

Building improvements to address energy poverty have most substantial thermal comfort and health effects

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ref. no. 332/2022, and; Jelgava, Latvia: Central Medical Ethics committee of Latvia, ref. no. 01–29.1.2/2267. Informed participant consent was collected on paper by a research assistant.

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Abstract

Interventions for energy poverty have increased in the wake of the energy crisis, with many nations attempting to ease experiences for their citizens. We use data collected as part of WELLBASED which explored the impact of interventions for energy poverty and improving health in 6 European Cities. By categorising interventions into structural, small measures, advice and financial support, we can differentiate between the energy poverty and health impacts of each category. We find through our longitudinal analysis there is little, if any, effect from small home improvements and energy advice, but that structural interventions for energy poverty have some positive thermal comfort and health effects. Further, direct financial support has clear positive effects on health and energy saving practices, and when financial support fluctuates, so do participants' living conditions. Governments should invest in a range of measures, with a recognition that structural measures and consistent financial support are most effective.

Introduction

Energy poverty, the inability to access adequate energy services¹, is high on the agenda in many nations. Energy poverty is linked to a range of physical and mental health conditions, accidents at home,² excess winter and summer deaths,²⁻⁷ and aggravation of the health effects of disability.⁸⁻¹¹ Governments are keen to find ways to intervene, reducing exposure to energy poverty and improving health status.

Existing evidence on the effects of energy poverty interventions mainly evaluate structural interventions,¹²⁻³⁵ such as fitting insulation, renewing the heating source or double-glazing windows, meaning evidence of the effect of other measures is not widely covered.^{36,37}

Alternative measures include advice interventions (energy audit, advice on benefits or energy tariffs) which help people improve their home energy efficiency. These are generally documented to have small effects, although advice delivered in person, by experienced advisors and coordinated with other forms of support can make a difference.³⁷⁻⁴³ Another category of small home improvements involves replacing inefficient domestic appliances or distributing energy efficiency kits containing small technical fixes (e.g. energy saving lightbulbs). Finally, governments commonly offer some form of financial support for citizens who are entitled to particular benefits, or in specific financial contexts.⁴⁴ Advice, small home improvements (small measures) and financial support interventions are in widespread use, maybe partly due to their relative low cost, and simplicity of delivery in comparison to more structural interventions.

Here we present results from an intervention study WELLBASED which tracked citizens (n=1094) from 6 cities in Europe from late 2022 to mid-2024. In this paper, we select answers from 4 longitudinal questionnaires over an 18-month period, which document people's experiences of energy poverty, especially thermal comfort in winter, and their health and wellbeing status. We also track participants' exposure to a range of interventions funded privately or received through WELLBASED itself, as well as the receipt of further interventions associated with broader government responses to the energy crisis. This was a unique opportunity to understand the effects of a range of interventions across a large and diverse European sample.

The aim of this research is to demonstrate the effect of different measures to address energy poverty on: i) people's ability to achieve thermal comfort and ii) on their health. Using two stages of analysis, i) exploring the relationship between interventions, energy poverty and health experiences; and ii) modelling the effects of energy poverty practices and interventions on achieving thermal comfort, our research shows that structural interventions tend to result in improvements in energy poverty experiences whereas outcomes are more mixed for other interventions.

Main text

Research was conducted in 6 European Cities: Edirne, Turkey; Heerlen, the Netherlands; Jelgava, Latvia; Leeds, England; Obuda, Hungary; Valencia, Spain. The central premise was to better understand the impact of urban interventions in tackling energy poverty and improving health. Energy poverty, health and wellbeing information was collected using self-reported questionnaires at 4 time points (baseline, 6, 12 and 15-18 months), completed by 1094 participants.¹ Participants were recruited because they were struggling to access adequate energy services. This was validated by the fact that 92% of our sample engaged in unhealthy coping practices (e.g. limiting heating or wearing extra clothes to save money); over half were unable to achieve thermal comfort in winter (58%) or summer (69%); 46% had arrears on energy bills in the last 12 months; and 45% experienced leaks, damp or rot.

The interventions received were categorised (top of Table1) and then grouped into three broad categories, which were combined to reflect the 'highest' level of energy intervention received: none, advice, small measures or structural (bottom of Table 1); and financial support with energy consumption was categorised to identify receipt of, or change in, support received² (see Table 3).³

[Table 1 here]

¹ A full list of variables used in the analysis and their distribution is shown in Table S1 in the Supplementary Material.

² Whilst it would have been interesting to note the variation in combinations of interventions, including levels of financial support, the small cell counts in our data precludes this.

³ Distributions by each European City can be found in Supplementary Tables S2 (Intervention types), S3 (Financial Support). Financial Support by Intervention type is shown in Table S4.

The analysis is longitudinal, exploring individual change over time, to understand responses to specific interventions. First, using measures of association to establish the strength and significance of relationships between energy poverty experiences, coping practices, and health outcomes for the different types of intervention and financial support. Second, regression analysis to explore the effects of the interventions on changes in thermal comfort, controlling for energy practices and health.

How is energy poverty affected by intervention type?

The relationship between intervention type, energy poverty, coping practices, financial support and health was explored through crosstabulations. Circumstances at baseline by intervention type are shown in Figure 1. Statistically significant associations are summarised in Table 2 (Intervention type) and Table 3 (Financial Support).

Figure 1a-c shows circumstances at baseline by intervention type reported at follow-up. At baseline, those who later report having received structural interventions during the study period were generally in a worse position in terms of energy poverty and health compared to those who report receiving other interventions, although they were in a similar position to those not receiving any intervention. For example, at baseline 66% of those who later reported having received structural interventions struggled to keep their home warm in winter compared to 39% receiving small measures, 42% receiving advice and 77% receiving no intervention (Cramer's $v=0.345$; $p<0.001$).

This is the first large questionnaire that we know of to measure coping practices (Figure 1b). At baseline, the majority of our sample (92%) engaged in negative coping practices. For example, the proportion wearing extra clothes to keep warm ranges from 67% among those who at follow-up report having received small measures to 86% of those who do not receive any intervention (Cramer's $v=0.154$; $p<0.001$); and the proportion limiting heating to save money ranges from 59% (Small measures) to 74% (Structural and no intervention)(Cramer's $v=0.132$; $p>0.001$).

[Figure 1a-c here]

We go on to explore changes in circumstances overtime by intervention type. A description of how variables have been coded is presented in the Methods section (Box 1), and frequencies in Supplementary Material (Table S1). Some categories do have low counts and results should be treated with caution. Nonetheless, key patterns are evident for different forms of intervention and associations are statistically significant.

We seek to capture the nuance of the variation in changes that can be experienced *within* as well as *between* intervention types. We therefore provide examples of associations in Figure 2 (Intervention Type) and Figure 3 (Financial Support). Figures for other variables included in

the analysis are provided in Supplementary Material (Figure S1 (Intervention Type) and S2 (Financial Support)).

In Figure 2a-e we show that in homes where **structural** interventions have been implemented, people have become able to achieve thermal comfort (being comfortably warm in winter (35%) and cool in summer (31%)); they engage less in negative coping practices (e.g 39% have stopped or reduced the frequency of turning heating/cooling off to save money); they are better able to manage utility bills, 34% have stopped or reduced the frequency of being in arrears; and their health has improved (decrease in pain or discomfort (35%), improvements in depression (28%), anxiety (35%) and stress (25%)).

In homes implementing **small measures**, things have generally stayed the same in a positive way. For example, people are not experiencing problems with thermal comfort (47% report homes as already being warm) or health (over half are not depressed (52%), anxious (51%) or stressed (56%) and rarely engaging in negative coping behaviours (e.g 23% never or rarely turn heating/cooling off to save money compared to 14% of those receiving structural interventions).

Where people have only received energy-related **advice** there is a mix of experiences. Some people continue to achieve thermal comfort (46% can keep homes warm in winter), are not in arrears (65%) and continue not to experience mental health issues (43% are not depressed, 46% not anxious and 63% not stressed). But others continue to engage in negative coping practices, such as wearing extra clothes (20%) or limiting when (38%) and where (28%) heating is used to save money and are also more likely to continue experiencing physical health problems causing pain or discomfort (31%).

Where **no interventions** have been implemented there is also a mix of experiences. Whilst some people have become able to achieve thermal comfort in winter (34%), others still struggle in winter (39%) and summer (42%). People are better able to keep on top of utility bills (41% stopped or reduced the frequency of arrears), and report improvements in mental health (depression (38%), anxiety (36%) and stress (31%)), but they continue to engage in negative coping practices to save money (35% turn heating/cooling off; 34% heat/cool only one room).

[Figure 2a-e here]

Figure 3a-e summarises data on the receipt of financial support towards the cost of energy. There are also patterns evident here in the way that changes in support affected people's experiences. We observe that participants who reported **not getting financial support** over the study period achieved thermal comfort in summer (58% were or became able to keep cool) and winter (80% were or became able to keep warm). They were not having problems with arrears, damp or mental health, although some engaged in negative coping practices to save money (e.g. 38% were or started turning heating/cooling off).

Where people did **receive financial support** or started to get support throughout the observed period, they did not achieve thermal comfort (66% who started getting financial support and 56% who continued to get financial support are not warm) and had damp (75% and 68% respectively, see Figure S2). However, over time they reduced engagement in negative coping practices (37% and 39% respectively stopped turning heating/cooling off) and arrears (40% stopped or reduced frequency of arrears) and reported improvements in health (38% / 40% had decreased pain and discomfort; 41% / 39% reported reductions in anxiety).

Where **financial support stopped** during the period under study problems with arrears dropped (57%). However, some negative coping practices continued (34% started/continued turning heating/cooling off, and 34% started or continued to heat one room to save money). People stopped having problems with damp, although continued to have physical (37%) and mental health (15% Anxiety; 16% depression) problems. Finally, **fluctuations in getting financial support** also showed fluctuations in achieving thermal comfort (13%), negative energy practices (27%), arrears (18%) and damp (15%).

[Figure 3a-e here]

Factors associated with keeping homes warm in winter.

Here we focus on one dimension of energy poverty, namely the ability to keep a home comfortably warm in winter. Two separate regression models were run to explore negative experiences (people started or continued to struggle to keep their home warm) and positive experiences of thermal comfort (people became able to keep their home warm). Full results are presented in Supplementary Material (Tables S5 and S6).

In both models, structural interventions produced the only significant changes: these resulted in a reduced likelihood of struggling to keep a home warm in winter (OR=0.44; $p<0.001$) and an increased likelihood of becoming able to keep a home warm (OR=1.95; $p<0.01$).

The likelihood of **struggling to keep a home warm** is higher where financial support has been received at some point (OR range from 1.95 to 3.30; $p<0.05$); people have moved in and out of arrears on utility bills (OR=2.10; $p<0.05$); and with having leaks, damp, or rot (OR=6.09; $p<0.001$). The likelihood is also higher where people are only heating one room

to save money (OR=3.31; $p<0.001$), but also where they have stopped or reduced the frequency of heating only one room (OR=2.85; $p<0.01$) or this practice has fluctuated (OR=2.26; $p<0.05$). They are also more likely to be wearing extra clothes to keep warm, but the margin of error is high, so results should be treated with caution.

By contrast **becoming able to keep a home warm** is more likely where people have stopped or reduced the frequency of arrears on utility bills (OR=2.99; $p<0.001$) or are not heating only one room (OR=2.08; $p<0.05$), although fluctuations in heating one room also increase the likelihood (OR=2.08; $p<0.05$). Not wearing extra clothes to keep warm as often, is also significant, although again the margin of error is high. The likelihood of becoming able to keep a home warm is lower where people have stopped turning heating off to save money (OR=0.82; $p<0.05$) or people have leaks, damp or rot (OR=0.50; $p<0.05$) (Table S5).

These results suggest the likelihood of achieving thermal comfort in winter increases the further away people get from being in arrears and closer towards utility bills becoming manageable. It also increases where people do not feel the need to limit when and where heating is used. Where the ability to use heating fluctuates there is a risk of moving from achieving thermal comfort, to struggling to keep warm.

Ability to achieve thermal comfort is also linked to health. **The likelihood of not being able to keep a home warm** is higher where there are increased levels of depression (OR=2.19; $p<0.05$), and where stress levels have fluctuated (OR=2.10; $p<0.01$). Where stress levels have reduced (OR=1.74; $p<0.05$) or pain and discomfort levels had fluctuated (OR=1.91; $p<0.05$) or decreased (OR=1.94; $p<0.01$) this is linked to the likelihood of **becoming able to keep a home warm** (Table S6). The nature of the data do not enable cause and effect to be determined, and it could be that stress and discomfort arise because of issues with thermal comfort, rather than pre-empting them.

Discussion

Drawing on this evidence, we can extract some key insights about the effects of different interventions. First, there were clear links between the level of intervention and the extent of effects. Advice only, and small measures had limited effects, whereas structural measures had a more positive impact on participants lives. Structural interventions resulted in a wide range of positive outcomes for those that received them, including being able to achieve thermal comfort in winter and summer, being less likely to be in debt or engaging in unhealthy coping practices, and better health. This group were more likely to be in a worse position at the outset, with more space for improvement, nonetheless, our work clearly suggests the need for more investment in structural measures.

For those receiving only advice the effect was not statistically significant. However, we should not read into this finding, that energy advice is worthless, instead it lends credence to Simcock and Bouzarovski's assertion that advice: "can help to partially ameliorate energy poverty, but its impacts are limited by structural factors that are beyond the immediate influence of advisors or individual citizens."³⁷ Energy advice is likely to be playing an important role in supporting more structural interventions, indeed 71% of those receiving structural measures, also received advice. Recent work from England showing the current

advice provision is geographically inconsistent, and may exacerbate inequalities,⁴⁵ as well as resourced in a way which makes it difficult to provide continuity of service,⁴¹ suggests there is also a need for more attention to the nature and consistency of advice provided.

The effects of financial support are more complex. Being in receipt of financial support, does not resolve all challenges, as people still struggle to achieve thermal comfort. However, it could be because people cannot afford to heat their home adequately that they are eligible for support. There is a clear pattern in the data that when financial support is withdrawn, people's situations worsen. This supports a longstanding recognition that people are likely to go in and out of energy poverty over time as their circumstances change.^{46,47} The fact that the presence or absence of financial support links to the fluctuation in experience of energy poverty suggests that consistency of support is important. Another financial aspect – the presence of energy bill arrears – is also strongly linked to the ability to keep warm, which suggests that policy needs to address energy debt to ensure effective outcomes.

The precariousness of energy poverty is also demonstrated where people are shifting between energy saving practices, notably limiting when and where heating is used, which increases the likelihood of achieving thermal comfort and also the likelihood of struggling to keep warm. It is reasonable to speculate that limiting heating may help manage utility bills, but reduce thermal comfort, whilst keeping heating on will achieve thermal comfort but may push people into arrears. The nuances in the results show that energy poverty is a complex process and that policy interventions need to pay attention to unhealthy coping practices as well as financial circumstances.

The links between being able to keep a home warm and mental and physical health are important. While we cannot track causation here, when people are cold in winter, results indicated they are more depressed and stressed; and when people are warm in winter stress, pain and discomfort are reduced. This is a helpful confirmation of the links between health and energy poverty,^{2,27,28,32} and further evidence that addressing health in this context is another important strand of policy.

Finally, a key limitation of our work was the sample recruited. Some of our participants did not report problems associated with energy poverty in the baseline data. This is likely to influence the extent to which they are eligible for, or seek out, measures to improve thermal comfort. The mixed results for those not receiving any intervention in particular, may reflect the polarity within this group where for example people may have already had an intervention (before the period of observation) or have not had an intervention because they cannot afford it or they are a tenant, and this is the responsibility of their landlord.

Methods

Project design

WELLBASED was designed to evaluate a comprehensive urban intervention programme to reduce energy poverty in 6 European Cities (Valencia, Spain; Heerlen, The Netherlands; Leeds, United Kingdom; Edirne, Turkey; Obuda, Hungary and Jelgava, Latvia). Research took place in partnership with practitioners who designed and delivered energy poverty interventions ranging from Advice to Structural measures to approximately half of the sample (see Table 1). The type of intervention received from WELLBASED varied by country (Table 2, and see Table S2):

[Table 2 here]

The study sample is based on convenience sampling. In total, 1350 participants were initially recruited to the project. Of these, 1260 completed questionnaires among whom 612 participants received WELLBASED interventions, 180 funded interventions privately and 468 received no interventions.

Data collection

WELLBASED is a mixed methods project, using quantitative and qualitative techniques to collect data. A full description of project methods is available.⁴⁸

Questionnaires were distributed to all participants for self-completion. Participants completed an initial questionnaire to provide 'baseline' data from June to September 2023. Questionnaires were then completed at 6 monthly intervals, providing longitudinal data 6, 12 and a final follow-up at 15-18 months after the baseline. Data collection finished by September 2024.

The questionnaires collected data on health and wellbeing, energy poverty and energy efficiency. They also collected information on any energy efficiency interventions that participants had received, whether this was through WELLBASED or not. The results presented here are based on analysis of these self-reported questionnaires, where information is available on variables used in the analysis (n=1094).

Creating longitudinal variables

The analysis used a longitudinal approach. It explored change over time by aggregating individual experiences rather than averaging change across a cohort. Variables have been coded to capture the complete experiences of participants at each time point (See Box 1). First variables for each time point were coded in such a way that they represent their position in the timeline. These time point variables were combined to produce a timeline of experience or behaviour for each participant. These experiences were then categorised to reflect a change in experience or behaviour that is negative (e.g. homes become cold, or people started or increased the frequency of a certain coping behaviour) or positive (e.g. homes become warm, or people stopped or decreased the frequency of a certain coping behaviour). They also reflect no change, where this can be negative (e.g. still struggling to keep home warm or engaging in negative energy behaviour) or positive (e.g. homes remain warm or not engaging in negative behaviours). Importantly for energy poverty they also capture 'fluctuations' where there is no consistent pattern in people's behaviour or experiences.

Box 1 provides a worked example to show how responses to whether people can keep their home warm in winter has been coded to create a longitudinal variable, which has been categorised to show:

- where circumstances have become worse: where previously a participant could keep their home warm, they are now not able to – labelled as 'become cold';
- where circumstances have stayed the same: a participant has consistently reported that they can, or cannot, keep their home warm – labelled as 'No change – yes' or 'No change – no';
- where circumstances have fluctuated: there is no consistent pattern in ability to keep a home warm – labelled as 'Fluctuated'; and
- where circumstances have got better: a participant initially could not keep their home warm but then report that they can keep their home warm – labelled as 'become warm'.

Box 1: Creating longitudinal variable to capture where things have changed or where they have stayed the same

1. Variables for each time point are recoded to position them in the timeline

Variable	Response set	Baseline t_0	6 mths t_1	12 mths t_2	18 mths t_3
Keep home warm in winter	No	1000	100	10	1
	Yes	2000	200	20	2
	Missing	9000	900	90	9

2. Individual time period variables are combined (summed) to create a single timeline: $t_0t_1t_2t_3$
For example:

	t_0	t_1	t_2	t_3	Combined t_0-t_3
Keep home warm in winter	Yes 2000	No 100	No 10	Missing 9	2119

3. The combined variable is categorised to identify changes, or not, in experiences. Categories are based on the condition there are valid entries for at least two time periods. Where this condition is not met responses are assigned as missing. For example:

Keep home warm in winter					Category
t_0	t_1	t_2	t_3	Combined t_0-t_3	
Yes	No	No	Missing		
2000	100	10	9	2119	Become cold
No	Missing	No	No		
1000	900	10	1	1911	No change – not warm
Yes	Yes	Yes	Yes		
2000	200	20	2	2222	No change – warm
No	No	Yes	Yes		
1000	100	20	2	1122	Become warm
No	Yes	No	Yes		
1000	200	10	2	1212	Fluctuated
Missing	No	Missing	Missing		
9000	100	90	9	9199	Missing

Stages of analysis

The analysis was conducted in two stages. First, exploratory analysis looked at the relationships between different elements of energy poverty, coping practices and health with intervention type and financial support using crosstabulations. The strength and significance of these associations was measured using Cramer's V.

The second stage of analysis focussed specifically on a key issue for those in energy poverty; the ability to keep a home comfortably warm in winter. Two binary variables were created to focus on the two extremes of experiences and two logistic regression models were run: Model 1 identified where things had got worse, through exploring the likelihood of not being

able to keep a home warm in winter; Model 2 identified where things had got better, exploring the likelihood of people becoming able to keep their warm home. Table 3 shows how the variable has been recoded to create the two binary dependent variables.

[Table 3 here]

Ethics

Ethics Approval was received by all project partners. The names of the review boards and the approval references are: Valencia, Spain: Ethics committee for research with medicines of the university clinical hospital of Valencia, ref. no. 2021/316; Heerlen, The Netherlands: Medical Ethical Committee (MEC) – Erasmus University Medical Center Rotterdam, ref. no. MEC-2022–0150; Leeds, United Kingdom: Ethics committee University of Leeds—AREA (Faculties of Business, Environment and Social Sciences), ref. no. 21–070; Edirne, Turkey: Trakya University Edirne Clinical Studies Ethical Committee, ref. no. 07/01; Obuda, Hungary: Scientific and Research Ethics Committee of the Medical Research Council of Hungary, ref. no. 332/2022, and; Jelgava, Latvia: Central Medical Ethics committee of Latvia, ref. no. 01–29.1.2/2267. Informed consent was collected on paper by a research assistant.

Tables

Table 1: Intervention descriptions and categories used in analysis

Intervention type	Interventions received during past 6 months	
None	No interventions	
Advice	Energy efficiency advice, including advice on energy bills Energy Audit at home Attended energy-efficiency group meeting	
Small measures	Support for replacement of inefficient domestic appliance Energy efficiency kit Access to home sensor data (damp, humidity, CO ₂)	
Structural	Window replacement Home insulation Heating system	
Combinations of interventions received	n	Intervention categories
No Intervention	404	None (n=404)
Advice	95	Advice (n=95)
Small Measures	100	Small Measures (n=389)
Advice, Small measures	289	
Structural	43	Structural (n=206)
Advice Structural	16	
Small Measures, Structural	30	
Advice, Small measures, Structural	117	
<i>Total</i>	1094	

Table 2: WELLBASED Interventions by country

Pilot city	WELLBASED interventions in brief
Obuda (Hungary)	Home energy audits; financial counselling; energy saving training; household management training, health examinations; attitude forming and community building activities; in-home air quality sensor installation; tailored appliance retrofit or upgrade.
Heerlen (the Netherlands)	Home energy audits; energy conservation training; energy debt counselling; installation of in-home indoor air quality displays.
Leeds (United Kingdom)	Retrofit of apartment buildings, referral to energy and financial counselling and social services.
Edirne (Türkiye)	Home socio-energy audits; new stoves fitted which provide heat throughout the home, and hot water; debt management counselling
Jelgava (Latvia)	Home energy audits; energy saving training including bill optimisation, energy kits.
Valencia (Spain)	Home socio-energy audits; energy bill counselling; debt management counselling; energy efficiency kit; energy conservation training, regular community gatherings.

Table 3: Recoding of Dependent variables for logistic regression

Change in keeping home warm in winter	Model 1: Struggle to keep home warm	Model 2: Home becomes warm
Become cold	1 Not warm	0 Other
No change – not warm		
Fluctuated		
No change -warm	0 Other	1 Become Warm
Become warm		

Figures



Figure 1a-c: Energy Poverty, coping practices and health at baseline by intervention type

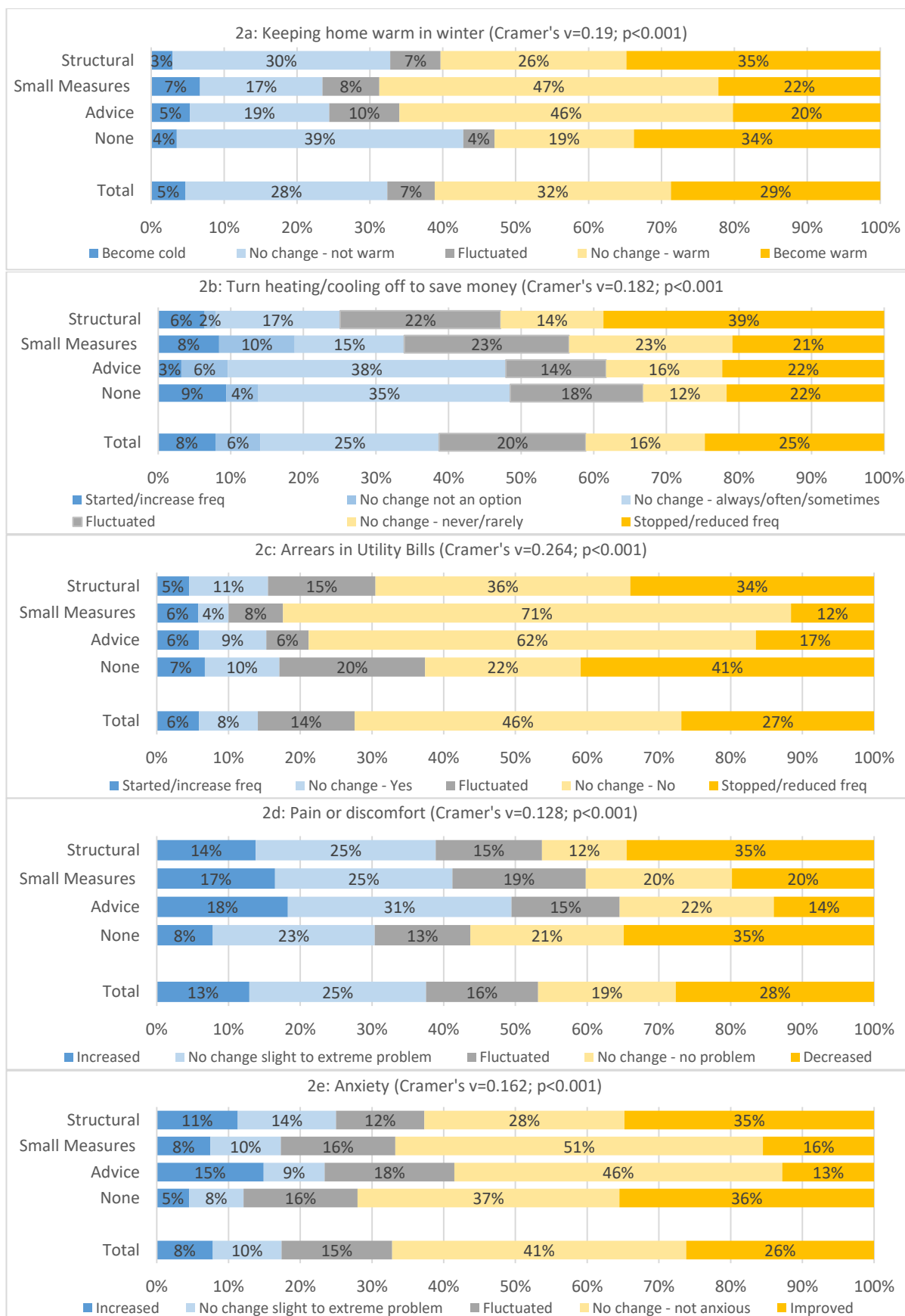


Figure 2a-e: Examples of changes in energy poverty experiences and health by intervention type

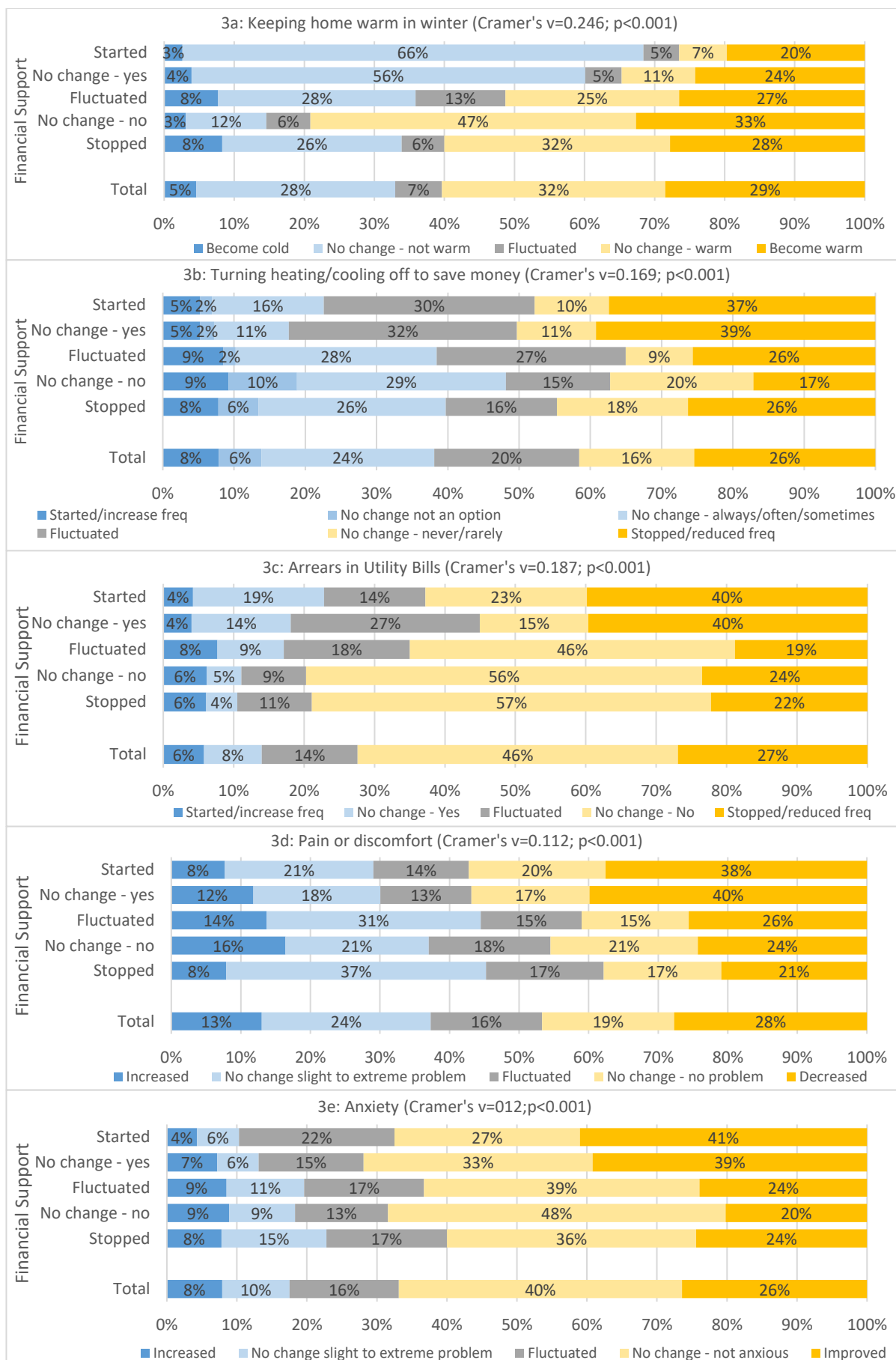


Figure 3a-e: Examples of observed changes in energy poverty experiences and health by financial support

Supplementary information

Table S1: Variables included in the analysis

Variable	Categories	%
Keeping home comfortably warm in winter	Become cold	5
	No change - not warm	28
	No change - warm	32
	Become warm	29
	Fluctuated	7
Total (n= 1082)		100
Keeping home cool in winter	Become hot	9
	No change - not cool	36
	No change - cool	15
	Become cool	29
	Fluctuated	11
Total (n= 1082)		100
Wearing extra clothes to keep warm	Started/increase freq	6
	No change - always/often/sometimes	18
	No change - never/rarely	13
	Stopped/reduced freq	43
	Fluctuated	21
Total (n= 1080)		100
Turn heating/cooling off to save money	Started/increase freq	8
	No change not an option	6
	No change - always/often/sometimes	25
	No change - never/rarely	16
	Stopped/reduced freq	25
	Fluctuated	20
Total (n= 1064)		100
Heating/cooling one room to save money	Started/increase freq	8
	No change not an option	6
	No change - always/often/sometimes	24
	No change - never/rarely	18
	Stopped/reduced freq	25
	Fluctuated	19
Total (n= 1073)		100
Turning off lights in the room you are using to save money	Started/increase freq	10
	No change - always/often/sometimes	24
	No change - never/rarely	15
	Stopped/reduced freq	28
	Fluctuated	22
Total (n= 1082)		100
Arrears in Utility Bills	Started/increase freq	6
	No change - Yes	8
	No change - No	46
	Stopped/reduced freq	27
	Fluctuated	14
Total (n= 1039)		100
Leaks, Damp, Rot	Started	8
	No change - Yes	32
	No change - No	38
	Stopped	13
	Fluctuated	10
Total (n= 1000)		100

Pain or discomfort	Increased	13
	No change slight to extreme problem	25
	No change - no problem	19
	Decreased	28
	Fluctuated	16
	Total (n= 1082)	100
Depression	Increased	8
	No change slight to extreme problem	9
	No change - not depressed	41
	Improved	26
	Fluctuated	16
	Total (n= 1083)	100
Anxiety	Increased	8
	No change slight to extreme problem	10
	No change - not anxious	41
	Improved	26
	Fluctuated	15
	Total (n= 1083)	100
Stress	Increased	6
	No change slight to extreme problem	5
	No change - not stressed	53
	Improved	23
	Fluctuated	12
	Total (n= 1080)	100

What interventions and financial support did people receive?

This section reports the first stage of analysis and describes the types and combinations of interventions that participants have received (through WELLBASED or privately) in each of the 6 cities. The most common combination of interventions was getting advice and implementing small measures. This was particularly so in Jelgava (45.6%), Valencia (44.5%), Obuda (16.2%) and Heerlen (24.6%). Using only one measure was common in Leeds (29.2% advice; 11.2% structural). Implementing all three interventions (advice, small measures and structural) was most common in Edirne (26.5%) and Obuda (20%), but less likely in the other cities. It should also be noted that the largest proportion of participants in Edirne (63.1%), Valencia (49.6%) and Leeds (36.6%) did not receive any intervention (Table S2).

Table S2: Combinations of interventions received by participants in each pilot city

Interventions	Edirne, TU	Heerlen , NL	Jelgava , LV	Leeds, GB	Obuda , HU	Valencia , ES	Total
None	63.1%	22.3%	5.8%	36.6%	12.4%	49.6%	36.9%
Advice	0.4%	11.4%	8.4%	29.1%	16.2%	1.8%	8.7%
Small Measures	---	21.7%	27.7%	5.2%	7.6%	1.4%	9.1%
Advice, Small measures	---	24.6%	45.8%	6.7%	41%	44.6%	26.4%
Structural	4.8%	5.7%	2.6%	11.2%	1%	0.4%	3.9%
Advice Structural	---	3.4%	0.6%	6%	1%	2.2%	1.5%
Small Measures, Structural	5.2%	5.1%	3.9%	0.6%	1%	---	2.7%
Advice, Small measures, Structural	26.5%	5.7%	5.2%	4.5%	20%	---	10.7%
Total %	100%	100%	100%	100%	100%	100%	100%
Total n	249	175	155	134	105	276	1094

Participants were also asked if they had received any support towards paying their energy bills. As described in Box 1 a longitudinal variable was created to identify those who started to get financial support, those who stopped getting support, those for whom there was no change in support received, and those for whom support fluctuated across the observed period. Table S3 shows variations in levels of financial support received in each city. The majority of participants did not get financial support at any point ranging from 41.6% in Heerlen to 73.1% in Obuda. The exception is in Edirne, where it was more common for participants to already be in receipt of financial support (45.8%), or to start getting support (32.9%).

Table S3: Financial support received across each pilot city

Financial Support	Edirne, TU	Heerlen, NL	Jelgava, LV	Leeds, GB	Obuda, HU	Valencia, ES	Totals
Stopped getting support	10.4%	35%	27.7%	18.5%	5.8%	9.3%	16.9%
No change – not getting support	0%	41.7%	56.1%	49.6%	73.1%	72.1%	45.8%
No change – getting support	45.8%	4.9%	4.5%	11.9%	10.6%	3%	15.3%
Support fluctuated	10.8%	11.7%	8.4%	14.1%	7.7%	11.5%	10.9%
Started getting support	32.9%	6.7%	3.2%	5.9%	2.9%	4.1%	11.2%
Total %	100%	100%	100%	100%	100%	100%	100%
Total n	249	163	155	135	104	269	1075

For interest Table S4 shows how financial support received is distributed across the different combinations of interventions. This generally reflects the finding that most participants were not in receipt of financial support, irrespective of receiving an intervention (40% - 58%) or not (45%). The exception is among those who implemented small measures and structural interventions, or all three intervention types who were more likely to be already getting financial support (34% and 33% respectively).

Table S4: Changes in financial support by types of intervention

Financial Support	None	Advice	Small measures	Advice + Small measures	Structural	Advice + Structural	Small Measures + Structural	Advice + Small Measures + Structural
Stopped	9%	23%	28%	20%	13%	31%	28%	20%
No change - no	45%	55%	58%	53%	40%	56%	24%	20%
No change - yes	20%	6%	3%	6%	16%	0%	34%	33%
Fluctuated	9%	11%	8%	14%	16%	13%	7%	12%
Started	17%	6%	3%	7%	16%	0%	7%	17%
TOTAL %	100%	100%	100%	100%	100%	100%	100%	100%
N	384	91	97	285	38	16	29	113

Figure S1: *Changes in energy poverty experiences and health by intervention type*

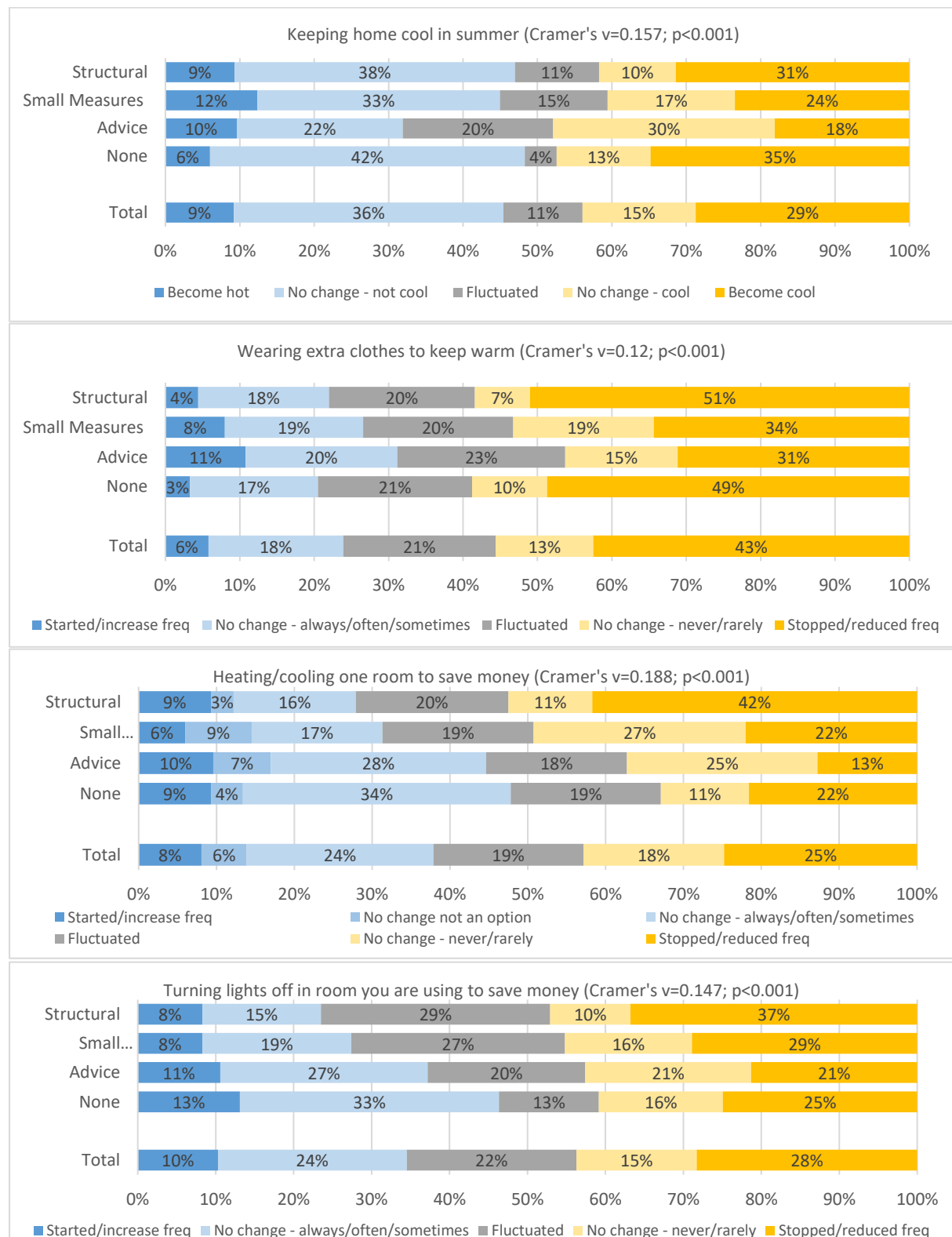


Figure S1 *cont*: Changes in energy poverty experiences and health by intervention type

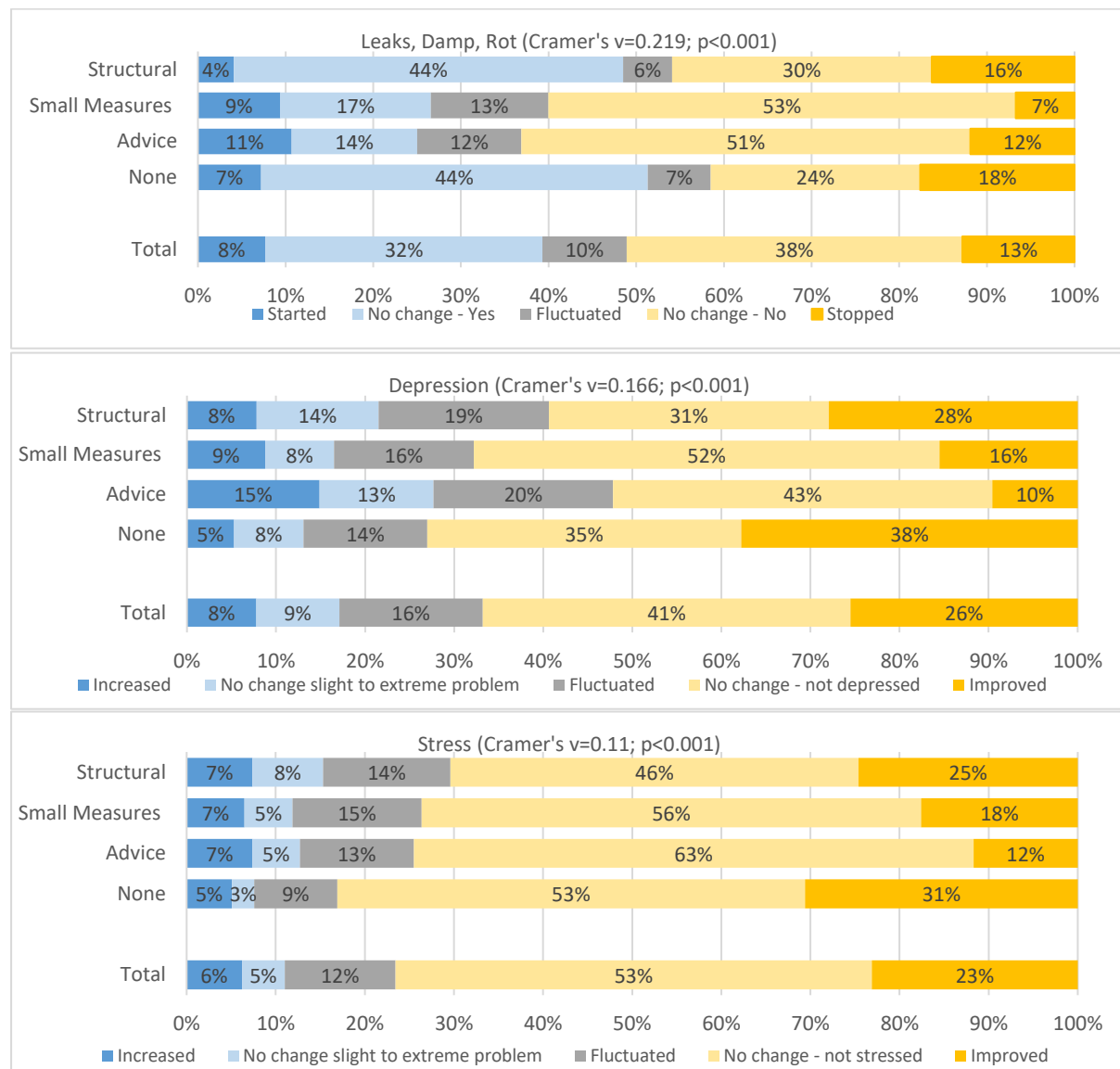


Figure S2: Changes in energy poverty experiences by financial support

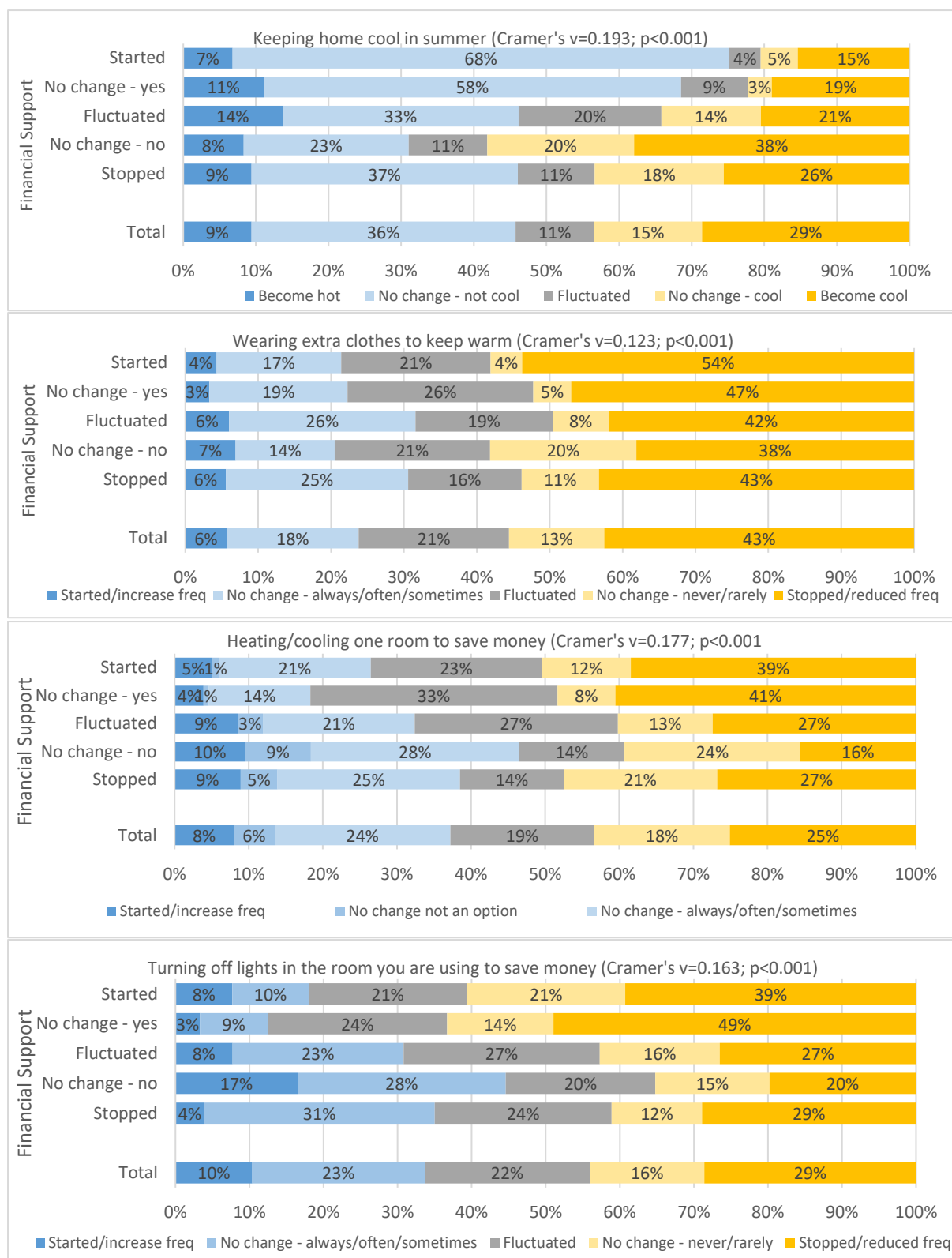


Figure S2 *cont*: Changes in energy poverty experiences by financial support

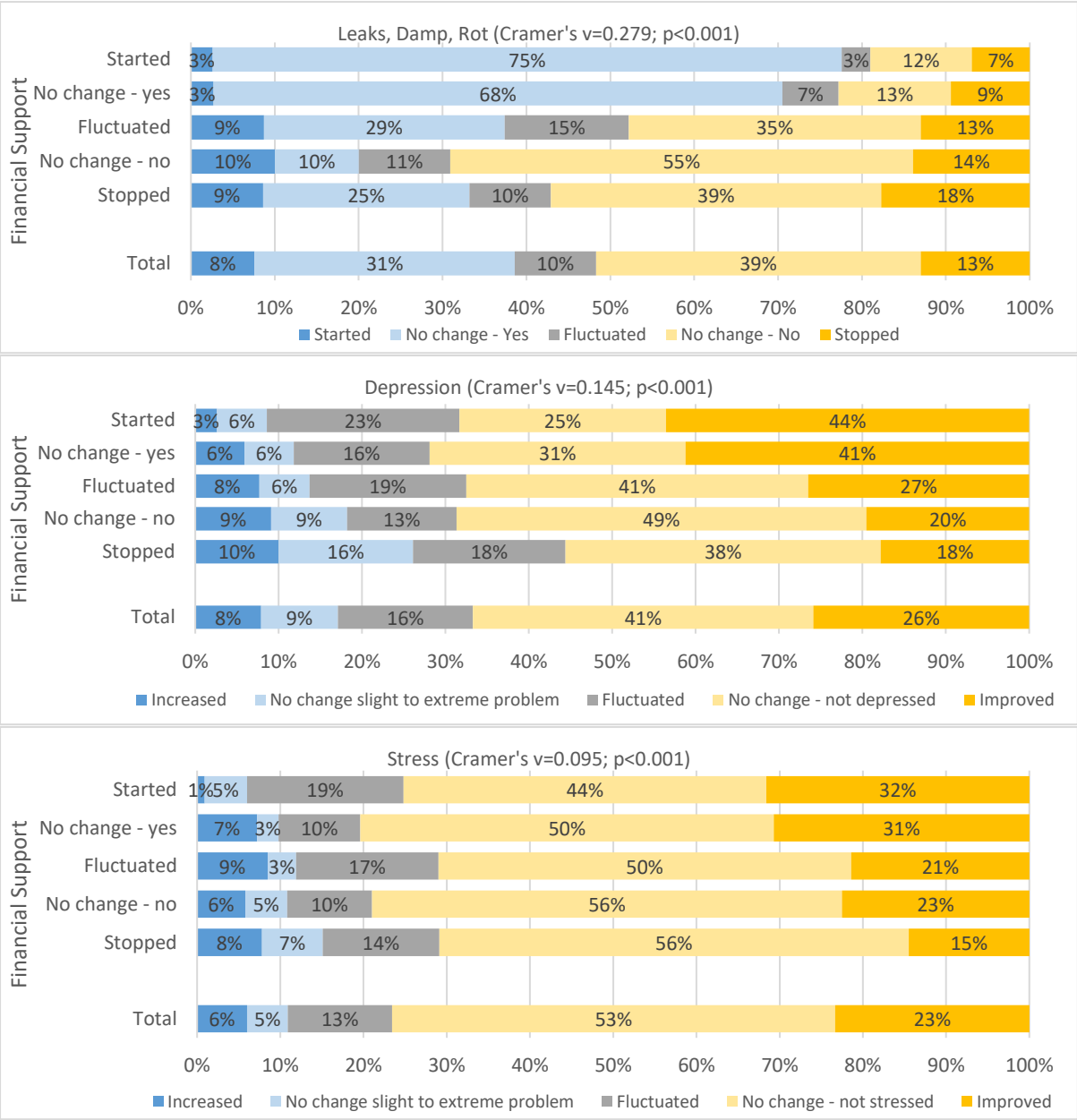


Table S5: Logistic regression results for not being able to keep home warm, and homes becoming warm*

Variable	Categories	Model 1: Cannot keep home warm				Model 2: Became able to keep home warm			
		OR	95% CI		Sig	OR	95% CI		Sig
			Lower	Upper			Lower	Upper	
Intervention	None	REF				REF			
	Advice	1.39	0.68	2.82	ns	0.81	0.38	1.69	ns
	Small Measures	0.90	0.54	1.49	ns	1.08	0.66	1.78	ns
	Structural	0.44	0.27	0.72	<0.001	1.97	1.23	3.17	<0.01
Financial support	No change - no	REF				REF			
	Stopped	1.523	0.93	2.52	ns	0.10	0.60	1.63	ns
	No change - yes	2.48	1.37	4.51	<0.01	0.72	0.39	1.36	ns
	Fluctuated	1.95	1.13	3.33	<0.05	0.79	0.45	1.39	ns
Wearing extra clothes	Started	3.30	1.18	6.34	<0.001	0.62	0.31	1.25	ns
	No change - never/ rarely	REF				REF			
	Started/increased freq	5.77	1.94	17.19	<0.05	0.72	0.22	2.37	ns
	No change - always/ often/sometimes	13.92	5.25	36.88	<0.001	1.05	0.44	2.50	ns
Turn off heating	Fluctuated	5.20	2.05	13.14	<0.001	2.36	1.08	5.18	<0.05
	Stopped/reduced freq	3.65	1.46	9.09	<0.01	4.87	2.29	10.37	<0.001
	No change - never/ rarely	REF				REF			
	Started/increased freq	1.78	0.74	4.30	ns	1.13	0.45	2.84	ns
Heat one room	No change - always/ often/sometimes	0.94	0.47	1.92	ns	1.22	0.60	2.48	ns
	Fluctuated	10.87	0.56	2.10	ns	0.82	0.42	1.58	<0.05
	Stopped/reduced freq	0.91	0.49	1.713	ns	0.72	0.39	1.33	ns
	No change - never/ rarely	REF				REF			
Turn off lights	Started/increased freq	1.79	0.72	4.42	ns	1.06	0.39	2.89	ns
	No change - always/ often/ sometimes	3.31	1.65	6.64	<0.001	1.61	0.78	3.30	ns
	Fluctuated	2.26	1.14	4.46	<0.05	2.08	1.05	4.12	<0.05
	Stopped/reduced freq	2.85	1.48	5.48	<0.01	2.08	1.08	3.98	<0.05
Arrears on Utility bills	No change - never/ rarely	REF				REF			
	Started/increased freq	0.44	0.20	0.10	<0.05	1.69	0.76	3.77	ns
	No change - always/ often/sometimes	0.60	0.30	1.20	ns	1.92	0.95	3.90	ns
	Fluctuated	0.88	0.47	1.64	ns	1.48	0.78	2.78	ns
Damp/rot	Stopped/reduced freq	0.97	0.53	1.78	ns	1.15	0.62	2.14	ns
	No change - no	REF				REF			
	Started/increased freq	1.78	0.83	3.82	ns	1.25	0.57	2.75	ns
	No change - yes	1.35	0.66	2.75	ns	1.13	0.53	2.42	ns
	Fluctuated	2.10	1.17	3.75	<0.05	1.62	0.91	2.89	ns
	Stopped/reduced freq	0.78	0.47	1.30	ns	2.99	1.84	4.86	<0.001
	No change - no	REF				REF			
	Started	2.08	1.07	4.03	ns	1.12	0.58	2.14	ns
	No change - yes	6.09	3.62	10.24	<0.001	0.50	0.29	0.88	<0.05
	Fluctuated	2.76	1.54	4.93	<0.001	0.85	0.46	1.55	ns
	Stopped	1.49	0.82	2.72	ns	1.48	0.85	2.57	ns
Chi sq; df; p-value		368.287; 38; <0.001				206.51; 38; <0.001			
Nagelkerke Pseudo Rsq		0.453				0.295			

*controlling for gender, household composition and tenure. Statistically significant results highlighted in yellow.

Table S6: How thermal comfort is associated with health: logistic regression*

		Home not warm				Home became warm			
Variable	Categories	OR	95% CI		p-value	OR	95% CI		p-value
			Upper	Lower			Upper	Lower	
Intervention	None	REF				REF			
	Advice	0.79	0.43	1.45	ns	0.59	0.30	1.15	ns
	Small measures	0.62	0.42	0.90	p<0.05	0.56	0.37	0.83	p<0.01
	Structural	0.42	0.27	0.64	p<0.001	1.74	1.14	2.66	p<0.05
Financial support	No change - no	REF				REF			
	Stopped	2.22	1.44	3.42	p<0.001	1.17	0.75	1.84	ns
	No change - yes	7.51	4.64	12.18	p<0.001	0.51	0.30	0.86	p<0.05
	Fluctuated	3.61	2.26	5.78	p<0.001	0.76	0.46	1.26	ns
	Started	9.90	5.71	17.16	p<0.001	0.40	0.22	0.73	p<0.05
Pain/ Discomfort	No change - no problem	REF				REF			
	Increased	0.78	0.44	1.37	ns	1.46	0.81	2.65	ns
	No change - slight to extreme problem	1.35	0.82	2.23	ns	1.30	0.75	2.25	ns
	Fluctuated	0.90	0.89	0.58	ns	1.91	1.12	3.25	p<0.05
	Decreased	0.79	0.49	1.26	ns	1.94	1.19	3.18	p<0.01
Depression	No change - not depressed	REF				REF			
	Deteriorated	2.19	1.10	4.40	p<0.05	0.39	0.16	0.94	p<0.05
	No change - mild/mod/severe	1.53	0.74	3.18	ns	0.55	0.25	1.24	ns
	Fluctuated	1.20	0.72	2.00	ns	1.16	0.67	1.95	ns
	Improved	1.17	0.73	1.89	ns	1.09	0.67	1.79	ns
Anxiety	No change - not anxious	REF				REF			
	Deteriorated	0.74	0.37	1.45	ns	1.73	0.84	3.58	ns
	No change - mild/mod/severe	1.44	0.71	2.91	ns	0.97	0.45	2.10	ns
	Fluctuated	0.90	0.53	1.50	ns	0.980	0.57	1.68	ns
	Improved	1.01	0.63	1.91	ns	1.16	0.725	1.85	ns
Stress	No change - not stressed	REF				REF			
	Deteriorated	1.45	0.72	2.93	ns	0.50	0.21	1.22	ns
	No change - mild/mod/severe	1.51	0.65	3.52	ns	0.37	0.12	1.14	ns
	Fluctuated	2.10	1.27	3.47	p<0.01	0.89	0.52	1.53	ns
	Improved	1.01	0.65	1.57	ns	1.74	1.13	2.69	p<0.05
Chi sq; df; p-value		220.756; 30; p<0.001				145.138; 30; p<0.001			
Nagelkerke Pseudo R sq		0.281				0.203			

*Controlling for gender, household composition and housing tenure. Significant results highlighted in yellow.

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