Programme Area: Smart Systems and Heat

Project: WP1 Consumer Insights

Title: A Segmentation Analysis of Households' Reasons for Changing their Heating Systems

Abstract:

This analysis evaluated whether a segmentation could be developed to predict the reasons why households changed their heating systems. Three different analysis attempts were made however the best of the models only predicted 55% of the reasons for changing the boiler correctly. The method used and results are set out in this report.

Context:

This project will provide insights into consumer behaviour relating to heat decisions. The project will be made up of four small pieces of consultancy work looking at specific issues:

- Consumer Response & Behavious Analysis
- Literature Review Personality and Risky Heat Decisions
- Household Heating Design Aids
- Segmentation Analysis

LOUGHBOROUGH UNIVERSITY

A Segmentation Analysis of Households' Reasons for Changing their Heating Systems

Prepared for Catapult Energy Systems

J Beckhelling

1.0 Summary

Three attempts at CHAID analyses were carried out to identify variables which could predict the reasons why different households changed their boiler. However none had an acceptable predictive power (measured by the percentage of correct predictions of the reasons for changing the boiler). The best of the models only predicted 55% of the reasons for changing the boiler correctly.

It appears that the variables which were expected to predict the reasons why households changed their heating systems do not have enough predictive power (measured by the percentage of correctly predicted reasons for changing the boiler) to be used to do this.

2.0 Introduction

In 2013, DECC commissioned Ipsos MORI and Energy Savings Trust to carry out research into participants' willingness to take up more efficient heating systems (Ipsos Mori and Energy Savings Trust, 2013). This report explored various types of energy efficient heating systems, including changing to a more efficient boiler. The report investigated the circumstances in which householders would change their boiler (e.g. the boiler had broken down, the boiler was no longer heating the house well enough), however the focus of the original analysis did not include whether there was a relationship between any of the household demographics and technical attributes of the home and the reasons they changed their boiler.

This analysis will conduct a secondary analysis of the data to identify the relationships (if any) between the householder demographics and attributes of the home and the reason why they changed their heating systems.

2.1 Households included in the analysis

The original research included data from 2,900 households. However, 1,064 of the households had not changed the heating system in their current home and could not provide any relevant information for the current analysis. An additional 30 households had installed a lower carbon heating system in their home (29 households) or had their heat supplied through a heat network, district or communal scheme (1 household). These homes were not the target of the original research and did not answer the majority of the survey questions, including the questions of

interest for this analysis. After these three groups of household were excluded, the data set for the analysis included 1,806 households.

However, later a further 238 households had to be excluded because their reasons for changing the boiler could not be identified and were not used in the summary of reason for changing the heating system sent in the research request (these households are described in section 3.1). The category “don’t know/can’t remember” was also excluded because it only contained 48 homes, which was less than the minimum category which could be identified in the analysis.

After all of the exclusions, there were 1,520 homes included in the analysis.

2.2 Variables included in the analysis

2.2.1 Dependent (outcome) variable

The original research request identified various reasons why householders had replaced their heating system (see Table 1 below). The purpose of this research is to establish whether attributes of the households and/ or the homes in which they lived could be used to predict the reason why they changed their heating system. Therefore, the reason for changing their heating system is the dependent variable in this analysis.

The research request grouped together the reasons householders had given for changing their heating into seven main reasons, however the dataset did not classify the reasons in the same way, so the seven main reasons had to be reconstructed for this analysis.

There were 238 households whose reason for changing their boiler was classed as “Other – Specified”. This group of households did not appear in the groups identified by the research request. The reasons they gave for changing their heating system were checked to see if they could be incorporated into the 7 main reasons. Unfortunately, only the first 25 characters of the specified reasons where given in the raw data, which did not provide enough information to reclassify these responses. These 238 households were excluded from the analysis partly to keep the classification consistent with that in the research request and partly because, in many of the cases, it was not clear if their responses should be re-classified into some of the main categories defined in the research request. When these households were excluded, the percentages of the reasons for changing the heating system defined in this analysis were generally within one percentage point of those in the original research request. This suggests the remaining differences may be due to different ways of handling rounding errors (See Appendix 1 for details).

2.3 Independent (explanatory) variables

2.3.1 Variables used in then analysis

The research request asked for 14 socio-technical variables to be included in the analysis as possible independent variables, however, it was only possible to include 11 of them. Replacement variables were used for two of these variables.

The ages of the children in the households could not be included in the analysis because the data only identified households which contained children (i.e. someone aged under 16 years old). Therefore the variable which showed whether there were children in the household was used in place of the children's ages.

The number of rooms in the home was not included in the dataset, however, the number of bedrooms in the home was reported, so this was used in the analysis in place of the number of rooms.

Finally, the raw dataset contained data on the number of years the householders had been resident in the home. However, when this was crosschecked against the ages of the adults in the household, 56 households were apparently resident in the home before the eldest adult in the household would have been born. A further 138 households would have moved into their home before the eldest adult was 17. The residence data where therefore considered unreliable. There were no other variables which could be substituted in its place, so no information about years of residence could be included in the analysis.

2.4 Variables derived for the analysis

Three variables were derived from the original data: Ages of the adults in the household; employment status; amount of insulation installed by the current owner sources of advice about changing the heating system.

With the exception of employment status, these variables were derived to convert a series of related variables into a single variable which could be included in the analysis. Details of the derivation of these variables are shown in Appendix 2.

3.0 Data analysis

3.1 Initial Data analysis

Initially, the individual variables were cross tabulated against the reason for changing the boiler and chi squared tests were carried out, to give an indication of how well the independent variables could be expected to predict the reasons for changing the boiler.

It was somewhat disappointing that only 5 of the 13 potential predictor variables had significant associations with the reasons for changing the boiler, however, they may have been sufficient to segment the data usefully, so a CHAID analysis was attempted. This included all of the variables, even those which were not significant in this initial analysis because CHAID analysis is a multivariate technique which may identify interactions between the independent variables which are not apparent with individual chi squared tests.

The cross tabulations of these data are shown in Appendix 3.

Table 1: Results of initial chi squared tests

Chi squared test of reason against:	Chi squared Value	df	p value(2-sided)	Significance
Number of people in the household	28.605	18	0.05	
Ages of the adults in the household	8.031	12	0.78	
Does someone aged under 16 live in the household?	7.282	6	0.30	
Tenure	10.376	6	0.11	
When the property was built	29.824	18	0.04	*
Property type	48.436	30	0.02	*
Number of bedrooms in dwelling	34.768	18	0.01	*
Employment status	23.210	18	0.18	
Social Grade	40.328	30	0.10	
Long standing illness or disability	6.451	6	0.38	
Location of household	46.216	12	0.00	***
How much insulation has the current owner installed?	34.010	30	0.28	
Where did people get advice about changing their boiler?	104.27	24	0.00	***

*= significant at the 5% level; **= significant at the 1% level; ***=significant at the 0.1% level

3.2 CHAID analysis

The CHAID analysis initially finds the variable which is the best predicts the reason why households changed their boiler. Then, it looks for the next best predictor for

the subgroups it has defined so far and following that, a third set of predictors. It will stop when it reaches a pre-determined minimum number of records in any of the subgroups or it cannot find a other significant predictor (based on the Chi Square test).

An initial CHAID analysis was carried out including all of the predictor variables (full details of the CHAID specification are shown in Appendix 4). The CHAID results are shown in appendix 5a, and the interpretation of the output is in appendix 5b. However, this analysis only predicted 35% of the households' reasons for changing their heating system correctly, which is unacceptably poor. The main reason for this is that the model could only find significant predictor for three of the reasons why the boiler had broken down . This may be due to the fact that the reasons for changing the boiler are dominated by two large categories (Broke down/about to break) (Table 2).

A second CHAID analysis was attempted which grouped the reasons into three groups "Broke down", "About the break", "other" (all of the other categories). This would split the reasons for the boiler change to be split into three roughly equal sized categories for the analysis (albeit at the cost of grouping together 4 disparate categories). This improved the model's performance somewhat, but even so, only 43% of the reasons for changing the boiler were correctly predicted (Table 3). The CHAID results for this analysis are shown in Appendix 6a and 6b, however given that the analysis correctly identified less than 50% of the households, they cannot be recommended as a reliable method to predict the reason for changing boilers..

A third attempt was made to try to predict which households would change their boiler when it broke down and which would change it when it was about to break down (as this analysis only included the categories "broke down" and "about to break", the sample size for this analysis was 920 homes). This analysis predicted 55% of households correctly, which again is not acceptable (Table 4). The result of this analysis are shown in Appendix 7a and 7b, but the result should be interpreted cautiously given the low percentage of houses correctly predicted.

A fourth and final attempt was made to try to distinguish between households that changed their boilers because it had broken down, was about to break, to improve the heating or to improve the home (the sample size for this analysis was 1329 homes). This analysis predicted 41% of households correctly (Table 5). The result of this analysis are shown in Appendix 8a and 8b.

The categories most frequently predicted by each CHAID analysis are generally the reasons chosen by the most householders. This suggests that the independent variables have little predictive power to predict the reasons for changing the boiler. It seems that, based on this sample, householders change their boilers either when they have broken down or when they are about to break down, regardless of the demographic characteristics of the households, or the technical features of their

homes. The best predictors of when the boiler is changed could be variables such as whether the householder thinks is it going to break down soon, whether it will last another winter, how badly it will affect them if the boiler breaks down before it is changed.

Table 2: Percentage correctly predicted in initial CHAID analysis

	Predicted						
Observed	Broke down	About to break	Improve home	Improve the heating system	High bills or maintenance costs	None of these	Percent Correct
Broke down	305	138	0	0	0	14	66.7%
About to break	257	190	0	0	0	16	41.0%
Improve home	111	73	0	0	0	9	0.0%
Improve the heating system	155	54	0	0	0	7	0.0%
High bills or maintenance costs	66	19	0	0	0	2	0.0%
None of these	62	8	0	0	0	34	32.7%
Overall Percentage	62.9%	31.7%	0.0%	0.0%	0.0%	5.4%	34.8%

Table 3: Percentage correctly predicted in second CHAID analysis

	Predicted			
Observed	Broke down	About to break	Other	Percent Correct
Broke down	0	200	257	0.0%
About to break	0	260	203	56.2%
Other	0	209	391	65.2%
Overall Percentage	0.0%	44.0%	56.0%	42.8%

Table 4: Percentage correctly predicted in third CHAID analysis

Observed	Predicted		
	Broke down	About to break	Percent Correct
Broke down	111	346	24.3%
About to break	72	391	84.4%
Overall Percentage	19.9%	80.1%	54.6%

Table 5: Percentage correctly predicted in fourth CHAID analysis

Observed	Predicted				
	BrokeDown	About to Break	Improve Home	Improve heating	Percent Correct
BrokeDown	188	269	0	0	41.1%
About to Break	113	350	0	0	75.6%
Improve Home	73	120	0	0	0.0%
Improve heating	98	118	0	0	0.0%
Overall Percentage	35.5%	64.5%	0.0%	0.0%	40.5%

4.0 Conclusions

Over one half of the householders in this sample changed their boilers either because they had broken down (29%) or it was about to break down (30%). Of the other reasons for changing the boiler, the most frequently quoted reason was to improve the heating system (14% of responses). Thus approximately three quarters (73%) of the householders changed their boiler because they were dissatisfied with its performance and over one half of them changed it because it was, at least, somewhat urgent.

Three attempts at CHAID analyses were carried out to identify variables which could predict the reasons why different households changed their boiler, however none had an acceptable predictive power (measured by the percentage of correct predictions of the reasons for changing the boiler). This suggests that, regardless of

their socio-technical attributes, households tend to put off changing their boiler until they perceive a significant need to do it.

4.0 References

Ipsos MORI and Energy Savings Trust , Homeowners' Willingness to Take up more Efficient Heating Systems, 2013

Appendix 1: Comparison of the percentage of households giving each reason to change their heating system

Reason for changing heating system	Sub categories	Percentages	
		research request	this analysis
It had broken down	**(none)**	**30**	**29**
About to break		**31**	**30**
	I was told that it would not last much longer and was better to replace before it broke down	14	13
	It had not broken down yet, but it needed repairs too often	14	13
	I was told that the parts I needed would no longer be available in the future	3	3
	It was no longer under warranty	<1	1
Home improvement		**15**	**12**
	As part of a wider renovation to my property	13	11
	It took up too much space	1	1
	I did not like the look of it / not in keeping with the style of my home	1	1
Improve heating system		**11**	**14**
	It was no longer producing as much heat as it used to / heating the home adequately	5	6
	It did not heat home / hot water quickly enough	3	4
	I was concerned that it was no longer safe to run	1	1
	It was difficult to control the temperature of the heating in different rooms	1	1
	It was difficult to control the timing of the heating	na	1
	It was not environmentally friendly enough	1	1
	It was too noisy when it was operating	<1	1

Appendix 1: Comparison of the percentage of households giving each reason to change their heating system (Continued)

Reason for changing heating system	Sub categories	Percentages	
		research request	this analysis
High bills or maintenance costs		**4**	**5**
	I had very high heating bills using my previous system	2	4
	Servicing/repairing the system was very expensive	1	1
	Took advantage of a financial incentive for replacing it e.g. Boiler Scrappage Scheme, manufacturer offer	1	1
Other		**10**	**10**
	Other (none of these)	7	7
	Don't know/can't remember	3	3
Other - specified		not mentioned	238 households - excluded from analysis

Note: Summing the subcategories may not produce the percentages quoted for the main categories due to rounding errors

Appendix 2: Details of derived variables

Ages of the adults in the household

The ages of the adults (num24 num34 num44 num54 num65 num65) were combined into one variable with three groups :

1. All working age (less than 65 years old)

2. Working and retirement age

3. All retirement age (all 65 years old or more)

Insulation installed by the current owner

This counted up the amount/types of insulation installed by the current owner. The following were counted as types of insulation some insulation and top up insulation were counted as 2 types to differentiate between houses which had top up insulation and those that hadn't. If a house owner had installed loft insulation up to the top up level that was counted as 2 level/types of insulation

1. Some loft insulation (but not up to the top of the beam)
2. Top up loft insulation
3. Draft proofing
4. Underfloor
5. Double glazing
6. Hot water tank insulation
7. Appropriate wall insulation

This was checked against the amount of insulation installed before the owner moved in, because it was possible that the current owners had not installed much insulation because the house was already insulated when they moved in. However, the current owners said they had installed most of the insulation in their homes themselves (it is possible that they were only aware of the insulation which they had installed themselves). For this reason, the amount of insulation in the home was used as an explanatory variable without adjusting for the insulation already in the home.

Appendix 2: Details of derived variables (cont)

Heat advice

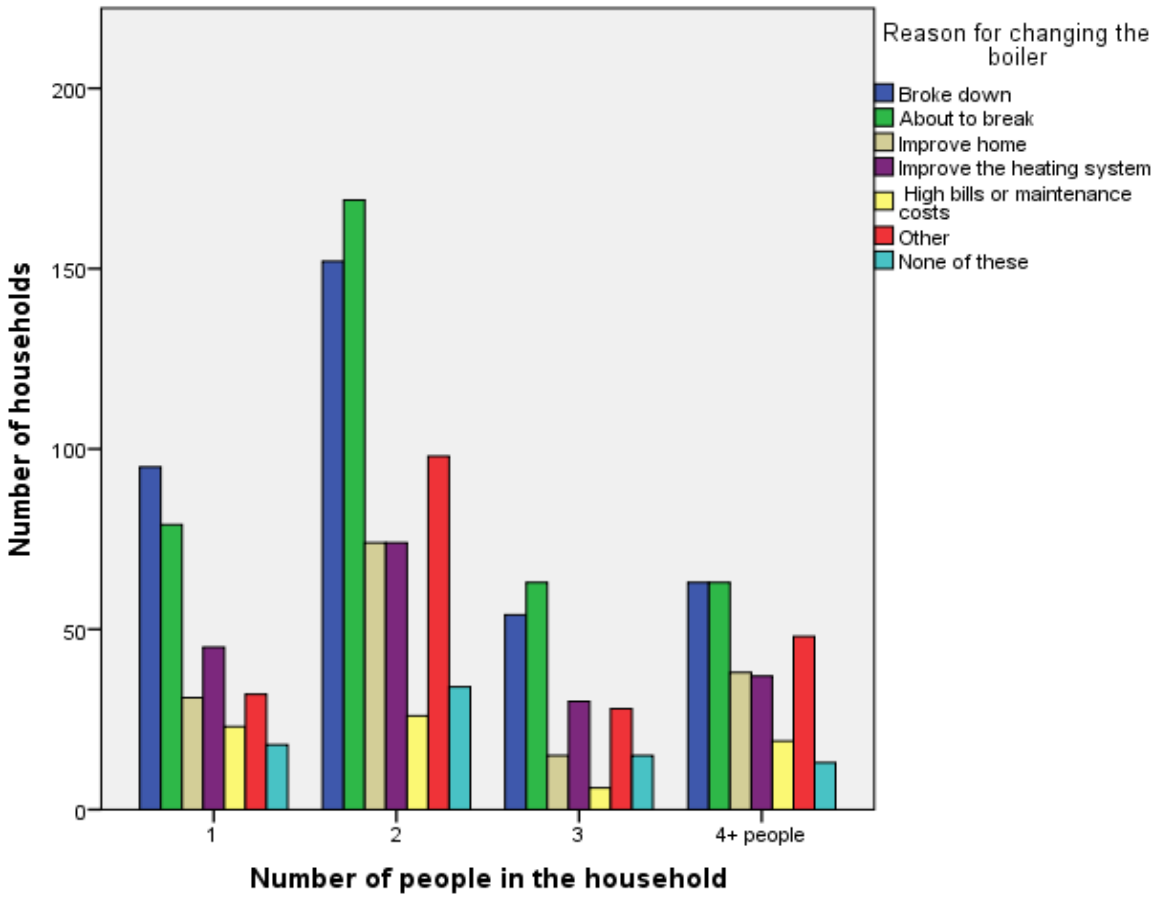
Nine individual variables asked for the sources of advice the householders consulted about changing their system. These were combined into a single variable with the following groups

1. Did not ask anyone for advice
2. Personal sources: family,friends and work colleagues; builder or repairman
3. Organisations: energy supplier; independent organisation or internet
4. Mixture of personal and organisational advice
5. Other advice

Appendix 3: Initial cross tabulations of the dependent and independent variables

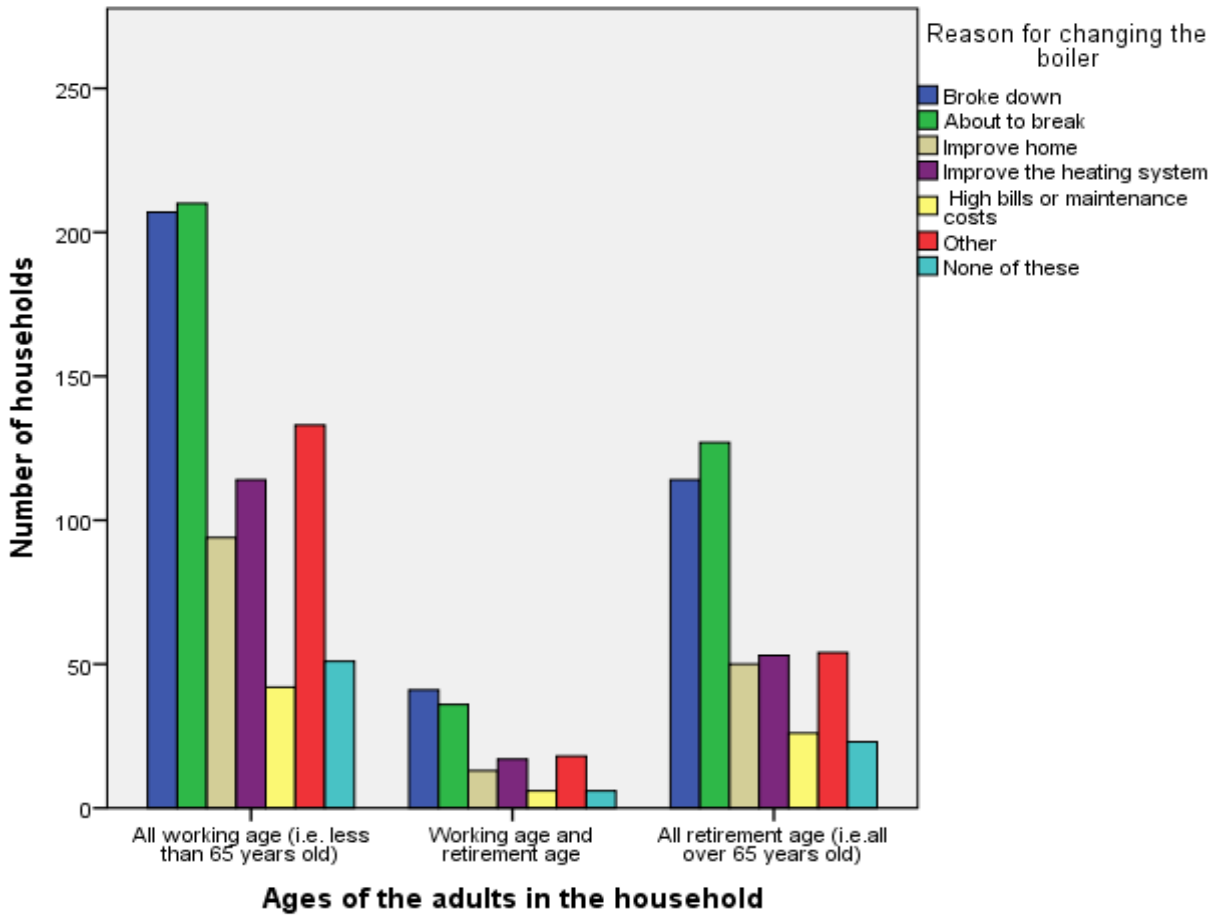
A3.1: Reason for changing the boiler by Number of people in the household

		Number of people in the household							
		1		2		3		4+ people	
		Count	%	Count	%	Count	%	Count	%
Reason for changing the boiler	Broke down	95	29.4	152	24.2	54	25.6	63	22.4
	About to break	79	24.5	169	27.0	63	29.9	63	22.4
	Improve home	31	9.6	74	11.8	15	7.1	38	13.5
	Improve the heating system	45	13.9	74	11.8	30	14.2	37	13.2
	High bills or maintenance costs	23	7.1	26	4.1	6	2.8	19	6.8
	Other	32	9.9	98	15.6	28	13.3	48	17.1
	None of these	18	5.6	34	5.4	15	7.1	13	4.6
	Total	323	100.0	627	100.0	211	100.0	281	100.0



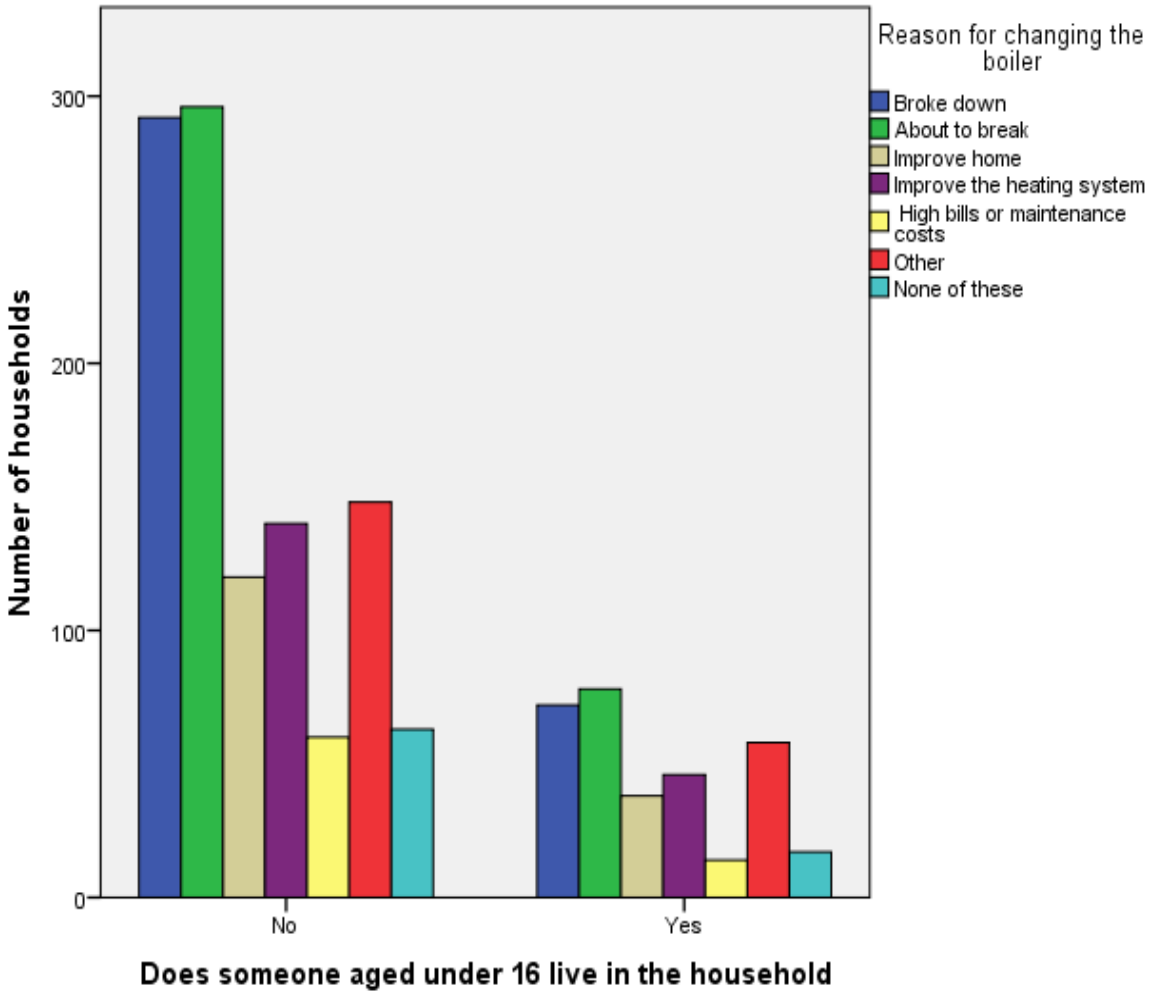
A3.2: Reason for changing the boiler by the ages of the adults in the household

		Ages of the adults in the household					
		All working age (i.e. less than 65 years old)		Working age and retirement age		All retirement age (i.e.all 65 years old or older)	
		Count	%	Count	%	Count	%
Reason for changing the boiler	Broke down	207	24.3	41	29.9	114	25.5
	About to break	210	24.7	36	26.3	127	28.4
	Improve home	94	11.0	13	9.5	50	11.2
	Improve the heating system	114	13.4	17	12.4	53	11.9
	High bills or maintenance costs	42	4.9	6	4.4	26	5.8
	Other	133	15.6	18	13.1	54	12.1
	None of these	51	6.0	6	4.4	23	5.1
	Total	851	100.0	137	100.0	447	100.0



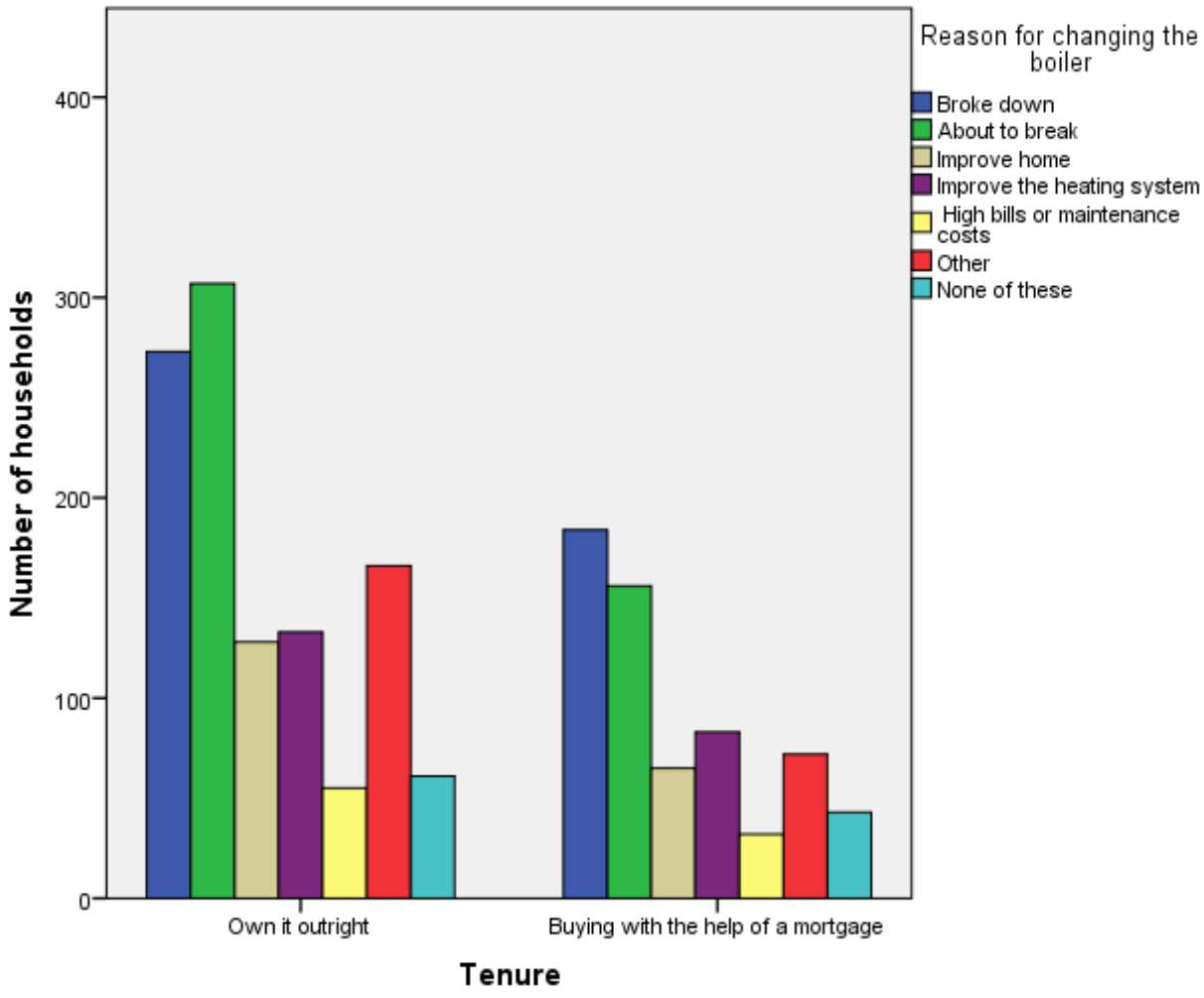
A3.3: Reason for changing the boiler by the presence of a someone aged under 16 in the household

		Does someone aged under 16 live in the household			
		No		Yes	
		Count	%	Count	%
Reason for changing the boiler	Broke down	292	26.1	72	22.3
	About to break	296	26.5	78	24.1
	Improve home	120	10.7	38	11.8
	Improve the heating system	140	12.5	46	14.2
	High bills or maintenance costs	60	5.4	14	4.3
	Other	148	13.2	58	18.0
	None of these	63	5.6	17	5.3
	Total	1119	100.0	323	100.0



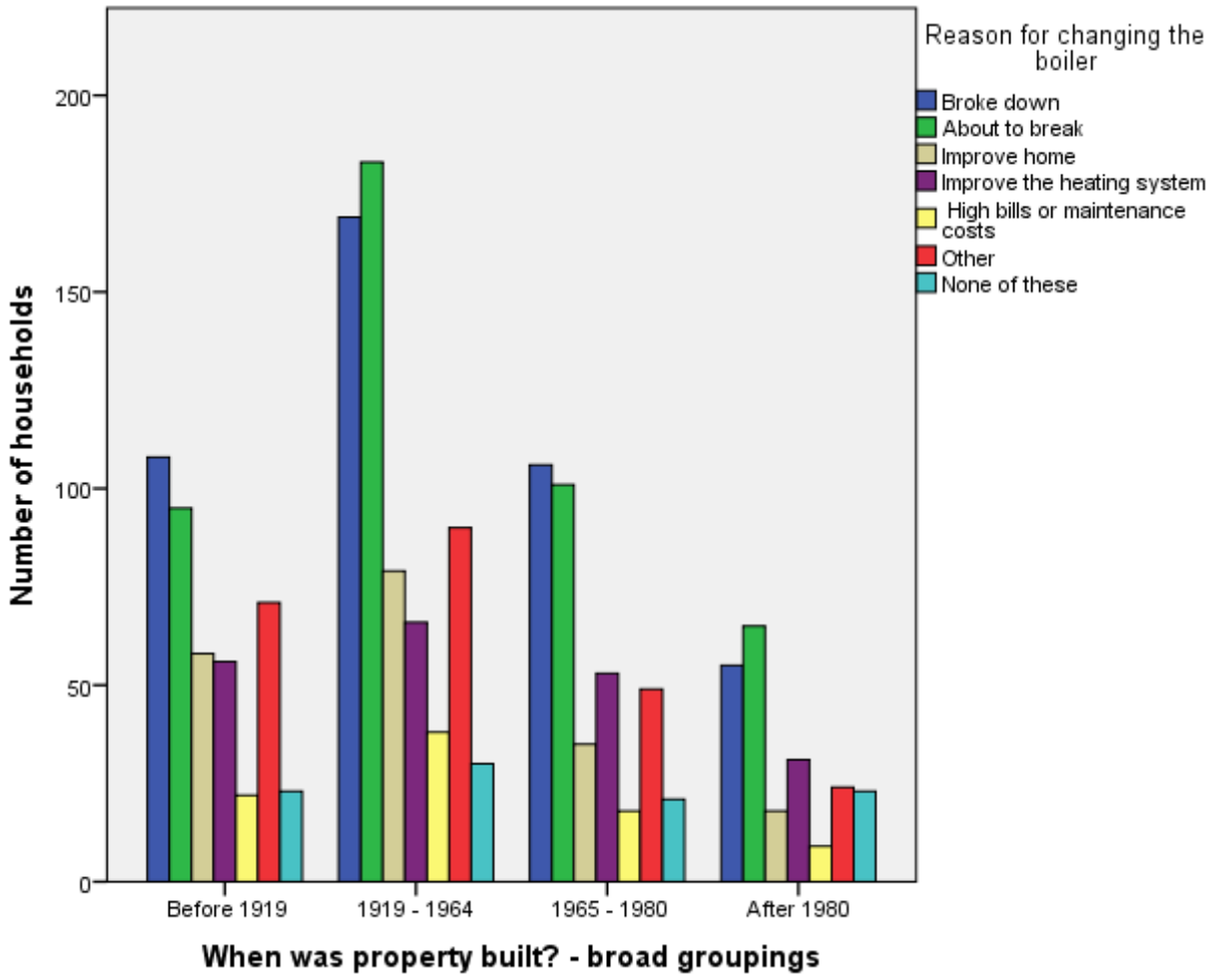
A3.4: Reason for changing the boiler by tenure

		Tenure			
		Own it outright		Buying with the help of a mortgage	
		Count	%	Count	%
Reason for changing the boiler	Broke down	273	24.3	184	29.0
	About to break	307	27.3	156	24.6
	Improve home	128	11.4	65	10.2
	Improve the heating system	133	11.8	83	13.1
	High bills or maintenance costs	55	4.9	32	5.0
	Other	166	14.8	72	11.3
	None of these	61	5.4	43	6.8
	Total	1123	100.0	635	100.0



A3.5: Reason for changing the boiler by the age of the property

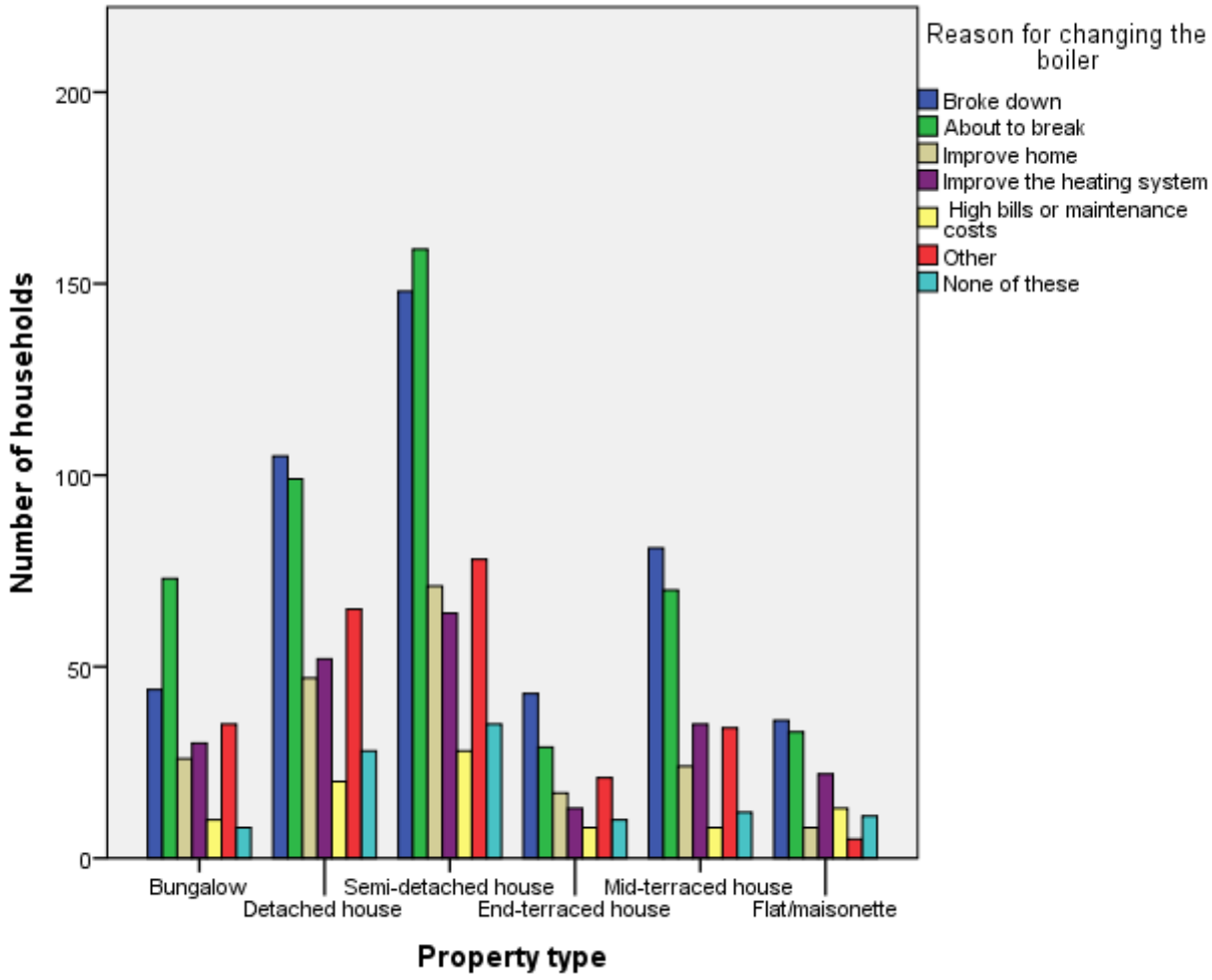
		When was property built? - broad groupings							
		Before 1919		1919 - 1964		1965 - 1980		After 1980	
		Count	%	Count	%	Count	%	Count	%
Reason for changing the boiler	Broke down	108	24.9	169	25.8	106	27.7	55	24.4
	About to break	95	21.9	183	27.9	101	26.4	65	28.9
	Improve home	58	13.4	79	12.1	35	9.1	18	8.0
	Improve the heating system	56	12.9	66	10.1	53	13.8	31	13.8
	High bills or maintenance costs	22	5.1	38	5.8	18	4.7	9	4.0
	Other	71	16.4	90	13.7	49	12.8	24	10.7
	None of these	23	5.3	30	4.6	21	5.5	23	10.2
	Total	433	100.0	655	100.0	383	100.0	225	100.0



A3.6: Reason for changing the boiler by the property type

		Property type											
		Bungalow		Detached house		Semi-detached house		End-terraced house		Mid-terraced house		Flat/maisonette	
		Count	%	Count	%	Count	%	Count	%	Count	%	Count	%
Reason for changing the boiler	Broke down	44	19.5	105	25.2	148	25.4	43	30.5	81	30.7	36	28.1
	About to break	73	32.3	99	23.8	159	27.3	29	20.6	70	26.5	33	25.8
	Improve home	26	11.5	47	11.3	71	12.2	17	12.1	24	9.1	8	6.3
	Improve the heating system	30	13.3	52	12.5	64	11.0	13	9.2	35	13.3	22	17.2
	High bills or maintenance costs	10	4.4	20	4.8	28	4.8	8	5.7	8	3.0	13	10.2
	Other	35	15.5	65	15.6	78	13.4	21	14.9	34	12.9	5	3.9
	None of these	8	3.5	28	6.7	35	6.0	10	7.1	12	4.5	11	8.6
	Total	226	100.0	416	100.0	583	100.0	141	100.0	264	100.0	128	100.0

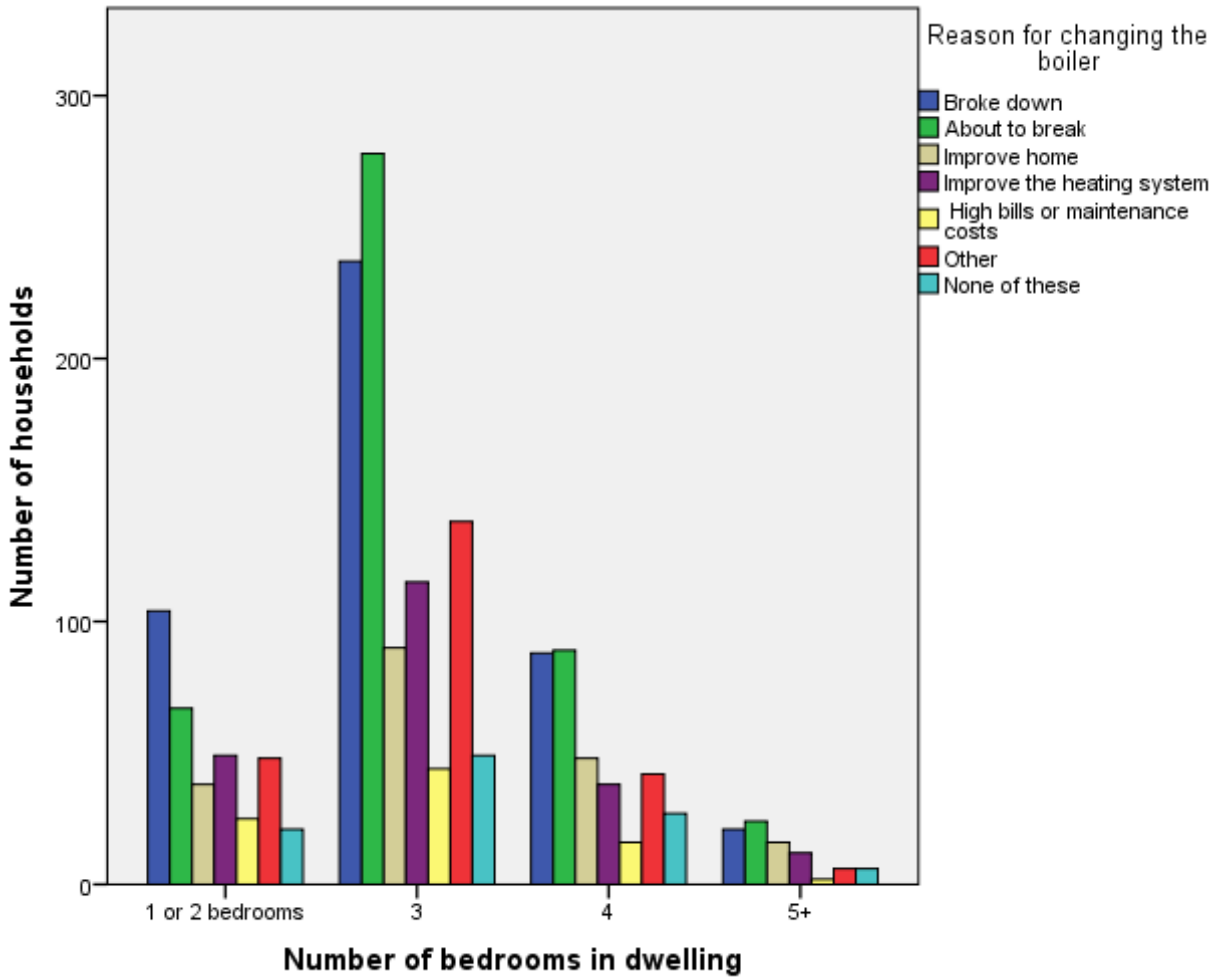
A3.6: Reason for changing the boiler by the property type (continued)



A3.7: Reason for changing the boiler by the number of bedrooms in the dwelling

		Number of bedrooms in dwelling							
		1 or 2 bedrooms		3		4		5+	
		Count	%	Count	%	Count	%	Count	%
Reason for changing the boiler	Broke down	104	29.5	237	24.9	88	25.3	21	24.1
	About to break	67	19.0	278	29.2	89	25.6	24	27.6
	Improve home	38	10.8	90	9.5	48	13.8	16	18.4
	Improve the heating system	49	13.9	115	12.1	38	10.9	12	13.8
	High bills or maintenance costs	25	7.1	44	4.6	16	4.6	2	2.3
	Other	48	13.6	138	14.5	42	12.1	6	6.9
	None of these	21	6.0	49	5.2	27	7.8	6	6.9
	Total	352	100.0	951	100.0	348	100.0	87	100.0

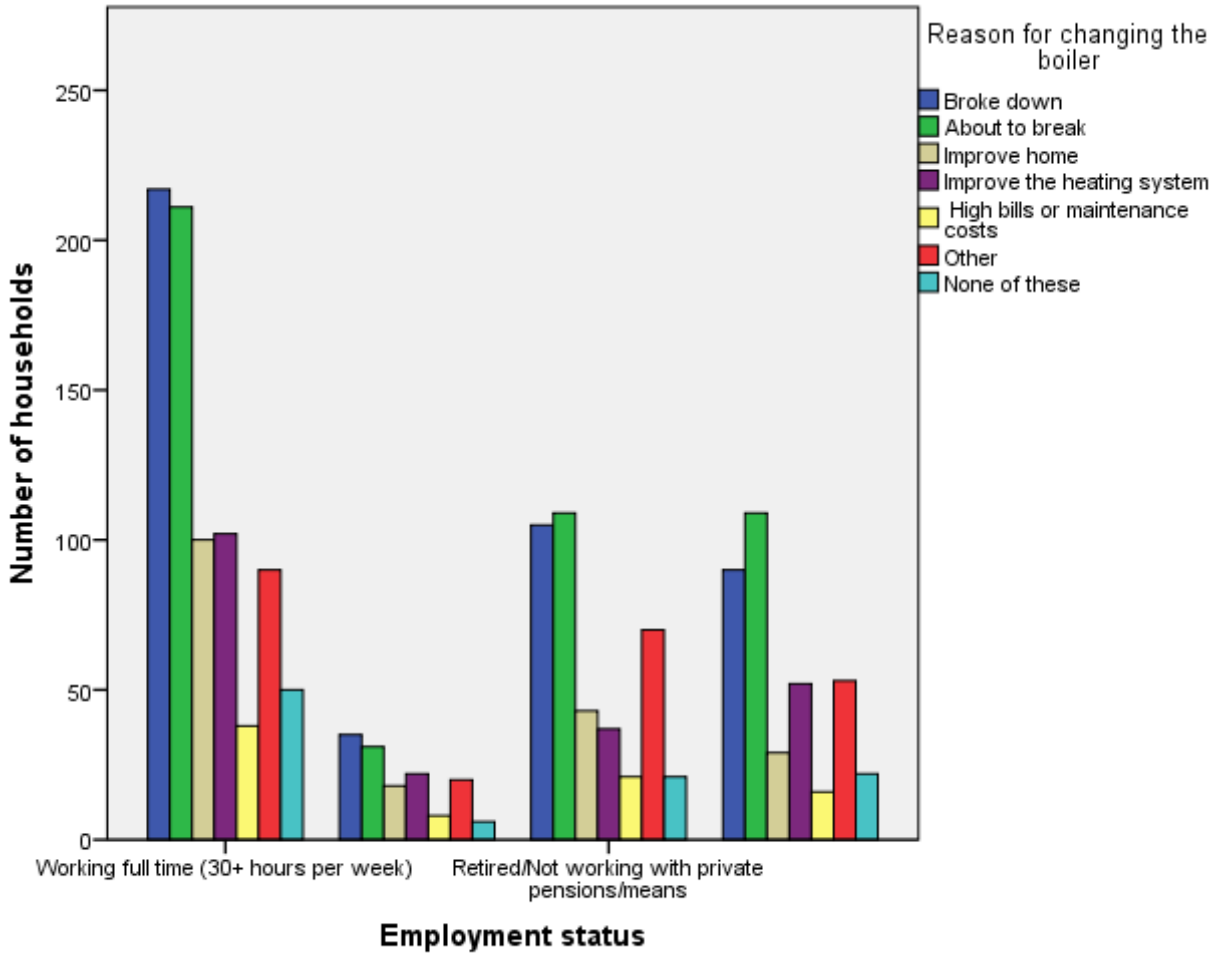
A3.7: Reason for changing the boiler by the number of bedrooms in the dwelling (continued)



A3.8: Reason for changing the boiler by the employment status

		Employment status							
		Working full time (30+ hours per week)		Working part time (less than 30 hours a week)		Retired/Not working with private pensions/means		Retired/Not working with state benefit/pension only	
		Count	%	Count	%	Count	%	Count	%
Reason for changing the boiler	Broke down	217	26.9	35	25.0	105	25.9	90	24.3
	About to break	211	26.1	31	22.1	109	26.8	109	29.4
	Improve home	100	12.4	18	12.9	43	10.6	29	7.8
	Improve the heating system	102	12.6	22	15.7	37	9.1	52	14.0
	High bills or maintenance costs	38	4.7	8	5.7	21	5.2	16	4.3
	Other	90	11.1	20	14.3	70	17.2	53	14.3
	None of these	50	6.2	6	4.3	21	5.2	22	5.9
	Total	808	100.0	140	100.0	406	100.0	371	100.0

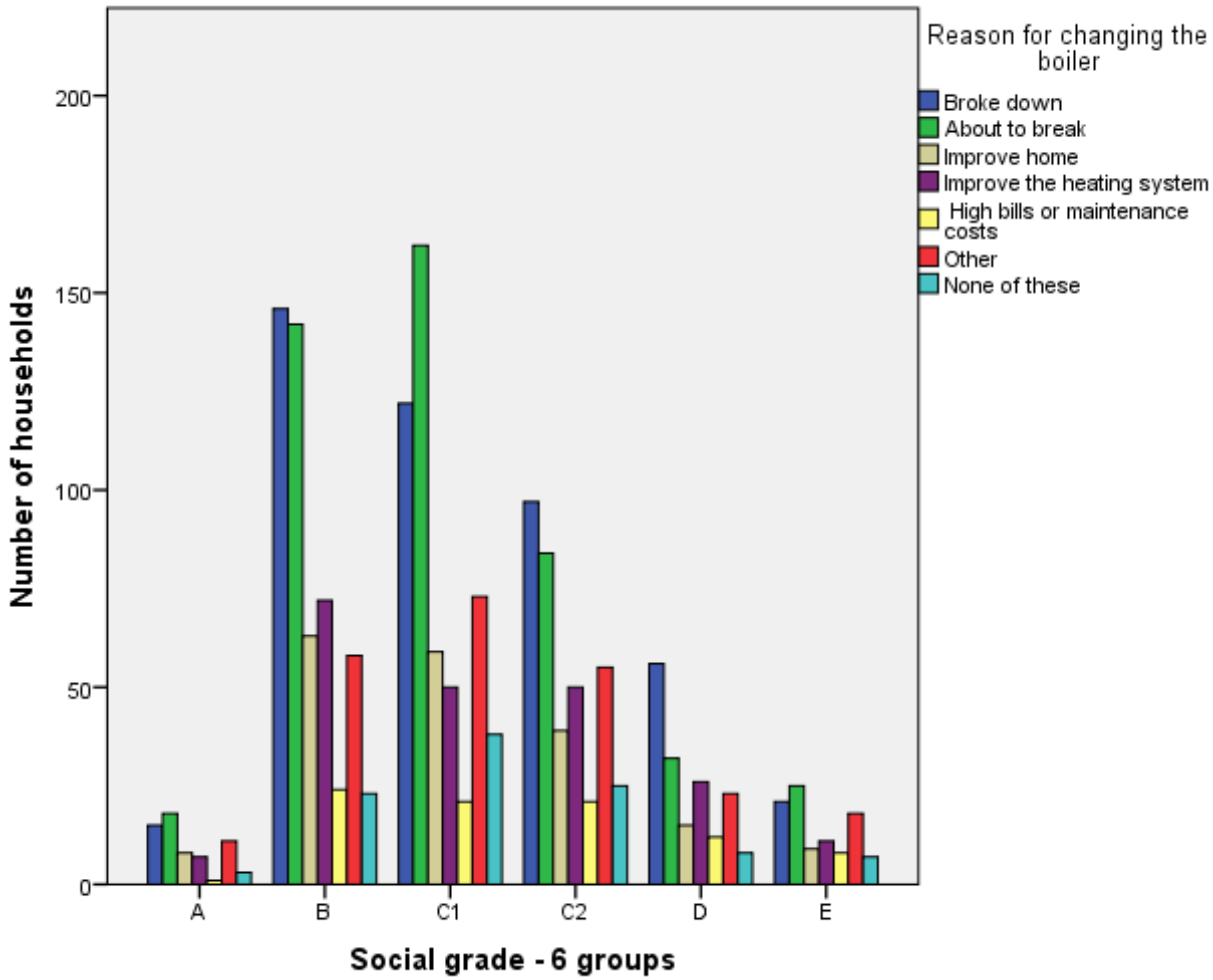
A3.8: Reason for changing the boiler by the employment status (continued)



A3.9: Reason for changing the boiler by social grade

		Social grade - 6 groups											
		A		B		C1		C2		D		E	
		Count	%	Count	%	Count	%	Count	%	Count	%	Count	%
Reason for changing the boiler	Broke down	15	23.8	146	27.7	122	23.2	97	26.1	56	32.6	21	21.2
	About to break	18	28.6	142	26.9	162	30.9	84	22.6	32	18.6	25	25.3
	Improve home	8	12.7	63	11.9	59	11.2	39	10.5	15	8.7	9	9.1
	Improve the heating system	7	11.1	72	13.6	50	9.5	50	13.5	26	15.1	11	11.1
	High bills or maintenance costs	1	1.6	24	4.5	21	4.0	21	5.7	12	7.0	8	8.1
	Other	11	17.5	58	11.0	73	13.9	55	14.8	23	13.4	18	18.2
	None of these	3	4.8	23	4.4	38	7.2	25	6.7	8	4.7	7	7.1
	Total	63	100.0	528	100.0	525	100.0	371	100.0	172	100.0	99	100.0

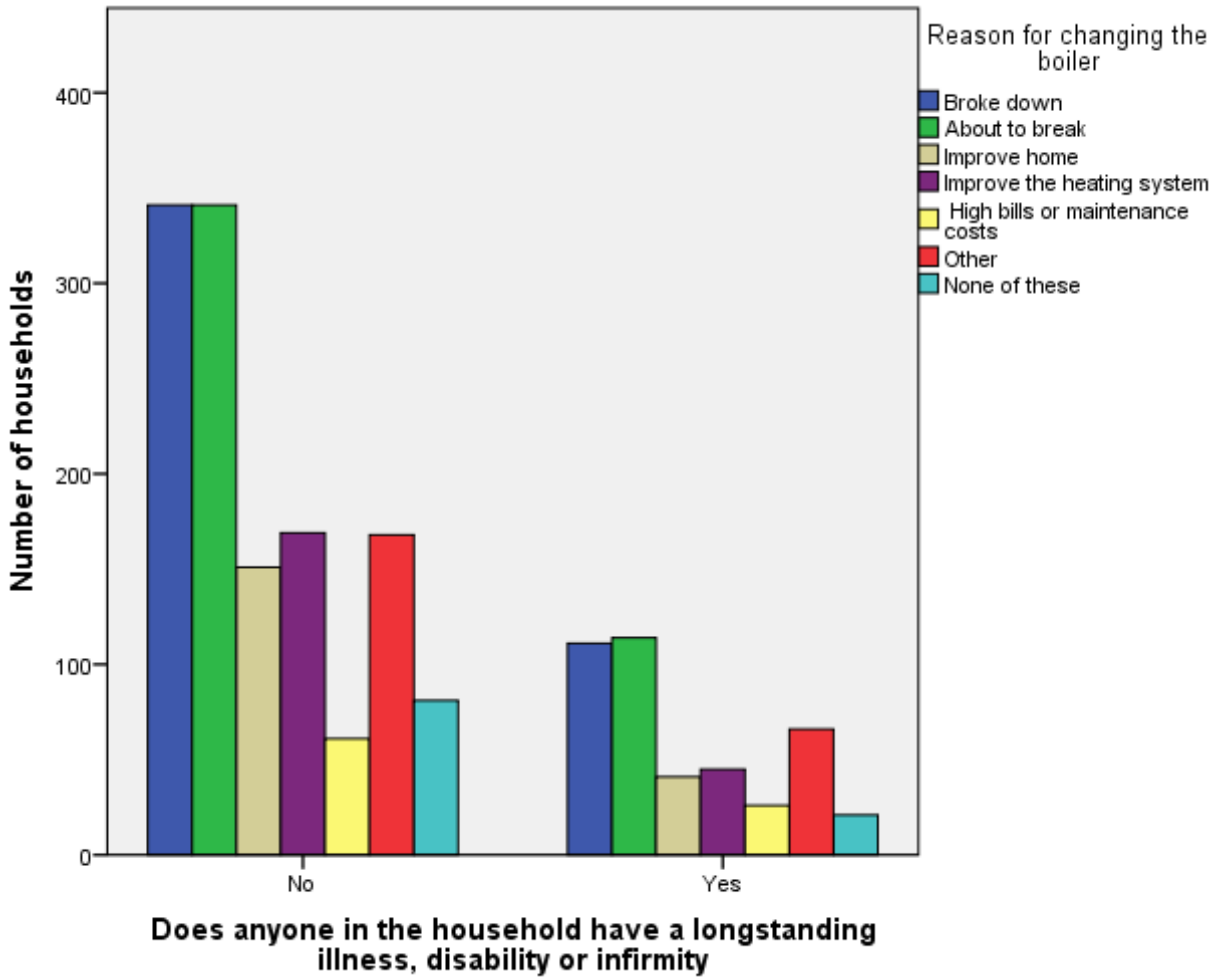
A3.9: Reason for changing the boiler by social grade (continued)



A3.10: Reason for changing the boiler by whether someone in the household has a long standing illness or disability

		Does anyone in the household have a longstanding illness, disability or infirmity			
		No		Yes	
		Count	%	Count	%
Reason for changing the boiler	Broke down	341	26.0	111	26.2
	About to break	341	26.0	114	26.9
	Improve home	151	11.5	41	9.7
	Improve the heating system	169	12.9	45	10.6
	High bills or maintenance costs	61	4.6	26	6.1
	Other	168	12.8	66	15.6
	None of these	81	6.2	21	5.0
	Total	1312	100.0	424	100.0

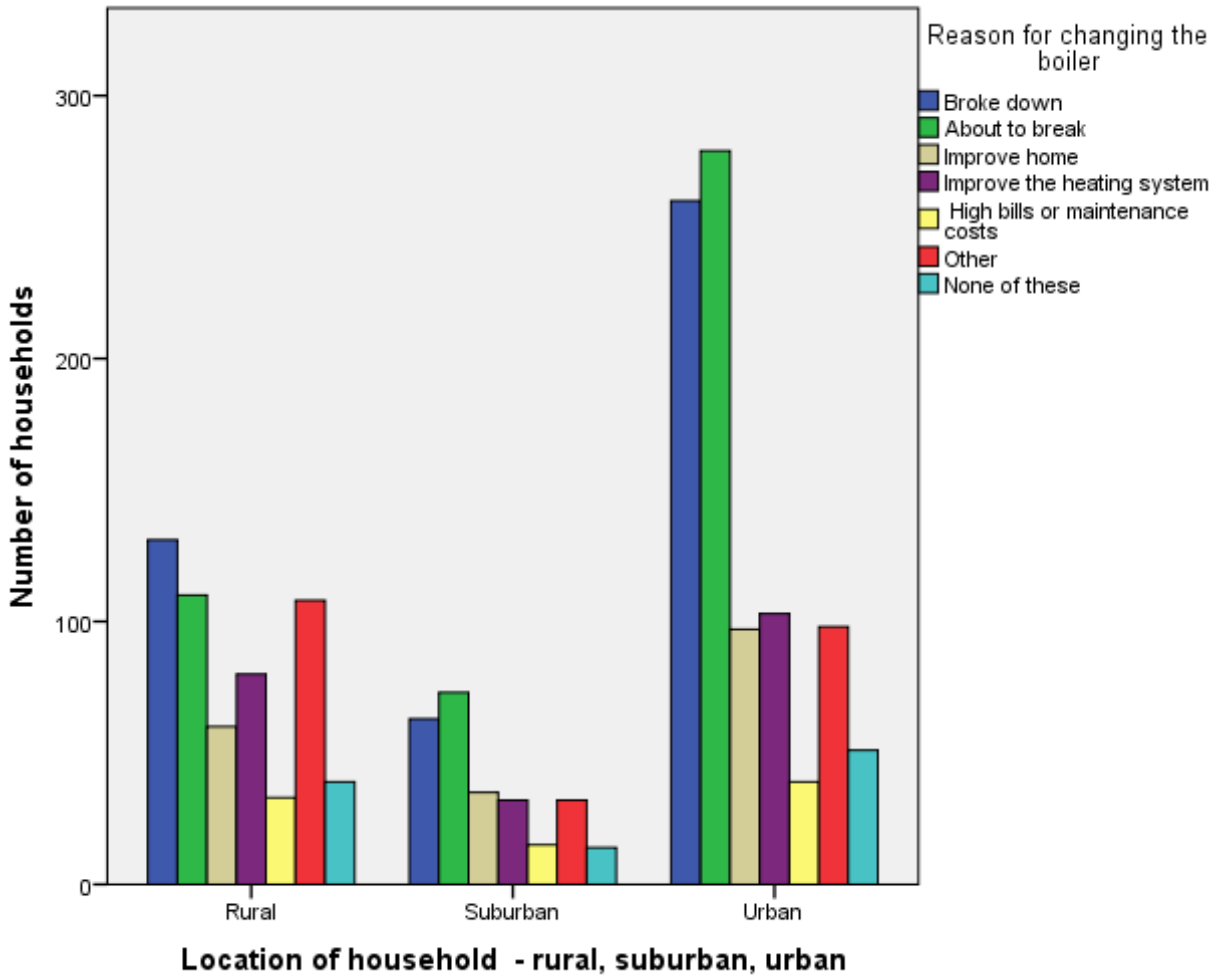
A3.10: Reason for changing the boiler by whether someone in the household has a long standing illness or disability (Continued)



A3.11: Reason for changing the boiler by location of house

		Location of household - rural, suburban, urban					
		Rural		Suburban		Urban	
		Count	%	Count	%	Count	%
Reason for changing the boiler	Broke down	131	23.4	63	23.9	260	28.0
	About to break	110	19.6	73	27.7	279	30.1
	Improve home	60	10.7	35	13.3	97	10.5
	Improve the heating system	80	14.3	32	12.1	103	11.1
	High bills or maintenance costs	33	5.9	15	5.7	39	4.2
	Other	108	19.3	32	12.1	98	10.6
	None of these	39	7.0	14	5.3	51	5.5
	Total	561	100.0	264	100.0	927	100.0

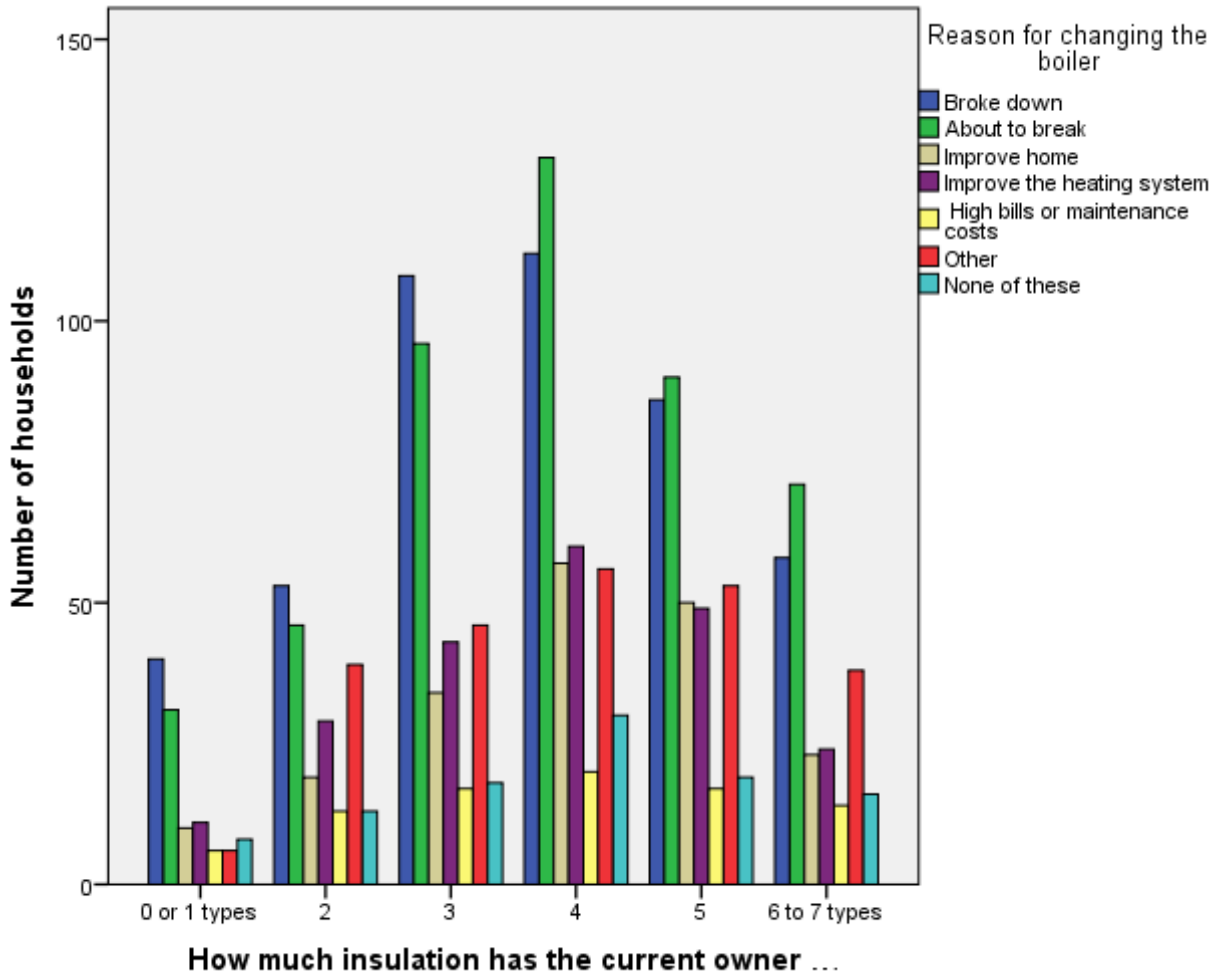
A3.11: Reason for changing the boiler by location of house (Continued)



A3.12: Reason for changing the boiler by amount of insulation installed by the owner

		How much insulation has the current owner installed											
		0 or 1 types		2		3		4		5		6 to 7 types	
		Count	%	Count	%	Count	%	Count	%	Count	%	Count	%
Reason for changing the boiler	Broke down	40	35.7	53	25.0	108	29.8	112	24.1	86	23.6	58	23.8
	About to break	31	27.7	46	21.7	96	26.5	129	27.8	90	24.7	71	29.1
	Improve home	10	8.9	19	9.0	34	9.4	57	12.3	50	13.7	23	9.4
	Improve the heating system	11	9.8	29	13.7	43	11.9	60	12.9	49	13.5	24	9.8
	High bills or maintenance costs	6	5.4	13	6.1	17	4.7	20	4.3	17	4.7	14	5.7
	Other	6	5.4	39	18.4	46	12.7	56	12.1	53	14.6	38	15.6
	None of these	8	7.1	13	6.1	18	5.0	30	6.5	19	5.2	16	6.6
	Total	112	100.0	212	100.0	362	100.0	464	100.0	364	100.0	244	100.0

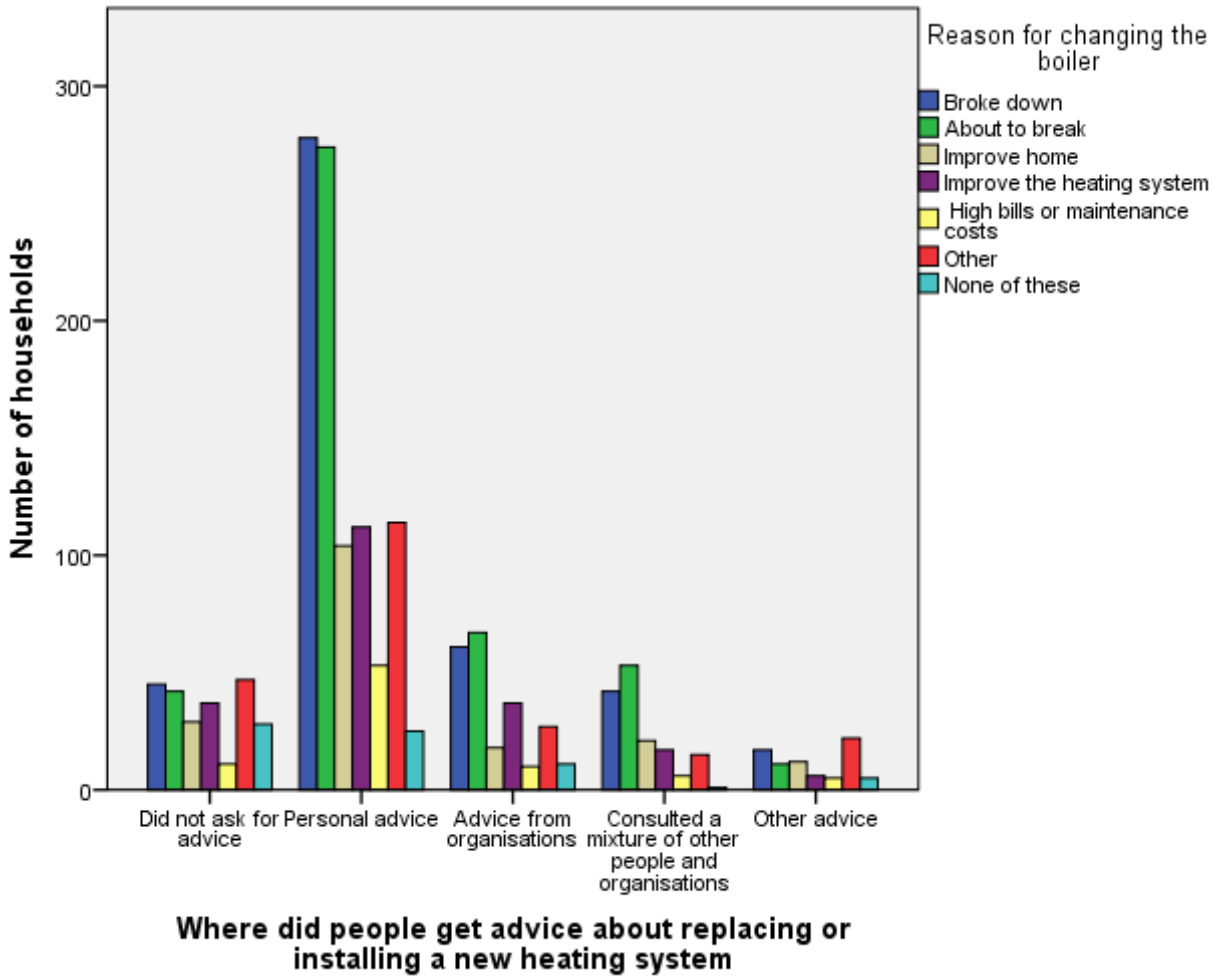
A3.12: Reason for changing the boiler by amount of insulation installed by the owner (Continued)



A3.13: Reason for changing the boiler by sources of advice about changing the heating system

		Where did people get advice about replacing or installing a new heating system									
		Did not ask for advice		Personal advice		Advice from organisations		Consulted a mixture of other people and organisations		Other advice	
		Count	%	Count	%	Count	%	Count	%	Count	%
Reason for changing the boiler	Broke down	45	18.8	278	29.0	61	26.4	42	27.1	17	21.8
	About to break	42	17.6	274	28.5	67	29.0	53	34.2	11	14.1
	Improve home	29	12.1	104	10.8	18	7.8	21	13.5	12	15.4
	Improve the heating system	37	15.5	112	11.7	37	16.0	17	11.0	6	7.7
	High bills or maintenance costs	11	4.6	53	5.5	10	4.3	6	3.9	5	6.4
	Other	47	19.7	114	11.9	27	11.7	15	9.7	22	28.2
	None of these	28	11.7	25	2.6	11	4.8	1	.6	5	6.4
	Total	239	100.0	960	100.0	231	100.0	155	100.0	78	100.0

A3.13: Reason for changing the boiler by sources of advice about changing the heating system (Continued)



Appendix 4: Specification for CHAID analysis

Dependent variable features

Dependent (outcome) variable: Reason (Reason for changing the heating system)

Categories of the dependent variable included in the analysis: Broke down, About the break, Improve the home, Improve the heating system, High bills or Maintenance costs, none of these (i.e. other)

Target categories (these are particularly important categories): None selected

Independent (predictor) variables

Variables chosen : dvHsize (Household size), adage (age of adults in household), childHH (presence of a child under 16 years old in the household), Tenure, Dwellage2 (Age of property), proptype (type of property e.g. bungalow, flat/maisonette, semi-detached house), bedrooms (Number of bedrooms), empstatus (employment status of chief income earner), socgrade6 (NSSEC social grades – 6 groups), Disability (Does anyone in the household have a long standing illness, disability or infirmity), Location (Location of property – urban, suburban, rural), inscount (Number of types of insulation installed in the house), ownins (Number of types of insulation installed by the owner), heatadvice.(Sources of advice about changing heating system)

Other Specification details

No influence variable was defined

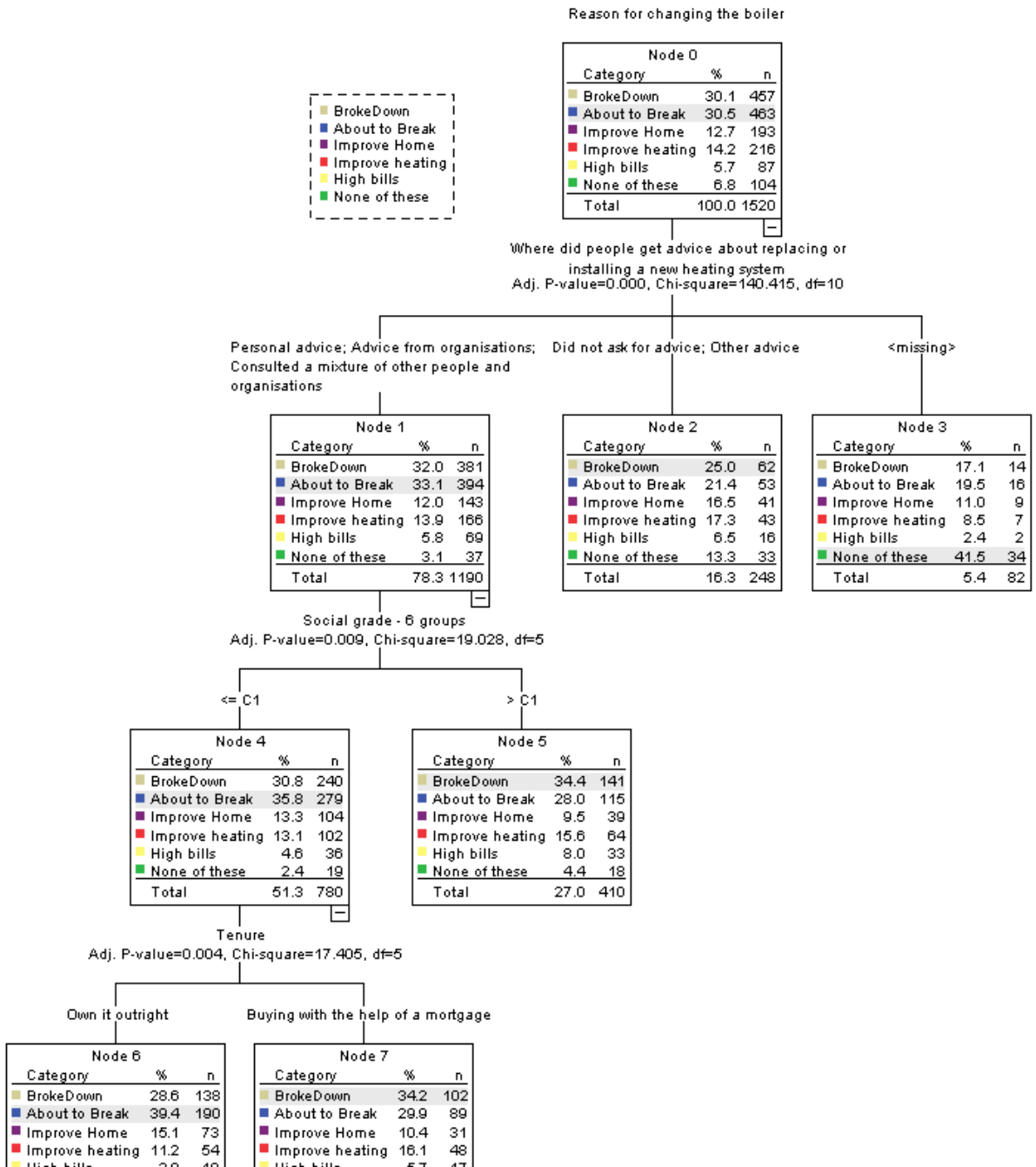
Minimum number of cases for parent node was set to 100

Minimum number of cases for child node was set to 50

Cross validation was selected using 10 folds (this helps prevent over fitting of the model).

The likelihood ratio test statistic was chosen for the test statistic for nominal variables (it will automatically be used for ordinal variables) – this text statistic is more robust than the Pearson chi squared statistic.

Appendix 5a: Initial CHAID Analysis Results (this correctly predicts 34.8% of reasons to change boilers)


Reason for changing the boiler
BrokeDown
About to Break
Improve Home
Improve heating
High bills
None of these
Node 0
Category % n
BrokeDown 30.1 457
About to Break 30.5 463
Improve Home 12.7 193
Improve heating 14.2 216
High bills 5.7 87
None of these 6.8 104
Total 100.0 1520
Where did people get advice about replacing or installing a new heating system
Adj. P-value=0.000, Chi-square=140.415, df=10
Personal advice; Advice from organisations; Consulted a mixture of other people and organisations
Did not ask for advice; Other advice
<missing>
Node 1
Category % n
BrokeDown 32.0 381
About to Break 33.1 394
Improve Home 12.0 143
Improve heating 13.9 166
High bills 5.8 69
None of these 3.1 37
Total 78.3 1190
Node 2
Category % n
BrokeDown 25.0 62
About to Break 21.4 53
Improve Home 16.5 41
Improve heating 17.3 43
High bills 6.5 16
None of these 13.3 33
Total 16.3 248
Node 3
Category % n
BrokeDown 17.1 14
About to Break 19.5 16
Improve Home 11.0 9
Improve heating 8.5 7
High bills 2.4 2
None of these 41.5 34
Total 5.4 82
Social grade - 6 groups
Adj. P-value=0.009, Chi-square=19.028, df=5
<= C1
> C1
Node 4
Category % n
BrokeDown 30.8 240
About to Break 35.8 279
Improve Home 13.3 104
Improve heating 13.1 102
High bills 4.6 36
None of these 2.4 19
Total 51.3 780
Node 5
Category % n
BrokeDown 34.4 141
About to Break 28.0 115
Improve Home 9.5 39
Improve heating 15.6 64
High bills 8.0 33
None of these 4.4 18
Total 27.0 410
Tenure
Adj. P-value=0.004, Chi-square=17.405, df=5
Own it outright
Buying with the help of a mortgage
Node 6
Category % n
BrokeDown 28.6 138
About to Break 39.4 190
Improve Home 15.1 73
Improve heating 11.2 54
Node 7
Category % n
BrokeDown 34.2 102
About to Break 29.9 89
Improve Home 10.4 31
Improve heating 16.1 48

Appendix 5b: Interpretation of Initial Chaid Analysis Results

The initial CHAID analysis identified 5 distinct groups with respect to the reasons for changing their boiler

Group1:
Households which took advice about changing their boiler from personal sources (family, friends, work colleagues); or from organisations; or from a mixture or personal sources and organisations
AND
Where the highest earner in the household was of social grade C1 or lower (i.e. C1, C2 D or E)
AND
Which owned their house outright

Group2:
Households which took advice about changing their boiler from personal sources (family, friends, work colleagues); or from organisations; or from a mixture or personal sources and organisations
AND
Where the highest earner in the household was of social grade C1 or lower (i.e. C1, C2 D or E)
AND
Which were buying their house through a mortgage

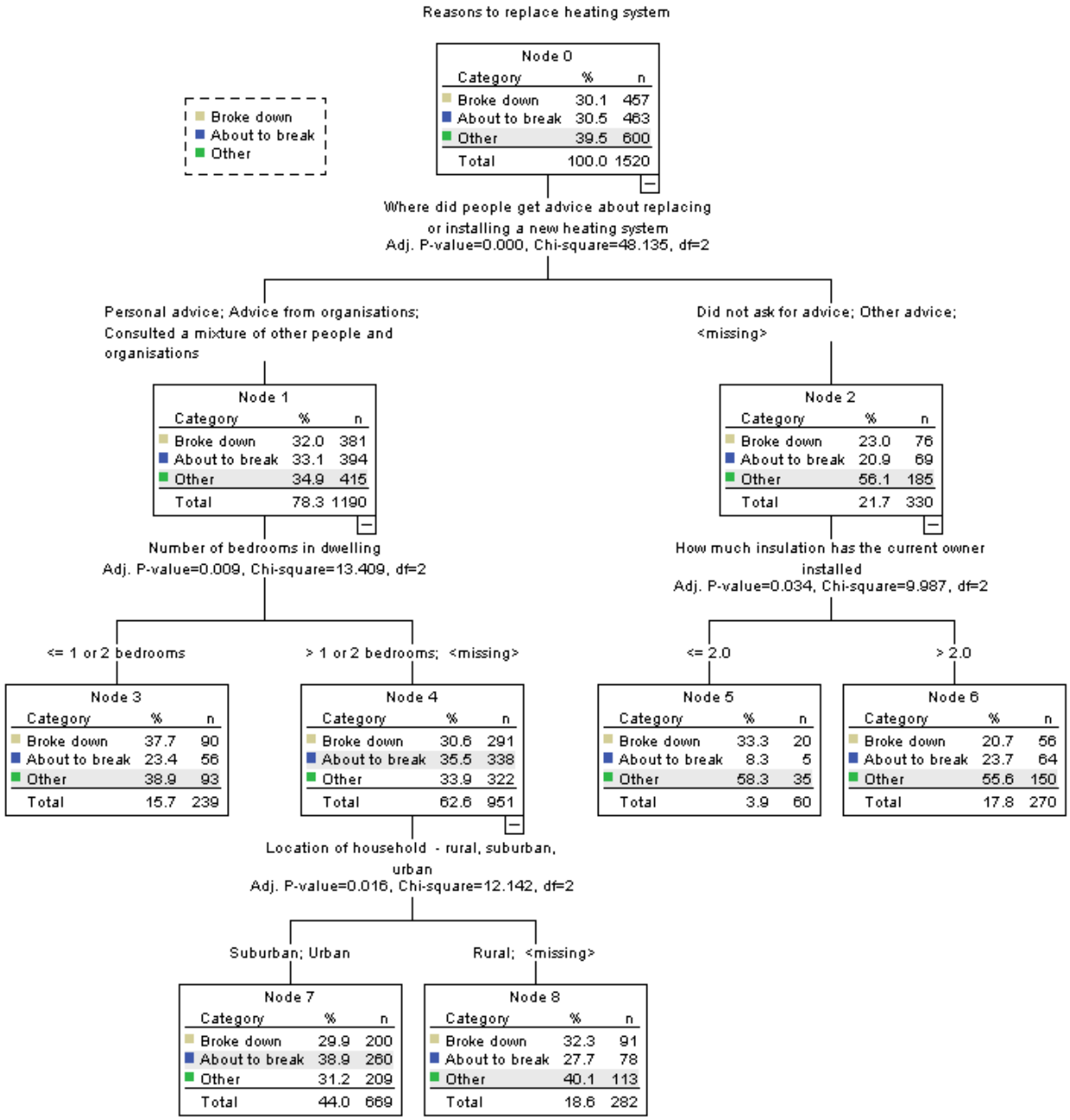
Group3:
Households which took advice about changing their boiler from personal sources (family, friends, work colleagues); or from organisations; or from a mixture or personal sources and organisations
AND
Where the highest earner in the household was of social grade A or B

Group4:

Households which either did not ask for advice about changing their boilers or who took it from other sources (i.e. Not from personal sources (family, friends, work colleagues); or from organisations; or from a mixture or personal sources and organisations)

Group5:
Households which gave no information about what advice they got about changing their boiler (i.e. the source of advice was missing for these households)

Appendix 6a: Second CHAID Analysis Results (this correctly predicts 42.8% of reasons to change boilers)


Reasons to replace heating system
Broke down
About to break
Other
Node 0
Category % n
Broke down 30.1 457
About to break 30.5 463
Other 39.5 600
Total 100.0 1520
Where did people get advice about replacing or installing a new heating system
Adj. P-value=0.000, Chi-square=48.135, df=2
Personal advice; Advice from organisations; Consulted a mixture of other people and organisations
Did not ask for advice; Other advice; <missing>
Node 1
Category % n
Broke down 32.0 381
About to break 33.1 394
Other 34.9 415
Total 78.3 1190
Node 2
Category % n
Broke down 23.0 76
About to break 20.9 69
Other 56.1 185
Total 21.7 330
Number of bedrooms in dwelling
Adj. P-value=0.009, Chi-square=13.409, df=2
How much insulation has the current owner installed
Adj. P-value=0.034, Chi-square=9.987, df=2
<= 1 or 2 bedrooms
> 1 or 2 bedrooms; <missing>
<= 2.0
> 2.0
Node 3
Category % n
Broke down 37.7 90
About to break 23.4 56
Other 38.9 93
Total 15.7 239
Node 4
Category % n
Broke down 30.6 291
About to break 35.5 338
Other 33.9 322
Total 62.6 951
Node 5
Category % n
Broke down 33.3 20
About to break 8.3 5
Other 58.3 35
Total 3.9 60
Node 6
Category % n
Broke down 20.7 56
About to break 23.7 64
Other 55.6 150
Total 17.8 270
Location of household - rural, suburban, urban
Adj. P-value=0.016, Chi-square=12.142, df=2
Suburban; Urban
Rural; <missing>
Node 7
Category % n
Broke down 29.9 200
About to break 38.9 260
Other 31.2 209
Total 44.0 669
Node 8
Category % n
Broke down 32.3 91
About to break 27.7 78
Other 40.1 113
Total 18.6 282

Appendix 6b: Interpretation of the Second Chaid Analysis Results

The second CHAID analysis identified 5 distinct groups with respect to the reasons for changing their boiler

Group1:
Households which took advice about changing their boiler from personal sources (family, friends, work colleagues); or from organisations; or from a mixture or personal sources and organisations
AND
Where the home contained 1 or 2 bedrooms

Group2:
Households which took advice about changing their boiler from personal sources (family, friends, work colleagues); or from organisations; or from a mixture or personal sources and organisations
AND
Where the home contained at least 3 bedrooms, or the homeowner did not say how many bedrooms it had
AND
Where the home was in a suburban or urban location

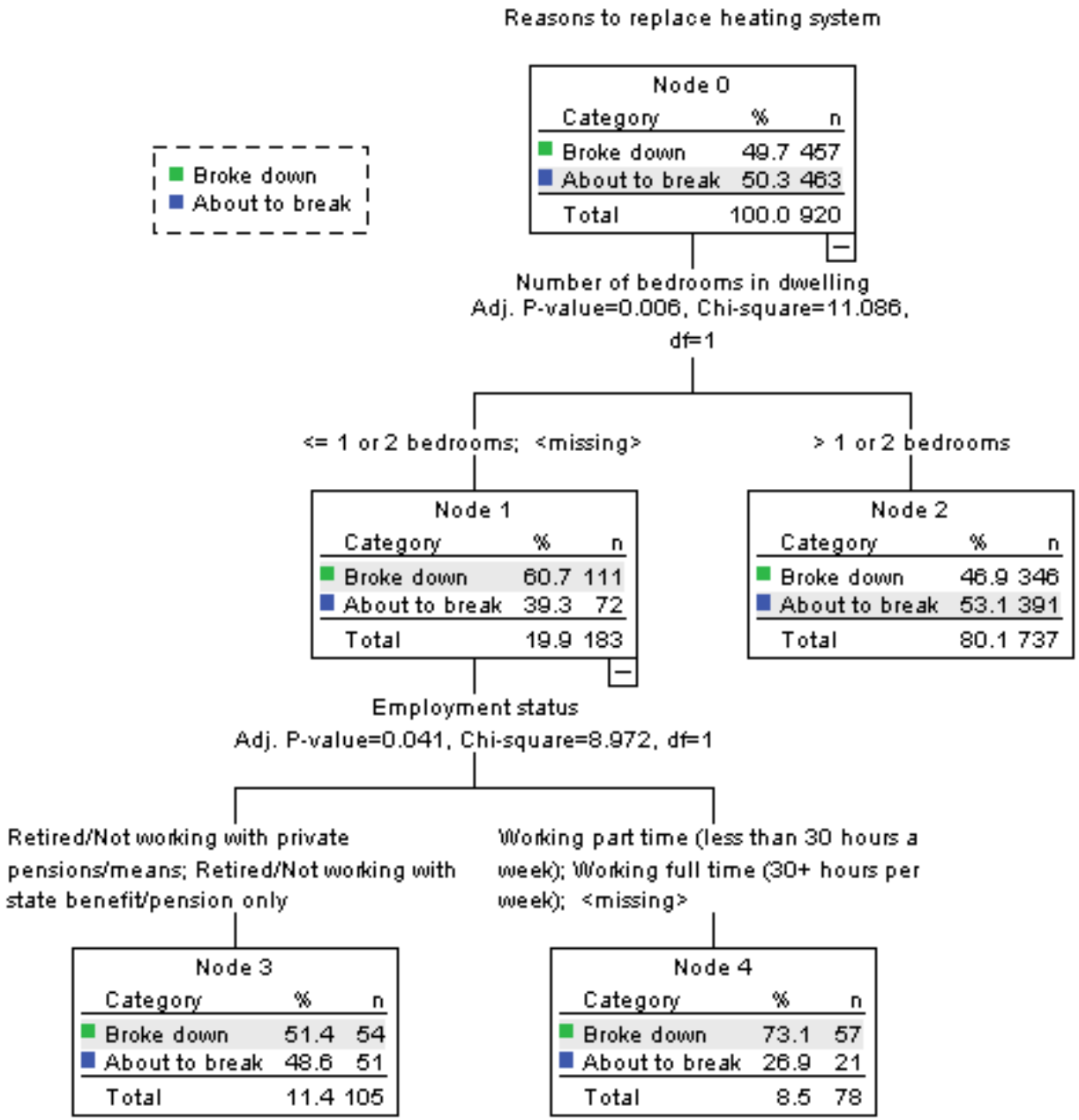
Group3:
Households which took advice about changing their boiler from personal sources (family, friends, work colleagues); or from organisations; or from a mixture or personal sources and organisations
AND
Where the home contained at least 3 bedrooms, or the homeowner did not say how many bedrooms it had
AND
Where the home was in a rural location

Group4:
Households which either did not ask for advice about changing their boilers or who took it from other sources (i.e. Not from personal sources (family, friends, work colleagues); or from organisations; or from a mixture or personal sources and organisations)

AND
Where the current homeowners had installed no more than 2 types of insulation

Group5:
Households which gave no information about what advice they got about changing their boiler (i.e. the source of advice was missing for these households)
AND
Where the current homeowners had installed more than 2 types of insulation

Appendix 7a: Third CHAID Analysis Results (this correctly predicts 54.6% of reasons to change boilers)


Reasons to replace heating system
Broke down
About to break
Node 0
Category % n
Broke down 49.7 457
About to break 50.3 463
Total 100.0 920
Number of bedrooms in dwelling
Adj. P-value=0.006, Chi-square=11.086, df=1
<= 1 or 2 bedrooms; <missing>
> 1 or 2 bedrooms
Node 1
Category % n
Broke down 60.7 111
About to break 39.3 72
Total 19.9 183
Node 2
Category % n
Broke down 46.9 346
About to break 53.1 391
Total 80.1 737
Employment status
Adj. P-value=0.041, Chi-square=8.972, df=1
Retired/Not working with private pensions/means; Retired/Not working with state benefit/pension only
Working part time (less than 30 hours a week); Working full time (30+ hours per week); <missing>
Node 3
Category % n
Broke down 51.4 54
About to break 48.6 51
Total 11.4 105
Node 4
Category % n
Broke down 73.1 57
About to break 26.9 21
Total 8.5 78

Appendix 7b: Interpretation of the Third Chaid Analysis Results

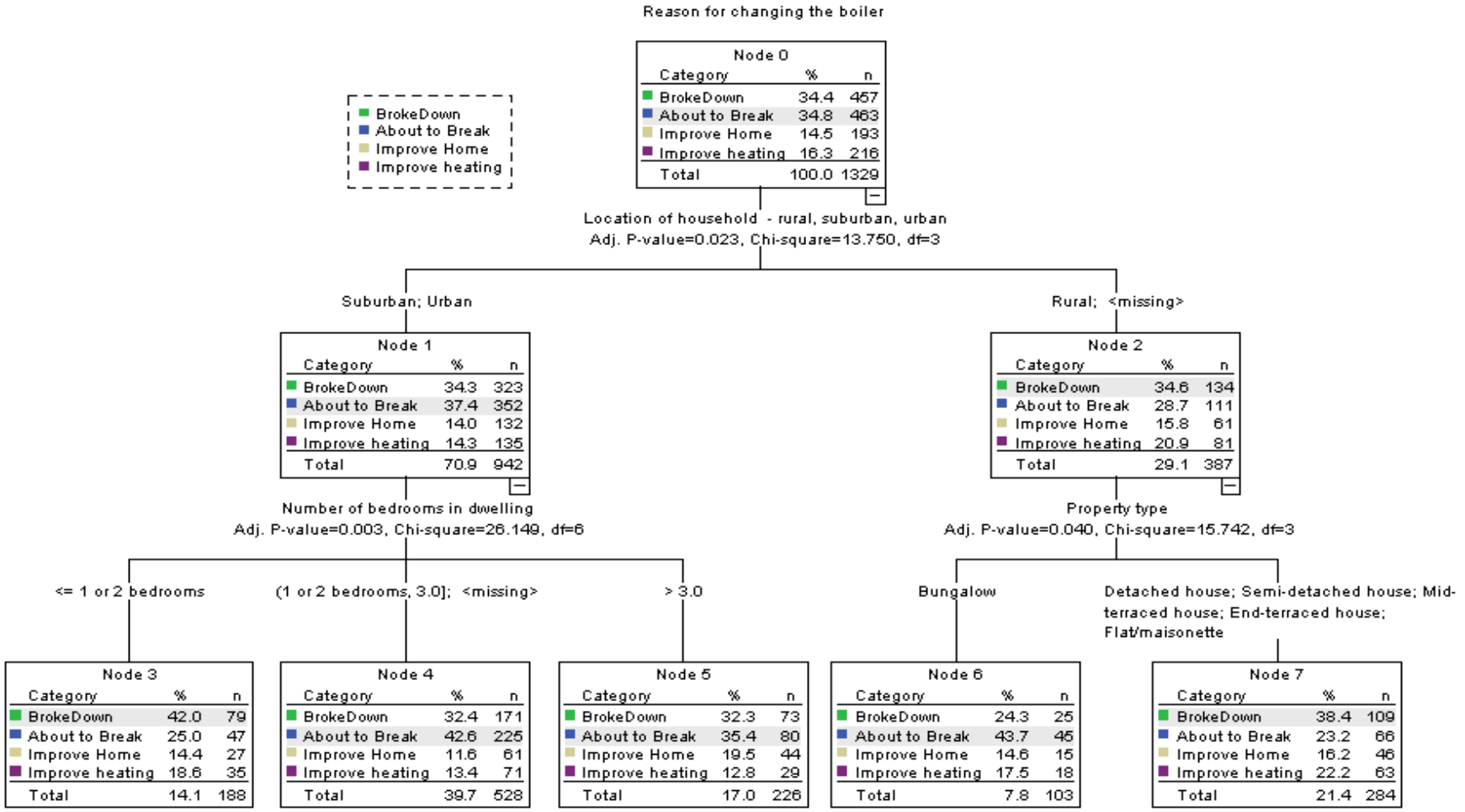
The third CHAID analysis only included the two biggest categories from the reasons to change the boiler: “Broke down“ and “about to break”. This analysis identified 3 distinct groups with respect to these two reasons for changing their boiler

Group1:
The home either contained 1 or 2 bedrooms or the number of bedrooms was missing
AND
The main earner in the household was either retired or not working with a private pensionincome or they were retired/ not working with a state pension/benefit

Group2:
The home either contained 1 or 2 bedrooms or the number of bedrooms was missing
AND
The main earner in the household either works (full or part time) or the employment status of the main earner is missing

Group3:
The home either contained 3 or more bedrooms

Appendix 8a: Fourth CHAID analysis Results



Appendix 8b: Interpretation of the Fourth Chaid Analysis Results

The third CHAID analysis only included the categories “Broke down“, “about to break”, “Imrove the home” and “Improve the heating”. This analysis identified 5 distinct groups with respect to these four reasons for changing the boiler

Group1:
The home was in a suburban or urban location
AND
The home contained 1 or 2 bedrooms

Group2:
The home was in a suburban or urban location
AND
The home either contained 3 bedrooms or the number of bedrooms was missing

Group3:
The home was in a suburban or urban location
AND
The home either contained more than 3 bedrooms

Group4:
The home was in a rural location
AND
The home was a bungalow

Group4:
The home was in a rural location
AND
The home was a bungalow