Fuel Poverty, Thermal Comfort, and Health in Low-Income Areas in Wales: Results from the First Wave of Data Collection for the Arbed Health Impact Study.

Charlotte Grey, Shiyu Jiang, Wouter Poortinga

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Contents

Appendix A: Description of the Arbed (intervention) and control areas

Appendix B: The Questionnaire

Abstract

This report presents the results of the first wave of data collection that was conducted as part of a community-based field study to examine the health impacts of structural energy performance investments in Wales under the Arbed programme. During the 2013-14 heating season, 5,457 questionnaires were distributed across a number of low-income areas where Arbed energy-efficiency improvements were planned (n=14), as well as a number of matched control areas where no energy-efficiency upgrades were planned (n=13). In total, 1,051 questionnaires were completed and returned (537 from Arbed and 514 from control areas), representing an overall response rate of 19.3%.

The questionnaire covered the topics of housing and housing conditions, heating and heating behaviours, subjective thermal comfort, fuel poverty, dietary choices, social isolation, financial stress, and health and wellbeing, with respondents' self-reported respiratory conditions and mental health status (MCS of SF-12) as the main health outcomes of the study. Analyses show that the Arbed and control samples were broadly similar in terms of socio-economic characteristics, and fuel poverty and health status; although there were some differences in terms of housing type and housing conditions.

The study found that about a third (32%) of the overall sample are in fuel poverty and one in ten (10%) in severe fuel poverty. In line with these results, a third of the sample (33%) find it difficult to meet the cost of fuel bills. A majority of the sample report that they put up with feeling cold in order to save money on fuel costs (62%). Respondents also reported often having difficulties meeting the costs of food and other necessities (24%), as well as moderate (24%) and high (18%) levels of financial stress. The social impacts of living in cold homes is reflected in around a quarter of the sample being reluctant to invite friends and family into their home and not having visited family or friends in the last two weeks (25% and 26%, respectively).

Responses indicate that respondents had a lower than average mental and physical health: 35% report fair or poor health; both the mental (MCS) and physical (PCS) component summary scores of the SF-12 were below the Welsh average (44.6 and 42.9, respectively); and more than three quarters (76%) had experienced at least one respiratory symptom in the last month. Health service use also appears higher in this sample than the national average (32% reported accessing primary care in our sample, compared to 17% from the Welsh Health Survey in 2013).

The data will be used to explore associations between housing conditions, fuel poverty and health as well as potential mediating pathways, and will become part of the controlled field study to examine the health impacts of structural energy performance investments in Wales.

Key Words: Arbed; Energy Efficiency; Fuel Poverty; Thermal Comfort; Health.

Acknowledgments

Abbreviations and Glossary

Arbed	A programme established in 2009 to bring environmental, social and economic benefits to Wales through coordinated investments into the energy performance of Welsh homes in low-income neighbourhoods.
BISF house	British steel framed house produced by the British Iron and Steel Federation
CHS	Carmarthenshire Health Standard
CMD	Common Mental (health) Disorder - comprises of different types of depression and anxiety, often coexisting.
ED	Emergency Department
EPC	Energy Performance Certificate
GP	General Practitioner
LPG	Liquid petroleum gas
LSOA	Lower Super Output Area
MCS	Mental Component Summary Score
NHS	National Health Service
ONS	Office of National Statistics
PCS	Physical Component Summary Score
SF-12	12-item Short Form Health Survey
SF-36	36-item Short Form Health Survey
U.S.	United States
WHS	Welsh Health Survey
WIMD	Welsh Index of Multiple Deprivation

Introduction

This paper presents the results of the first wave of data collection that was conducted as part of a community-based field study to examine the health impacts of structural energy performance investments in low income neighbourhoods across Wales. The aims of the overall study are to find evidence as to whether improving the energy performance of houses can improve the physical and mental health of its occupants, and to explore the potential social and economic processes that may link the investments to better health outcomes.

The study deals with the negative health impacts of cold homes and fuel poverty, and whether these can be alleviated through targeted energy efficiency investments. Energy efficiency investments are often seen as the only permanent solution to the problem, as they effectively 'fuel-poverty proof' the housing stock (DTI 2006). These not only provide better living conditions for occupants, they are also likely to reduce morbidity and mortality, and as a result health inequalities and the financial burden on the NHS (Marmot et al. 2011).

Fuel poverty is central to understanding the relationships between housing and health. Fuel poverty is the situation where a household cannot heat their home to a comfortable level at a reasonable cost. This may result in households either not heating their home adequately or having to make financial trade-offs in order to stay warm (Gilbertson et al. 2012; Harrington et al. 2005) with the potential for debt problems (Hills 2011). Much of the evidence linking fuel poverty to poor health outcomes is related to living in cold homes. Exposure to low temperatures has been shown to be linked to poor respiratory, circulatory and mental health, as well as excess winter mortality (Marmot et al. 2011).

Physical and mental health can also be undermined by trading warmth for other household essentials, such as food. This food-fuel trade-off is known as the 'heat or eat' dilemma (Beatty et al. 2011). Fuel poverty may further be detrimental to mental and social wellbeing as a result of the financial stress it places on households (Marmot et al. 2011), a lack of thermal comfort (Gilbertson et al. 2012), and social isolation caused by economising and a reluctance to invite friends and family into a cold home (DTI 2001). These latter pathways are less well understood, as such social outcomes are more difficult to assess due to their subjective nature (Hills 2011). The existing evidence for psychological, social and economic pathways comes mainly from qualitative studies (Thomson et al. 2013). Very few quantitative studies have attempted to explore how such processes may contribute to physical and mental health outcomes (Liddell and Morris 2010).

This working paper provides a description of the first wave of data collected during the 2013-14 heating season as a baseline for future comparison. There are several aspects of the study that will be developed in future analyses and publications. In particular, the data will be used to explore associations between housing conditions, fuel poverty and health, as well as potential mediating pathways. The sample will become part of the controlled field study to examine the health impacts of structural energy performance investments in Wales.

Methodology

Procedure and Study Areas

Data for the first wave of data collection were collected during the 2013-14 heating season (November 2013 to January 2014) in low-income areas where Arbed energy-efficiency improvements were planned (n=14), as well as a number of matched control areas where no energy-efficiency upgrades were planned (n=13; see Figure 2). Arbed schemes where work had already started were excluded from the study. The control areas were selected using the Welsh Index of Multiple Deprivation (WIMD) and with the help of Local Authorities where the Arbed schemes were taking place. Anglesey was the only Arbed scheme that did not have a matched control group (see Table 1). The selected areas are described in Appendix A.

Figure 2. Locations of the included Arbed intervention (blue) and control (red) areas

NORTH/MID WALES
Wrexham
Gwynedd
Anglesey
Denbighshire/Flintshire
Ceredigion

SOUTH WALES
Cardiff
Merthyr Tydfil
Carmarthenshire
Bridgend
Blaenau Gwent
Rhondda Cynon Taff
Caerphilly
Newport
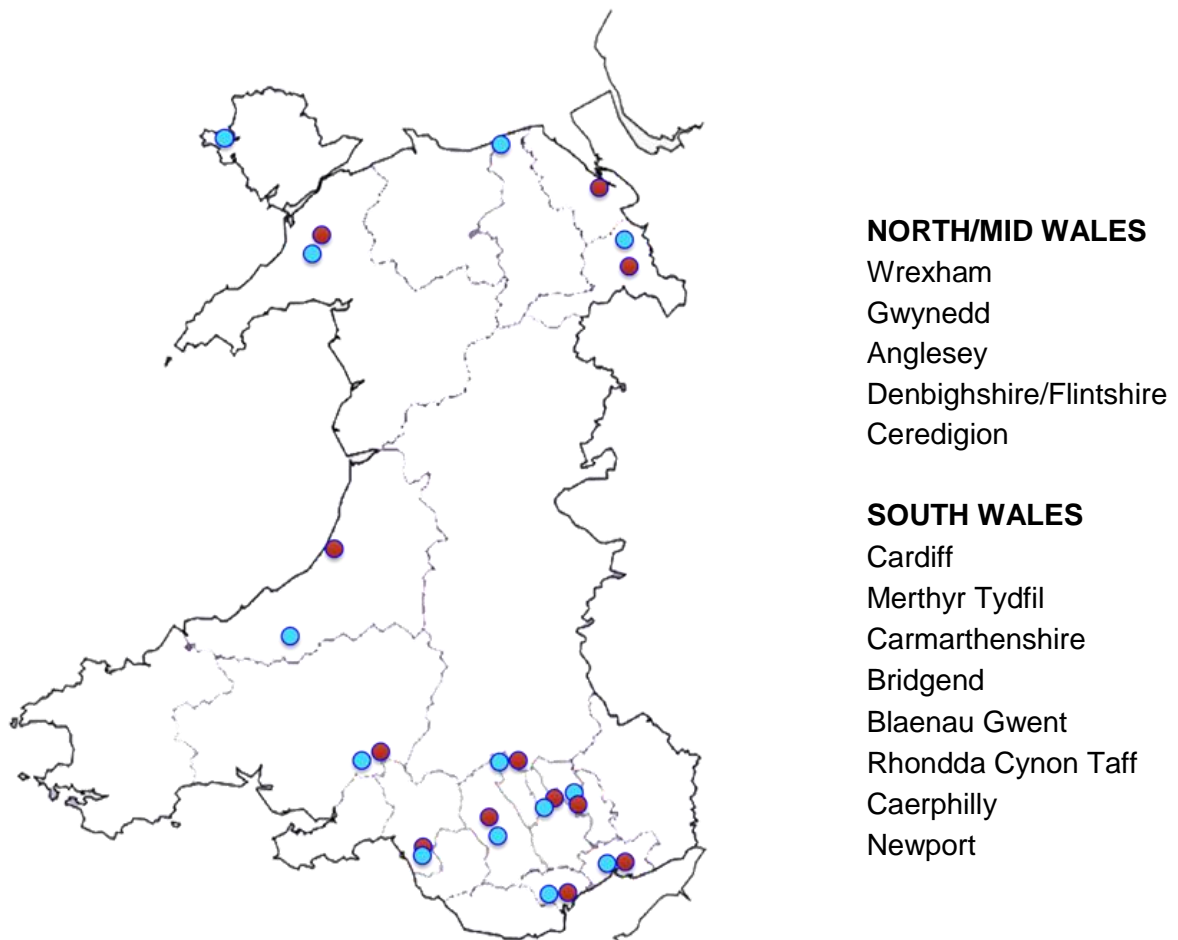
Data were collected via the *drop-off-and-collect* method of survey administration (Steele et al. 2001). This involved the personal delivery of the questionnaires to occupants to invite them to take part in the research. Researchers then returned at a later date (usually within a week) to pick up the questionnaires. When at the time of delivery no occupants were at home, a questionnaire with cover letter was left in their letterbox. Similarly, a reminder to return the questionnaire was left when occupants were away at the time of the return visit. The questionnaires could then be returned via Freepost. The same method of data collection was used in the Arbed and control neighbourhoods. Participants were asked to provide their contact details and to provide consent to be recontacted.

Table 1. Distribution of surveys, returns, and consent rates for the included Arbed and control areas

Region and Local Authority	Arbed			Control		
	Distributed #	Returned[1] # (%)	Consent[2] # (%)	Distributed #	Returned[1] # (%)	Consent[2] # (%)
North/Mid Wales						
Wrexham	381	116 (30.4)	99 (85.3)	275	51 (18.5)	42 (82.4)
Gwynedd	285	70 (22.5)	64 (91.4)	327	113 (34.6)	98 (86.7)
Anglesey	58	8 (13.8)	7 (87.5)	---	---	---
Denbighshire/ Flintshire	129	30 (23.3)	27 (90.0)	83	13 (15.7)	11 (84.6)
Ceredigion	110	27 (24.5)	24 (88.8)	289	65 (22.5)	54 (83.1)
South Wales						
Cardiff	141	27 (19.1)	26 (96.3)	255	42 (16.5)	37 (88.1)
Merthyr Tydfil (year 1)	137	34 (24.8)	24 (70.6)	214	44 (20.6)	34 (77.3)
Merthyr Tydfil (year 2)	229	42 (18.3)	39 (92.9)	232	30 (12.9)	23 (76.7)
Carmarthenshire	174	41 (23.6)	38 (92.7)	222	44 (19.8)	39 (88.6)
Bridgend	281	54 (19.2)	40 (74.1)	290	32 (11.0)	26 (81.3)
Blaenau Gwent	260	32 (12.3)	29 (90.6)	278	23 (8.3)	19 (82.6)
Rhondda Cynon Taff	176	21 (11.9)	18 (85.7)	155	30 (19.3)	22 (73.3)
Caerphilly	117	23 (19.6)	22 (95.7)	133	17 (12.8)	13 (76.5)
Newport	118	12 (10.2)	10 (83.3)	122	10 (8.2)	8 (80.0)
Total	**2,596**	**537 (20.7)**	**467 (87.1)**	**2,875**	**514 (17.9)**	**426 (82.9)**

Note: # number of surveys; [1] percentage returned out of number distributed; [2] percentage consent out of number returned.

In total, 5,457 questionnaires were distributed across the 27 Arbed and control areas (see Table 1), of which 1,051 questionnaires completed and returned. This represented a response rate of 19.3%. Of the respondents who returned the questionnaire, 893 consented to be contacted again for the second wave of data collection (a consent rate of 85.0%). Table 1 shows that that there is considerable variation in response rates across the different areas (between 6.6% and 43.5%). The consent rates were more comparable across the different areas (between 70.6% and 96.3%). Some of the variation in response rates is due to differences in occupation (some areas had more un-occupied properties at the time of the study). It is also possible that the differences in response rates are caused by differences in the makeup of the areas, although an analysis of the dataset shows that the Welsh Index of Multiple Deprivation (WIMD) was not significantly associated with the response rate.

Respondents and Sample Characteristics

Table 2 shows the socioeconomic characteristics of the Arbed and control samples. The two samples were broadly comparable in terms of socio-demographic characteristics. Over 60% of the returned questionnaires were completed by women; a higher proportion of questionnaires were returned by residents aged over 55; and 23% of all households had children residing in the home, with those in the Arbed sample being more likely to have at least one child living in their household (χ^2(1, N=1,021)=8.648, p=0.003). Only a small number of the households (5-6%) were made up of single adults with children. The largest proportion of respondents were retired (41%) followed by those working full time (21%). Just over a quarter of the sample (27%) received housing benefits, with respondents from the Arbed sample being slightly more likely to receive them than those from the control areas (30% versus 24%; χ^2(1, N=1,019)=5.996, p=0.014). In both cases the highest proportion of household incomes were between £10,000 and £19,999 (34% in the Arbed area and 33% in the control area).

Table 2. Socio-demographic characteristics of the samples (%)

		Arbed (n=537)	Control (n=514)	Overall (n=1,051)
Gender	Male	36.5	35.0	35.8
	Female	60.9	61.7	61.3
	Not answered	2.6	3.3	2.9
Age (years)	Under 25	3.7	3.1	3.4
	26-35	10.4	9.9	10.2
	36-45	12.8	11.3	12.1
	46-54	15.1	12.1	13.6
	55-64	23.5	22.6	23.0
	65 or above	33.0	38.9	35.9
	Not answered	1.5	2.1	1.8
Household composition	Households with children	26.3	18.7	22.5
	Not answered	2.8	2.9	2.9
	Households with more than one adult	57.9	55.3	57.5
	Not answered	2.4	2.5	2.5
	Single parent households	6.5	5.4	6.0
Marital status	Single	14.2	13.8	14.0
	Married/cohabiting	53.3	52.3	52.8
	Separated/divorced	16.8	17.5	17.1
	Widowed	14.2	14.8	14.5
	Other/not answered	1.7	1.6	1.6
Employment status	Employed full time	20.9	21.8	21.3
	Employed part time	11.4	9.5	10.5
	Self employed	2.6	2.3	2.5
	Unemployed, looking for work	5.4	3.7	4.6
	Retired	38.9	43.2	41.0
	Full time house person	5.0	4.1	4.6
	Not working because of poor health or disability	12.1	10.5	11.3
	Other/not answered	3.7	4.9	4.3
Income	£0-4,999	4.3	4.5	4.4
	£5,000-9,999	23.5	21.6	22.5
	£10,000-19,999	33.7	32.9	33.3
	£20,000-29,999	14.9	14.8	14.8
	£30,000 or higher	14.5	15.6	15.0
	Not answered	9.1	10.7	9.9
Housing benefits	Yes	30.4	23.5	27.0
	No	66.9	73.2	69.9
	Not answered	2.8	3.3	3.0

The Questionnaire

The questionnaire covered the topics of housing and housing conditions, heating and heating behaviours, subjective thermal comfort, fuel poverty, dietary choices, social isolation, financial stress, and health and wellbeing. The health and wellbeing section included quality of life, as measured by the SF-12 scale, self-reported respiratory conditions, treatment of medical conditions, health service use and subjective wellbeing. Respondents' self-reported respiratory conditions and mental health status (MCS of SF-12) were the main health outcomes of the study. The socio-demographic section of the questionnaire contained questions about gender, age, household composition, marital status, employment status, household income, and housing benefits (see Table 2). The full questionnaire can be found in Appendix B.

Housing and Housing Conditions. Respondents were asked multiple questions about their home (i.e. housing type, building age, number of bedrooms, tenure and time of residence at their current home) and housing conditions. Housing conditions were assessed by asking respondents whether they currently experience a number of problems in their home, including condensation, leaking roof, damp walls and/or floors, rot in windows or door frames, draught and mould. They were also asked to what extent they are satisfied with the current state of repair of their home, as a subjective measure of the overall condition of their home.

Heating and Heating Behaviours. Respondents were asked about their heating system, fuel use and heating behaviours, including which rooms they heat on a typical winter days and evenings.

Subjective Thermal Comfort. Thermal comfort was measured subjectively by asking respondents about their level of satisfaction with the temperature in their home on a typical winter day. This question was previously used in the *Carmarthenshire Homes Standard (CHS) Health Impact Study* (Poortinga 2012). Respondents were further asked whether the overall warmth in their home is colder or warmer than they would like during the winter. This question was previously used by Anderson et al. 2010.

Fuel Poverty. Fuel poverty was assessed in multiple ways. We used three subjective indicators of fuel poverty to explore whether households experience difficulties heating their home to an adequate level and/or paying their fuel bills (Hills 2011). First, respondents were asked whether they put up with feeling cold to save heating costs. This question was previously used in the *New Zealand Housing and Health Research Programme* (Howden-Chapman et al. 2005). Second, respondents were asked how often it is difficult to meet the cost of fuel bills. This item is part of the financial stress scale (detailed below). Third, one of the subjective thermal comfort items ("*How would you describe the overall level of warmth in your home during the winter?*") was used as an indicator to see whether a home is heated to an adequate level. Fuel poverty was further assessed using respondents' self-reported fuel costs and income (Welsh Government 2014b).

Dietary Choices (Food Security). This study used three questions from the *U.S. Adult Food Security Survey* (2012) developed by the *U.S. Department of Agriculture* to determine households' economic access to sufficient food in terms of quantity, quality, and variety. Food security is defined as access at all times to enough food for an active, healthy life, including readily available nutritionally adequate and safe foods that can be acquired in socially acceptable ways (Bickel et al. 2000). One of the financial stress items (reported below) was used to assess difficulties meeting the cost of food and other necessities.

Social Isolation. Social isolation was measured by asking respondent whether they have ever felt reluctant to invite people to their home because of difficulties keeping it warm. This question was previously used in the *Adult Psychiatric Morbidity in England* study (McManus et al. 2007). The respondents were also asked how frequently they had either gone out to visit family and friends or had family/friends visit their home in the past two weeks. This question was adapted from the *Scottish Central Heating Programme* study (Platt et al. 2007).

Financial Stress. This study used the financial stress scale from the Renton-I study (Thomson et al. 2007) to explore how often respondents find it difficult to meet the cost of eight different household expenses (i.e. rent or mortgage, repairs or maintenance of home, fuel bills, telephone bills, bills that come up from time to time [council tax, insurance etc], credit payments, food and other necessities, and 'treats' like a night out). Respondents were further asked about their general level of financial stress (see Rosengren 2004), and whether they feel financially better or worse off as compared to a year ago.

Health-Related Quality of Life. This study used the SF-12 scale to assess overall quality of life (Ware et al. 2002). The 12-item scale includes questions on physical and mental health, covering the eight subdomains of general health, physical functioning, role functioning (physical), bodily pain, vitality, role functioning (emotional), mental health, and social functioning. The items can be combined to form separate physical and mental health summary scores (PCS/MCS). The scale includes a widely-used self-reported health item (asking respondents to rate their own general health on a four-point scale from excellent to poor), which can be used as stand-alone measure.

Self-Reported Respiratory Conditions. Upper and lower respiratory symptoms were measured using questions adapted from Fisk et al. (2007) and World Health Organization (2009). These have previously used in the *CHS Health Impact Study* (Poortinga 2012), and comprise of a list of symptoms of lower respiratory illness/asthma and upper respiratory tract conditions that are indicative of poor respiratory health.

The survey included the short version of the *European Community Respiratory Health Survey* (ECRHS 2014) containing nine questions about the presence of symptoms that might be indicative of asthma or lower respiratory ill-health. The survey was designed to estimate prevalence of asthma, asthma-like symptoms and airway responsiveness (Burney et al. 1994).

Treatment of Medical Conditions. The questionnaire included a question asking respondents whether they are currently being treated by their GP or hospital for a number of cardiovascular, respiratory, and mental health conditions, as well as for arthritis. The question was adapted from the *Welsh Health Survey* (Welsh Government 2014c) and previously used in the *CHS Health Impact Study* (Poortinga 2012).

Health Service Use. Health service use was assessed with three questions adapted from the *Welsh Health Survey* (Welsh Government 2014c). Respondents were asked how many times they had visited a family doctor (GP) during the past two weeks, how many times they did go to an emergency department (Accidents & Emergency) during the past 12 months, and how many times they had visited a hospital (as an in or out patient) during the past 12 months.

Subjective Wellbeing. Subjective wellbeing was measured using four questions developed by the *Office for National Statistics* (Dolan et al. 2011). The questions were developed to measure three different aspects of subjective wellbeing, including respondents' *life satisfaction* (an evaluation or 'global assessment' measure), *happiness* and *anxiousness* (both experience measures, reflecting feelings over short periods of time), and *worthwhileness* (a 'eudemonic' measure)[1]. Respondents could answer the questions using an 11-point scales ranging from 'not at all' to 'completely'.

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[1] Eudemonic measures aim to capture factors not necessarily reflected in evaluative or experience measures, such as autonomy, control, competence, engagement, good personal relationships, a sense of meaning, purpose and achievement (Dolan et al. 2011).

Results

Housing and Housing Conditions

This section describes the housing characteristics of the study samples and the conditions the houses are reported to be in. Table 3 shows that the majority of respondents from the Arbed and control areas live in semi-detached and terraced housing, and have resided in their home for more than nine years. The respondents are most likely to be owner-occupiers (67%). Twenty two percent (22%) rent their house from a local authority or registered social landlord. Private rentals make up about 9% of all tenures. Most respondents' homes were reported to have been built before 1919. Only a small proportion of homes was built after 1980 (4%).

Table 3. Housing characteristics of the samples (%)

		Arbed (n=537)	Control (n=514)	Overall (n=1,051)
House type	Detached house	9.3	12.5	10.8
	Semi-detached house	43.8	33.7	38.8
	Terraced house	36.1	42.8	39.4
	Bungalow	5.4	3.1	4.3
	Flat	3.0	4.9	3.9
Building age	Before 1919	32.6	43.0	37.7
	1919-1945	29.6	23.0	26.4
	1945-1965	20.5	17.7	19.1
	1965-1979	7.3	6.0	6.7
	1980 or later	4.3	4.1	4.2
Number of Bedrooms	One	2.6	4.3	3.4
	Two	18.8	23.0	20.8
	Three	67.0	61.5	64.3
	Four or more	8.8	7.8	8.3
Time lived in current home	Less than one year	6.0	4.1	5.0
	1-4 years	11.7	14.2	12.9
	5-9 years	13.6	13.4	13.5
	More than 9 years	67.6	66.5	67.1
Tenure	Owner occupied	63.7	70.8	67.2
	Private rental	8.8	8.4	8.6
	Local authority rental	20.1	12.8	16.6
	Registered social landlord rental	4.3	5.6	4.9

A significant difference in satisfaction with the current state of repair of the home was found between people living in the Arbed and those living in the control areas, χ^2(4, N=1,036)=11.644, p=0.020 (see Figure 3). Fewer people from the Arbed areas were either very or fairly satisfied with the state of repair of their home, as compared to those from the control areas (57% versus 64% respectively). About 24% of the respondents from the Arbed areas and 20% of the respondents from the control areas were fairly or dissatisfied with the state of repair their home.

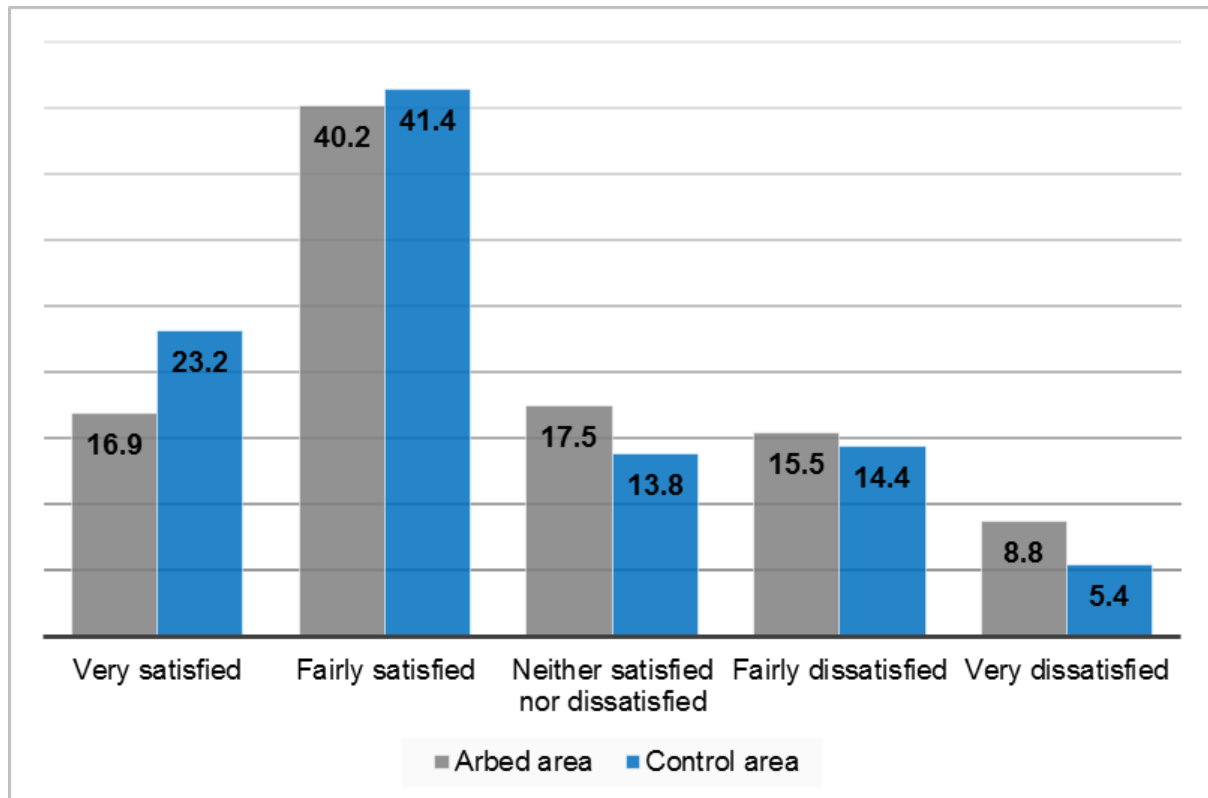**Figure 3. Satisfaction with the current state of repair of home**

Table 4 shows the proportion of respondents reporting housing-related problems in the Arbed and control areas. Overall, about 75% of people reported that they were experiencing at least one problem, most commonly condensation or draught (both 46%). Thirty ficve percent (35%) of the overall sample reported damp, and 30% reported mould.

Respondents from the Arbed areas were more likely than those from the control areas to report housing problems (80% versus 70%), χ^2(1, N=1,042)=12.702, p=0.000. In particular, respondents from the Arbed areas were more likely than those from the control areas to report draught, χ^2(1, N=1,042)=8.890, p=0.003.

Table 4. Reported housing problems (%)

	Arbed (n=537)	Control (n=514)	Overall (n=1051)
Condensation	48.8	43.2	46.1
Leaking roof	16.6	13.2	14.9
Damp	38.2	32.1	35.2
Rot	10.4	8.0	9.2
Draught	50.5	41.1	45.9
Mould	31.3	28.0	29.7
No housing problems	19.6	28.8	24.1
One or more housing problems	79.9	70.0	75.1

The level of satisfaction with the state of repair of the home was directly associated with the number of reported housing problems (condensation, leaking roof, damp walls and floors, rot in windows and door frames, draught, and mould), χ^2(24, N=1,036)=387.903, p=0.000. Figure 4 shows that respondents reporting a higher number of housing problems are more dissatisfied with the current state of repair of their home.

Figure 4. Association between reported housing problems and satisfaction with current state of repair of home[2]

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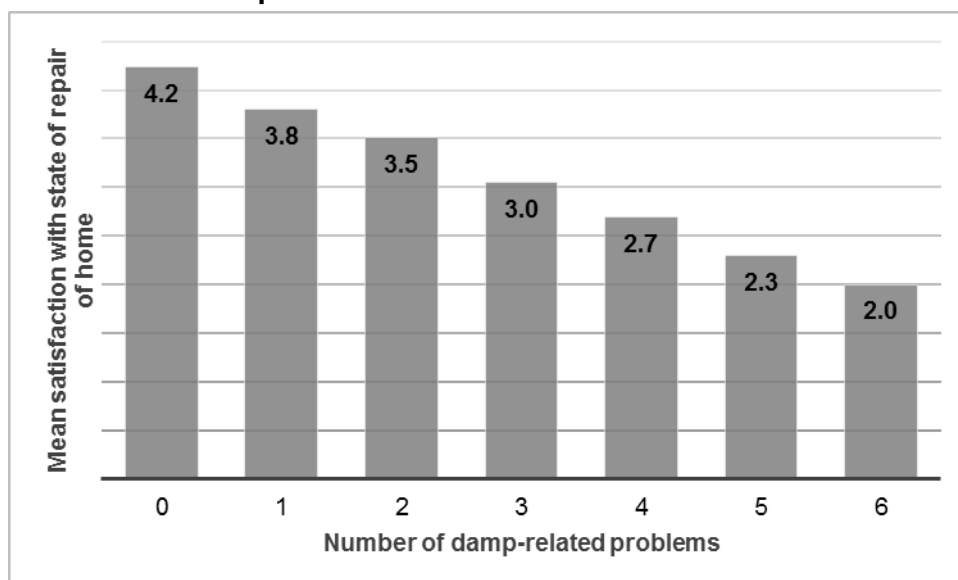
[2] Satisfaction scale ranges from 1 'very dissatisfied' to 5 'very satisfied'

Of all the people who responded to the survey, only about 7% reported not having central heating. No significant difference was found between the Arbed and control samples, χ^2(1, N=1,011)=1.216, p=0.270. As can be seen in Figure 5, 58% of respondents reported using gas central heating, 22% oil-fired central heating, and 9% electric central heating. About one out of six (17%) reported using solid fuels and about one out of twenty (4%) bulk LPG (liquid petroleum gas) to heat their home. Just over a quarter (26%) reported using some type of portable heater to warm their home (i.e. a gas, electric or oil-filled portable heater). Electric heaters were often used in addition to other heating systems.

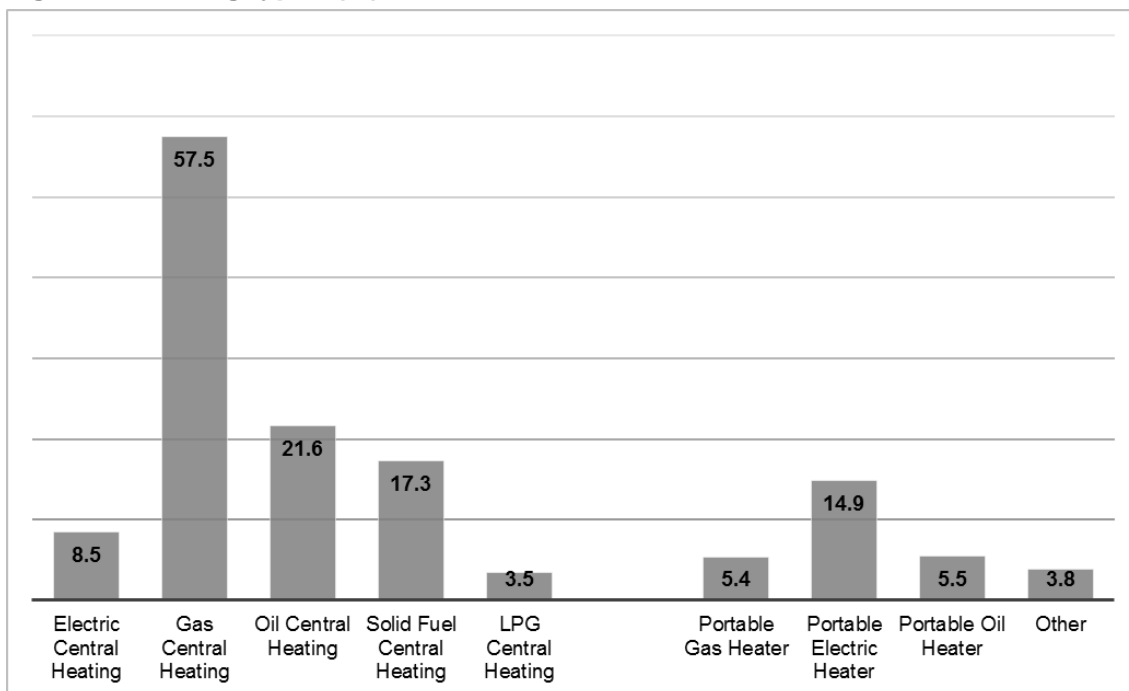**Figure 5. Heating types (%)**

Table 5 shows the number of rooms respondents heat on a typical winter day and evening. A small percentage of residents reported not heating any room during the day (7%) or in the in the evening (2%). About 20% of respondents would only heat one or two rooms on a typical winter evening. A Mann-Whitney test indicated that the Arbed and control groups had different daytime heating patterns, U=127,415, p=0.044, but similar evening heating patterns, U=128,475, p=0.072.

Table 5. Number of rooms heated on a typical winter day and evening (%)

	Number of Rooms Heated								
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Day									
Arbed (n=537)	6.0	11.7	8.8	9.3	13.6	13.2	13.0	18.6	5.6
Control (n=514)	8.2	13.2	7.4	9.9	15.8	14.0	13.2	11.7	6.2
Total (n=1,051)	7.0	12.5	8.1	9.6	14.7	13.6	13.1	15.2	5.9
Evening									
Arbed (n=537)	2.4	9.7	6.9	10.8	14.0	15.3	14.2	20.7	6.0
Control (n=514)	1.4	10.7	10.7	11.9	13.4	17.3	13.2	13.0	8.0
Total (n=1,051)	1.9	10.2	8.8	11.3	13.7	16.3	13.7	16.9	6.9

Subjective Thermal Comfort

Figure 6 shows satisfaction with the home temperature on a typical winter day for respondents from the Arbed and control areas. Overall, respondents from the Arbed areas were less likely to be satisfied (47%) than those from the control areas (55%), $\chi^2(4, N=1,041)=11.150$, $p=0.025$. respondents from the Arbed areas were more likely to be dissatisfied (38%) than those from the control areas (28%).

Figure 6. Satisfaction with home temperature on a typical winter day (%)
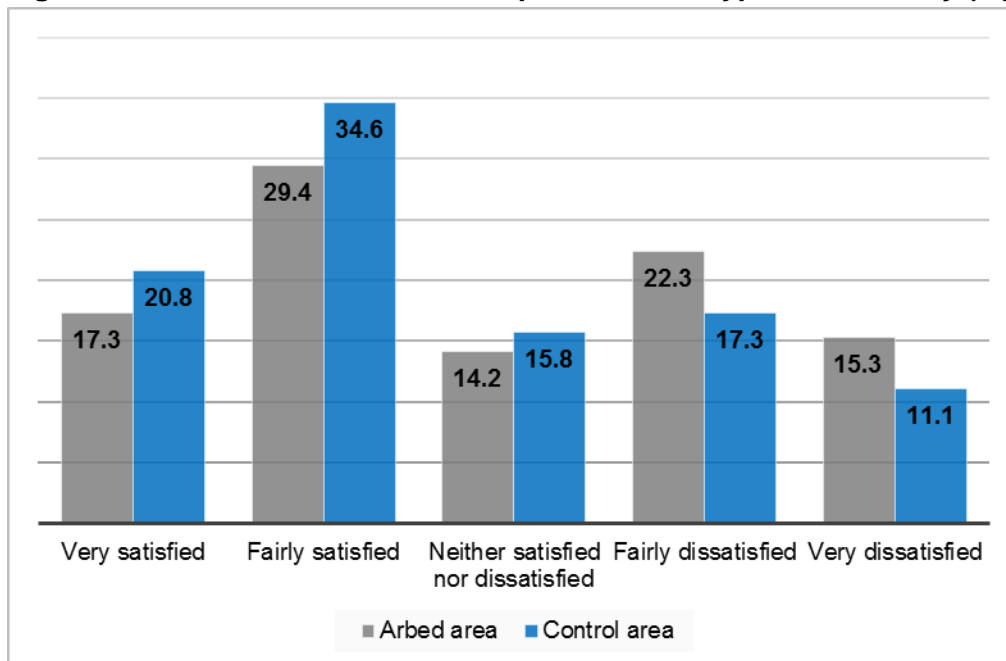
Table 6 shows that about 61% of the overall sample reported that the level of warmth in their home was colder than they would have liked. A significant difference was found between respondents from the Arbed and control areas, $\chi^2(5, N=1,041)=12.995$, p=0.023. Respondents from the Arbed area were more likely to report that the level of warmth in their home was colder than they would have liked. Respondents from the control areas were more likely to report that the level of warmth in their home was about right.

Table 6. Respondents' perceived level of warmth in the home during the winter (%)

	Arbed (n=537)	Control (n=514)	Overall (n=1,051)
Much colder than would have liked	28.5	22.2	25.4
Bit colder than would have liked	35.9	36.0	36.0
About right	29.8	38.5	34.1
Bit warmer than would have liked	2.2	1.0	1.6
A lot warmer than would have liked	0.4	0.2	0.3
Both too warm and too cold	1.9	1.6	1.0

Figure 7 shows the relationship between the number of reported housing problems and the mean satisfaction with the indoor temperature inside the home during a typical winter day. Those reporting more housing problems were generally less satisfied with the indoor temperature of their home, $\chi^2(24, N=1,036)=275.329$, p=0.000.

Figure 7. Association between reported housing problems and mean satisfaction with indoor temperatures on a typical winter day[3]
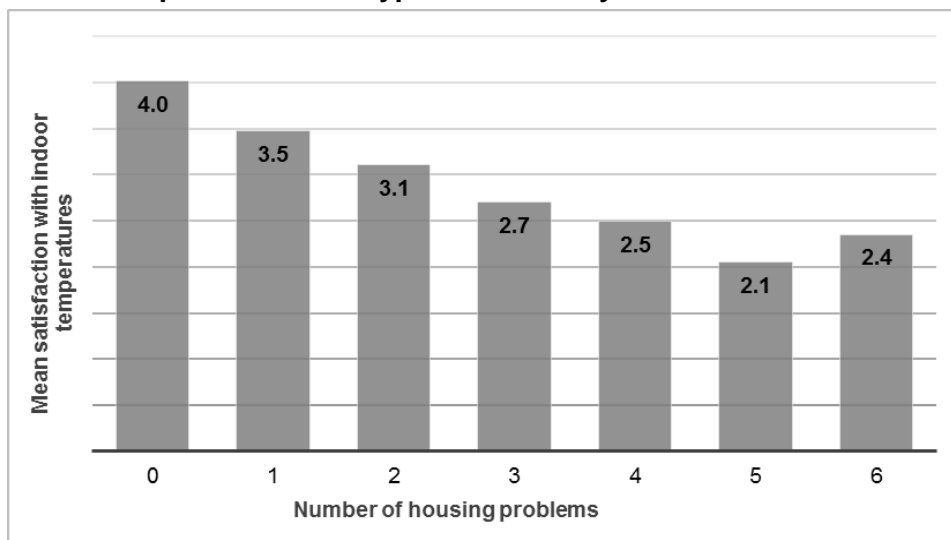
[3] Scale ranges from 1 'very dissatisfied' to 5 'very satisfied'.

Less than half (45%) of the respondents in the Arbed and control areas pay their energy bills by direct debit, the cheapest way of paying for fuel bills (Figure 8). Just under a third of respondents (28%) used prepayment meters to pay for their gas and electricity bills. Hills (2012) found that households using prepayment meters are at a higher risk of fuel poverty, as prepayment meters are generally the most expensive way to pay for fuel.

Figure 8. Payment methods for gas and electricity
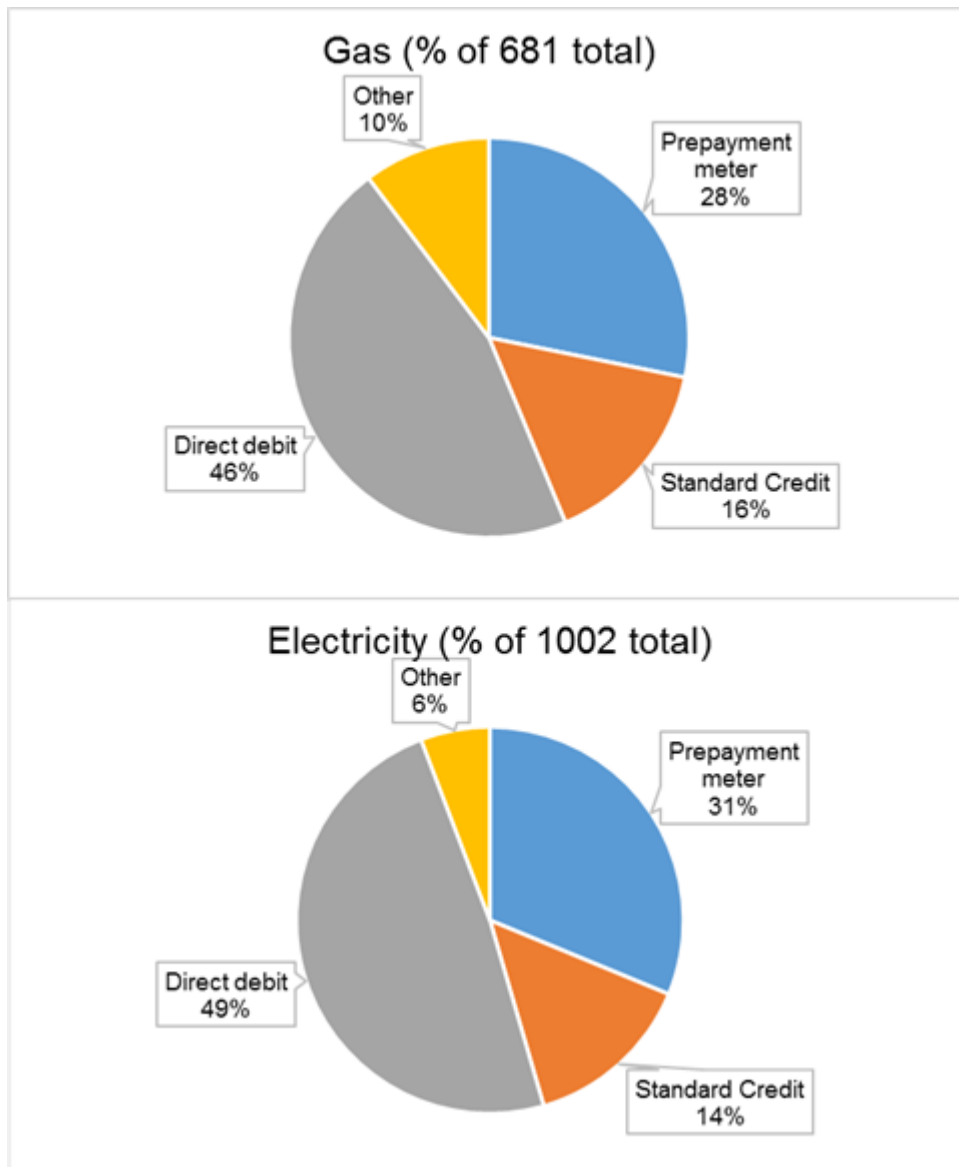
Respondents from the control areas (50%) were more likely to pay their gas bills by direct debit than those from the Arbed areas (43%), χ^2(1, N=1,046)=7.147, p=0.008, which may partly reflect that some of the Arbed areas are currently not connected to the gas mains network. Respondents from these areas are more likely to pay for an oil tank in full (also see Grey et al. 2015).

Fuel Poverty

This section reports the results relating to fuel poverty. Table 7 shows that 62% of all respondents reported that they had put up with feeling cold in the past 12 months in order to save on heating costs. The difference in responses between those living in the Arbed and control areas approached significance, χ2(1, N=1,033)=3.811, p=0.051. Respondents living in the Arbed areas were slightly more likely to say that they put up with feeling cold to save money as compared to those living in the control areas (65% and 60%, respectively).

Table 7. In the past 12 months have you put up with feeling cold to save on heating costs? (%)

	Arbed (n=537)	Control (n=514)	Overall (n=1,051)
Yes	64.8	59.7	62.3
No	33.0	39.1	35.2

Figure 9 shows that lower income households were more likely than higher income households to put up with feeling cold in order to save heating costs. While an overwhelming majority (91%) puts up with feeling cold in the lowest income category, only 56% did so in the highest income category.

Figure 9. Association between household income and putting up with feeling cold to save heating costs (%)
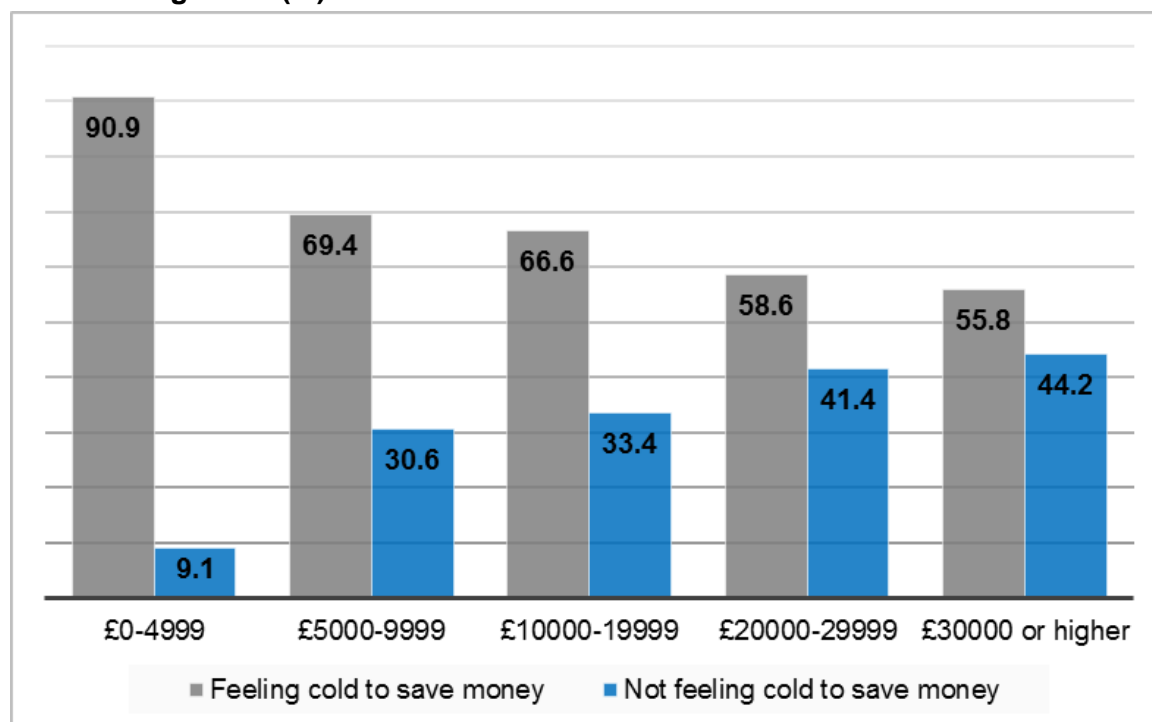
Table 8 shows about one third of the overall sample (33%) quite or very often experienced difficulties meeting the cost of gas, electricity and other fuel bills. No significant difference was found between the Arbed and control samples, χ^2(3, N=1,016)=6.696, p=0.082.

Table 8. How often is it difficult to meet the cost of gas, electricity and other fuel bills? (%)

	Arbed (n=537)	Control (n=514)	Overall (n=1,051)
Very often	15.5	10.9	13.2
Quite often	20.9	18.7	19.8
Only occasionally	22.7	26.8	24.7
Never	38.2	39.7	38.9

Figure 10 shows the self-reported fuel use for the overall sample, banded into four categories. The fuel use bands were determined using the standard deviation of the question (SD=£781). Respondents within the standard deviation around the median of £1,440 (£1,050-£1,830) were considered moderate fuel users (n=416); those below £1,050 were considered low fuel users (n=248); and those with a fuel use between £1,831 and £2,610 (1,830 plus on standard deviation of £781) were considered high fuel users (n=222). Respondents will fuel bills higher than £2,611 were considered very high fuel users (n=82).There were no significant differences between respondents living in the Arbed areas and control areas, χ^2(3, N=968)=3.555, p=0.314.

Figure 10. Self-reported fuel use (%)[4]
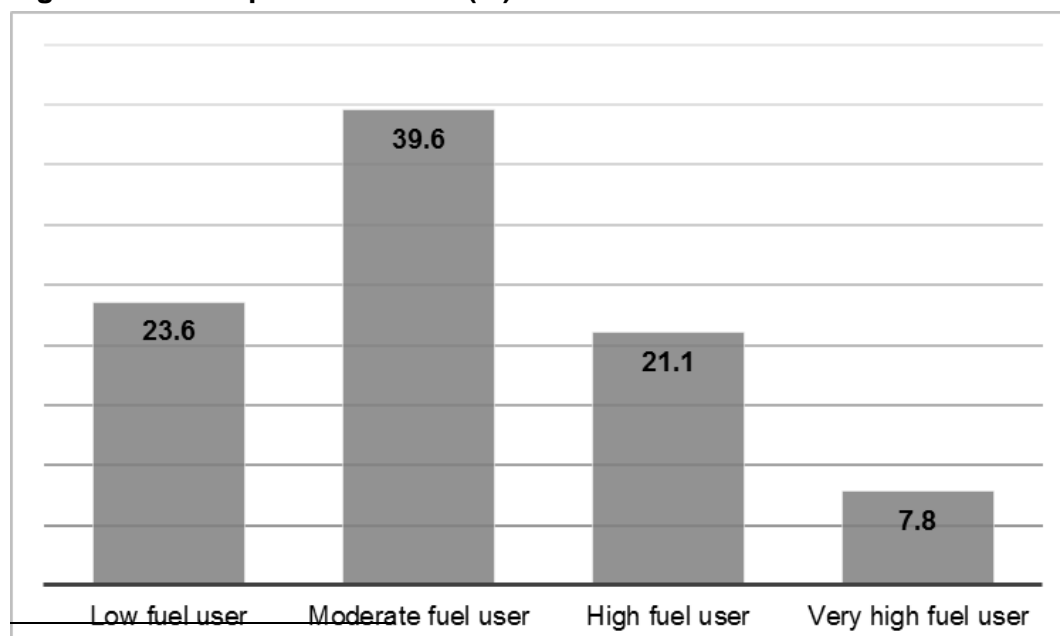
[4] A low fuel user spends less than £1,050 per annum on all fuel bills, a moderate user between £1,051 and £1,830, a high user between £1,831 and £2,610, and a very high user spends more than £2,611 per annum on all fuel bills. Bands represent standard deviations away from the median.

Households' fuel poverty status was calculated using their self-reported fuel bills and income. Households spending more than 10% of their income on fuel were considered to be in fuel poverty. Those spending more than 20% of their income on fuel were considered to be in severe fuel poverty (Welsh Government 2014b). Figure 11 shows that 22% of respondents live in fuel poverty according to this measure, and a further 10% in severe fuel poverty. We were unable to determine the fuel poverty status of about 20% of the sample because they did not provide information on their fuel bills and/or income. No significant difference was observed between respondents from the Arbed and control areas, χ^2 (2, N=838)=1.679, p=0.432.

Figure 11. Fuel poverty status (%)
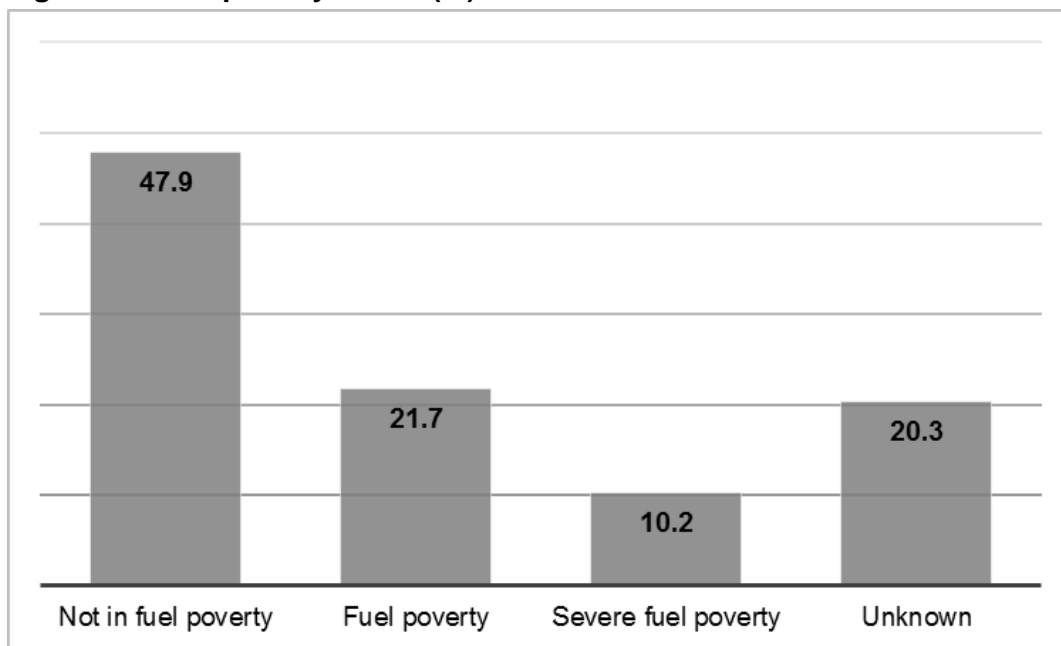
Figure 12 shows that fuel poverty status is strongly associated with reported difficulties meeting the cost of gas, electricity and other fuel bills, χ^2 (6, N=823)=91.422, p=0.000. About 42% of the respondents in fuel poverty, and 66% of the respondents in severe fuel poverty, quite or very often experienced difficulties meeting the cost of gas, electricity and other fuel bills. In contrast, only 25% of the respondents who were not in fuel poverty quite or very often experienced difficulties meeting the cost of gas, electricity and other fuel bills.

Figure 12. Association between fuel poverty status and difficulties meeting the cost of gas, electricity and other fuel bills.
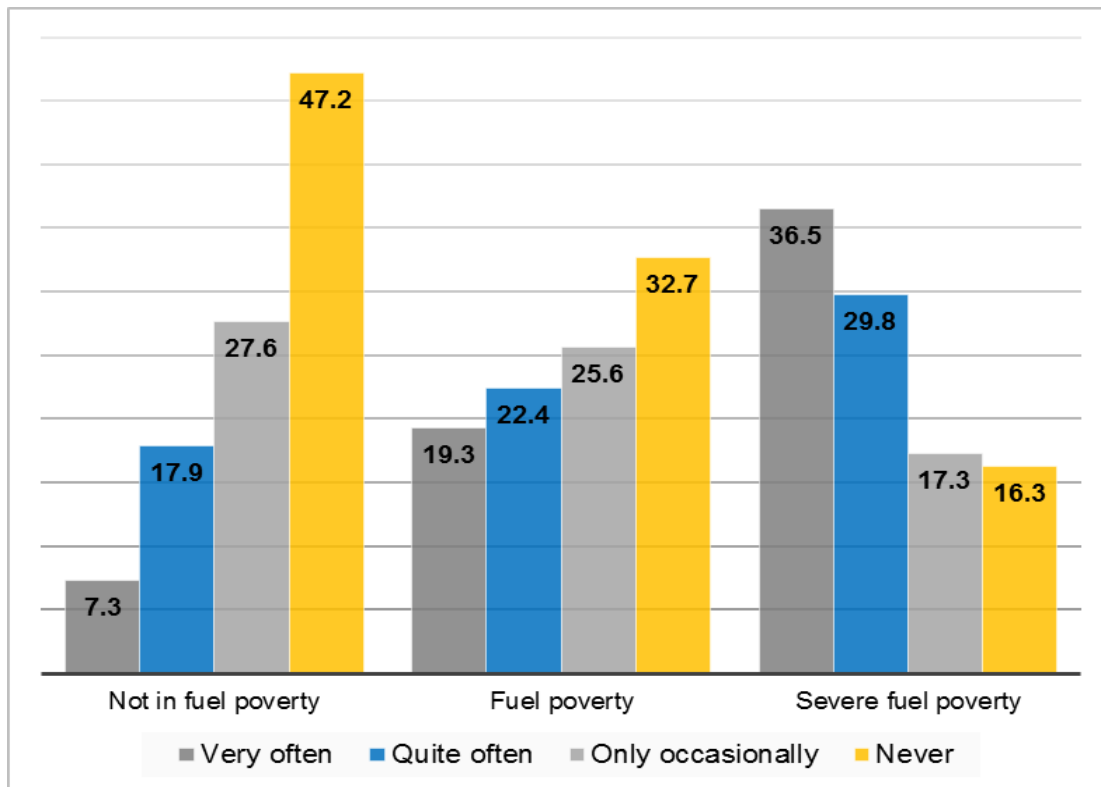
Dietary Choices (Food Security)

Respondents were asked about their diet over the past 12 months in order to explore how fuel poverty may affect access to an adequate diet. The questions could be answered on a four-point scale ranging from 'very often' to 'never'. Table 9 shows that about a third of the respondents (37%) at least occasionally experienced financial difficulties leading to restricted dietary choice, with about 15% reporting that this happened quite or very often. Thirty one percent (31%) of the sample at least occasionally experienced financial difficulties leading to an unbalanced diet, with about 15% reporting that this happened quite or very often. Thirty two percent (32%) of the sample at least occasionally cut the size of their meal/skip meals because there wasn't enough money for food, with about 14% reporting that this happened quite or very often.
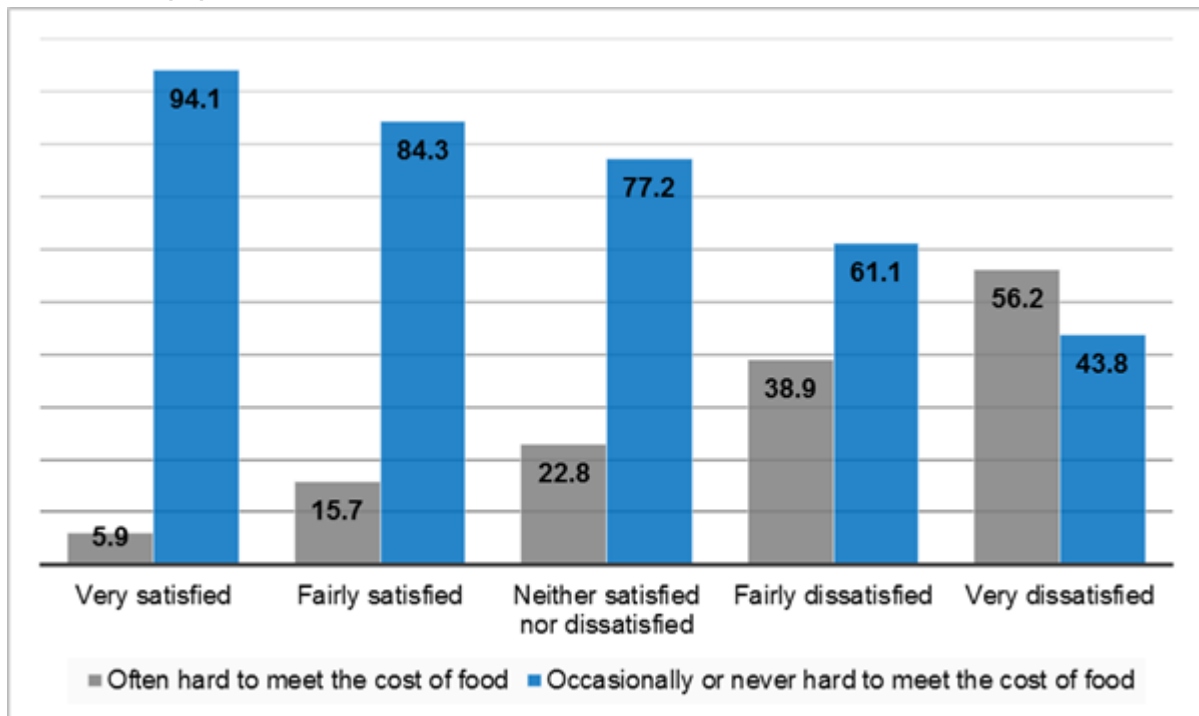
Significant differences were found between the Arbed and control areas in terms of food not lasting and not having enough money to get more, χ^2(3, N=1,032)=7.992, p=0.046. A significant difference was also found in terms of respondents not being able to afford to eat balanced meals, χ^2(3, N=1,029)=9.207, p=0.027. In both cases respondents from the Arbed areas reported poorer food security. No difference was found in terms of respondents skipping meals because there wasn't enough money for food, χ^2(3, N=1,034)=3.616, p=0.306.

Table 9. Self-reported food security (%)

In the last 12 months…		Very Often	Quite Often	Only Occasionally	Never
The food I bought just didn't last and I didn't have money to get more	Arbed	4.2	14.0	22.1	59.8
	Control	5.6	8.8	21.5	64.1
	Total	4.5	11.2	21.4	60.8
I couldn't afford to eat balanced meals	Arbed	6.1	11.2	17.8	65.0
	Control	6.8	6.6	15.0	71.7
	Total	6.3	8.8	16.1	66.8
Did you ever cut the size of your meals or skip meals because there wasn't enough money for food	Arbed	8.3	7.3	19.7	64.7
	Control	7.4	6.4	16.1	70.1
	Total	7.7	6.8	17.7	66.2

Figure 13 shows the relationship between subjective thermal comfort and reported difficulties meeting the cost of food and other necessities (see Financial Stress section). The results suggest that respondents with lower levels of thermal comfort more frequently have difficulties meeting the cost of food and other necessities, χ^2(4, N=986)=142.564, p=0.000. This is a linear relationship χ^2(1, N=986)=138.561, p=0.000.

Figure 13. Association between subjective thermal comfort and difficulties meeting food costs (%)

Social Isolation

This study found that a quarter of the whole sample (25%) have felt reluctant to invite friends or family into their home because of difficulties keeping it warm. No significant difference was found between the Arbed and control areas, χ^2(1, N=1,036)=3.318, p=0.069.

Table 10 show that 26% of the sample had not gone out at all in the past two weeks to visit their family and friends, and 23% had not at all had friends and family visit them in their home. One tenth of the sample (10%) had both not gone out or had friends/family visit them in the past two weeks. There were no differences between the Arbed and control areas in terms of the reported frequency of going out to visit family or friends, χ^2(3, N=1,042)=1.268, p=0.737. However, respondents living in the Arbed areas had fewer visits from their friends/family than those living in the control areas, χ^2(3, N=1,036)=8.919, p=0.030.

Table 10. Frequency of contacts with friends and family (%)

In the last 2 weeks how many time have you…		Not at all	1-2 times	3-6 times	> 6 times
Gone out to visit family or friends	Arbed	26.0	43.1	20.3	9.8
	Control	26.3	44.5	19.2	9.5
	Total	26.0	43.1	20.3	9.8
Had friends/family to visit you in your home	Arbed	25.1	49.7	14.7	8.5
	Control	21.2	49.6	19.8	10.1
	Total	23.2	49.7	17.2	9.8

Financial Stress

Financial stress and status were assessed in multiple ways. First, respondents were asked eight questions about how difficult it is to meet the costs of different household expenditures. Table 11 shows that respondents had the least difficulties meeting the cost of rent or mortgage, followed by credit payments and telephone bills. Respondents had the most difficulties meeting the cost of "treats like a night out, or presents for the family", "gas, electricity and other fuel bills", and "repairs of maintenance for their home".

Table 11. Reported financial stress[5]

Code	How often is it difficult to meet the cost of	Mean (SD)	1 (%)	2 (%)	3 (%)	4 (%)
RM	The rent or mortgage	3.50 (0.86)	4.2	7.5	13.9	57.7
RP	Repairs of maintenance for your home	2.89 (1.05)	12.9	16.2	29.5	31.8
FB	Gas, electricity and other fuel bills	2.92 (1.07)	13.2	19.8	24.7	38.9
TB	The telephone bill	3.28 (0.93)	5.7	13.4	22.5	51.2
CT	Bills for council tax, insurance etc. that come up from time to time	3.16 (0.98)	8.2	14.4	25.4	46.1
CP	Credit payments (e.g. Visa, store cards)	3.39 (0.94)	6.3	8.1	15.6	52.9
FD	Food and other necessities	3.15 (0.99)	8.2	15.6	24.6	46.0
TS	Treats like a night out/presents for family	2.55 (1.17)	26.1	17.7	24.6	27.2

Note: percentages do not always add up to 100% because of non-response; SD=standard deviation; 1=very often; 2=quite often; 3=only occasionally; 4=never.

Table 12 shows the Spearman's rank correlation between the different financial stress items. It appeared that all items were highly correlated at the 0.1% ($p<0.001$) significance level. Difficulties meeting the cost of fuel bills (FB) had the strongest correlations with difficulties meeting the cost of "Bills for council tax, insurance etc. that come up from time to time" (CT), "The telephone bill" (TB), and "food and other necessities" (FD).

**Table 12. Correlation matrix of financial stress items (Spearman's rho)**

	RM	RP	FB	TB	CT	CP	FD	TS
RM	1	0.369	0.544	0.539	0.595	0.539	0.549	0.427
RP	0.369	1	0.452	0.402	0.463	0.393	0.426	0.473
FB	0.544	0.452	1	0.754	0.735	0.542	0.754	0.600
TB	0.539	0.402	0.754	1	0.707	0.566	0.707	0.518
CT	0.595	0.463	0.735	0.707	1	0.541	0.640	0.493
CP	0.539	0.393	0.542	0.566	0.541	1	0.535	0.484
FD	0.549	0.426	0.754	0.707	0.640	0.535	1	0.638
TS	0.427	0.473	0.600	0.518	0.493	0.484	0.638	1

Note: all correlations are significant at the $p<0.001$ level (2-tailed); RM=Rent or mortgage; RP=Repairs of maintenance for your home; FB=Gas, electricity and other fuel bills; TB=Telephone bill; CT=Bills for council tax, insurance etc; CP=Credit payments; FD=Food and other necessities; TS=Treats like a night out or presents for the family.

[5] Scale ranges from 1 'very often' to 4 'never'

Second, respondents were asked to indicate the overall level of financial stress they feel. Figure 14 shows that 42% of the overall sample reported that they feel either moderate or high financial stress. Only 18% of the overall sample reported feeling no financial stress at all. There were no significant differences between respondents living in the Arbed and those living in the control areas, χ^2(4, N=1,031)=1.999, p=0.736.

Figure 14. What level of financial stress do you feel?
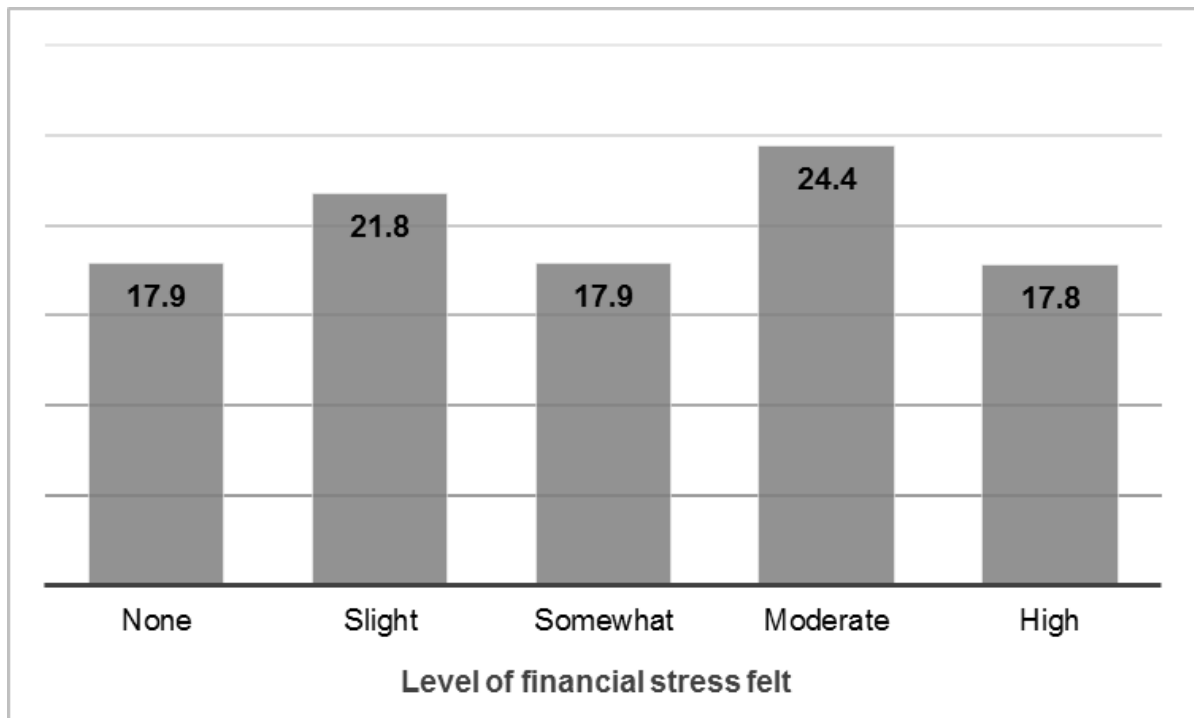
Third, respondents were asked whether they feel financially better off, worse off, or just the same as compared to a year ago. Figure 15 shows that 54% of people said that they now feel financially worse off; 39% reported that they feel financially just the same; and only 7% reported that they feel financially better off as compared to a year ago. There were no significant differences between respondents living in the Arbed areas and those living in the control areas, χ^2(2, N=1,025)=3.815, p=0.148.

Figure 15. Compared to a year ago, do you feel financially better off, just the same, or worse off?
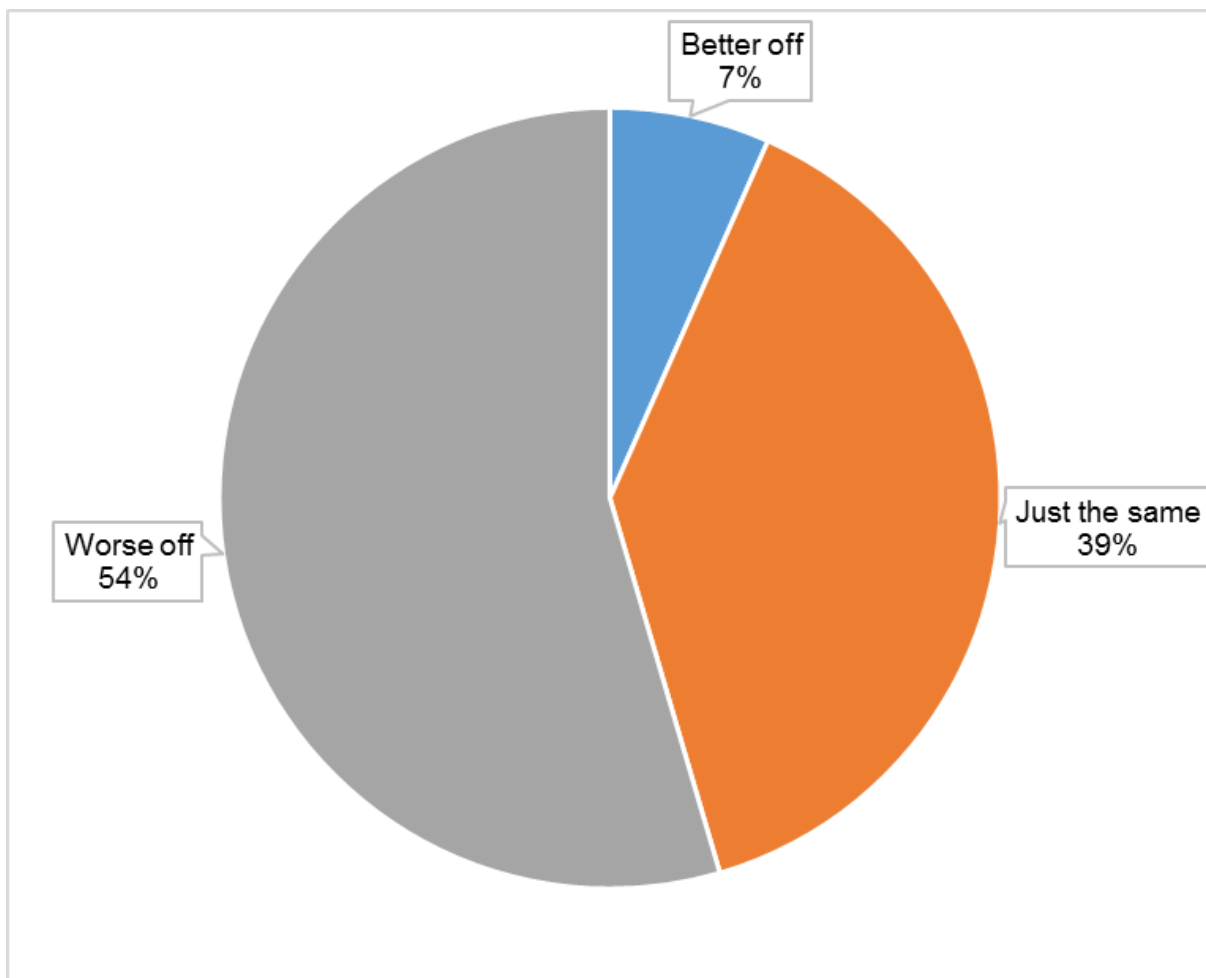
Health and Wellbeing

The health and wellbeing section of the questionnaire included measures of health-related quality of life (the SF-12 health survey; Ware et al. 2002), self-reported respiratory conditions, treatment of medical conditions, health service use, and subjective wellbeing.

Health-Related Quality of Life (SF-12)

Figure 16 shows the responses to the self-reported health question of the SF-12 health survey. Nearly two-fifth (38%) of all respondents reported having fair or poor health, and 33% reported having very good or excellent health. This compares to 21% and 50% respectively for the Welsh population as a whole (Welsh Government 2012a). There were no significant differences between respondents living in the Arbed areas and the control areas, χ^2(4, N=1,048)=6.258, p=0.181.

Figure 16. Self-reported health compared to the 2012 Welsh Health Survey (WHS)
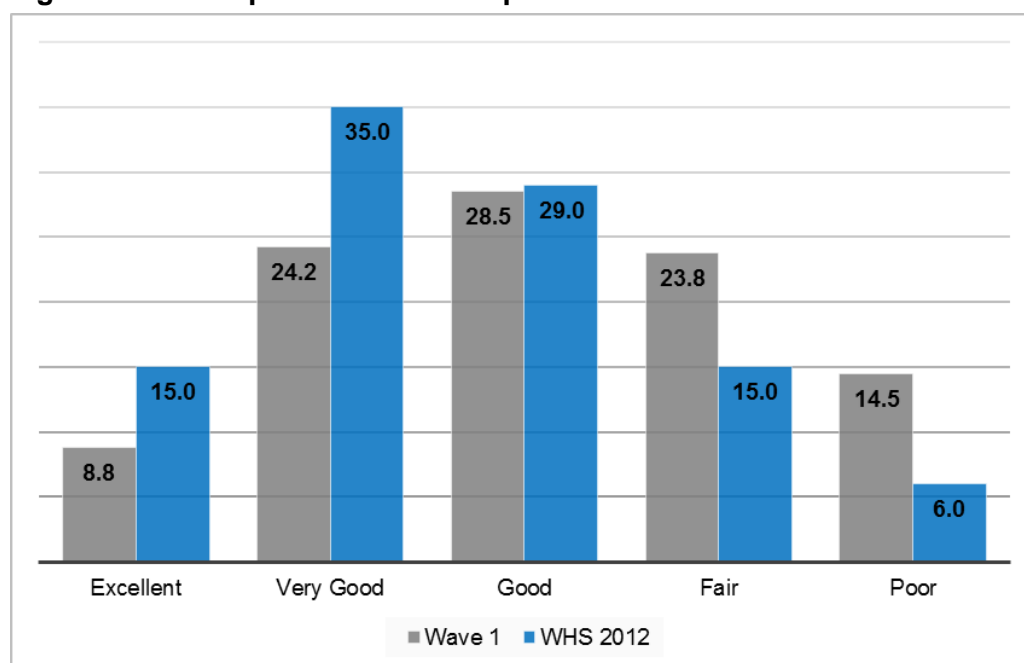
The *Physical and Mental Health Summary scores* (PCS & MCS) were calculated from the SF-12 health survey, with a scale ranging from 0 to 100. The PCS and MCS combine the twelve questions in such a way that they compare to a norm with a mean score of 50 and a standard deviation of 10 (this study, just like the Welsh Health Survey, used the norm-based scoring for the 2009 general U.S. population). Figures 17 and 18 show the distribution of the PCS and MCS scores, respectively. The population averages were well below the mean norm scores of 50 (PCS: 42.94; MCS: 44.63). A Mann-Whitney test indicated that there were no significant differences in the distribution of the MCS scores between the Arbed and control groups, U=118,554, p=0.328. However, there were differences in the distribution of

PCS scores, U=123,385, p=0.035. The PCS scores were slightly lower in the Arbed areas (M=42.09, SD=14.42) than in the control areas (M=43.83, SD=14.38).

Figure 17. The Physical Health Summary Score (PCS)
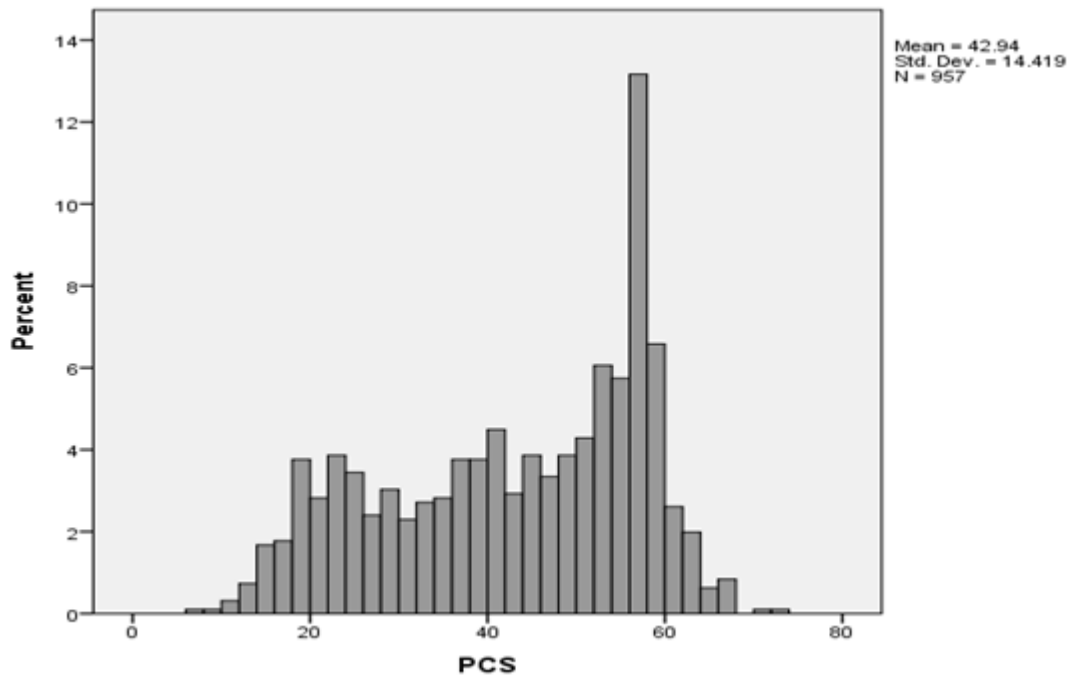
Figure 18. The Mental Health Summary Score (MCS)
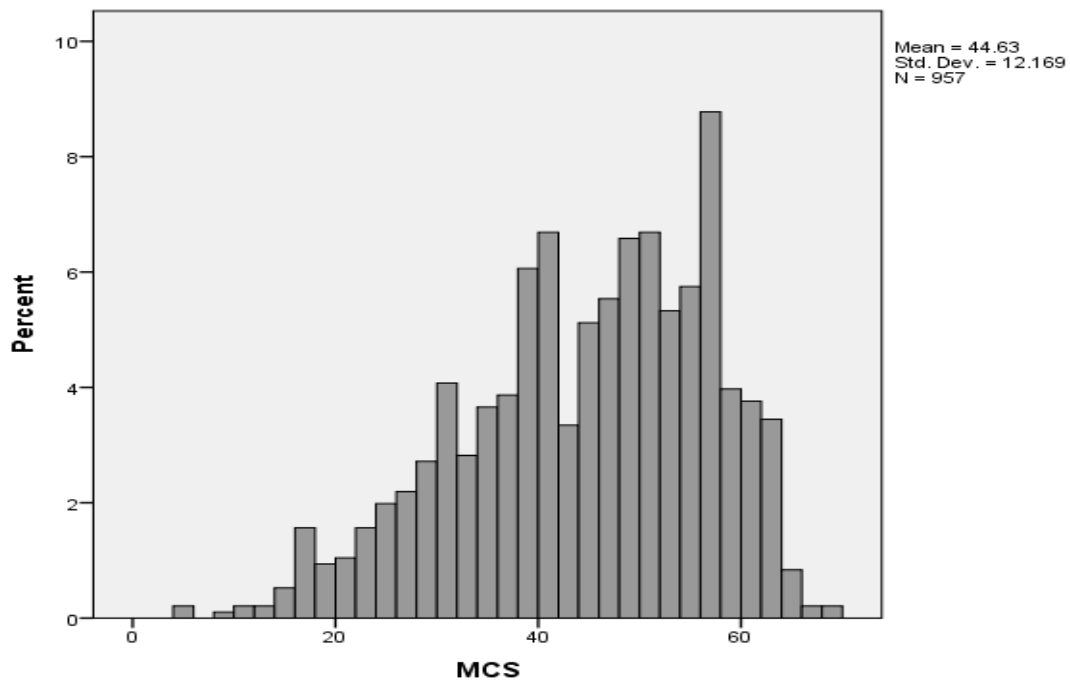
Figures 19 and 20 show the PCS and MCS scores for different age groups. The figures show that, while physical health deteriorates with age, there is a U-shaped relationship between age and mental health. Figure 20 shows that the 36-45 and 46-54 age groups have the lowest MCS scores, and the 21-25, 26-35 and the 65 and over age groups the highest. In all cases the PCS and MSC scores were below the age-adjusted norm scores.

Figure 19. The Physical Health Summary (PCS) scores for different age groups.
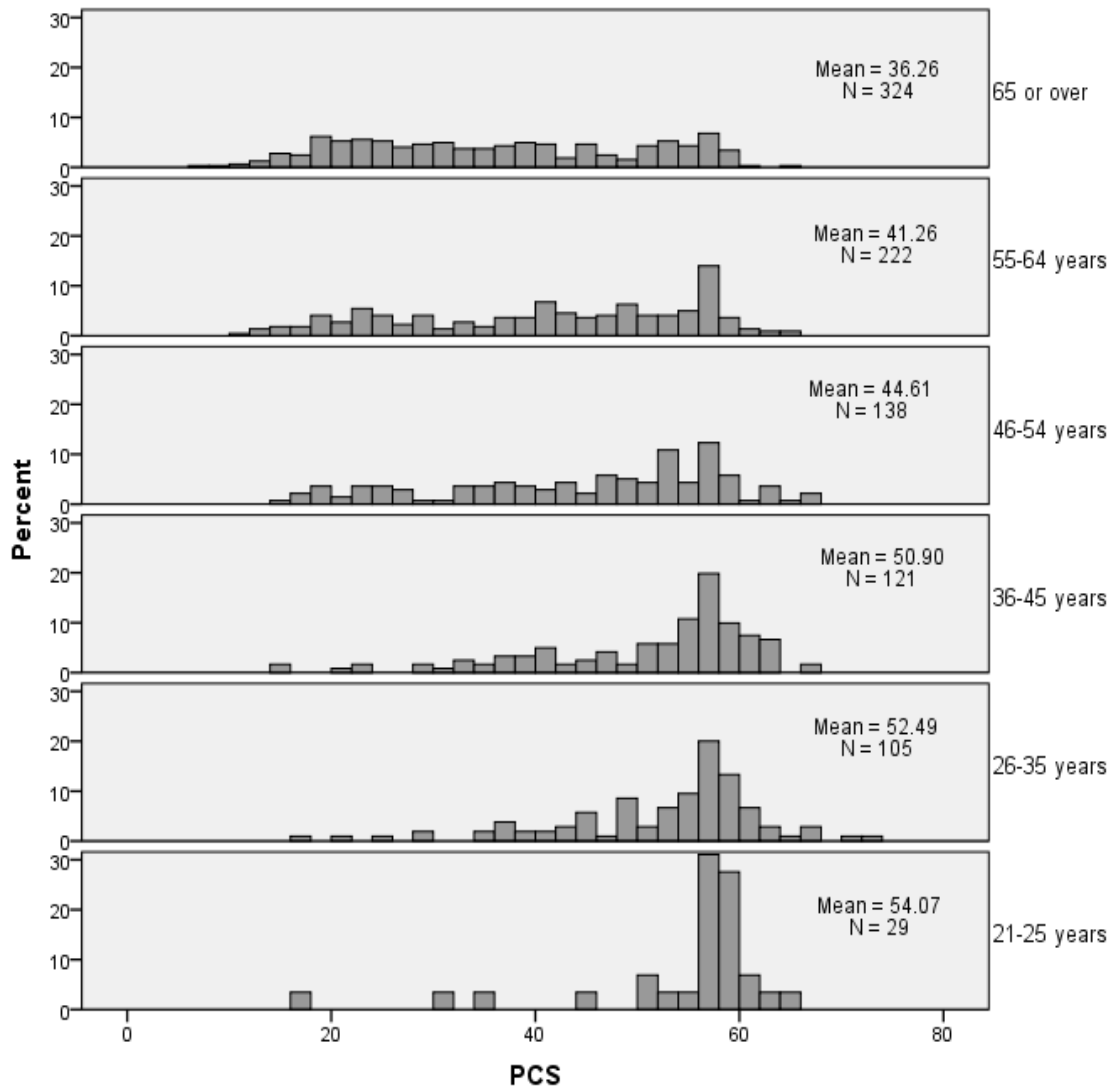
Figure 20. The Mental Health Summary (MCS) score for different age groups.
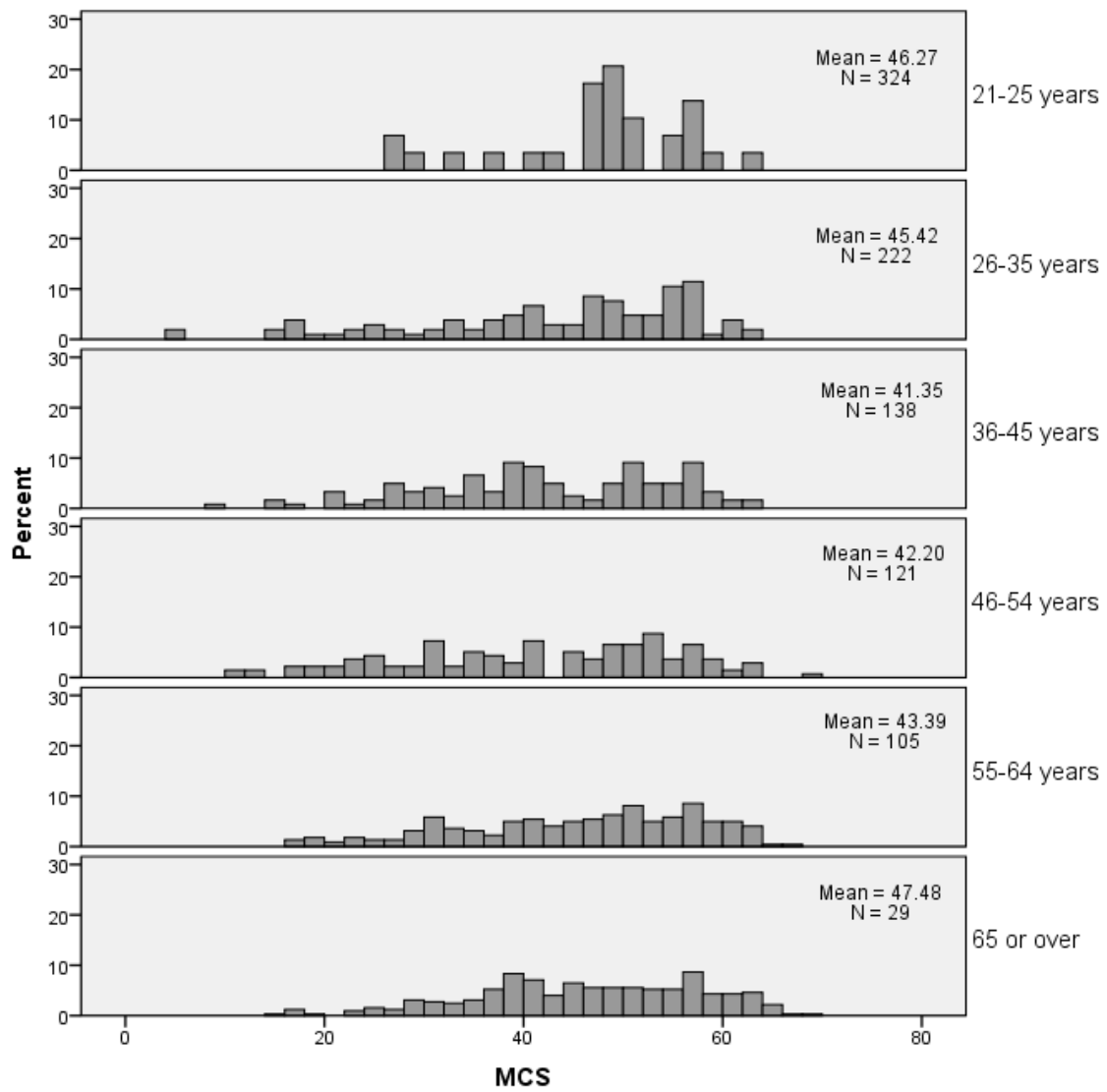
Figure 21 shows the association between financial stress and mental health, as measured by the MCS of the SF-12 health survey. Respondents who reported high levels of financial stress were more likely to have lower-than-average mental health (i.e. lower than the norm score of 50), while those reporting low levels of financial stress were more likely to have higher-than-average mental health, χ^2(4, N=942)=132.040 p=0.000. This was a linear relationship, χ^2(1, N=942)=131.009, p=0.000.

Figure 21. Association between financial stress and mental health (%)
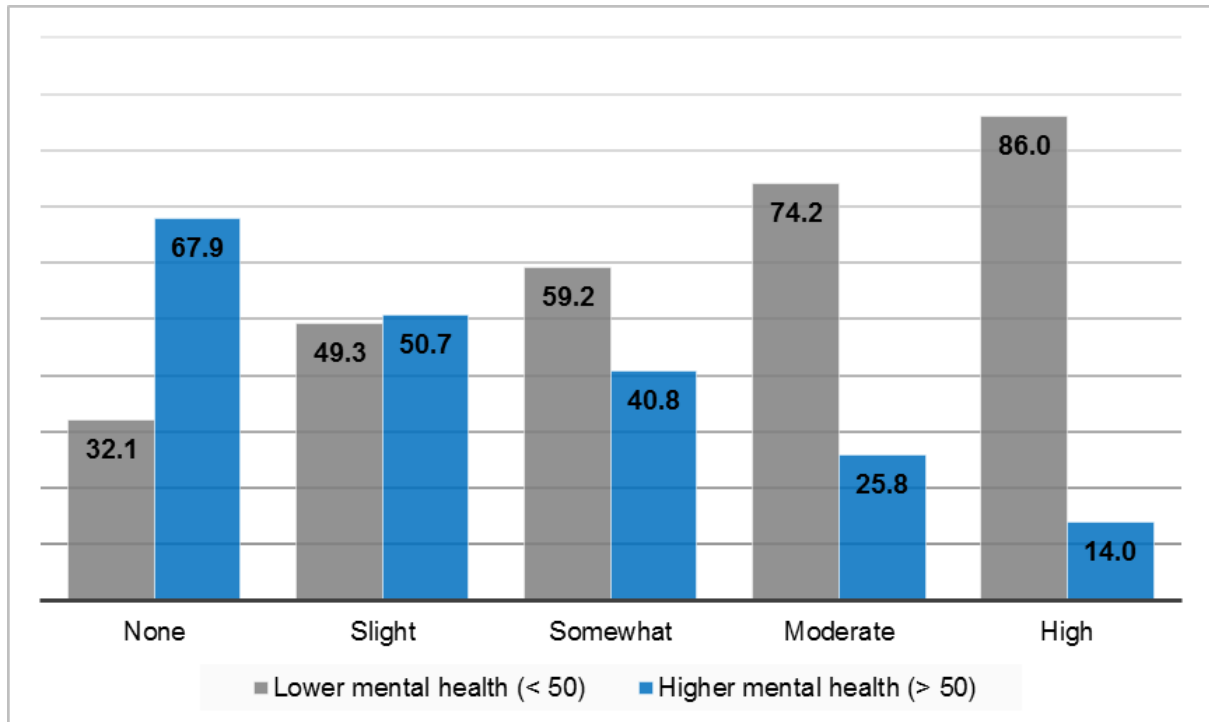
Self-Reported Respiratory Conditions

Table 13 shows the respiratory symptoms that were experienced by respondents in the past month. The most common symptom was coughing (44%), followed by a runny nose (40%), shortness of breath (35%), and sneezing (32%). Just under a quarter (24%) of the sample experienced no respiratory symptoms at all in the past month

Table 13. Reported respiratory symptoms

Symptom	Indicator	%
Coughing	*Asthma*	44.2
Runny nose	*Upper respiratory infection/allergy/sinusitis*	40.3
Shortness of breath	*Asthma*	34.7
Sneezing	*Upper respiratory infection/allergy*	32.4
Sore throat	*Upper respiratory infection*	28.4
Bring up phlegm	*Respiratory infection*	26.8
Blocked nose	*Upper respiratory infection/allergy/sinusitis*	25.1
Chest tightness	*Asthma*	22.8
Wheezing attack	*Asthma*	14.2
Sinus swelling	*Upper respiratory infection/allergy/sinusitis*	14.1
None of the above	---	24.2

Table 14 shows the total number of symptoms reported by the respondents. Just under a quarter (24%) of the sample experienced no respiratory symptoms at all in the past month, while over a third (36%) reported at least four respiratory symptoms. A significant difference was found between respondents from the Arbed and control areas, $\chi^2(4, N=1,050)=16.293$, p=0.003. Respondents from the control areas reported fewer respiratory symptoms than respondents from the Arbed areas. While 29% of the respondents from the control areas reported no respiratory symptoms at all, only 19% of the respondents from the Arbed areas did so.

Table 14. Number of reported respiratory symptoms (%)

	None	One	Two	Three	Four or more
Arbed (n=537)	19.2	15.6	13.6	14.3	37.2
Control (n=514)	29.4	12.1	13.1	11.5	33.9
Total (n=1,051)	24.2	13.9	13.3	13.0	35.9

Table 15 shows the responses to nine questions of the short version of the European Community Respiratory Health Survey (ECRHS 2014). The survey assesses the presence of symptoms that might be indicative of asthma or lower respiratory ill-health. It was found that just over 32% of the respondents had not experienced any of the symptoms in the past 12 months. When "nasal allergies including hay fever" are excluded, the number of respondents with no symptoms increases to 39%. Table 15 shows that the most experienced symptoms were "waking up by an attack of coughing at any time" (38%) and "wheezing and whistling in your chest at any time" (37%).

Table 15. Reported asthma symptoms

	%
Waking up by an attack of coughing at any time	38.2
Wheezing and whistling in your chest at any time	37.2
Breathless while the wheezing was present	26.0
Waking up with feeling of tightness in the chest	25.0
Nasal allergies including hay fever	24.3
Wheezing or whistling when not had a cold	24.0
Currently taking medication for asthma	23.3
Waking up by an attack of shortness of breath at any time	19.4
Attack of asthma	11.4
No symptoms	32.3

Table 16 shows the total number of reported asthma symptoms over the past 12 months, as derived from the short version of the European Community Respiratory Health Survey. Over a quarter of respondents (28%) reported four or more asthma-related symptoms in the last 12 months. There were no differences in the number of reported asthma symptoms between the Arbed and control areas, χ^2(6, N=1,051)=4.889, p=0.558.

Table 16. Number of reported asthma symptoms

	%
None	32.3
One	21.7
Two	11.3
Three	6.9
Four or more	27.7

Treatment of Medical Conditions

Table 17 shows how many of the respondents reported being currently treated by their GP or hospital for a range of cardiovascular, respiratory, mental health, and other conditions. Nearly one out of three (29%) reported being treated for hypertension and a quarter (25%) reported being treated for arthritis. More than two-fifth of the overall sample (42%) reported not being treated for any of the included conditions. The results in Table 17 suggests that our study population is more likely to be treated for a number of conditions than the Welsh population as a whole, in particular hypertension (29% versus 20%), anxiety (13% versus 7%) and arthritis (25% versus 12%). No significant differences were found between the Arbed and control areas for any of the conditions.

Table 17. Self-reported current treatment for cardiovascular, respiratory and mental conditions (%)

		Wave 1 (n=1,051)	WHS 2012[6] (n=15,687)
Cardiovascular	Angina	6.6	3.5
	Heart failure	3.3	1.3
	Hypertension	29.1	19.8
	Another heart condition	7.4	3.5
Respiratory	Asthma	13.2	10.5
	Emphysema	2.8	1.1
	Bronchitis	3.0	1.7
	Another respiratory illness	5.2	3.4
Mental health	Depression	13.6	8.9
	Anxiety	12.5	6.9
	Another mental illness	3.0	2.2
Other	Arthritis	24.9	11.9

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[6] Welsh Government 2012a

Health Service Use

Table 18 reports how often people had visited their GP in the past two weeks, and how often an emergency department (ED) and the hospital (as an in or out patient) during the past twelve months. More than a third (35%) of respondents reported using at least one of the services over the stated periods. Thirty two percent (32%) of our study population reported having visited their GP at least once over the two week period. This compares to 17% for the Welsh population as a whole (Welsh Government 2013b). There were no significant differences between the Arbed and control areas for any of the three health services (GP χ^2(4, N=1,051)=7.571, p=0.109; Emergency Department χ^2(4, N=1,051)=1.912, p=0.752; Hospital χ^2(4, N=1,051)=2.134, p=0.711).

Table 18. Self-reported number of visits to GP, emergency department (ED) and hospital

	GP[1]	ED[2]	Hospital[2]
None	66.1	77.9	48.7
One	21.6	11.8	12.7
Two	7.7	5.3	12.7
Three	1.9	1.2	6.4
Four or more	1.1	2.1	18.2
Not answered	1.5	1.6	1.4

Note: (1) during the past two weeks; (2) during the past 12 months.

Subjective Wellbeing

Subjective wellbeing was measured using four questions developed to measure different aspects of subjective wellbeing, including respondent's overall *life satisfaction*, *happiness*, *anxiety*, and *worthwhileness* (Dolan et al. 2011). Respondents answered the questions on a 11-point end-labelled scale, ranging from 0 'not at all' to 10 'completely'. For *Life Satisfaction*, *Worthwhile* and *Happiness.* The responses were subsequently grouped to reflect Very Low (0-4), Low (5-6), Medium (7-8), and High (9-10) subjective wellbeing. The scores for *Anxiety* were reversed to make them comparable to the other items.

It appeared that respondents to our survey were less happy and satisfied with life, found things they do in life less worthwhile, and were more anxious than the Welsh population as a whole (see Table 19, Welsh Government 2012b). This is perhaps not surprising considering that the study takes place in some of the most deprived areas in Wales. No significant differences were found between the Arbed and control areas (Life satisfaction, χ^2(3, N=1,042)=2.908, p=0.406; Worthwhileness, χ^2(3, N=1,039)=4.459, p=0.216; Happiness, χ^2(3, N=1,045)=4.694, p=0.196; Anxiety: (χ^2(3, N=1,035)=4.173, p=0.243).

Table 19. Subjective wellbeing compared to the 2012 Welsh Health Survey (WHS)

		Very Low (%)	*Low (%)*	*Medium (%)*	*High (%)*	*Mean*
Satisfied with life	Wave 1 (n=1,041)	22.9	20.4	30.6	25.2	**6.4**
	WHS 2012 (n=9,124)	7.3	17.6	47.3	27.8	**7.4**
Worthwhile	Wave 1 (n=1,039)	17.2	18.3	31.7	31.7	**6.9**
	WHS 2012 (n=9,085)	5.2	15.8	46.1	33.0	**7.7**
Happy	Wave 1 (1,045)	21.9	20.6	24.8	32.2	**6.6**
	WHS 2012 (n=9,119)	11.3	16.6	38.1	34.0	**7.3**
Anxious	Wave 1 (n=1,035)	26.9	14.7	16.7	40.1	**3.3**
	WHS 2012 (n=9,108)	22.2	18.2	21.9	37.8	**3.1**

Discussion

This working paper describes the main findings of the first wave of data collection that was conducted as part of a community-based field study to examine the health impacts of structural energy performance investments in Wales. The study was conducted across a number of low-income areas where Arbed energy-efficiency improvements were planned and a number of matched control areas where no energy-efficiency upgrades were planned.

The results show that the samples derived from the Arbed and control areas were broadly similar in terms of their socio-economic characteristics, and fuel poverty and health status. Respondents from the Arbed areas were slightly younger than respondents from the control areas, and were more likely to live in a household with children and to receive housing benefits. Respondents lived mostly in a terraced or semi-detached houses, and had resided there for at least nine years. Most houses were built before 1945, had three bedrooms, and were heated by a gas central heating system. A majority of both samples reported that they experienced at least one housing-related problem, often draught or condensation, with respondents from the Arbed areas being somewhat more likely to report them. Despite these differences, respondents from the Arbed and control areas were equally satisfied with the state of repair of their home.

In this study, a considerable number of respondents reported paying their gas and electricity bills by prepayment meter (about one in three). Low-income households often choose to have a prepayment meter because it allows them to budget their fuel payments better (Hills, 2011; also see Grey et al. 2015). This puts them at greater risk of fuel poverty, as prepayment meters are generally the most expensive way to pay for fuel. Indeed, the study found high levels of fuel poverty within the communities. The study found that about a third of the overall sample are in fuel poverty, and one in ten in severe fuel poverty. Furthermore, a majority reported having put up with feeling cold to save money over the past year and at least occasionally experienced difficulties meeting the costs of their fuel bills.

The study identified a number of adverse social outcomes generally associated with fuel poverty. Social isolation, financial stress, and an inadequate diet were a problem to a large number of respondents. Around a quarter experienced social isolation, both in terms of being reluctant to invite friends or family over to their homes and in terms of going out to visit them; and more than two out of five reported moderate-to-high levels of financial stress. Many respondents experienced difficulties meeting the cost of fuel bills and food, suggesting that they may have been affected by the 'heat or eat' dilemma.

Our study sample had poorer physical and mental health as compared to the general Welsh population. Respondents were more likely to report fair or poor health, and the physical and mental component scores of the SF-12 (PCS and MCS) were below the Welsh average. Furthermore, respondents in our study had a lower level of subjective wellbeing; they were less happy and satisfied with life, found things they do less worthwhile, and were more

anxious than the Welsh population as a whole. Respondents also reported higher levels of health service use and treatment for a number of conditions, including hypertension, anxiety and arthritis. The observed health differences are perhaps not surprising given that the study was conducted in some of the most deprived areas in Wales and that older age groups were over-represented.

There were also indications of poor respiratory health. More than three quarters of the sample had experienced at least one respiratory symptom in the last month, and over a third had experienced at least four. The results suggest that respondents from the Arbed areas had slightly worse respiratory health than those from the control areas, although no significant differences were found in the number of reported asthma symptoms.

This working paper provides a description of the first wave of data collected during the 2013-14 heating season as a baseline for future comparison. There are several aspects of the study that will be developed in future analyses and publications. The data described in this working paper will be used to explore associations between housing conditions, fuel poverty and health, as well as potential mediating social and economic pathways. The sample will become part of the controlled field study to examine the health impacts of structural energy performance investments in Wales. All respondents who provided consent will be recontacted after the Arbed energy-efficiency improvements have taken place. Respondents from the Arbed and matched control areas will be recontacted at the same time. This will allow for before and after comparison in both the intervention and control populations, and will show whether the improved energy efficiency of intervention homes have an impact on the health and wellbeing of the occupants.

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Appendix A: Description of the Arbed (intervention) and control areas

Cardiff intervention: Caerau is a suburb located three miles to the west of Cardiff centre. Housing is a mixture of housing association flats, bricked terraced houses, traditionally built semi-detached houses, and semi-detached BISF houses. The Arbed work that will take place here is external wall insulation (EWI) and boiler upgrades. (Caerau 7 Lower Super Output Area (LSOA), Welsh Index of Multiple deprivation (WIMD) score of 170, Communities First).

Cardiff control: is closely located to the Cardiff intervention area, with a similar mixture of housing types. (Caerau 4 LSOA, WMID 277, Communities First).

Carmarthenshire intervention: Brynamman is a village located on the south facing side of the Black Mountain, part of the Brecon Beacons National Park, in an old coal mining area. The area is currently off the mains gas network, and contains mainly older small stone terraced houses. The Arbed work that will extend the mains gas network to the village, and provide boiler upgrades. (Quarterbach 1 LSOA, WIMD 651).

Carmarthenshire control: is located close to the intervention area within Brynamman in Carmarthenshire, with a similar mixture of housing types. (Quarterbach 2 LSOA, WIMD 689).

Caerphilly intervention: Hollybush is an old coal mining village situated between Blackwood and Tredegar, above the Sirhowy Valley. The area is currently off the mains gas network, with a combination of older small stone terraced houses and post 1965 and 1980s detached homes. The Arbed work that will extend the gas network to homes in the village, and provide EWI and boiler upgrades. (Argoed 2 LSOA, WIMD 565, Communities First).

Caerphilly control: Markham was a garden village built to accommodate coal miners, and lies just over one kilometre from Hollybush in the Upper Sirhowy Valley. Markham is serviced by the gas network, and contains a similar mixture of housing types to Hollybush. (Argoed 1 LSOA, WIMD 188, Communities First).

Newport intervention: Malpas Court is a suburb to the north of Newport, near junction 26 of the M4 motorway. The houses in this area were originally built as a council housing estate.

Currently Malpas contains a mixture of private and socially owned flats and semi-detached houses. The Arbed work that will take place is EWI and boiler upgrades. (Malpas 2 LSOA, WIMD 142, Communities First).

Newport control: Bettws lies to the west of Malpas, and is a suburb located north of Newport, near junction 26 of the M4 motorway. Bettws was built in the 1960s as one of the largest housing estates in Europe, and contains a mixture of semi-detached houses and flats. Over 40% of the houses are socially owned. (Bettws 5 LSOA, WIMD 266, Communities First).

Rhondda Cynon Taff (RCT) intervention: Maerdy is an old mining village lying above the head of the Rhondda Fach valley. Housing is 19th century small stone terraced houses. The Arbed work that will take place here is EWI and boiler upgrades. (Maerdy 1 LSOA with a WIMD 107, Communities First).

RCT control: Treherbert is an old mining village lying at the head of the Rhondda Fawr valley. Housing is a mixture of housing association flats, small stone terraced houses, and more modern semi-detached homes. (Treherbert 2 LSOA, WIMD 129, Communities First).

Merthyr intervention (year 1): Taff Merthyr Garden Village ('Stormtown') was built in the 1930s as a garden village, in an exposed hillside location 10 kilometres southeast of Merthyr Tydfil in the Taff Bargoed valley. The village is currently off the mains gas network and housing is predominantly stone terraced houses. The Arbed work that will take place is connecting the village to the gas network, EWI and boiler upgrades. (Bedlinog 2 LSOA, WIMD 323, Communities First).

Merthyr control (year 1): Ponstiscill is a rural village in the Taf Fechan valley and sited by a bridge over the Taf Fechan river, near Ponstiscill reservoir. This village is situated on the southern edge of the Brecon Beacons National Park and to the north of Merthyr Tydfil. The village is old and properties vary from over 150 year old stone cottages to new detached housing. The village is off the mains gas network. (Vaynor 1 LSOA, WIMD 391, Communities First). Two streets BISF semi-detached houses in Bedlinog 2 were also selected as controls for the Garden Village intervention area (see Merthyr intervention year 1).

Merthyr intervention (year 2): Penydarren lies to the north of Merthyr Tydfil, just south of the Heads of the Valleys Road. The area previously hosted an ironworks, and contains predominantly semi-detached houses. The Arbed work is EWI and boiler upgrades. (Penydarren 2 LSOA, WIMD 109, Communities First).

Merthyr control (year 2)**:** Treharris is an old mining town with a population of over 6000 located 10 kilometres south of Merthyr Tydfil in the Taff Bargoed valley. The area contains predominantly old stone terraced homes. (Treharris 3 and 4 LSOAs, with WIMD scores of 324 and 340 respectively, both Communities First).

Bridgend intervention: Caerau is a former coal mining village located four kilometres to the north of Maesteg in the Llynfi valley (Bridgend). Housing is a combination of old stone terraced houses, and semi-detached council built housing from the 1940s and 1970s. The Arbed work being undertaken is EWI and boiler upgrades. (Caerau 1 LSOA, WIMD 8, Communities First).

Bridgend control: is located close to the intervention area within Caerau (Bridgend) with similar housing types. (Caerau 2 LSOA, WIMD 38, Communities First).

Blaenau Gwent intervention: Six Bells is an old coal mining village that lies just south of Abertillery, 26 kilometres north-west of Newport in the Ebbw Fach valley. Housing contains predominantly brick and stone terraced houses. The Arbed work being undertaken is boiler upgrades. (Six Bells 2 LSOA, WIMD 942, Communities First).

Blaenau Gwent control: Llanhilleth is an old mining village about three kilometres south of Six Bells in the Ebbw Fach valley. Housing contains predominantly old stone terraced houses. (Llanhilleth 3 LSOA, WIMD 400, Communities First).

Mid and North Wales

Gwynedd intervention: Carmel, Cilgwyn and Y Fron are small rural villages on the sides of the mountain Moel Tryfan overlooking the Nantlle Valley and the Irish Sea. The area was used for slate mining in the 19th century. Carmel, Cilgwyn and Y Fron are made up of mostly terraced Victorian housing with some stone cottages and more modern houses. The villages

are all off the mains gas network. Arbed is extending the mains gas, EWI and boiler upgrades to the villages. (Talysarn LSOA, WIMD 506, Communities First).

Gwynedd control: used households from the villages of Talysarn and Deiniolen. Talysarn is a village in the slate quarrying Nantlle Valley. Talysarn contains predominantly terraced brick houses. (Talysarn LSOA, WIMD 506, Communities First).

Deiniolen is an old slate mining village is a village at the foot of Elidir Fawr (a mountain in Snowdonia). Deiniolen has views over Caernarfon and the Irish Sea, and is off the mains gas network. Deiniolen contains predominantly brick terraced houses. (Deiniolen LSOA, WIMD 754).

Anglesey intervention: Holyhead is a port town on the coast of Anglesey. Housing is predominantly semi-detached and terraced homes. Arbed work is predominantly EWI and boiler upgrades. (Holyhead Town LSOA, WIMD 246, Communities First).

Anglesey intervention: none

Wrexham intervention: Llay is village just over five kilometers north of Wrexham in an old coal mining area, comprising predominantly of semi-detached and terraced brick housing, with some social housing flats and a small number of prefab retirement bungalows. Arbed work taking place is predominantly EWI and boiler upgrades. (Llay 3 LSOA, WIMD 359, Communities First).

Wrexham control: households from the villages of Llay and Chirk were used as control samples in Wrexham. Llay is as described above. Chirk is located about 10 kilometres south of Wrexham and 10 kilometres north of Oswestry. Chirk is a former coal mining community, and housing comprises predominantly of semi-detached brick homes, a small number of flats above local shops, and a small number of prefab retirement bungalows. (Chirk North 2 LSOA, WIMD 569).

Denbighshire intervention: Rhyl is a coastal town situated on the north east coast of Wales, at the mouth of the river Clwyd. Housing in Rhyl comprises of bricked terraced homes and large Victorian terraced houses that have been converted into flats. Arbed work taking place

in Rhyl is predominantly EWI and boiler upgrades. (Rhyl West 3 LSOA, WIMD 34, Communities First).

Flintshire control: Flint is a coastal town in Flintshire, lying on the estuary of the river Dee. Housing is a combination of semi-detached and terrace brick homes and flats. (Flint Castle LSOA, WIMD of 209, with a few houses in Flint Oakenholt 2 LSOA, WIMD 697).

Ceredigion intervention: Llandysul is a small rural town near the river Teifi in Ceredigion, historically the area was part of the woollen industry. Housing in the intervention area are off the mains gas network, and are brick semi-detached properties with a few terraced retirement bungalows. Arbed work taking place in Llandysul is bringing mains gas, EWI and boiler upgrades. (Llandysul Town LSOA, WIMD 737).

Ceredigion control: Penparcau is a village in Ceredigion two kilometres east of the town of Aberystwyth. Housing is a mixture of semi-detached and terraced brick homes, with some socially owned flats. (Penparcau 1 and 2 LSOAs, WIMD 652 and 747 respectively).