would like to go into a bit more detail regarding how you control your house and in particular how you heat and cool the building.

Questions	Answers recorded here
1. Generally, is there one person in the house who takes responsibility for controlling the heating and hot water? • If so who is it that controls these systems?	
2. Typically, how do you as a household heat the house during the coldest months of the year? (Central heating, separate heating devices in individual rooms, a mixture of the two?)	
3. When the house is occupied during the coldest months of the year do you tend to have the central heating on *constantly* or *timed* to come on at certain times?	
4. Generally is the whole property heated or do you have unoccupied rooms that are not heated?	
5. Do you use separate heating devices in any rooms <u>in addition to</u> the central heating? (E.g. oil filled radiators, electric fan heaters, gas/electric fires, wood burning stoves etc.) • If so what devices do you use and in what rooms?	

6. Typically, how do you as a household heat the house in the spring and autumn? (e.g. Central heating on for shorter periods of time, or separate heating devices in individual rooms?)	
7. Do you have any heating or electricity supplied to any outbuildings? • If so what do you have and where? • How often do you use these outbuildings?	
8. Typically, how do you cool the house during hot periods?	
9. Do you ever use cooling devices such as fans or portable air conditioning units to cool the house / increase air movement during hot periods? • If so what devices do you use and where do you use them?	
10. Which appliances in the house (or outbuildings) do you think use the most amount of power? • E.g. kettles, immersion heater, kids games consoles, large TV in the lounge, tools in the outbuildings etc?	
11. Do you have an idea how much energy you use? (not the cost)	

Interaction with touch points and controls

Questions	Answers recorded here
1. How is your hot water heated?	
2. Do you have an immersion heater for your hot water? • If so how regularly do you use it?	
3. Do you have your hot water timed to come on at certain times during the day? • If so do you time the hot water to come on at different times for different days of the week? • Do you change the timings depending on the season?	
4. What type of shower(s) do you have? • Fed from the tap • Electric shower (electric heating element) • Power shower (electric pump) (Are the electric showers used all year round?)	
5. What type of bath(s) do you have? • Standard • Corner • Whirlpool / Jacuzzi bath	
6. Do members of the household generally take showers or baths?	

7. How often do you and the other people in the house turn the lights off in unoccupied rooms / areas? (Every time, often, sometimes, rarely, never)	
8. Do you turn plug sockets off at the wall for items that would otherwise use some electricity, e.g. appliances with standby, chargers etc? (Whenever they are not in use, sometimes, rarely, never)	
9. On a scale of 1-5 to what extent do **you** think about the environmental impacts of your energy use when at home? 1= Not at all – 5= a great deal	
10. What impact, if any, does this have on the way **you** use your house?	
11. On a scale of 1-5, to what extent do you think **other members** of your household consider the environmental impacts of their energy use? 1= Not at all – 5= A great deal	
12. What impact, if any, does this have on the way that **they** use this house?	

Section 4. DE technologies

This section of questions relates directly to your DE technology / technologies and your experiences of using them.

Questions	Answers recorded here
0. When were your DE technologies installed?	
1. Whose decision was is to install the renewable technologies you have in your home? • Why did you decide to install the technologies you have in your home?	
2. What information were you provided with about how to use your DE technology and who provided you with the information? • Instruction manuals • Practical demonstration • User guide	
3. Overall, on a scale of 1-5 how happy are you with your DE technology / technologies. 1= Very unhappy – 5=Very happy	

4. On a scale of 1-5 how would you rate the current performance of your DE technologies? 1 = Very poor – 5 Very good	
5. On a scale of 1-5 how easy to control do you find your DE technology? 1= Very difficult – 5=Very easy • Note any aspects that make it difficult to control.	
6. On a scale of 1-5 How well do you understand how to control your systems? 1=Not at all – 5= completely	
7. What, if anything, do you think is particularly good about your DE technology?	
8. What, if anything, do you think is particularly bad about your DE technology?	
9. In what ways do feel the performance could be improved?	

10. What would you change about your current system if you could?	
11. Does your system have display controls? • If so what kind? (Digital display?) If possible take picture with permission.	
12. In what ways do you feel the controls systems could be improved?	
13. How often do you look at any display readouts from your DE technology? (Everyday, once a week, once a month, once a quarter?)	
14. How often do you interact with the controls for your DE technology? (Everyday, once a week, once a month, once a quarter?)	
15. What do you adjust most often when you interact with the controls?	
16. Does your renewable technology always provide you with the power / heat you need when you need it? • If not, how could this be improved?	

17. If you find you have more than you need, what do you do with any excess power/heat/hot water?	
18. What effect, if any, has the DE technology had on your energy bills?	
19. What effect, if any, has the DE technology had on how you use energy in your home?	
20. How do your renewable technologies interact with the fossil fuel power you use?	
21. Do you have any other feedback you would like to give us about your DE technology?	

Home owners only 22. If you had the time and money would you invest in other DE technologies? • If so what would you invest in and why? • What has stopped you investing up to this point in time?	

Section 5. Participation in the study

I would like to ask you some questions about why you chose to take part in this study. This project is a pilot for a much larger study looking at many more homes in the UK, so we are keen to learn lessons from you and your experiences.

Questions	**Answers recorded here**
1. Why did you choose to take part in this project?	
2. (Removed)	
3. Do you currently have any concerns or reservations about participating in the study? • If so what are they?	
4. Did you have any reservations about taking part in the study before you agreed to participate? • If so what were the reservations?	

5. Are there any aspects of participating in this study you feel would put <u>other people</u> off taking part?	
6. Do you feel you have received adequate information about the project and your involvement?	
7. What did you think of the householder agreement? Was it clear and easy to understand? • Is there any ways you feel it could be improved for future studies?	
8. Overall how did you find the recruitment process? • Is there anything that could be improved upon?	

Section 6. Detailed Occupant demographic information

Finally, I would like to ask you some more detailed questions about those living in the house. We are collecting this information to allow us to compare the findings from this study with the findings from other larger studies.

Micro Distributed Energy and Energy Services Management
Application to existing UK residential buildings

Remember- If there are any questions you feel uncomfortable answering just let me know and we will move on to another question. All the information you give will be entirely confidential.

<table>
<tr><th>Questions</th><th>Answers recorded here</th></tr>
<tr><td>1. What is the marital status of those living in the house?</td><td>1 Married/civil partnership,
2 Co-habiting,
3 Lone parent,
4 Other multi person arrangement,
5 Single person occupancy</td></tr>
<tr><td>2. Which of these descriptions best applies to each of the occupants living in the house?</td><td>
<table>
<tr><td></td><td>Working: 30 hours a week or more</td></tr>
<tr><td></td><td>Working: less than 30 hours a week</td></tr>
<tr><td></td><td>Government training scheme</td></tr>
<tr><td></td><td>Long-term sick or disabled</td></tr>
<tr><td></td><td>Registered unemployed</td></tr>
<tr><td></td><td>Not registered unemployed but seeking work</td></tr>
<tr><td></td><td>Looking after children/home/family</td></tr>
<tr><td></td><td>Caring for a disabled or elderly person</td></tr>
<tr><td></td><td>Retired (including retired early)</td></tr>
<tr><td></td><td>Student</td></tr>
<tr><td></td><td>Other</td></tr>
</table>
</td></tr>
<tr><td>3. What is the highest level of education achieved by the adults living in the house?</td><td>
<table>
<tr><td></td><td>No qualifications</td></tr>
<tr><td></td><td>GCSE/O-level/CSE/NVQ1/NVQ2 or equiv</td></tr>
<tr><td></td><td>A-level/NVQ3 or equiv</td></tr>
<tr><td></td><td>NVQ4/NVQ5 or equiv</td></tr>
<tr><td></td><td>Degree/HNC/teacher training/nursing</td></tr>
<tr><td></td><td>Post graduate degree/MSc/MA</td></tr>
<tr><td></td><td>PhD/DPhil or equiv</td></tr>
</table>
</td></tr>
</table>

4. This card shows various possible sources of income. Can you please tell me which kinds of income occupants of this household receive?

	Earnings from employment
	Earnings from self-employment
	Pension from former employer
	Personal pension
	State pension
	Child benefit
	Income support
	Tax credits
	Other state benefits
	Interest from savings
	Interest from investments
	Other kinds of regular allowance from outside the household
	Income from rent
	Other sources
	No source of income

5. Thinking of the household as a whole, which band represents the total income of the household before all deductions?

	WEEKLY	MONTHLY	ANNUAL
A	Up to £49	Up to £216	Up to £2,599
B	£50 up to £99	£217 up to £432	£2,600 up to £5,199
C	£100 up to £199	£433 up to £866	£5,200 up to £10,399
D	£200 up to £299	£867 up to £1,299	£10,400 up to £15,599
E	£300 up to £399	£1,300 up to £1,732	£15,600 up to £20,799
F	£400 up to £499	£1,733 up to £2,166	£20,800 up to £25,999
G	£500 up to £599	£2,167 up to £2,599	£26,000 up to £31,199
H	£600 up to £699	£2,600 up to £3,032	£31,200 up to £36,399
I	£700 up to £799	£3,033 up to £3,466	£36,400 up to £41,599
J	£800 up to £899	£3,467 up to £3,899	£41,600 up to £46,799
K	£900 up to £999	£3,900 up to £4,332	£46,800 up to £51,999
L	£1000 or more	£4,333 or more	£52,000 or more

- Thank interviewee for their time.
- Explain when the next interview will be.

Appendix C – Interview 2 full schedule

Data collection point 2 – Interview schedule

Introduction

- The main purpose of this interview is to understand if anything has changed since the first interview in terms of how you use your house and the technologies in it and your comfort levels. We are also interested in getting further feedback on how you feel your domestic energy technology/technologies are performing

- This interview will be shorter than the last and will take between 20 and 30 minutes. As with the last interview there are no right or wrong answers to these questions. Please be as honest as possible, your answers will not be judged by anyone. We are interested in <u>your</u> experiences and behaviours.

- If there are any questions you feel uncomfortable answering just let me know and we will move on to another question.

- All the information you give will be entirely confidential. All notes and recordings will be securely stored and destroyed at the end of the research. Your answers will only be used for the purposes of this research project and will only be made available to the project partners. Any reported findings will be anonymised.

Explain that this info is needed when the initial phone call is made	
1. Please could you tell me the exact make and model of your system(s)? (This information should be available from any user guide or technical manual provided with the system or on the device itself)	
2. Which company installed your system(s)?	

Basic Demographic information

I'd like to start by asking you some questions about yourself and the other people who live in the property.

Questions	Answers recorded here
1. Since the first interview, has anyone moved out or moved in to the house? (i.e. are exactly the same people living in the house) (if yes, ask questions 1a – 1b)	
1a. What is the age and sex of the people living in the house?	
1b. Do you have anyone who lives in the house for part of the year and elsewhere for the rest of the year? (E.g. children who live elsewhere during university or school term times or people who work away for periods of time?) If so when is the house occupied by this person / these people?	

Section 1. Occupancy patterns

The next set of questions is about the house and how it is occupied. These questions will help us to understand typically who is in the house and when the house is occupied. This information will help us to interpret and understand the physical monitoring data we are collecting.

Questions	Answers recorded here
1. Since your last interview has the frequency of visitors to your home changed? (i.e. guests visiting and either staying the night or just visiting during the day/evening) (if yes, ask questions 1a – 1b)	

1a. On average, how often do you now have guests visiting the house but <u>not</u> staying over night? (Once a week, once a fortnight, once a month, once a quarter, once every 6 months, once a year)	
1b. On average, how often do you now have guests staying one or more nights at the house? (Once a week, once a fortnight, once a month, once a quarter, once every 6 months, once a year.)	
2. Since the last interview have the occupancy patterns changed in any way? (i.e. when occupants are generally in or away from the house) (if yes, ask question 2a)	
2a. Over a typical week, when is the house occupied and by whom? Do you have a regular pattern? • Probe regarding normal working hours, school times etc	
3. Do you and the other occupants partake in any <u>regular</u> activities that bring additional people to the house or mean you spend time away from the house (e.g. regular group meetings at the house, or clubs / society meetings elsewhere)? • If so, typically, when do these activities take place?	
4. Over the next 12 months do you have	

any planned holidays or extended periods when the house will not be occupied? • If so when will these periods be and how long will you be away from the house for (length of time in each month)? (if you prefer you can contact us after any periods spent away from the house)	
5. Do you have any planned periods when there will be people coming to visit, e.g. Christmas or family members coming for holidays? • If so when will these periods be and how long (length of time in each month)?	
6. Have there been any changes in the amount of time household members spend in the house? If yes, please rate on scale of 1-5 below the current amount of spent in the home: 1= Majority of free time spent in the house 5= Majority of free time spent away from the house • If there is a marked difference between the occupant rate for each occupant in the household	

Additional Questions	
1. Have there been any structural changes to your home since the last interview? If yes, what has changed?	
2. Do you plan to make any structural changes to your home in the next 12 months? If yes, what is planned?	

3. Since the last interview, have you installed any insulation to your home? If yes, what have you done?	
4. Since the last interview, have there been any changes in your home that might affect energy usage?	

Section 2. Environmental conditions in the house

The next set of questions is about how comfortable you find the conditions in your house and how easy it is to control the temperature, lighting, ventilation etc.

Temperature

Questions	**Answers recorded here**
1. Generally, how would you describe the temperature in the house over the recent winter period? 1 Uncomfortably cold, 2 comfortably cool, 3 comfortable, 4 comfortably warm, 5 uncomfortably hot.	
2. Over the winter period, how easy has it been to control the temperature in the house and get the temperature to a comfortable level? 1=Very difficult to control – 5 Very easy to control	
3. Are there any areas in the house where the temperature is particularly hot or cold?	

Lighting

Questions	**Answers recorded here**
4. Since the last interview, have you made any changes to the amount of low energy bulbs in the house? If yes, What proportion of the electric lighting in the house has low energy bulbs?	

Ventilation and air quality

Questions	Answers recorded here
5. Since the last interview have you experienced any problems with mould or condensation in any parts of the house? If so where?	

Section 3. Typical energy use and behaviour

In this section I would like to go into a bit more detail regarding how you control your house and in particular how you heat and cool the building.

Questions	Answers recorded here
1. During the winter months, how have you heated the house? (Central heating, separate heating devices in individual rooms, a mixture of the two?)	
2. During the winter months, did you tend to have the central heating on *constantly* or *timed* to come on at certain times?	
3. Generally has the whole property been heated or have you had any unoccupied rooms that have not been heated?	
4. Do you heat any rooms in the house to a higher or lower temperature than the other rooms in the house? • If so which rooms and why?	
5. Have you used any separate heating devices in any rooms <u>in addition to</u> the central heating over the winter months? (E.g. oil filled radiators, electric fan heaters, gas/electric fires, wood burning stoves etc.)	

If so what devices have you used and in what rooms?	
6. As the temperature increases, how do you anticipate heating the house in the spring? (e.g. Central heating on for shorter periods of time, or set to lower temperature, use separate heating devices in individual rooms?)	
7. How conscious are you of the energy you use in your home. 1. Not at all – 5 Very conscious	
8. Do you make a conscious effort to save energy in your home?	
9. What do you and the other members of your household do to save energy?	

Interaction with touch points and controls

Questions	**Answers recorded here**
1. Since the last interview, have there been any changes in the way that your hot water is heated? (if yes, ask questions 1a – 1c)	
1a. How is your hot water currently heated?	

1b. Do you have an immersion heater for your hot water? • If so how regularly are you using it?	
1c. Do you currently have your hot water timed to come on at certain times during the day? • If so do you time the hot water to come on at different times for different days of the week? • Do you change the timings depending on the season?	
2. Since the last interview have there been any changes to the type of shower or baths in your house? (if yes, ask questions 2a – 2c)	
2a. What type of shower(s) do you now have? • Fed from the tap • Electric shower (electric heating element) • Power shower (electric pump) (If they have an electric shower, ask if this is used all year round?)	
2b. What type of bath(s) do you now have? • Standard • Corner • Whirlpool / Jacuzzi bath	

Section 4. DE technologies

This section of questions relates directly to your DE technology / technologies and your experiences of using them.

Additional Question for households with Biomass only (see trial list)	**Answers recorded here**
1. What fuel are they using (rape seed oil pellets, wood pellets, typical size or weight – should say on the bag or invoice)	
2. Roughly how much fuel are they using (let them define the weight / period e.g. 3 tons a season or 2x 500kg bags a week etc)	

Questions	**Answers recorded here**
(If not sufficiently covered in interview 1 ask the following) 1. Why did you choose to install renewable technologies in your home? Prompts – green bling – was its appearance important? Comfort – Moral conscience – climate change Energy saving -	
2. On a scale of 1-5, how happy have you been with your DE technology/technologies since the last interview? 1= Very unhappy – 5=Very happy	

3. On a scale of 1-5, how would you rate the performance of your DE technologies since the last interview? 1 = Very poor – 5 Very good	
4. On a scale of 1-5 how easy to control have you found your DE technology since the last interview? 1= Very difficult – 5=Very easy • Note any aspects that make it difficult to control.	
5. On a scale of 1-5 How well do you currently understand how to control your systems? 1=Not at all – 5= completely	
6. Since the last interview have you noticed anything particularly good or bad about your DE technology? What features were good? What features were bad?	
7. In what ways (if any) do feel the performance could be improved	
8. Are there any ways you feel the controls systems could be improved?	

9. Since the last interview how often have you looked at any display readouts from your DE technology? (Everyday, once a week, once a month, once a quarter?)	
10. Since the last interview how often have you interacted with the controls for your DE technology? (Everyday, once a week, once a month, once a quarter?)	
11. What (if anything) do you adjust most often when you interact with the system?	
12. Does your renewable technology always provide you with the power / heat you need when you need it? • If not, how could this be improved?	
13. If you find you have more than you need, what do you do with any excess power/heat/hot water?	
14. What effect, if any, has the DE technology had on your energy bills?	

15. Has the DE technology affected the way you use your house or the way you use energy? (If yes, what impact does the technology have on the way you use your house?)	
16. Do you have any other feedback you would like to give us about your DE technology?	
17. Do you think you used more, less or about the same energy in your home over this winter period compared with previous winters?	

Section 5. Participation in the study

I would like to ask you some questions about why you chose to take part in this study. This project is a pilot for a much larger study looking a many more homes in the UK, so we are keen to learn lessons from you and your experiences.

Questions	**Answers recorded here**
1. Overall, how have you found participating in the study?	
2. Would you like to make any further comment about participating in the field trial?	

- Thank interviewee for their time.
- Explain when the next interview will be.