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Evaluation of Woodfields Low Carbon Refurbishment

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Executive Summary

In March 2007 Drum Housing Association, part of the Radian Group, completed a low carbon energy performance upgrade to six semi-detached bungalows and houses on the Woodfields estate in Kingsley, Hampshire. Assisted by Camco's Generation Homes project (supported by the Energy Saving Trust), a package of complementary renewable energy and energy efficiency measures were installed at Woodfields with the objective of realising a minimum 75% reduction in carbon emissions. Also, in March 2007, Drum Housing completed the installation of 18 ground source heat pump heating systems in the neighbouring Schoolfields Estate in Kingsley, Hampshire.

Two years on from the completion of both projects, Camco has examined and analysed performance data provided by Drum Housing Association from the properties at Woodfields & Schoolfields to evaluate post-occupancy energy performance and the carbon emissions reductions delivered.

The key findings are summarised below.

Woodfields Performance

- SAP modelling shows that the properties were improved during the refurbishment from a SAP Rating band F to band D (reflecting energy running costs), with a greater improvement in the Environmental Impact Rating band G to band C (reflecting carbon emissions). Under standard occupancy conditions this is equivalent to an emissions reduction achievement of over 80% for space heating & hot water and over 70% for total household emissions (including electrical appliance use).
- Actual data collected for the period 2008-9 shows similar post-refurbishment performance to that predicted by SAP. Carbon emissions for space heating & hot water energy consumption based on this monitored data are 1.5-1.9 tCO_2/yr for four out of the five households for which data is available (the same range predicted by SAP). This suggests that the refurbishment package is successfully delivering the expected level of energy performance in practice. One property has higher emissions for space heating and hot water at 3.21 tCO_2/yr, the reasons for which are not clear.
- Appliance based electricity use varies more widely between properties, ranging from 0.94 to 4.77 tCO_2/yr. Electrical appliance is a function of lifestyle choices which are often beyond the influence of a social landlord. However despite apparently high appliance use in some households, three dwellings show total emissions reductions against the SAP baseline of c.80%, are achieving close to the Generation Homes Standard of 2 tCO_2/yr[1] for total household emissions, including appliance use.
- In terms of energy bills, which were estimated by tenants via self completion questionnaires for the period before and after refurbishment, two properties show reductions of 12% and 56% respectively, while two show an increase, in one case by 40%. However in this latter case the property had the lowest energy bills prior to refurbishment, suggesting they may have been unable previously to adequately heat their property, and have now realised the improvements in improved thermal comfort. It should be noted that energy prices were also generally rising during this period and the analysis did not normalise figures for this effect.
- The data suggests the GSHP and PV systems are in general performing well, with a possible need to re-examine GSHP temperature setting and timer controls in some properties to ensure they are optimised to tenants needs.

[1] *http://www.generationhomes.org.uk/GH_standard.htm*

- Tenant feedback showed mixed results, suggesting that some tenants were not always as warm as they would like to be during winter months. Since the indoor temperature data generally shows average daily temperatures in the range 17-21°C, it may reflect the adjustment away from the 'point source' heating systems (i.e. open fires) many were used to prior to refurbishment in the main living spaces. It may also suggest that GSHP daily heating profiles controls should be adjusted (for instance to increase temperatures during the early morning period 7-8am, when households are typically getting up, and when some properties were experiencing their lowest levels).

Table ES1: Actual monitored post-refurbishment carbon emissions against theoretical SAP baseline

Actual monitored post-refurbishment carbon emissions against theoretical SAP baseline at Woodfields										
	Pre-refurbishment (SAP & CSH) (tCO_2/yr)			Post-refurbishment (actual monitored) (tCO_2/yr)				% Carbon Reduction		
Site	Space heating & HW	Appl-iances & lights	Total	Space heating & HW	Appl-iances & lights	PV gener-ation	Total	Space heating & HW	Appl-iances & lights	Total
Woodfields B	10.86	1.66	12.52	1.58	0.94	0.44	2.08	**-85%**	-43%	**-83%**
Woodfields C	9.19	1.09	10.28	1.49	0.97	0.45	2.01	**-84%**	-11%	**-80%**
Woodfields D	9.19	1.09	10.28	1.91	0.68	0.41	2.17	**-79%**	-38%	**-79%**
Woodfields E	10.86	1.66	12.52	3.21	4.77	0.52	7.46	**-70%**	+188%	**-40%**
Woodfields F	10.86	1.66	12.52	1.67	2.12	0.45	3.35	**-85%**	+28%	**-73%**

Schoolfields Performance

- The installation of the GSHP systems at the Schoolfields properties suggests average carbon emissions reductions of 31% across the four properties for which data is available. This is based on tenants' own estimates of fuel bills before and after installation.
- Two of the four properties are performing as expected with a 56% and 64% reduction in emissions, while one shows only a small reduction at 5% and another actually indicates a small increase of 3%. In the absence of actual metered data to verify these findings, or further information on tenants behaviour, it is difficult to explain these results, but could point to some households realising the improvements as an increase in thermal comfort.
- The only property for which a before and after EPC is available shows an emissions reduction for space heating and hot water consumption of 58%.

Table ES2: Carbon emissions pre- and post-GSHP installation at Schoolfields

Summary of pre- and post-installation carbon emissions for Schoolfields Properties							
Site	Heating Type	House Type	Bed-rooms	Occupants (estimated)	Pre-GSHP (tCO2)	Post-GSHP (tCO2)	% Reduction
Schoolfields A	E7 Electric	Flat	1	2	3.8	3.9	**+3%**
Schoolfields D	E7 Electric	Flat	2	3	4.3	4.1	**-5%**
Schoolfields G	Coal	Terraced House	2	3	9.2	4.0	**-56%**
Schoolfields H	Coal	Terraced House	3	4	9.1	3.3	**-64%**

1 Introduction

In March 2007 Drum Housing Association (DHA), part of the Radian Group, completed a low carbon energy performance upgrade to six semi-detached bungalows and houses on the Woodfields estate in Kingsley, Hampshire. Assisted by Camco's Generation Homes project (supported by the Energy Saving Trust), a package of complementary renewable energy and energy efficiency measures were installed at Woodfields with the objective of realising a minimum 75% carbon emissions reduction. Also, in March 2007, DHA completed the installation of 18 ground source heat pump heating systems in the neighbouring Schoolfields Estate in Kingsley, Hampshire.

Two years on from the completion of both projects, Camco has interpreted and analysed performance data provided by DHA from the properties at Woodfields & Schoolfields to evaluate post-occupancy energy performance and the delivered carbon emissions reductions delivered.

The key indicators used include household carbon emissions, energy consumption, fuel costs, and renewable energy system performance. The Woodfields scheme, with its integrated low carbon refurbishment package, was subject to a greater level of monitoring than the neighbouring Schoolfields, which enabled a more in depth analysis for these properties. The quantitative data at Woodfields was supplemented by tenant interviews with households to help interpret results and give more qualitative feedback.

2 Methodology

2.1 Overview of Schemes

This section describes the background to the both the Woodfields & Schoolfields schemes. Note that to preserve anonymity all properties have been alphabetically referenced.

2.1.1 Woodfields Low Energy Refurbishment

This scheme comprises three 3-bedroom semi-detached houses (Woodfields B, E and F) and three 2-bedroom bungalows (Woodfields A, C and D[2]), all constructed in the 1950s. All are cavity wall construction with pitched roofs and open loft spaces. The scheme is located in a rural area of Hampshire and the properties are clustered in a cul-de-sac. The estate contains more properties but not all are under DHA ownership. DHA were keen to extend aspects of the scheme to the private households on the estate but these households declined to participate, principally due to the investment costs involved.

There is no mains gas supply and therefore heating and hot water were originally provided by a combination of a solid fuel-fired back-boilers and electrical storage heaters:

- Woodfields C – Electric E7 slimline storage heaters in the living room and bed-room only, with all fireplaces sealed off. Electric immersion water heating.
- Woodfields D – Electric E7 slimline storage heaters in most rooms, with an open coal fireplace in the main living area, used regularly. Electric immersion water heating.
- Woodfields B, E and F – heating and hot water provided by solid fuel 'Parkray' room sealed units with back boiler to radiators, and electric immersion heater for summer hot water use.

When DHA inherited the properties in 1996 they were single glazed with no cavity wall or loft insulation. Fuel bills at the properties were high with several over £1200/yr[3].

Table 2.1 Key characteristics of dwellings at Woodfields

Key characteristics of dwellings at Woodfields					
Site	**Property Type**	**Bedrooms**	**Occupants**	**Floor Area**	**Fuel Type**
Woodfields B	Semi-detached house	3	4	61 m^2	Coal
Woodfields C	Semi-detached bungalow	1	2	61 m^2	E7 electric
Woodfields D	Semi-detached bungalow	2	3	86 m^2	E7 electric + open coal fire
Woodfields E	Semi-detached house	3	4	61 m^2	Coal
Woodfields F	Semi-detached house	3	4	86 m^2	Coal

DHA's objectives were to provide new and affordable heating options to the tenants, which were easily controllable and also environmentally friendly. A comprehensive low-carbon package was specified and implemented. The technical approach targeted: a) heat losses through the building fabric, b) reducing energy use through equipment and appliances and c) offsetting residual energy demand through renewables.

The low carbon refurbishment package included the following range of energy efficiency measures and renewable energy systems:

[2] *Note that the data for No 1 Woodfields provided by DHA is either incomplete or missing so has been disregarded in this analysis.*
[3] *At 2006 prices*

Energy efficiency:

- Cavity wall insulation
- Loft insulation (300mm)
- Full double glazing
- Draught-proofing
- Mechanical ventilation with heat recovery (through the wall systems)
- Waste water heat recovery
- Low-energy light bulbs
- Shower fittings (the properties had previously only had baths)

Renewable energy:

- Ground source heat pumps – 3.5 and 5 kW systems providing space heating & hot water
- Solar Photovoltaics (PV) – 1 kWp systems

The Woodfields Low Energy Refurbishment scheme received substantial grant funding under the Energy Saving Trust's Innovation Programme through the Generation Homes project managed by Camco.

A four page case study of the Woodfields scheme is available on www.generationhomes.org.uk/Pilot_Project.htm

Key features are summarised below.

(a) Heating and hot water

New heating systems were installed in the form of Ground Source Heat Pumps (GSHP), replacing the original electric night storage heaters and solid fuel back boilers. Depending on the property size, 3.5kW systems were used for the bungalows and 5kW ones for the houses. GSHPs provide the entire demand for heating and hot water. Their expected coefficient of performance (COP) is typically between 3.0-3.5 for space heating and about 2.5 for hot water. Low-temperature radiators were fitted throughout. A two-part hot water cylinder was installed in each dwelling (for storing heat and providing hot water on demand).

The GSHPs require a liquid-filled loop buried in the ground to pick up the stored heat. Ground temperature is constant at about 10 degrees Celsius. For the Woodfields scheme, a pair of 40m deep boreholes were used for each property (initially a single 80m deep borehole was specified, but due to unfavourable ground conditions, drilling below 40m proved technically difficult). The GSHP plant is placed externally in a weatherproof box.

(b) Solar electricity

Each property was equipped with a roof-mounted array of 1kWp Photovoltaic panels. The system generates DC electricity from solar radiation which is transformed into AC current using an inverter. This power is used directly in the household for lights and appliances, but also to power the heat pump, thus further reducing its carbon impact. Some tenants have chosen to have export meters enabling any surplus power to be sold to the energy utility.

(c) Waste water heat recovery

This innovative measure can recover up to 60% of the heat still embodied in bathroom water going down the drain. The product applied was the Canadian-made Power-Pipe, which requires vertical installation. Therefore, only the three houses with bathrooms on the first floor were

suitable. The device is a copper pipe which replaces a section of the soil stack; there is a thinner copper coil wrapped around the main pipe carrying cold mains water.

As waste water falls down the stack, it clings to the inside of the stack and heat is transferred to the cold supply in the coil and on to the shower thus delivering preheated water. The Power-Pipe was installed externally replacing the existing waste pipe and boxed-in for security and thermal insulation.

(d) Energy efficiency upgrades

In addition to cavity wall insulation, loft insulation, and double glazing throughout, further internal features were added. The properties without showers were fitted with those, thus saving water and energy (for hot water). The bathrooms were fitted with humidity sensors and mechanical ventilation with heat recovery. To improve air-tightness, the original air bricks and redundant flues were also filled.

2.1.2 Schoolfields Ground Source Heat Pump Installations

Schoolfields is a mixed development of 20 units built during the 1980's comprising 2 and 3 bedroom houses and 1 and 2 bedroom flats. The village of Kingsley is not on mains gas and the existing heating systems were a mixture of solid fuel back boilers with radiators and electric storage heaters, many of which were reaching the end of their useful life.

The properties were originally constructed with full cavity insulation and had previously been fitted with PVCu replacement double glazing. To ensure heat loss was minimised it was decided to top up the loft insulation to a minimum of 250mm prior to installing the new heating.

Residents at the site were unhappy about solid fuel heating and running costs. Because these homes were off-gas and a programmable heating system was required, the options available to DHA were limited, making ground source heat pumps an attractive choice compared to the obvious alternative of electric night storage heaters.

The estate was chosen with an expectation of limited take up by residents. In the event all 18 existing DHA residents took up the offer, and with the repurchase of one further flat only the remaining owner occupier declined the works.

5kW ground source heat pump systems with vertical boreholes were installed in each case, in conjunction with low temperature radiator systems, as for the neighbouring Woodfields scheme. The proximity of the Schoolfields & the Woodfields estates helped to bring down the costs of the GSHP systems overall.

2.2 Baseline Performance Data

This section describes the process for collection of baseline (i.e. pre-refurbishment) energy consumption and carbon emissions data for each of the schemes.

2.2.1 Woodfields Baseline Data

Due to the speed of implementation of the Woodfields project, following the narrow window of the funding opportunity under the EST-funded Generation Homes programme, it was not possible to undertake comprehensive pre-refurbishment monitoring of energy consumption and internal temperature of the dwellings.

The baseline (pre-refurbishment) energy performance data for the six properties at Woodfields therefore comprises the following:

- Four self-completion questionnaires on household energy bills completed by the residents of Woodfields B, C, D and F, collected by DHA in 2007. Tenants were asked to provide the values of actual or estimated fuel bills for electricity and solid fuel over the previous 12 and

24 months. Standard emissions factors for electricity and coal, together with historic unit cost data for 2006-7, enabled conversion of the cost data into carbon emissions data[4]. The values of tenants' estimated bills vary widely (see Section 3). Copies of actual energy bills were not available so it has not been possible to verify this data as part of this analysis. Although it is useful to see what tenants thought they were spending on energy bills annually, without original energy bills to back this up, or monthly meter readings from the properties covering a full heating season, this estimated baseline data is not considered sufficiently reliable to use as the sole source of baseline performance data for the Woodfields properties.

- Therefore a theoretical pre-refurbishment baseline has been constructed, using a combination of the Standard Assessment Procedure (SAP), for space heating, hot water and lighting based energy consumption, and a calculation for appliance based electricity consumption based on the equation used in the Code for Sustainable Homes. The SAP is the Government's recommended system for home energy rating.
- Two baseline scenarios were developed using SAP to represent the properties as they were when DHA took ownership in 1996:
    - Woodfields B to represent the two storey dwellings
    - Woodfields D to represent the single storey dwellings
- The key input assumptions for these two baseline scenarios are summarised in the table below.

Table 2.2 Input assumptions for SAP baselines at Woodfields B and D

Input assumptions for SAP baselines at Woodfields B and D				
	Main heating	**Hot water**	**Fabric**	**Renewables**
Woodfields B – 3-bed semi-detached house	Coal (sealed room heater with back boiler & rads), plus secondary open coal fire	From boiler with summer immersion	No loft insulation, no cavity fill, single glazing	None
Woodfields D – 2-bed semi-detached bungalow	Electric night storage heaters on E7, with secondary open coal fire	Off-peak immersion	No loft insulation, no cavity fill, single glazing	None

- The additional electricity consumption from appliances was calculated using the Code for Sustainable Homes methodology which predicts theoretical annual electricity consumption for a given floor area and the number of occupants. Although developed primarily for use in new build applications, the calculation can be considered applicable for existing homes since it primarily equates to contemporary patterns of appliance ownership and use.
- The SAP energy data was added to the CSH appliance energy data to provide the total 'theoretical' energy consumption for the two representative properties prior to refurbishment, under standard occupancy conditions[5].

2.2.2 Schoolfields Baseline Data

As with Woodfields, it was not possible to undertake monitoring of energy consumption within the Schoolfields dwellings prior to the installation of the GSHP systems.

[4] The carbon emissions factors used in this report are consistent with Building Regulations Part L 2006; 0.422 kgCO2/kWh for grid electricity, 0.317 kgCO2/kWh for solid fuel, and 0.568 for grid displaced electricity (i.e. generated by PV).
[5] Standard occupancy assumes that the house is heated for nine hours a day during weekdays and 16 hours a day at weekends, with the living room heated to 21 degrees centigrade and the rest of the house at 18 degrees centigrade.

The baseline performance data for the 18 properties at Schoolfields therefore comprises the following:

- Four self-completion questionnaires on household fuel bills completed by Schoolfields A, D, G and H. Tenants were asked to provide actual or estimated fuel bills for electricity and solid fuel over the previous 12 and 24 months. Copies of actual energy bills were not available so it was not possible to verify this data as part of this analysis.
- Energy Performance Certificate (EPC) analysis of one of the properties. Whilst the EPC was generated in 2009 it was compiled based on the dwelling as it was before to the refurbishment.

2.3 Post-Occupancy Performance Data

2.3.1 Woodfields Post-Occupancy Performance Data

Monitoring equipment was installed in all the properties at Woodfields during the refurbishment to record the following:

- Grid electricity – electricity consumed internally by lights and appliances (kWh)
- GSHP electricity – electricity consumed internally by the GSHP for space heating & hot water (kWh)
- PV generation – electricity generated by the PV system (kWh)
- PV export – electricity exported from PV system to the local grid (kWh)
- GSHP heat generated for space heating & hot water (kWh)
- Internal space temperatures (degrees)

The data collection process consisted of manual meter readings undertaken by DHA at periodic intervals. To enable full evaluation of the performance of the energy upgrades it would have been ideal to have a minimum of monthly meter readings, taken on the same day of the month, for all properties, covering at least two heating seasons. In practice, remote meters could not be financially justified under the funding available, and it was difficult for DHA to gain regular access to the properties to read meters on a manual basis. Therefore this analysis has been based on the three available meter readings taken at the following times:

- October 2007
- April 2008
- February 2009

The results in this report have been based on the period from April 2008 to mid-February 2009, which was the closest period to a whole year's data which was available. Degree day data was used to help extrapolate the data to cover the missing months and illustrate a whole year's performance. Energy consumption figures were converted into carbon dioxide emissions using the standard emissions factors consistent with SAP methodology (see Section 2.2.1).

While data from the heat meters was examined, it unfortunately showed a number of discrepancies which raised concerns over the quality of calibration of the meters themselves at the time of installation, so had to be disregarded in the analysis.

The internal temperature data loggers gathered data at regular intervals for the entire period, and a sample of the temperature results is presented in Section 3.6.

Data collected from the waste water heat recovery systems was analysed and results presented as part of a separate report.

Tenant satisfaction surveys were conducted at Woodfields A, B, C, D and F and the results are summarised in Section 3.5.

Following commissioning of the refurbished properties a pressure test was carried out to establish the level of air tightness. The results showed that at 50Pa pressure the average air leakage for the bungalows was 4.5 m^3/m^2.h and for the houses 4.5 – 5.5 m^3/m^2.h. This is well below the Building Regulations requirement of 10 m^3/m^2.h, but further improvements to the properties were identified that could reduce leakage to 3.0-3.5 m^3/m^2.h.

The results of the post-occupancy data analysis is presented in Section 3.

2.3.2 Schoolfields Post-Occupancy Performance Data

Monitoring equipment was installed in all the properties at Schoolfields to record the following:

- Grid electricity (kWh)
- GSHP electricity (kWh)

As for Woodfields, remote metering was not financially possible at the scheme, and monthly manual meter readings made difficult by availability of time and difficulty with access to residents' properties. As a result the data collection process consisted of manual meter readings undertaken by DHA in the following months:

- April 2008
- February 2009

Degree day data was used to help extrapolate the data to cover the missing months and illustrate a whole year's performance.

The results of this post-occupancy data analysis are presented in Section 4.

3 Results for Woodfields

3.1 Carbon Emissions Reductions

This section presents the pre- and post-refurbishment carbon emissions at Woodfields and the overall reductions achieved.

3.1.1 Carbon emissions reductions using SAP analysis

Table 3.1 shows the pre- and post-refurbishment SAP and Environmental Impact (EI) ratings for two of the dwellings at Woodfields[6]. The two dwellings were selected to be representative of the main property types at Woodfields, as described in Section 2.

Table 3.1 SAP Comparison Before and After Refurbishment for Nos 3 and 10

SAP Comparison Before and After Refurbishment For Woodfields B and D								
	Pre-refurbishment				Post-refurbishment			
Site	SAP Score	SAP rating	EI Score	EI Rating	SAP Score	SAP rating	EI Score	EI Rating
Woodfields B	28	F	16	G	65	D	78	C
Woodfields D	18	G	10	G	68	D	79	C

Prior to refurbishment, the EI rating for both dwellings was lower than the SAP score, reflecting the highly carbon intensive heating reliant on storage heaters and coal. However after refurbishment the EI score is significantly higher than the SAP at 78, showing the improvements had a bigger effect on reducing environmental impact (CO_2 emissions) than on reducing fuel bills. Both dwellings achieve a SAP rating of 'D' post-refurbishment, and an EI rating of 'C'.

Table 3.2 illustrates the pre- and post-refurbishment carbon emissions based on this 'before and after' SAP analysis. The SAP analysis has been supplemented with predicted appliance based electricity consumption using the formula used in the Code for Sustainable Homes, as described in Section 2.

These results show that, under 'standard occupancy' conditions, the properties are capable of realising carbon emissions reductions of 82-83% for space heating & hot water, and 72-77% for total energy use. This is in line with the original predictions of carbon savings at the Woodfields properties of 75%.

Table 3.2 Carbon emissions using pre- and post-refurbishment SAP analysis, for Nos 3 and 10

Carbon emissions from pre- and postrefurbishment SAP analysis for Woodfields B and D									
	Pre-refurbishment (SAP & CSH) (tCO_2/yr)			Post-refurbishment (SAP & CSH) (tCO_2/yr)			% Carbon Reduction		
Site	Space heating & hot water	Appliances & lights	Total	Space heating & hot water	Appliances & lights	Total	Space heating & hot water	Appliances & lights	Total
Woodfields B	10.86	1.66	12.52	1.94	1.53	3.47	**-82%**	-8%	**-72%**
Woodfields D	9.19	1.09	10.28	1.54	0.84	2.38	**-83%**	-23%	**-77%**

[6] *While the SAP rating provides a measure of the cost of fuel bills to the property, the Environmental Impact Rating provides a measure of the carbon emissions associated with this fuel consumption.*

In practice, given the poor state of energy performance of the properties pre-refurbishment, it is unlikely that tenants were actually able to afford to heat the properties to standard occupancy conditions, meaning that actual measured carbon emissions reductions may be lower than predicted by SAP analysis. Therefore it is instructive also to look at actual monitored post-refurbishment consumption (Section 3.1.2), as well as tenants' estimated pre-refurbishment fuel bills (Section 3.1.3).

3.1.2 Carbon emissions reductions using theoretical baseline and monitored data

Energy consumption in the properties was monitored post-refurbishment as described in Section 2.

The results show that for most households, the space heating & hot water energy consumption monitored post-refurbishment is very similar to that predicted by SAP. Carbon emissions for space heating & hot water energy consumption lie in the range 1.5-1.9 tCO_2/yr for four out of five households (the same range predicted by SAP for the sample properties, Table 3.2). This indicates that the refurbishment package has delivered the expected level of energy performance in practice.

In one property, Woodfields E, energy consumption for space & hot water heating is notably higher than the rest. The reasons for this are not clear, partly because unfortunately temperature data was not available for this property.

Measured consumption of lighting & discretionary appliance use vary much more widely between properties, from 0.68 to 4.77 tCO_2/yr. Appliance based electricity use is subject to lifestyle choices which are to a large extent beyond the influence of a social landlord. In theory it could have indicated over-reliance on electric back-up heating (for instance if the GSHP systems had not been providing adequate heat). However feedback from the tenants suggests back-up heating is rarely used, and indicates instead above average usage of other electrical appliances.

Overall the actual monitored carbon emissions show a reduction against the theoretical baseline of between 70-85% for space heating & hot water, and 40-83% for total energy use, with absolute emissions close to the Generation Homes Standard of 2 tCO_2/yr for three out of the five households[7].

Table 3.3 Actual monitored post-refurbishment carbon emissions against theoretical SAP baseline

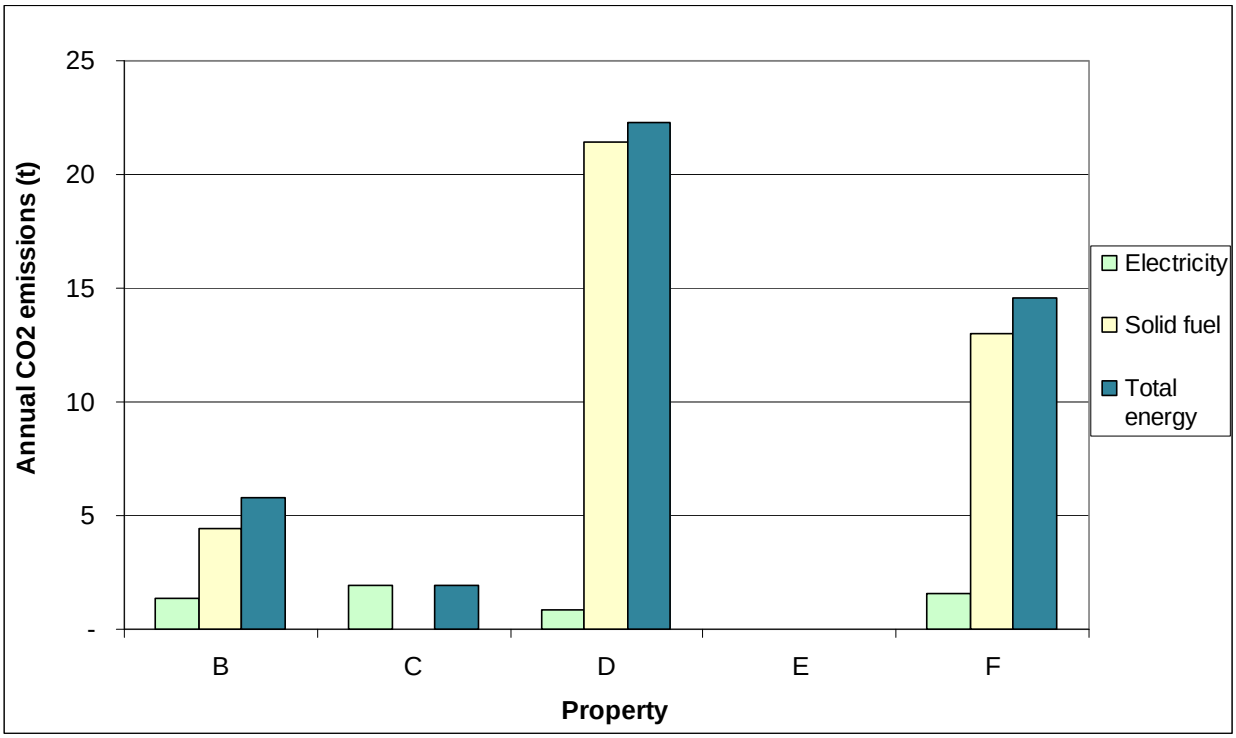
Actual monitored post-refurbishment carbon emissions against theoretical SAP baseline										
	Pre-refurbishment (SAP & CSH) (tCO_2/yr)			Post-refurbishment (actual monitored) (tCO_2/yr)				% Carbon Reduction		
Site	Space heating & HW	Appl-iances & lights	Total	Space heating & HW	Appl-iances & lights	PV gener-ation	Total	Space heating & HW	Appl-iances & lights	Total
Woodfields B	10.86	1.66	12.52	1.58	0.94	0.44	2.08	**-85%**	-43%	**-83%**
Woodfields C	9.19	1.09	10.28	1.49	0.97	0.45	2.01	**-84%**	-11%	**-80%**
Woodfields D	9.19	1.09	10.28	1.91	0.68	0.41	2.17	**-79%**	-38%	**-79%**
Woodfields E	10.86	1.66	12.52	3.21	4.77	0.52	7.46	**-70%**	+188%	**-40%**
Woodfields F	10.86	1.66	12.52	1.67	2.12	0.45	3.35	**-85%**	+28%	**-73%**

[7] *http://www.generationhomes.org.uk/GH_standard.htm*

3.1.3 Carbon emissions reductions using tenants' estimated baseline

As described in Section 2, the tenants' estimated fuel bills prior to refurbishment varied widely between the households. The chart below illustrates the range of annual carbon emissions, by fuel source, for the properties, based on the fuel bill estimates provided by tenants for the years 2006-7. Note the very high estimated fuel bills for the properties with reliance on coal fired heating.

Figure 3.1 Annual carbon emissions from energy cost data provided by tenants for year 2006



From the range of estimates provided we can draw two possible conclusions:

- That lifestyle, and/or ability to pay for fuel bills, varied widely between households in the period 2006-7.
- That the tenants' self-estimates may contain inaccuracies which undermine the validity of the data as a reliable baseline for comparisons.

The following table presents the results of comparisons of tenants' estimated fuel bills with the actual monitored post-refurbishment consumption, each converted into carbon emissions.

Table 3.4 Summary of pre- and post-refurbishment carbon emissions using tenants' estimated baseline

Summary of pre- and postrefurbishment carbon emissions based on tenants' estimated baseline			
Site	**Pre-refurbishment (from tenants' estimates) (tCO_2/yr)**	**Post-refurbishment (actual monitored) (tCO_2/yr)**	**% Carbon Reduction (total household emissions)**
Woodfields B	5.77	2.08	-64%
Woodfields C	1.95	2.01	+3%
Woodfields D	22.26	2.17	-90%
Woodfields E [8]	-	7.46	-
Woodfields F	14.56	3.35	-77%

[8] *Tenants energy bill estimate not available*

Carbon emissions reductions using tenant's estimated fuel bills show reductions in total household carbon emissions in the range 64-90% in three out of the five properties, broadly echoing the substantial reductions suggested by the SAP modelling and the monitored energy results. However, one property (Woodfields C) shows a small increase. In practice this may be because the household was unable to afford to heat the property adequately prior to refurbishment. Woodfields C is a small bungalow, previously heated only by electric storage heaters, and it is possible that this household has instead realised the improvements as an increase in comfort. A comparison for Woodfields E was not possible because of the absence of pre-refurbishment data.

3.2 Energy Costs

The table below shows the energy costs provided by the tenants in their self completion questions for the pre-refurbishment period, together with the actual monitored energy costs after refurbishment.

Table 3.5 Title Summary of pre- and post-refurbishment energy costs

Summary of pre- and post-refurbishment energy costs							
Site	Heating Type	House Type	Pre Refurbishment (tenants' estimates)			Post Refurbishment (actual)	% Reduction
			Electricity (£/yr)	Solid Fuel (£/yr)	**Total Cost (£/yr)**	**Total Cost (£/yr)**	
Woodfields B	Coal	3-bed SD house	£ 320	£ 280	**£600**	**£657**	+9%
Woodfields C	E7 electric	1-bed SD bungalow	£ 468	N/A	**£468**	**£655**	+40%
Woodfields D	E7 electric + open coal fire	2-bed SD bungalow	£ 200	£ 1,352	**£1,552**	**£683**	-56%
Woodfields E	Coal	3-bed SD house	Not available	Not available	**N/A**	**£2,332**	-
Woodfields F	Coal	3-bed SD house	£ 380	£ 819	**£1,199**	**£1,053**	-12%

General observations:

- Two properties, Woodfields D and F, have experienced reductions in their energy bills of 56% and 12% respectively.
- Two properties, Woodfields B and C, have experienced increases in their energy bills of 9% and 40% respectively.
- The self-completion questionnaire was not available for Woodfields E. However, it is likely this property would have seen an increase in energy bills since the current running costs are very high at £2,332, largely due to the very high appliance based electricity consumption.
- It is difficult to interpret this data without knowing what fraction of the pre- and post-refurbishment energy costs were due to space heating and hot water.

3.3 GSHP System Performance

3.3.1 Energy Performance of GSHP Systems

The Coefficient of Performance (COP) represents the efficiency with which the GSHP is operating. A typical seasonal COP for a GSHP system providing only space heating (using low temperature radiators) would be around 3.75. A typical seasonal COP for a system providing domestic hot water would be around 2.75. In general terms, the higher the overall temperature difference delivered by a heat pump system, the lower the COP. In practice for a scheme providing both space heating and domestic hot water we would expect the value of the COP to lie somewhere between the two.

The table below shows the COPs experienced by the properties at Woodfields.

Table 3.6 GSHP Coefficient of Performance

GSHP Coefficient of Performance	
Site	**GSHP COP**
Woodfields B	3.203
Woodfields C	1.880
Woodfields D	3.209
Woodfields E	3.143
Woodfields F	3.518

The table below shows the portion of total energy consumption required by the GSHP systems for space heating and hot water post-refurbishment.

Table 3.7 Summary of actual (measured) post-refurbishment energy consumption

Summary of actual (measured) post-refurbishment energy consumption				
Site	**Space heating & hot water electricity demand (kWh/yr)**	**Lighting & appliance electricity demand (kWh/yr)**	**Total household electricity demand (kWh/yr)**	**GSHP % of total**
Woodfields B	3,749	2,222	5,972	63%
Woodfields C	3,531	2,307	5,838	60%
Woodfields D	4,516	1,608	6,124	74%
Woodfields E	7,612	11,296	18,908	40%
Woodfields F	3,967	5,032	8,999	44%

Observations include:

- Overall the performance data from the GSHP systems indicate most systems are operating as expected for a system running space heating and hot water combined, with COPs for Woodfields B, D and F of 3.2, 3.2 and 3.5 respectively.
- The one exception is at Woodfields C where the COP is much lower than the rest; indicating a possible problem in system control or performance. Despite being a small 1-bed bungalow, Woodfields C has the second highest level of GSHP electricity consumption of all five properties. The tenant also claims to be cold, and even though the GSHP system is set to the highest space heating level, is resorting to back up electric panel heating. This high consumption together with the low COP, could suggest a possible problem which should be investigated with the installer.

- The COP for Woodfields F is the highest of all the properties, indicating the most efficient system. One possible reason for this is that the residents of Woodfdields F state that they have very low hot water consumption, which would result in the GSHP operating for more of its time in the lower temperature (and more efficient) space heating mode. Another possibility suggested by this higher efficiency is that the GSHP system controls could be set to provide a lower space heating output temperature.

3.3.2 Reliability of GSHP Systems

After some initial teething problems during the period immediately post-installation, the GSHP systems have on the whole performed adequately at the properties at Woodfields. However as can be seen from the tenant feedback in Section 3.5, there have been some areas of concern raised by tenants. One of these relates to the reliability of systems following power cuts, which often require the system controls to be re-set before they will re-commence. This can be a problem in rural areas where power cuts occur more frequently. It is exacerbated by the system controls prioritising domestic hot water rather than space heating once power connection is resumed (this prolonging the time taken to bring the house up to temperature).

The second area of concern is indoor temperature, particularly during extreme cold periods. During the extreme cold snap in January 2010, systems struggled to reach 18°C internally and resident complaints were received about the cold. Discussions with the supplier highlighted that systems were designed to deliver the design temperature down to an external temperature of minus 3°C. At temperatures below this the systems would not be able to deliver the design temperature. The only remedy would be to provide additional insulation to the walls (i.e. internal or external wall insulation in addition to cavity wall insulation) or to provide some degree of back-up electric heating during extreme cold spells (although even back-up electric heating would not be available during a power cut). The experience at Woodfields suggests it is expedient to allow for some degree of electric back-up heating during extreme cold spells, and factor this into projected carbon and running cost savings for ASHP or GSHP systems from the start.

3.4 PV Generation & Export

3.4.1 PV Generation

The PV generation & export from the systems is presented below. PV generation & export data has been based on the same period as the post-refurbishment energy consumption, and extrapolated for the months February and March 2009 to make a full year's data set.

Table 3.8 Title: Summary of PV Generation & Export

PV Generation & Export		
Site	**Total PV generation (kWh/yr)**	**PV Export (kWh/yr)**
Woodfields B	775	270
Woodfields C	799	0
Woodfields D	729	265
Woodfields E	919	93
Woodfields F	787	202

Overall the systems are all generating what would be expected for a 1kWp system at this latitude in UK climatic conditions (typically between 750-850 kWh/yr). Only Woodfields E varies significantly from this, with an output so unusually high it suggests a possible error in the meter.

3.4.2 PV Export

The proportion of PV electricity export is similar in most properties with the exception of no 9 and Woodfields E. In the case of Woodfields C it is not clear why no export has been achieved, but could indicate meter error since it is unlikely that all generation would be consumed internally. In the case of Woodfields E, this property is consuming 3 times the average appliance based electricity consumption, as noted in earlier sections. It would follow that a higher dwelling consumption would have a better chance of using the PV generation internally rather than exporting to the grid.

3.5 Tenant Feedback

The full responses from the tenant interviews are presented in Appendix 1 & 2.

The key highlights from the tenant interviews are as follows:

- The interviews suggested that the hot water provision was working well. Although the questionnaire suggested a range of views on hot water reliability (Q5), the results to Q3 suggested that 4 out of 5 households thought 'there was always plenty of hot water'.
- There were some concerns over the reliability of the heating systems. 2 out of 5 households claimed 'it doesn't work sometimes' and 1 described it as 'very unreliable'. However to balance this 1 was 'satisfied' with reliability and 1 felt it was 'very reliable'.
- In terms of space heating, 4 out of 5 households claimed they were 'sometimes' or 'often' too cold in winter. Only one said they were 'always warm enough'. No households complained of over-heating during winter.
- 3 out of 5 households claimed to sometimes use back-up electric panel or fan heaters to supplement heating from the GSHP. This may well be confusing the GSHP controls, and will also be increasing electricity consumption and CO_2 emissions beyond what was predicted.
- Despite the efforts by Drum Housing Association to educate residents about their energy systems, many tenants still claim to be confused as to how to best operate their heating. 4 out of 5 households claimed they 'didn't fully understand' how to operate the heating controls, and only one described the heating & hot water controls as 'understandable'. Sometimes following power cuts which outlast the internal battery life the GSHP systems have to be re-set by the supplier.
- Most households wanted more information in order to run their heating systems more efficiently and would welcome more information on their PV systems.
- Of the three properties who were interviewed and are exporting PV generated electricity to the grid (Woodfields B, D and F), only one of them was aware of realising any financial value from this export, with the others 'not sure'.
- Of the four households who were living in the properties prior to refurbishment, one (Woodfields D) thought the improvements offered 'good' value for money, with a slight saving, two perceived them to be 'average value for money', with similar bills to before (Woodfields B and C), and one (Woodfields F) was not sure since there had been a dispute with the electricity company over energy bills. These perceptions are broadly backed up by the comparison of before and after energy bills in Section 3.1.3, although residents at Woodfields D seem to be undervaluing the true scale of savings achieved if their pre-refurbishment cost estimate is to be believed, and at Woodfields C energy bills appear to have slightly increased.

Recommendations following this tenant feedback are:

- Improve tenant education on GSHP heating systems – include reiterating to tenants how to control the systems and achieve lowest running costs (including why not to resort to electric panel heaters and how this may confuse the thermostat and lead to higher energy bills).
- Provide tenant handbook to leave in properties to support the above.
- Include in this awareness raising how to maximise benefits from the PV systems using favourable export tariff arrangements.
- Review with the GSHP installer/supplier possible reasons for sub-optimal performance of the systems and how tenant thermal comfort could be improved.

3.6 Internal Temperature Data

The monitored internal temperatures within the properties at Woodfields help make sense of some of the qualitative feedback from tenants.

The monitored internal temperature readings for the properties suggest that average daily temperatures range between around 17 degrees and 22 degrees during the winter heating season. The following two graphs illustrate daily average temperatures over two representative months in the heating season during 2008, for Woodfields B and D.

Figure 3.2 Daily average internal temperature during November & December 2008, Woodfields B

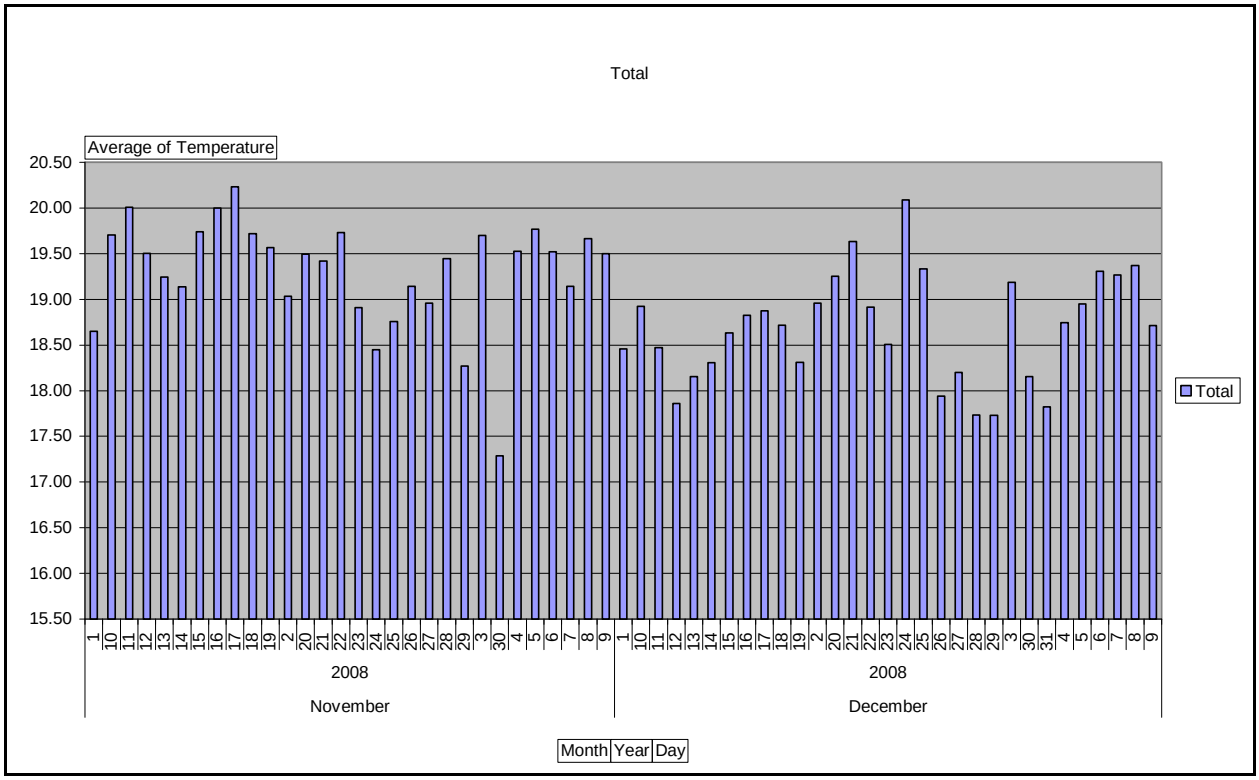
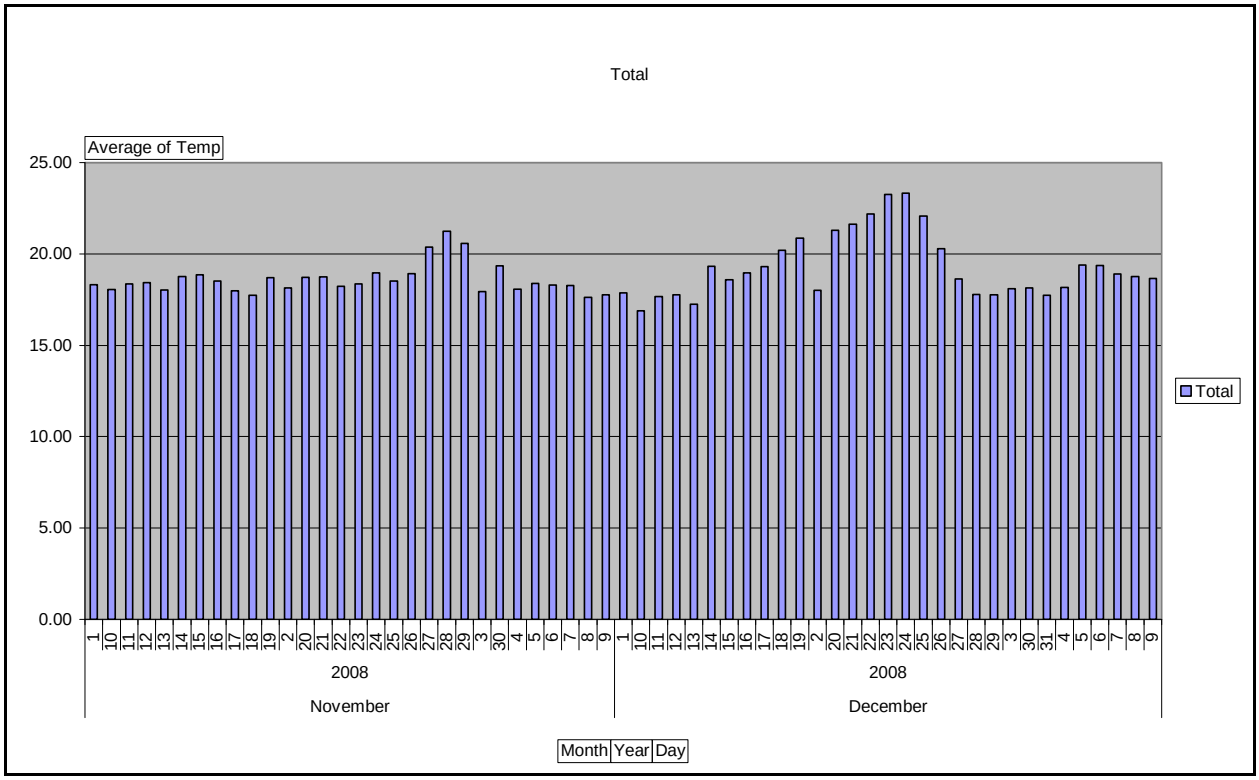


Figure 3.3 Daily average internal temperature during November & December 2008, Woodfields D



The following graphs show the daily minimum temperatures over the same time period, in the same properties, which sometimes fall to 16 degrees.

Figure 3.4 Daily minimum internal temperatures during November & December 2008, Woodfields B

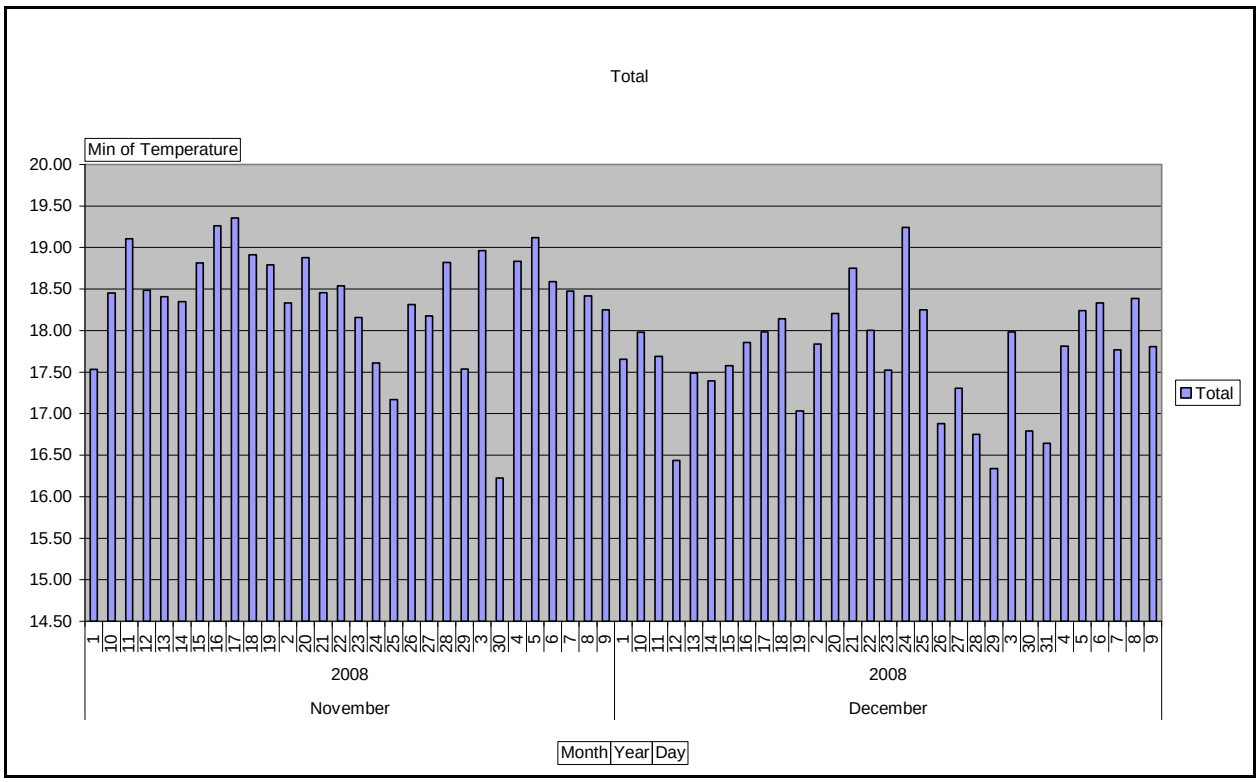
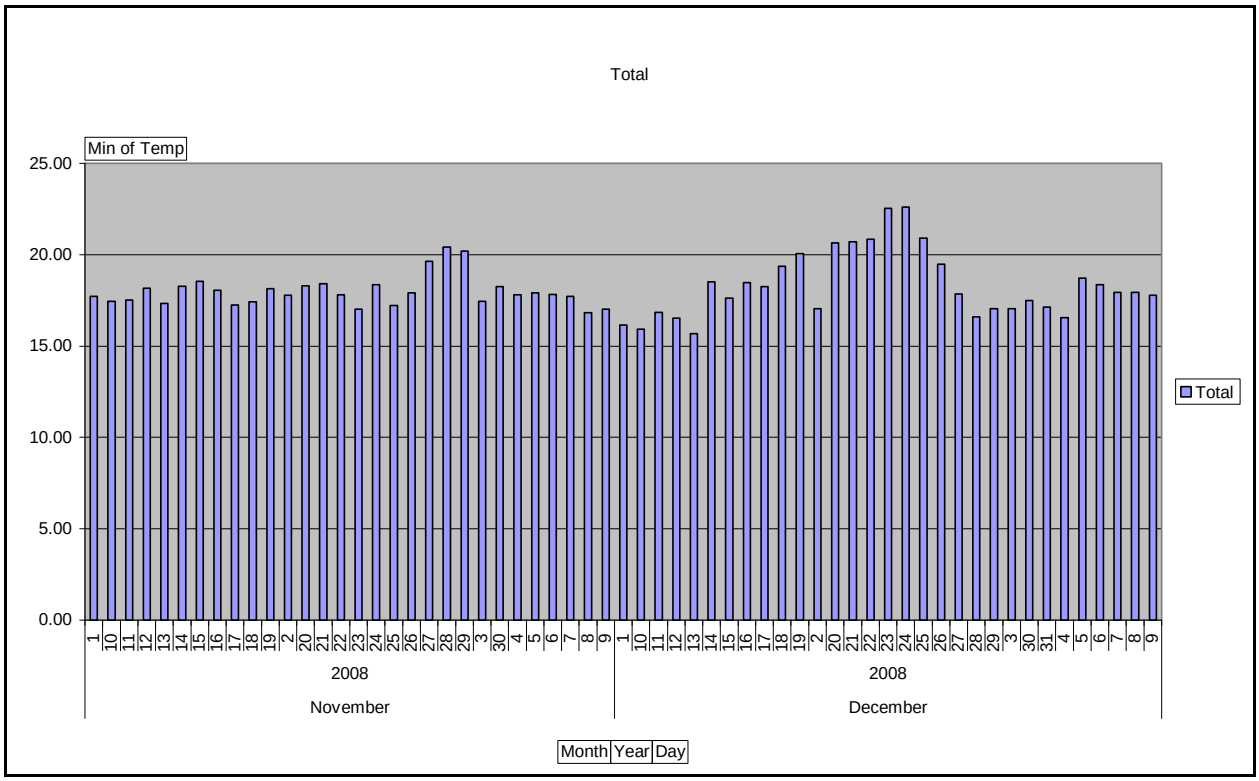
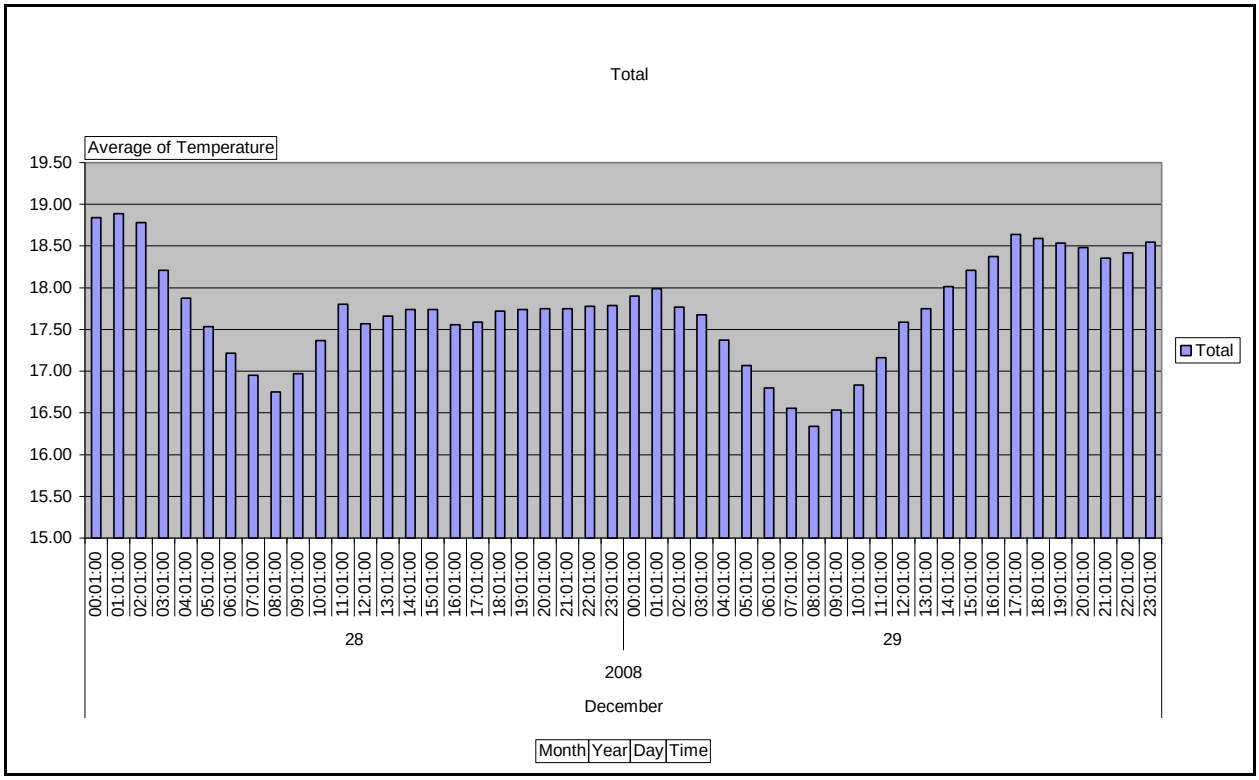


Figure 3.5 Daily minimum internal temperatures during November & December 2008, Woodfields D



To understand the implications of these minimum temperatures it is instructive to examine the daily temperature profile for a sample of 'low temperature' days. This next graph shows this for 2 days in December for Woodfields B. We can see that the minimum internal temperature is occurring in the morning at around 8am. If this is true of all properties it may help explain why tenants complain of 'feeling cold' since the early morning is typically one of the key times when householders like their home to feel warm. It may suggest the need to re-examine controls.

Figure 3.6 Hourly temperature profile for two days in mid-winter, Woodfields B



From looking at the average and minimum temperatures during these two sample months it is possible to appreciate why some tenants may have complained of a lack of thermal comfort. While 18-20 degrees is a reasonable living temperature for a household as a whole, in the absence of a point source of heating (which some of the tenants were used to before refurbishment in the form of a coal fire) it would be possible to 'feel cold' especially in the main living space and particularly during evening times when physical activity is low.

Overall an examination of the temperature data suggests that the households are experiencing a reasonable level of warmth and are not 'excessively cold'. However a closer inspection of the data together with the qualitative feedback from tenants suggest it may be worth revisiting the controls of the GSHP systems with the installer to see if it is possible to increase thermal comfort possibly at particular times of day (such as in early morning when households are getting up).

4 Results for Schoolfields

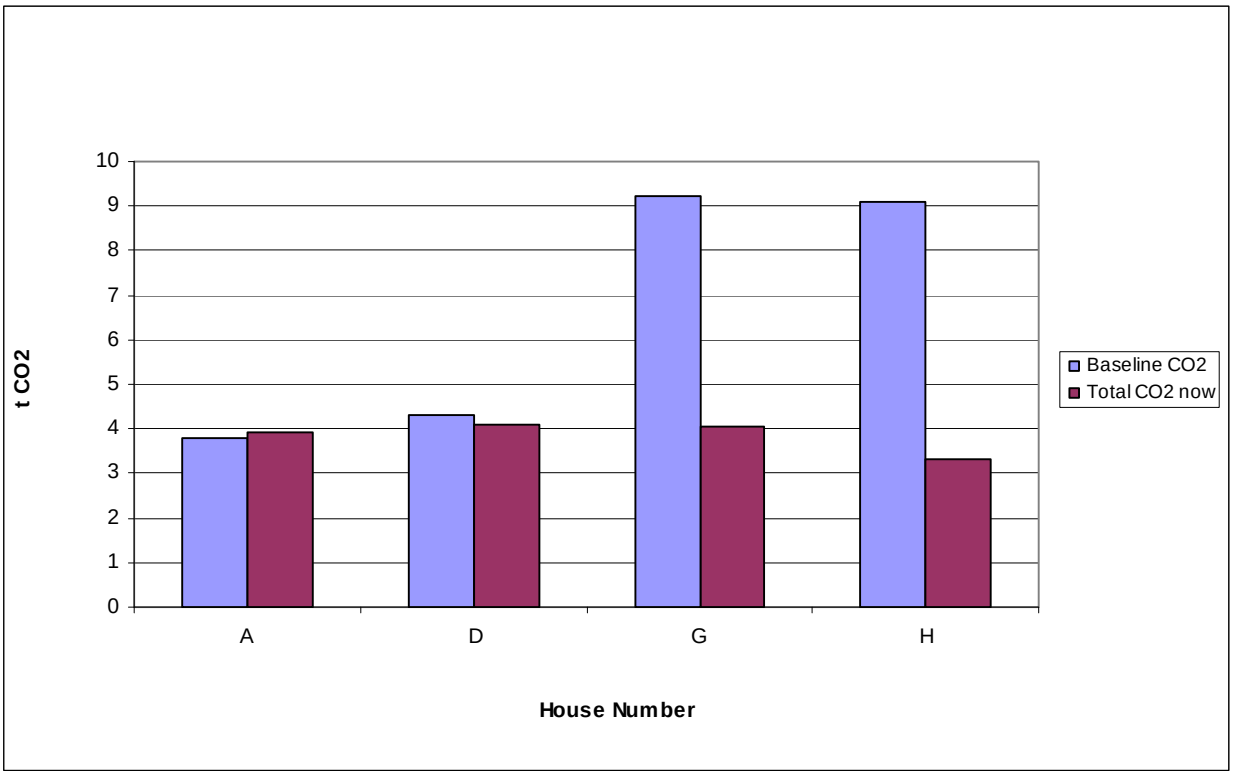
4.1 Carbon Emissions Reduction

The table and graph below summarises the property types at Schoolfields together with the baseline (pre-refurbishment) and post-refurbishment carbon emissions. Baseline emissions have been calculated from tenants' self-completion questionnaires as described in Section 2. Post-installations emissions (i.e. following installation of the GSHP systems) are based on monitored data collected by DHA for the period 2008-9.

Table 4.1 Carbon emissions pre- and post-GSHP installation

Summary of pre- and post-installation carbon emissions							
Site	**Heating Type**	**House Type**	**Bed-rooms**	**Occupants (estimated)**	**Pre-GSHP (tCO2)**	**Post-GSHP (tCO2)**	**% Reduction**
Schoolfields A	E7 Electric	Flat	1	2	3.8	3.9	**+3%**
Schoolfields D	E7 Electric	Flat	2	3	4.3	4.1	**-5%**
Schoolfields G	Coal	Terraced House	2	3	9.2	4.0	**-56%**
Schoolfields H	Coal	Terraced House	3	4	9.1	3.3	**-64%**

Figure 4.1 Carbon emissions pre- and post-GSHP installation



The results show a range of performance. Two of the properties, Schoolfields G and H, are performing as expected, with a 56% and 64% reduction in carbon emissions respectively. Schoolfields D however shows only a small improvement with a 5% reduction, and Schoolfields A actually shows a small 3% increase in emissions post-installation. In the absence of actual metered baseline data, or an understanding of any changes in tenants' behaviour, it is not

possible to fully verify or explain these unexpected results. However, when examining the ratio of space heating consumption (GSHP) to total energy in Table 4.4, Schoolfields A has the second lowest ratio, indicating that Schoolfields A proportionally uses more appliance-based electricity than other properties on the estate. In addition the total post-installation energy usage for Schoolfields A is close to the average for the entire set of dwellings. As this is only one of two 1 bedroom flats with in the mix of dwellings, it seems disproportionally high.

On average across the four properties, the results suggest that a 31% reduction in carbon emissions has been achieved as a result of the GSHP installations.

The only EPC report available for the Schoolfields properties indicates a reduction in carbon emissions of 58% post installation.

Table 4.2 EPC based carbon emissions

Summary of pre- and post-installation EPC emissions							
Site	Heating Type	House Type	Bed-rooms	Occupants (estimated)	Pre Refurb' (tCO_2)	Post Refurb' (tCO_2)	% Reduction
Schoolfields J	Coal	Terraced - end	3	4	6.2	2.6	-58%

4.2 Energy Consumption & Cost Reduction

Table 4.3 shows the costs of energy before and after the GSHP installations for the four properties for which data is available.

Table 4.3 Energy costs pre- and post- GSHP installation

Summary of pre- and post-installation energy costs							
Site	Heating Type	House Type	Bed-rooms	Occupants (estimated)	Pre Refurb' (£)	Post Refurb' (£)	% Reduction
Schoolfields A	E7 Electric	Flat	1	2	708	945	-34%
Schoolfields D	E7 Electric	Flat	2	3	807	993	-23%
Schoolfields G	Coal	Terraced House	2	3	990	977	+1%
Schoolfields H	Coal	Terraced House	3	4	990	798	+19%

The cost analysis shows similar pattern to that of the energy consumption, however, with less savings. It should be noted that the data was collected over a period of generally rising energy prices, and the results have not been normalised to take into account this effect. Also the tenants' estimates could have been based on estimated energy bills or could contain errors such as not reflecting a full year's consumption.

Table 4.4 shows electricity consumption of the GSHP systems against total electricity consumption for all the properties at Schoolfields. From an examination of this data the following observations can made:

- As already mentioned **Schoolfields A** has a disproportionally high total energy consumption that seems not to be related to the heating or hot water usage.
- The houses have relatively consistent hot water and heating demands between 3,700-5,000 kwh/year with the exception of:

- **Schoolfields K** which has a significantly higher total heating and hot water usage of 10,476 kWh per year, greater than double the average
- **Schoolfields M** which has a significantly lower heating and hot water usage of 1,741 kWh/year, less than half of the average

Unfortunately there is no other information available to suggest reasons for these exceptions. However, further investigation could be worthwhile, especially in the case of the over consumption, as this could reflect either a lack of understanding by the tenants of how to operate the system, or a potential commissioning problem with the GSHP system itself.

Table 4.4 Summary of electricity consumption

Summary of total electricity consumption and GSHP electricity consumption						
House Ref	House Type	Bed-rooms	Occupants (estimated)	Heating & Hot water Electricity (kWh/yr)	Total Electricity (kWh/yr)	Heating & Hot water % of total
A	Flat	1	2	2,925	7,270	40.2%
B	Flat	1	2	947	1,937	48.9%
C						
D	Flat	2	2	3,769	7,637	49.3%
E	Terraced – end	2	2	3,089	6,038	51.2%
F	Terraced House	2	2	4,734	7,625	62.1%
G	Terraced House	2	2	4,833	7,517	64.3%
H	Terraced House	3	2	4,184	6,141	68.1%
I	Terraced – end	3	2	4,593	8,062	57.0%
J	Terraced – end	3	2	4,992	9,257	53.9%
K	Terraced House	3	2	10,476	12,411	84.4%
L	Terraced House	3	2	4,174	7,893	52.9%
M	Terraced – end	2	2	1,741	6,124	28.4%
N	Terraced – end	3	2	4,931	10,590	46.6%
O	Terraced House	3	2	3,708	7,768	47.7%
			Average:	**4,221**	**7,591**	**53.9%**

4.3 GSHP Performance

Like at Woodfields, the Schoolfields GSHP systems have on the whole performed adequately as an alternative to electric night storage heaters or coal fired heating in these rural off-gas properties. However, like at Woodfields (see Section 3.3.2), tenants have had some concerns about availability of systems and the speed of achieving satisfactory temperature following prolonged power cuts, and in general more complaints have been received about properties failing to deliver sufficient thermal comfort than at Woodfields (probably because of the lower level of energy performance specification and air tightness at the Schoolfields properties). Like at Woodfields, the solution is either increased levels of insulation (e.g. internal or external wall insulation in addition to cavity fill), or accepting that some degree of electric back-up heating will be necessary during extreme cold spells.

Appendix 1: Results of Tenant Interviews (1)

Woodfields A

The occupier was not living at the property prior to the installation of the systems. They do not feel they were inducted sufficiently on the operation of the systems, and indeed there have been a number of technicians sent out to make adjustments to the controls who often did not understand the way the system operates or how to set it. They noted that the person responsible for the project and occupiers had since left the HA and moved overseas.

Although they admitted it was hearsay they understood that the GSHP installers had hit a rock bed and been unable to install the systems to an adequate depth.

Hot water & Heating

- The occupiers felt that the hot water system was excellent and they had a very reliable system. Although a new pump had had to be installed in the immersion heater.
- The occupiers stated they were too cold throughout winter, and never suffered from over heating.
- With regard to reliability they were very pleased with the hot water provision but not at all with the heating.
- The occupiers companies that the radiators simply heated up gently then turned off, and that there were no regulators on each radiator. At the time of the interview the radiators were on but very little heat was being emitted.

Bills & electricity export

- The occupiers felt that the energy costs were acceptable for the property but disappointed that the heating is unreliable. They did not have a reference to compare the bills prior to the work to the costs now.
- They did not know if electricity was being exported to the grid and do not have a feed-in agreement set up.
- They estimated their bills at £130 per quarter.

Understanding the technologies & efficiency

- Controls – having two electricity meters and a solar meter is too complex. The controls are not easy to understand for either the residents of service technicians. As a result they do not try and control the heating system once it has been set.
- GSHP – The occupiers had no information or understanding of the GSHP/Powerpipe/PV or energy efficiency.

Woodfields B

The current occupiers were living at this property prior to the installation of these systems.

Controls in the property are regularly reset when power cuts outlast the backup batteries. The occupants find the controllers too complex to use or reset, and rely on calling out a technician. This appears to have disengaged the occupiers from the performance of the systems installed as they fell unable to firstly understand and secondly operate the controls.

In the living room the property only has one radiator at a low temperature, so the occupiers regularly use an electric heater. The main control on the GSHP was set at “Low” so an

explanation was given during the interview of how to raise this. They highlighted that there was no heating in the kitchen, and no space for radiators.

Hot water & Heating

- Whilst the occupiers felt that they had sufficient hot water they felt there could be an improvement, particularly because they felt their demand was low as they only use showers.
- They raised a concern that the hot water could not be on at the same time as the heating, and on a daily basis the hot water goes off to allow the heating.
- Only one of the occupant felt able to use the heating controls, and the economy setting was not adequate for heating at all.

Bills & electricity export

- The winter bill for 2008/09 was circa £500.
- They received payments from Southern Energy initially at 28p/kWh.
- They felt that with proper management of the heating system they would get good value from the energy systems.

Understanding the technologies & efficiency

- Controls – Too complex however they could get the temperature and hot water supply they require.
- GSHP – They did not really understand much about the system and would like to have a better understanding.
- Powerpipe – Felt they had an adequate understanding of the working principles.
- PV – Had a basic idea of the working principles, felt it was pointless in the winter, and that the council had some degree of responsibility for the installation and M&O although unclear what.
- Efficiency – They felt they had a good personal understanding anyway, but had not received much guidance.

Woodfields C

The current occupier was living at the property at the time of the installation of these systems.

Overall she is disappointed by the results and had expected the property to be cosy and warm following the work, but instead she often finds she is cold. As a result she is completely unsure whether the systems are effective or if the situation is an improvement.

Further to the performance concerns, the occupier has had considerable difficulty with the electricity suppliers, with bills from different companies and no income from feeding electricity to the grid.

During the installation works, and afterwards the occupier felt stressed; particularly after the works they felt they were badly treated and that this was exacerbated by no information being provided to them. They were disappointed with the quality of the works and the expectations they had, some of the pipe work was left exposed, and decorating work promised was not undertaken.

Hot water & Heating

- The occupier described the hot water provision as “Brilliant”, and very reliable.

- The radiators do not get hot enough for the occupiers needs, the occupier backs up the heating system with an electric heater in the living room, and keeps the chairs near to the radiators for maximum warmth.
- The occupier described the heating in the bathroom as ineffective.
- Overall the occupier said that they find the temperature in their home too cold, and they never get too hot. The occupier had the GSHP set at the highest level.
- With regards to the reliability the occupier felt that the self regulation was effective, but this did not compensate for the heating performance.

Bills & electricity export

- The occupier had only recently moved to the property before the systems were installed and felt they had no comparison as to whether the value of the operations, but they did not feel that there were discernable savings.

Understanding the technologies & efficiency

- Controls – the occupier finds the controls are understandable to use, and this enabled them to adjust the temperature as they needed.
- GSHP – The occupier felt they had a good enough understanding of the system.
- PV – The occupier did not feel they had enough information about the PV panels, particularly with regard to export to the grid.
- Efficiency – The occupier felt they had a decent personal understanding of energy efficiency.

Woodfields D

The occupiers have been living at this property since before the installation works were undertaken.

Heating & Hot water

- The occupier finds the property does get too cold, and in the winter uses a secondary electric heater.
- They did not find any problems with over heating in the property.
- The occupier felt that the hot water supply was adequate for themselves, but would not be for more than one person.
- The occupier was satisfied with the reliability of both the heating and hot water systems.

Bills & electricity export

- Overall the occupier felt that the works presented good value, and that they had noticed a slight saving on the energy costs.
- The occupier also had a feed-in arrangement established, but could not give a value for the income generated.

Understanding the technologies & efficiency

- Controls – The occupier does not make much use of the controls and prefers to leave them as they are set. However they still felt they were not warm enough in the winter.

- GSHP – The occupier was concerned they had not received much information about the GSHP particularly as the installers had said that they were not able to achieve the depths required for the installation.
- PV – The PV system had been explained to them, but they would have liked a better understanding of the system and maintenance.
- Efficiency – The occupier felt they did not have much information or understanding of energy efficiency in the property.

Woodfields F

The occupiers are long term residents having lived there since the mid 1960s.

Hot water & Heating

- In general they found that they did not get too hot or cold and have sufficient hot water provision.
- They are far happier without a fire for heating.
- However they experience infrequent local power cuts and this results in the controls resetting themselves, requiring a service call to have them reset.
- The do not use the shower much, and felt that their hot water demand was very low.

Bills & electricity export

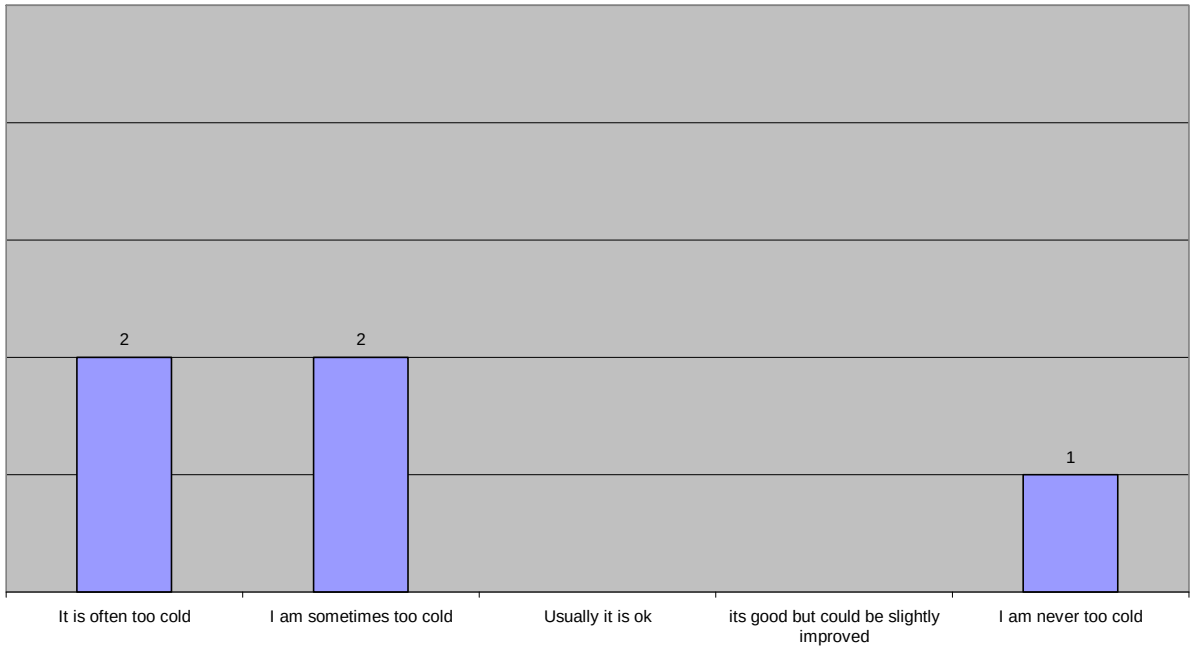
- The couple felt they could not comment on the bills and value for the energy as they have had a bill dispute since the installation. The first bill they received was for £2,500 which is now reduced to £400.
- The bills themselves are far more complex, and they did not know if they feed-in to the grid or not. They would very much like someone to review the problems they are having with their bills to explain the feed-in tariff and resolve the outstanding amounts since the installations.

Understanding the technologies & efficiency

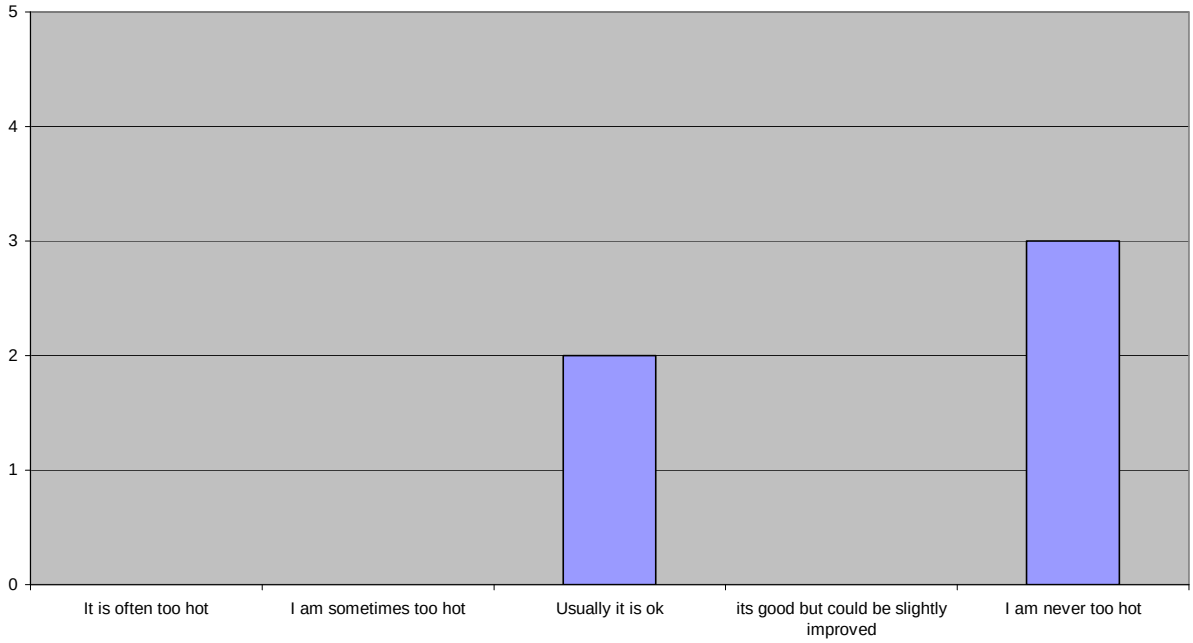
- Controls – The controls are far too complex for the couple who described themselves as elderly and unused to the technology. They noted that the service technicians often take about half an hour to reset the systems.
- GSHP – The occupiers felt that they understood the principles of the system but did not understand how to control the system themselves so were reliant on the controls which they felt was unreliable and too complex.
- Powerpipe – They did not understand the powerpipe system.
- PV – They felt they had a good level of information provided regarding the solar panels
- Efficiency – Whilst they had been provided a leaflet they felt that they already had a good lifestyle with regard to energy consumption and did not refer to the information provided.

Appendix 2: Results of Tenant Interviews (2)

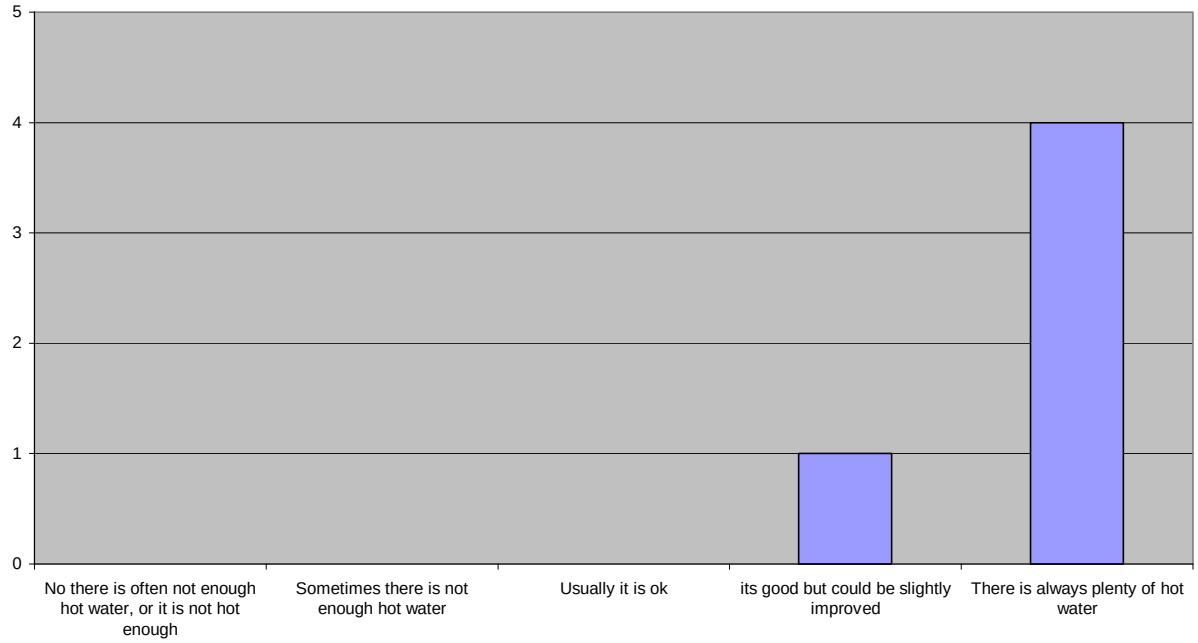
Q1. Does your home get too cold?



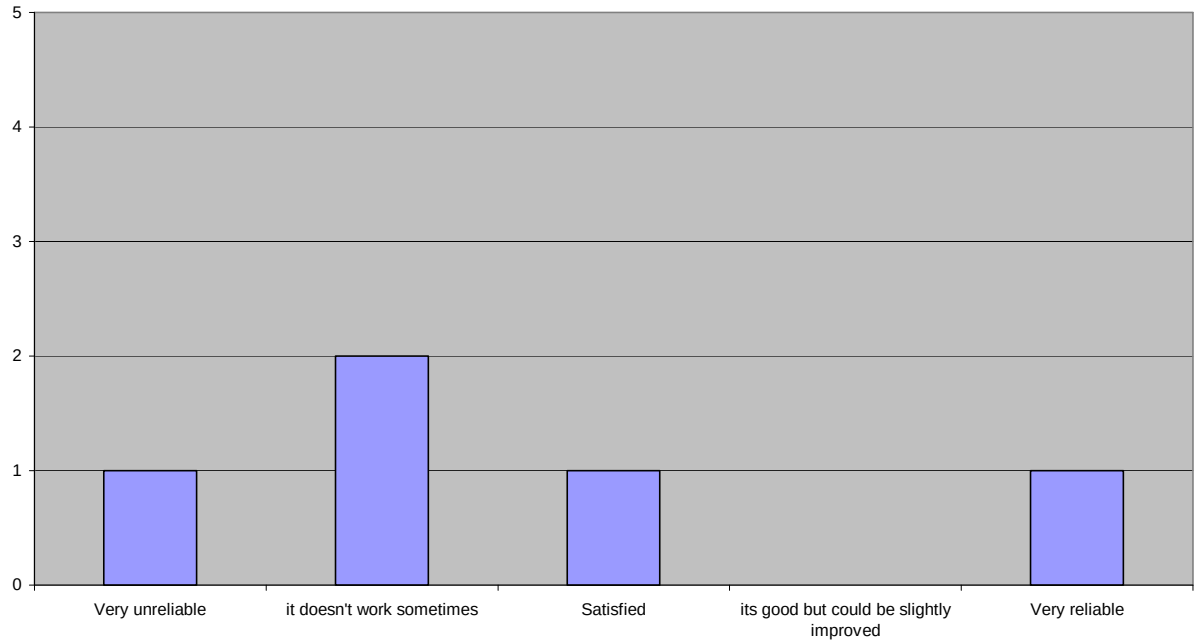
Q.2 Does your home get too hot?



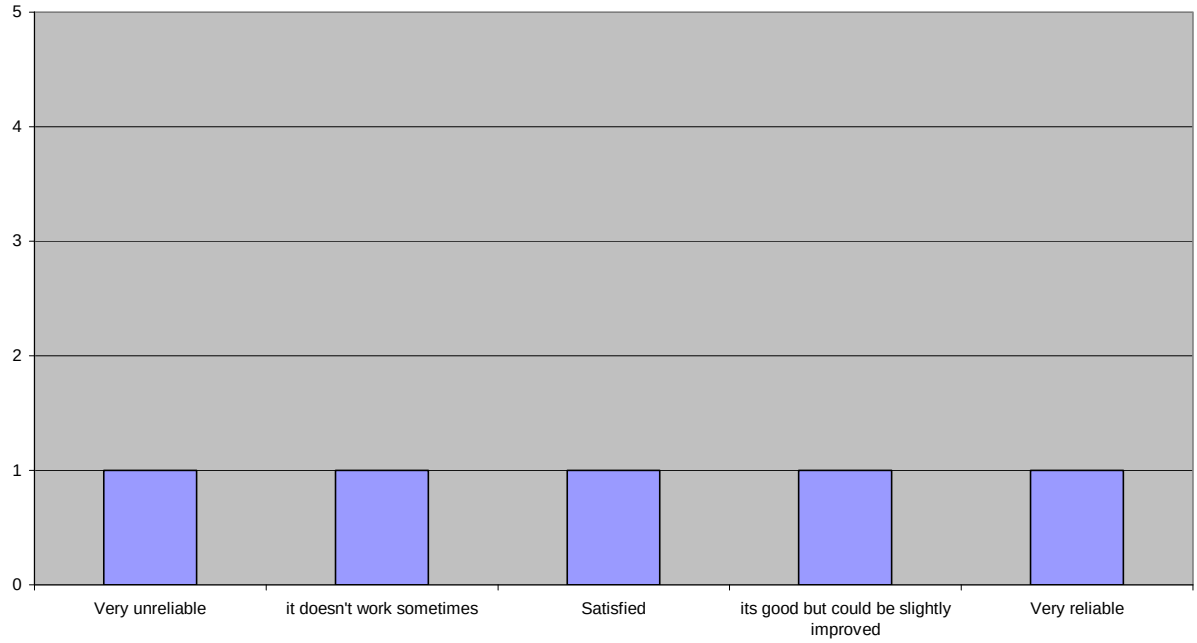
Q.3 Do have plenty of hot water?



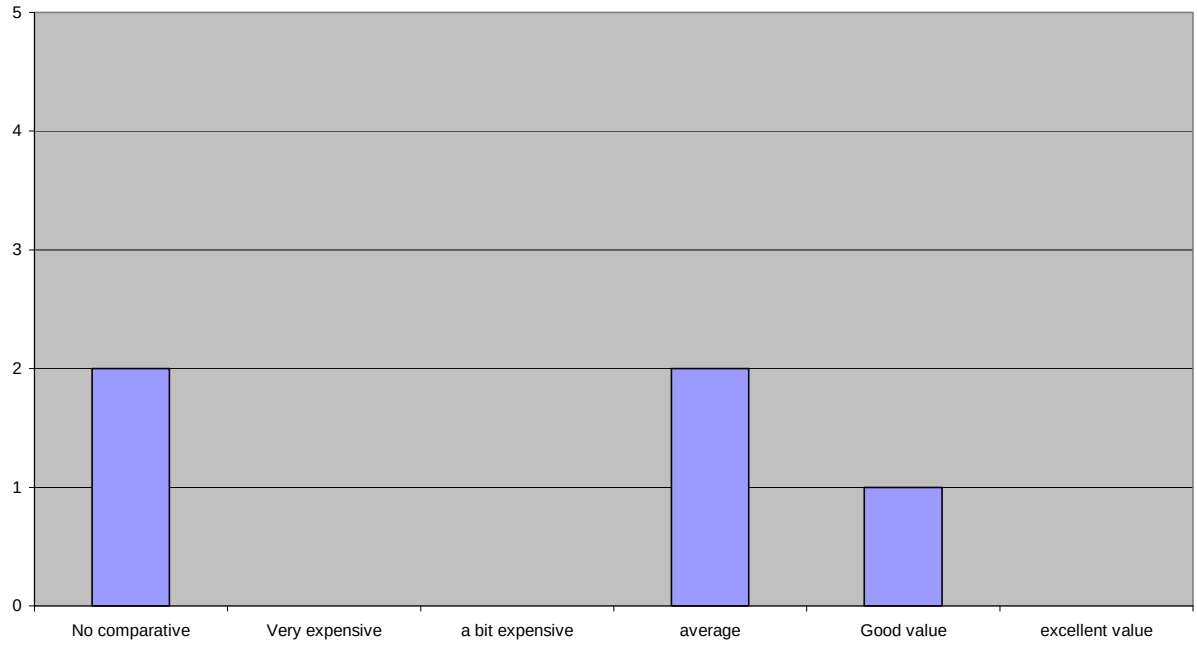
Q.4 Is the heating system reliable



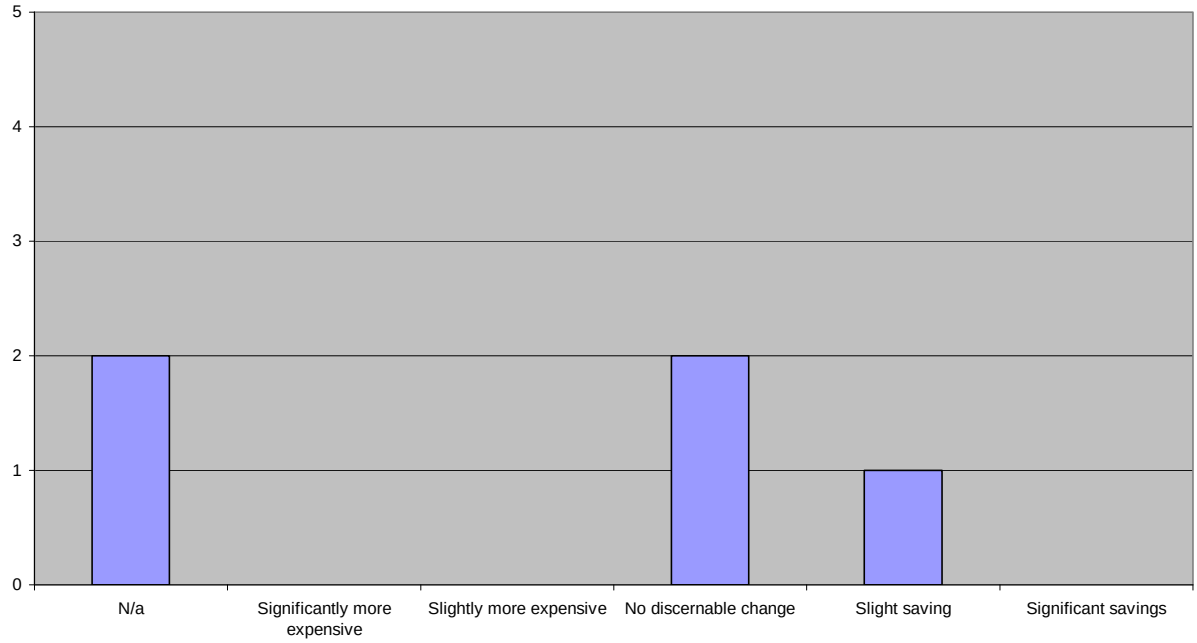
Q.5 Is the hot water system reliable



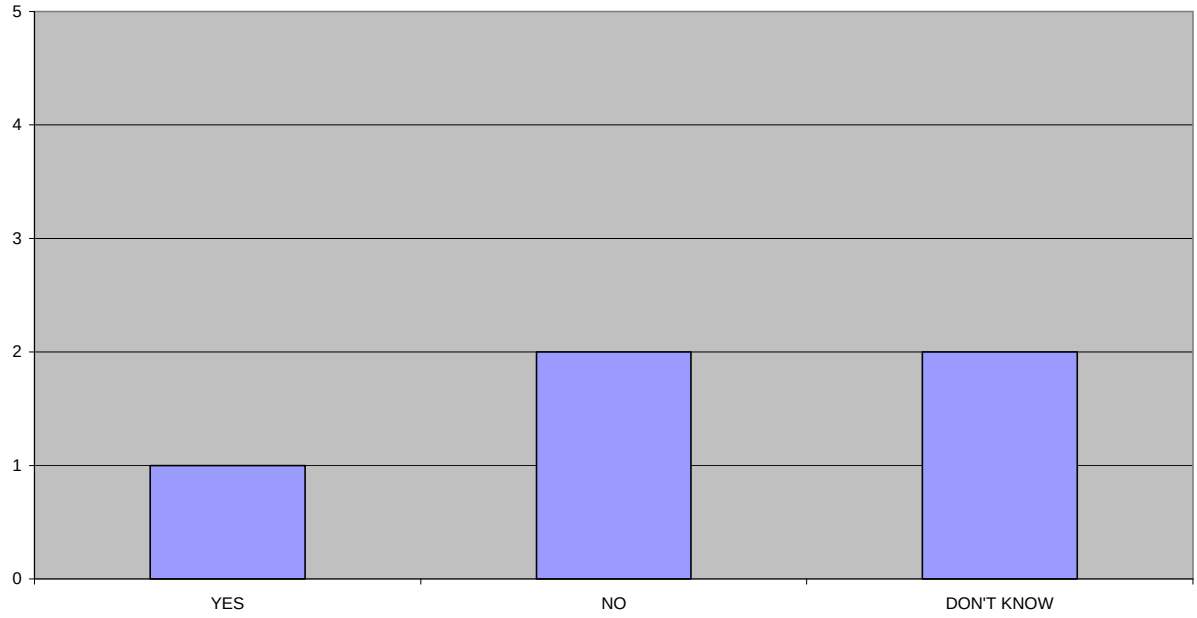
Q.6 Do you think that your payments for your own heating and hot water are good value for money?



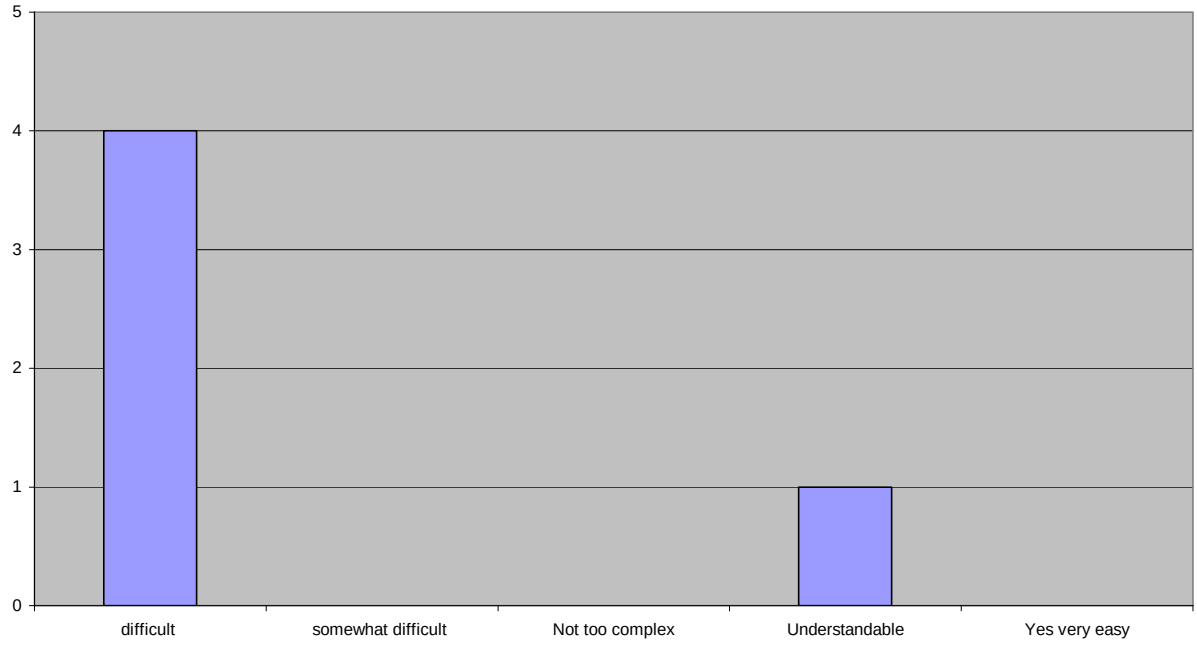
Q.7 Has there been a noticeable change in costs for heating and hotwater



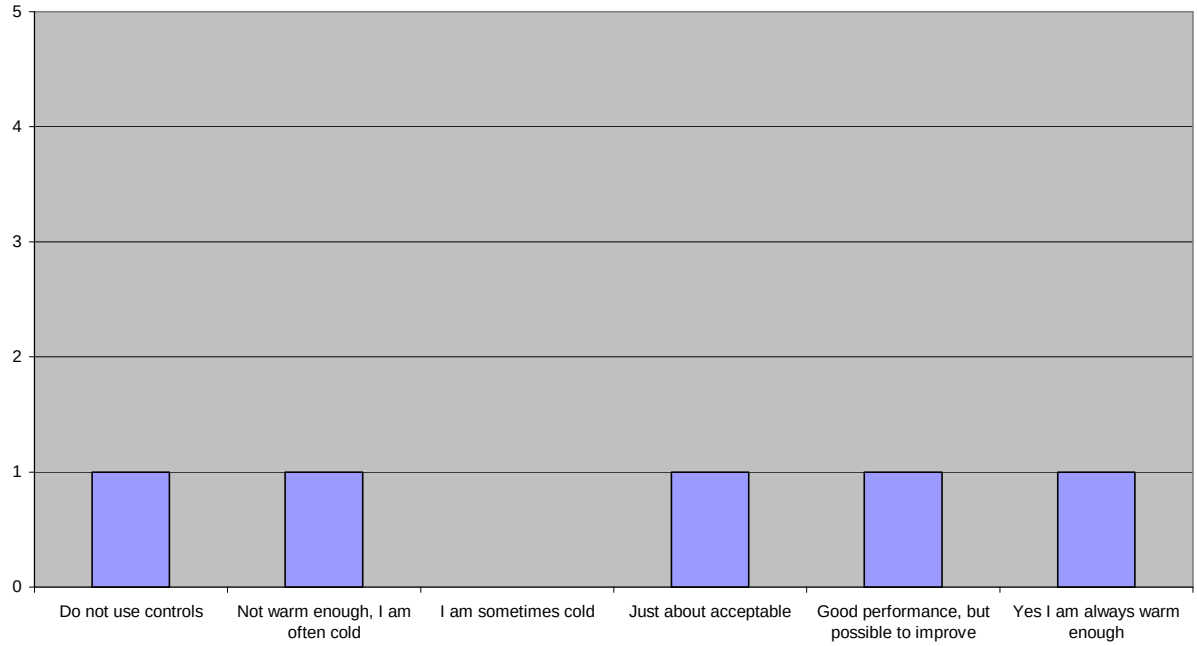
Q.8 Do you receive and financial benefit from excess electricity being sold back to the grid or a discount on your bills



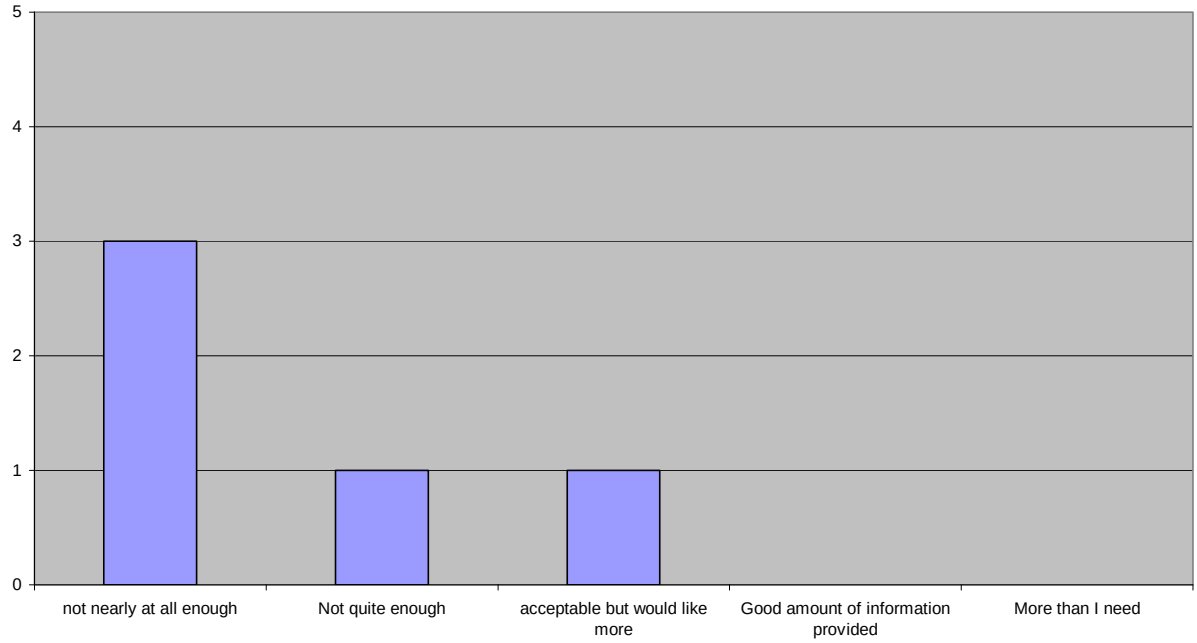
Q.10 Do you feel the heating and hot water controls are easy to understand in principle?



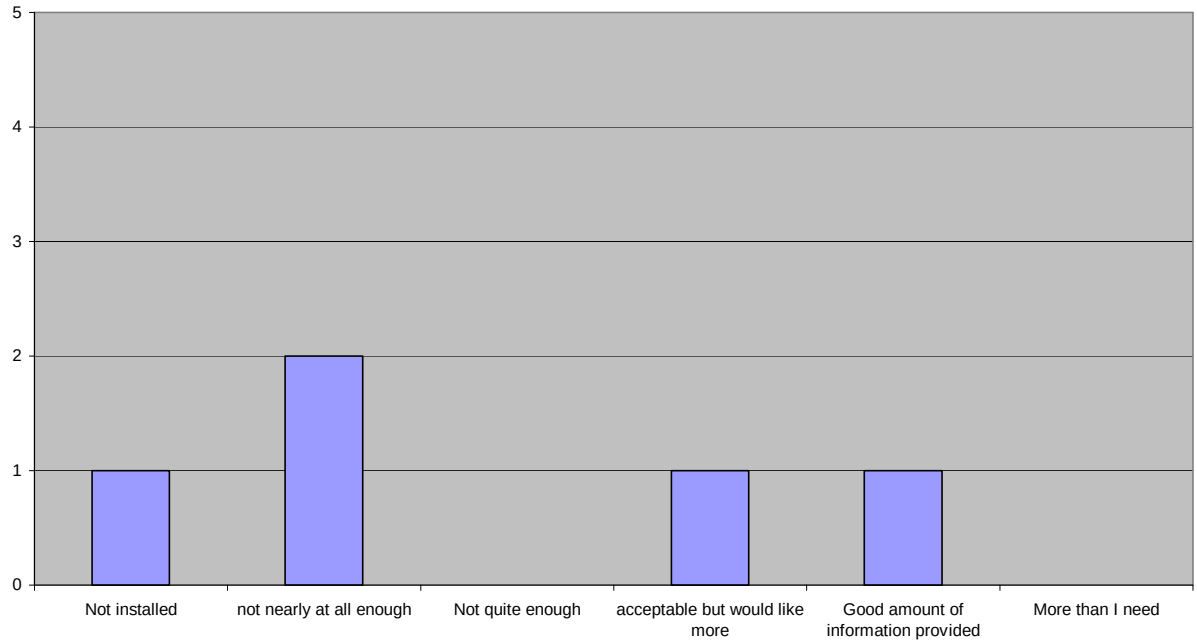
Q.11 do you generally succeed in getting temperatures and hot water just right by using the control?



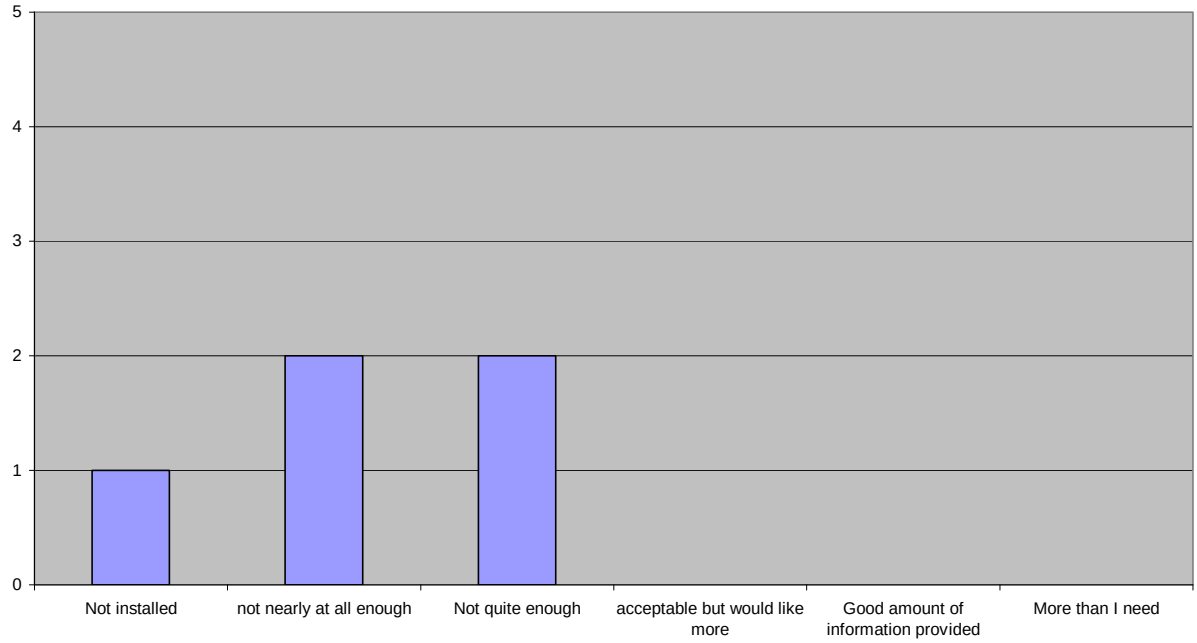
Q. 12 Do you feel you have enough information about your GSHP?



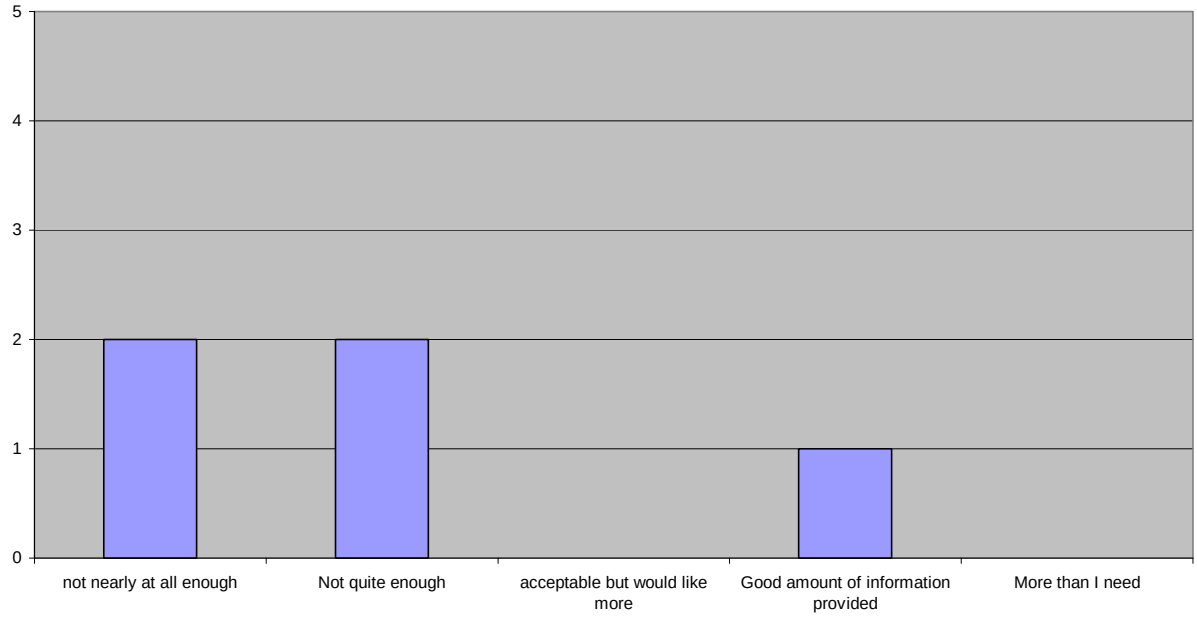
Q.13 Do you feel you have enough information about your Powerpipe?

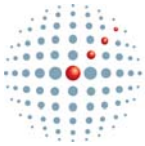


Q.14 Do you feel you have enough information about your PV (solar panels)?



Q.15 Do you feel you have enough information on running your household as energy efficiently as possible? (lighting, aeration regimes, setpoints)





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