Article:

Burlinson, A. orcid.org/0000-0001-5156-0057, Davillas, A., Giulietti, M. et al. (1 more author) (2024) Household energy price resilience in the face of gas and electricity market crises. Energy Economics, 132. 107414. ISSN 0140-9883

https://doi.org/10.1016/j.eneco.2024.107414

Energy Economics 132 (2024) 107414

Contents lists available at ScienceDirect

Energy Economics

journal homepage: www.elsevier.com/locate/eneeco

Household energy price resilience in the face of gas and electricity market crises

Andrew Burlinson [a], Apostolos Davillas [b], Monica Giulietti [c,*], Catherine Waddams Price [d]

[a] Department of Economics, University of Sheffield, Centre for Competition Policy Univesrity of East Anglia, and UK Energy Research Centre, UK
[b] Department of Economics, University of Macedonia, Greece
[c] Nottingham Univeristy Business School University of Nottingham, Centre for Competition Policy University of East Anglia, and UK Energy Research Centre, UK
[d] Centre for Competition Policy, University of East Anglia and UK Energy Research Centre, UK

ARTICLE INFO

JEL codes:
L94
E31
D12
I19

Keywords:
Energy crisis
Energy resilience
Energy prices
Health and wellbeing

ABSTRACT

Despite the provision of financial support by the Government in response to the recent energy crisis, the resilience of households to the ensuing high energy prices remains to be established. In this study we propose a new definition of resilience, specifically ‘energy price resilience’, and put forward an empirical approach to capture low energy price resilience (LENRES). We also assess its associated socio-economic and demographic factors using a representative UK panel. Using models that account for time-invariant unobserved heterogeneity, we further explore the association between LENRES and a rich set of health, disability, and wellbeing outcomes for adults and children through two fundamental routes: (1) the low energy and thermal affordability channel (LEA); and (2) the low energy and financial solvency channel (LES). We find that employment status, housing tenure, inability to save, energy prepayment methods, and household composition are systematic socio-economic correlates of LENRES. Moreover, LENRES is associated with worse health, disability, and wellbeing outcomes for adults; these associations are primarily driven by the LES component. On the other hand, in the case of children, LENRES at home is only systematically associated with life satisfaction, rather than general health. Our results suggest that targeted energy interventions could generate wider societal benefits.

1. Introduction

The UK’s energy system has been put under pressure as a result of supply chain bottlenecks which were exacerbated by the Covid-19 pandemic and by the energy crisis following the war in Ukraine. These have resulted in high and volatile energy prices which have pushed millions of households further into energy-related deprivation, while millions more became vulnerable. (IEA, 2022a). In the UK, Government policy has attempted to mitigate the impact of the crisis with different forms of financial support, such as the energy price guarantee, which have been universal rather than targeted, therefore allowing for speed of action in the intervention, but potentially failing to provide the necessary support to the most vulnerable in society (DESNZ, 2023a).[1] As existing sources of price volatility persist and new sources emerge at the national and international level, policy interventions in the energy market will need to be better targeted to avoid further detriment particularly to the most vulnerable households. We suggest a definition and a quantifiable measure of household energy price resilience that can be used to inform policymaking aimed at preventing the worst economic, health and wellbeing consequences of high and prolonged energy price events.

An early study of energy resilience can be traced to Roege et al. (2014: p.250) who rely on the following definition: “*the ability to prepare for and adapt to changing conditions and withstand and recover rapidly from [energy supply] disruptions*”. While they provide initial descriptions and metrics for this concept, they do so from the perspective of the energy system; they define an energy resilience matrix, which includes a variety of physical, informational, cognitive and social factors that should be considered in risk management processes for different energy systems. Gupta et al. (2019) further stress the role of planning and preparation in

* Corresponding author.
E-mail address: Monica.Giulietti@nottingham.ac.uk (M. Giulietti).

[1] The recent energy price crisis initiated “epidemic levels” of hardship in the UK (Marmot Review Team, 2022; Citizens Advice, 2024). Despite the Government’s interventions, recent UK Government estimates show that about 50% of households (12 million) now spend >10% of their residual income on energy, after deducting housing costs (DESNZ, 2023b), a threefold increase compared to pre-pandemic levels.

https://doi.org/10.1016/j.eneco.2024.107414
Received 28 July 2023; Received in revised form 3 February 2024; Accepted 16 February 2024
Available online 21 February 2024

energy systems characterised by high penetration of non-dispatchable decentralised renewable energy. Relying on household surveys, they investigate the role that solar photovoltaic systems and batteries could play in increasing the resilience of a socially deprived community in Oxfordshire. While this offers some interesting evidence about the role of new technologies in promoting resilience, their exercise is geographically limited, non-representative at the national level, and based on a small sample.

More recent attempts to define household energy resilience are mainly based on the energy security perspective (Hasselqvist et al., 2022): with reference to households being able to use various means (backup sources, energy efficiency, flexibility, energy self-sufficiency) to cope with, and recover quickly from, increased supply variability (power outages/shortages) in order to ensure a good life on the path towards a low-carbon future. Specifically, the authors create a scenario based on Sweden to assess the potential impact of (short) power outages and caps on power use, which might emerge more frequently in a low carbon energy system. Their research investigates hypothetical situations of energy shortage and the practical ways to mitigate their negative effects.

As discussed in Middlemiss (2022)'s extensive literature review, previous research shows that when energy prices rise, households adopt different financial strategies if they cannot afford energy, so that their savings diminish and/or they incur debt in order to maintain acceptable levels of thermal comfort (Harrington et al., 2005; Hills, 2011; Anderson et al., 2012; Grey et al., 2017; Munyanyi et al., 2021). Such evidence echoes recent literature documenting decisions made by lower-income households facing the difficult choice between energy and other necessities (Guan et al., 2023). However, many of the studies discussed by Middlemiss (2022) and those mentioned above assess the impact of energy prices using qualitative and self-reported information based on in-depth interviews with relatively small samples of households or focus groups, rather than a representative sample of the population. In other cases, the focus is on specific demographic or ethnic groups, or on specific socio-economic conditions.

The concerns of academics and policymakers about increasing levels of fuel poverty and energy debt are driven in part by the impact that the persistent disruption to, and affordability of, energy services can have on households' quality of life, more specifically on their physical and mental health and their wellbeing. The nature of this impact has been documented in an established body of evidence which has unearthed links between fuel poverty and the physical health of households, including higher rates of mortality and higher cardiovascular, inflammatory and mental health risks (see, e.g., Thomson et al., 2001; Marmot Review Team, 2011). Public Health England (2014) carried out systematic literature reviews of the links between housing conditions and health outcomes at the international level, highlighting that cold homes have a harmful effect on people's health. Moreover, Kahouli (2020)'s and Llorca et al. (2020)'s studies reveal that fuel poverty adversely impacts self-assessed health in France and Spain, respectively. Their analyses rely on representative samples of the population and apply instrumental variable fixed effects and probit models, respectively. Specifically, Kahouli (2020) measures fuel poverty by the conventional established 10% indicator (i.e., spending in equivalised terms at least 10% of household income on fuel), but they also consider a self-reported measure of the ability to heat the property. Llorca et al. (2020), on the other hand, measure fuel poverty by an index which reflects the risk of experiencing fuel poverty. However, neither Kahouli (2020) nor Llorca et al. (2020) consider the potential role of general or energy-specific debt in a household's ability to manage energy costs. Moreover, Awaworyi Churchill and Smyth (2021) use a fixed effects panel data model to explore the deleterious impact of fuel poverty (measured by objective and subjective indicators) on general health of the population in Australia. Building on this context, several studies have identified financial distress as a potential mediator between fuel poverty and health outcomes (Hills, 2011; Marmot Review Team, 2011; Burlinson et al., 2021).

Overall, much of the existing literature measures fuel poverty with traditional indicators relating energy expenditure to income (see Deller et al., 2021, for an overview of these studies). As discussed above, existing studies in the related literature have often relied on relatively small samples and qualitative investigations of the way in which households cope with the pressures of unexpected disruption to energy services (e.g. Gupta et al., 2019; Munyanyi et al., 2021). On the other hand, those studies that have relied on representative samples of the population have not yet considered some of the financial strategies adopted by households and the role of energy-debt in order to mitigate the impact of high energy price events (e.g. Kahouli, 2020; Llorca et al.,2020).

In this study, we investigate whether the concept of (household) energy price resilience can be used to understand the challenges faced by the most vulnerable consumers during energy crises and to identify the key socio-economic and demographic factors which are associated with low levels of energy price resilience. We also provide empirical evidence on the association between low energy price resilience and a rich set of health, disability, and wellbeing outcomes. We do this by applying our proposed definition of energy price resilience to a representative panel of UK households (Understanding Society: the UK Household Longitudinal Study; UKHLS), drawing upon five waves of UKHLS between January 2016 and May 2022. For our main empirical analysis, we rely on linear probability models which account for time-invariant unobserved heterogeneity.

This paper contributes to the related literature by proposing an alternative yet complementary perspective on household energy resilience, focused on the issues which relate to prices and affordability. A change in perspective allows us to develop a novel definition of resilience, namely *energy price resilience*. We suggest that households with low energy price resilience (*LENRES*) struggle to heat the home at reasonable cost and/or experience financial difficulties and indebtedness when faced with high energy price events. We therefore propose a measure to evaluate the impact of high energy price events, operating through two fundamental routes: (1) the energy and thermal affordability (*EA*) channel; and (2) the energy and financial solvency (*ES*) channel.

Our paper contributes to the related literature first by proposing a definition of energy price resilience and an empirical method to *measure* this issue. To achieve this aim, we rely on commonly accepted measures which respectively underpin the channels for *low thermal and energy affordability (LEA)* and for *low energy and financial solvency (LES)*. The proposed definition of energy price resilience is informed by the related literature discussed above, but also by the algorithm for measuring financial resilience put forward by the UK's Financial Conduct Authority (FCA, 2017, Table A.2) which identifies households with low financial resilience in their Financial Lives Survey (FCA, 2022). Our proposed definition of *LENRES* incorporates and extends measures which are included in some definitions of energy poverty and enables the exploration of channels which affect households in times of affordability stress.

Our second contribution is the application of the measurement of energy price resilience and its channels to a representative UK population sample to explore the socio-economic and demographic makeup of low energy price resilience. We also explore the association between energy price resilience and a rich set of health, disability, and wellbeing outcomes for household members, as well as the relative contribution of the underlying channels (energy and thermal affordability; energy and financial solvency) to the observed associations.

We find that around one quarter of individuals in our sample belong to households with low levels of energy resilience and that employment status, housing tenure, inability to save or having no access to savings, energy prepayment methods, and household composition are systematically associated with low energy price resilience at the household level. *LENRES* is associated with worse health, disability, and wellbeing outcomes for adults. These associations are primarily driven by the *LES* component, while the role of the *LEA* component appears less pronounced. On the other hand, in the case of children *LENRES* is only systematically associated with life satisfaction measures rather than general health. The fact that *LENRES* at home is not associated with children's general health (measured BY a self-reported health measure) may be evidence of the absence of the inequality of opportunity spiral for children's later life outcomes arising from health impairments during childhood. Households facing more affordability challenges *(LEA)* than solvency (*LES)* issues, are associated with deleterious life satisfaction outcomes for the children living in the household.

The rest of the paper is organised as follows: section 2 provides background information and our proposed definition of energy price resilience; section 3 presents the data and methodology used in our analysis. Section 4 presents our results, and section 5 offers conclusions and policy recommendations.

2. Background and definition of energy price resilience

In this section we provide background on how the recent energy crisis has affected retail prices in the UK and the government's response; we emphasise our focus on demand-side rather than supply-side events; we define our measure of energy price resilience; and we identify the relevant channels for measurement.

We turn first to the recent energy crisis and its effects on UK residential consumers. Like the rest of Europe (International Energy Agency (IEA), 2022b), the UK faced steep increases in wholesale gas prices between October 2020 and October 2021, with a further 50 % increase by March 2022; because of the UK's high dependence on gas for electricity generation, this translated into similar increases in electricity wholesale prices over the same period (Ofgem, 2023a). While wholesale prices fell from these very high levels after the 2022–23 winter, in late 2023 they remained at more than twice their level of three years earlier (Clifford Talbot, 2023). Despite government interventions, these changes in wholesale prices translated into a doubling of retail tariffs between 2021 and 2023 (Bolton and Stewart, 2024).

The UK regulator had imposed a price cap on some residential prices in 2019, and by 2022 this applied to most of the market. This had limited the annual bill for typical consumption (of both gas and electricity) to around £1000 a year between 2019 and 2021, rising gradually from the summer of 2021 to reflect increased costs in the previous months. Despite further Government interventions, a typical residential consumer faced an increase of around two thirds in their annual bills by winter 2022–23 compared with the previous year.

Low income and vulnerable households are particularly adversely affected by high energy prices (see e.g. Deller et al., 2021). The UK government has schemes to help households in receipt of certain state benefits, but most of its energy support in 2022–23 was provided universally, regardless of need. Since this was withdrawn there have been increasing calls for a social energy tariff, and in November 2022 the government announced that it would adopt a "new approach to consumer protection from April 2024" (HM Government, 2022). However, a promised consultation on social tariffs in summer 2023 did not materialise (Hansard, 2023), and the review was delayed until 2024. Our definition and analysis of energy price resilience provides insight into the characteristics of households who might particularly benefit from such support.

Recent energy price increases and their disproportionate effect on households in vulnerable circumstances motivate the second aspect of this section, our focus on aspects of energy resilience from the demand-side, rather than on energy resilience from the perspective of externally imposed supply disruptions.[2] External supply interruptions have been low in the UK,[3] and disconnections for non-payment of debt have remained close to zero due to protections enforced by the energy regulator. In contrast, the number of *self-disconnections* remains high; this occurs when customers with a pay-as-you-go prepayment meter (PPM) run out of credit because they are unable to top up their meter, usually because they cannot afford to do so. According to recent evidence, around 2 million households (out of about 4 million PPM customers) are self-disconnecting at least once per month; and of the consumers who self-disconnected in 2022, around one fifth did so for >24 h (Citizens Advice, 2023). Even more hidden are the actions of households on constrained budgets who 'self-ration' and respond to energy price increases by using coping mechanisms such as reducing fuel consumption below levels recommended for good health (see e.g. Anderson et al., 2012).

These considerations lead us to suggest an alternative, and complementary, definition of household 'energy *price* resilience' as follows:

> *The ability of a household to maintain (reattain) sufficient levels of energy and thermal affordability and/or energy and financial solvency in the face of high energy price events.*

Our definition complements those by Abi Ghanem et al. (2016) and Hasselqvist et al. (2022), in their efforts to establish ways in which households can be resilient within energy systems but deviates from those established in the literature in its focus on *prices* (and therefore on issues related to affordability), rather than the supply of energy. It also complements more traditional approaches to the broader concept of fuel poverty by accounting for an explicit financial dimension.

We regard households as energy price resilient if, despite facing significant increases in energy prices, they are able to maintain, or at least reattain (without significant detriment), sufficient levels of energy and thermal affordability and/or energy and financial solvency. These channels are akin to the thermal comfort and financial security pathways previously identified by Gilbertson et al. (2006, 2012) and they can be seen as the key psychosocial routes through which energy deprivation may impact people's health and wellbeing. (e.g., Davillas et al., 2022).

Depending on the extent to which energy prices rise, particularly if this happens unexpectedly, households may have to rely on their current financial liquidity (income, savings, credit and so on) in order to maintain levels of affordability and solvency, and consequently help to protect their health and wellbeing. However, budgetary and other constraints may mean that higher energy prices result in a reduction in energy consumption, adverse internal conditions of the home (e.g., low temperatures) and/or increased levels of financial precarity (e.g., falling behind on bills) for some households. Our definition of energy price resilience refocuses low resilience on the potential burden which price increases may impose on households, including the impact on households' health, disability, and wellbeing outcomes, if they are unable to maintain or reattain sufficient levels of energy and thermal affordability and/or energy and financial solvency. Fig. 1 illustrates our definition of energy price resilience and identifies the channels through which it can be measured, focusing on energy and thermal affordability, and energy and financial solvency as the two primary channels.

[2] Abi Ghanem et al. (2016) defined household energy resilience in the aftermath of storms in February 2014 with power (supply) outages in mind; a households' resilience is contextualised by whether they can modify and adapt their daily practices in the event of power cuts– often prioritising thermal comfort over other basic needs.

[3] The average number of minutes lost per customer per year from external supply interruptions lay between 30 and 50 min, depending on the network operator, equivalent to services remaining uninterrupted 99.999% of the time (Ofgem, 2021).

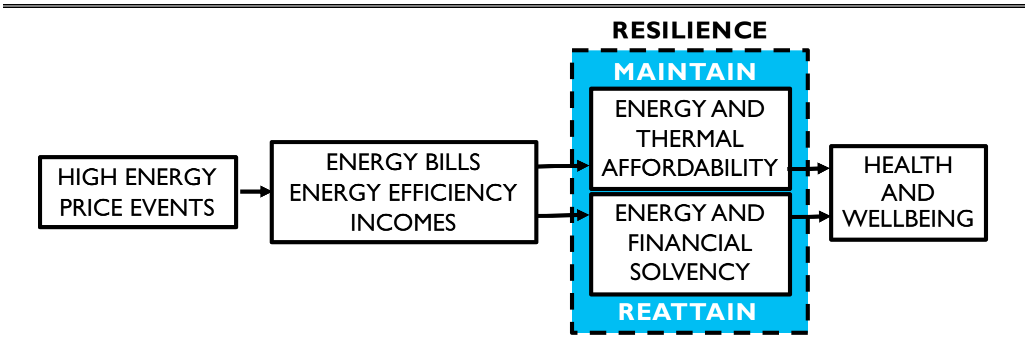

Fig. 1. An illustration of household energy price resilience.

Specifically, in the context of our study, a household which exhibits either low *energy and thermal affordability (LEA)* or *low energy and financial solvency (LES)* is classified as experiencing *LENRES* (Fig. 1). Individuals identified as exhibiting low energy and thermal affordability *(LEA)* are captured using perception- and expenditure-based measures if the household:

1) is unable to keep the accommodation warm enough during winter, due to inability to afford it; or
2) spends >10% of their income on energy.[4]

Low energy and financial solvency (LES) similarly relies on both a perception-based variable, which captures financial difficulties, and a (quasi-) objective variable to capture issues of energy and financial solvency. Individuals exhibit low energy and financial solvency *(LES)* if they:

3) currently and personally find managing their finances at least quite difficult; or
4) are members of a household which has fallen behind on at least some of their bills, including electricity, gas, and other utilities.

These measures of energy insolvency and indebtedness are strongly associated with energy-cost related financial issues (Burlinson et al., 2021). Indeed, our measure of energy insolvency evokes the Financial Conduct Authority (FCA, 2021)'s concept of financial resilience, which it views as one of four key drivers of vulnerability. *LES* captures the experience of households in the face of high energy price events through the financial insecurity channel.

The constituent parts of *LENRES,* when considered independently, are related to measures of energy poverty, deprivation and/or vulnerability (see e.g. Deller et al., 2021). The two components of *LEA* have been used as alternative measures of fuel or energy poverty in part of the existing literature.[5] For example, such perception- and expenditure-based measures have been utilised to capture energy affordability in various contexts to explore their relation to health and financial outcomes (see, e.g., Awaworyi Churchill and Smyth, 2021; Burlinson et al., 2021; Davillas et al., 2022). As such, these variables have often been used as indicators of fuel/energy deprivation and are underpinned by several factors affecting the ability to maintain sufficient levels of thermal comfort, including energy prices, energy efficiency, and consumer behaviour (Deller et al., 2021). However, to the best of our knowledge, this is the first study that proposes a broader energy price resilience measure that simultaneously incorporates the concepts of both aspects of energy-related affordability, and energy and financial solvency, capturing households' financial challenges, including arrears on energy bills. We further discuss to what extent our measure differs from existing narrower measures of fuel poverty/deprivation in Section 3 below.

3. Data and methodology

Our data comes from the longitudinal survey of the UK, Understanding Society: the UK Household Longitudinal Study (UKHLS) (University of Essex, 2022). Given that our estimation strategy accounts for time invariant unobserved heterogeneity, we require longitudinal data on our *LENRES* measure, and therefore draw upon a panel of individuals participating in the UKHLS between Wave 8 (January 2016 – May 2018) and Wave 12 (January 2020 – May 2022) of the UKHLS.[6] Our panel in the main analysis consists of 100,848 person-wave observations over the period of interest (roughly 20,170 individuals per wave, given it is an unbalanced sample), upon adjusting for outliers, item and unit missingness. All data used in the analysis is weighted using UKHLS' longitudinal sample weights.

3.1. Measuring low energy price resilience

Summary statistics and descriptions of the variables used to measure energy price resilience are presented in Table 1. We find that around 5% of individuals belong to households that are unable to keep their home warm due to affordability reasons, while around 17% spend >10% of their income on energy. Combining these two dichotomous measures (into the *LEA* dichotomous measure), around 20% of individuals live in a household that cannot afford adequate levels of heating *and/or* spends a relatively large share of their income on energy.

Turning to solvency measures, Table 1 shows that just under 7% of individuals in our sample found managing their current personal financial circumstances to be quite or very difficult, while almost 5% of households had fallen behind on at least some of their household bills (including electricity, gas, water rates, telephone, and other bills). Around 10% of adults experienced financial difficulties and/or belong to a household which is behind on paying utility bills (comprised in the *LES* dichotomous measure).

The *LEA* and *LES* dichotomous measures – defined by combining elements (1) and (2) for *LEA,* and (3) and (4) for *LES,* as shown in Table 1 – represent the two channels that are used to create our composite measure of *LENRES*. An individual that belongs to a household deemed

[4] Income (after deducting housing costs) and energy expenditure are equivalised factors following the approach adopted in Hills (2012) and are deflated using the retail price index (base year, 2009) (ONS, 2023).

[5] The Low-Income-High-Cost index (Hill, 2011) has also been used as a measure of fuel poverty in England in the past but has been replaced by the modified LILEE index (DESZN, 2023a, 2023b). The devolved UK authorities of Scotland, Wals and Northen Ireland use modified version of the 10% measure.

[6] We focus on Wave 8 onwards due to the fact that a core component of our measure of *LENRES* is only available intermittently prior to this wave in UKHLS.

Table 1
Definitions and mean values: a) low energy and thermal affordability (*LEA*) measure ; b) low energy and financial solvency measure (*LES*).

Variables	*Definition*	*Mean*
Low energy and thermal affordability (LEA)		
(1) Inadequate heating	*In winter, are you able to keep this accommodation warm enough? If you cannot afford to, please answer no: 1 = 'no' and 0 = 'yes'.*	*0.046*
(2) 10% of income spent of energy	*1 = Equivalised annual household energy expenditure exceeds 10% of annual equivalised household income (after deducting housing costs); 0 = otherwise.*	*0.170*
LEA measure: (1) And/or (2)	*1 = Inadequate heating and/or spending 10% of income on energy; 0 = otherwise*	*0.199*
Low energy and financial solvency (LES)		
(3) Financial difficulties	How well would you say you yourself are managing financially these days? 1 = Finding it quite difficult or very difficult; 0 = otherwise.	0.069
(4) Behind on bills	Sometimes people are not able to pay every household bill when it falls due. May we ask, are you up to date with all your household bills such as electricity, gas, water rates, telephone and other bills or are you behind with any of them? 1 = Behind on some or all bills; 0 = otherwise.	0.050
LES measure: (3) And/or (4)	1 = Financial difficulties and/or behind on utility bills; 0 = otherwise	0.099
N		100,848

Notes: Mean values are weighted using sample weights. Energy expenditure and income have specific equivalisation factors following the approach adopted in Hills (2012) and are deflated using the retail price index (base year, 2009) (Office for National Statistics, 2023).

vulnerable by any one of these measures is characterised as experiencing *LENRES*.[7] Table 2 presents the cross-tabulations between the two channels. We find that about 75% of individuals do not belong to households with low levels of energy price resilience (cell A). In contrast, around one quarter (24.9%) of individuals are described as living in households with low energy price resilience, as defined by using the *LEA*, the *LES* channel, or any combination of them (cells B, C and D); this is the proportion of our sample who are classified as *LENRES*.

Given that an individual is identified as experiencing *LENRES* if they are classified as deprived by any of the four dichotomous components in Table 1, we provide a deeper investigation of the composition of the four components of *LENRES* in Table A1 (in the appendix). While about 25% of our sample is identified as *LENRES*, about 1.6% of *LENRES* households (less than half of 1 % of the whole sample) display all four dimensions of low energy resilience (i.e., the respondents are jointly identified as having inadequate heating, 10 % of income spent of energy, financial difficulties and being behind on bills). About half of those experiencing *LENRES* (13% of the whole sample) qualify exclusively on the basis of spending >10% of income on energy, while the remaining proportion is attributed to the other components and the overlap across all four components, as shown in Table A1.

These results show that *LENRES* is, therefore related to the traditional expenditure fuel poverty measure defined by Boardman (1991). However, it differs in two important respects. The first is that it is based on actual rather than modelled required expenditure, a common approximation because of data constraints. Deller and Waddams Price (2018) show that, contrary to general belief, actual expenditure (and fuel poverty measures based on it) are not consistently lower than modelled required expenditure based on achieving a given temperature within a building, and that the two track each other closely. The second, and more important, difference between *LENRES* and a traditional expenditure share measure, is the contribution of other factors, both thermal comfort-related and financial; as mentioned above, about half of those who qualify as LENRES do this solely through the "10% of income spent of energy", with the remaining proportion attributed to the other three components and the overlap across all components. Overall, this descriptive analysis shows how our composite measure of *LENRES* both relates to, and departs from, alternative measures of various energy poverty and deprivation concepts when they are considered independently, bringing new breadth to the analysis by combining energy and thermal affordability with energy-related and financial solvency.

It should also be explicitly mentioned here that the level of *LENRES* appears to be relatively stable over time[8]; however, there is a marked increase to 32% of individuals living in households characterised by *LENRES* in 2022. This captures the onset of the energy crisis affecting households' ability to remain resilient across the UK during our period of study.[9]

3.2. Health, disability and wellbeing outcomes for adults and children

Disruptions to households' resilience in energy markets are likely to be negatively related to their health and wellbeing, if households are unable to maintain or reattain sufficient levels of energy and thermal affordability and/or energy and financial solvency. Thus, it is of utmost importance to assess whether our measure of *LENRES* is systematically associated with a set of health, disability, and wellbeing outcomes of members of the households, including adults *and* children.

3.2.1. Adult household members

Self-assessed health (SAH) is one of the most commonly used survey questions to measure peoples' health (e.g., Contoyannis and Jones, 2004; Contoyannis et al., 2004; Johnson, 2010; Currie et al., 2015). Our dataset contains longitudinal information on SAH as the same question is asked to each individual in Waves 8–12, which compose the working sample for this study. The exact wording of the SAH question in the UKHLS is: "In general, would you say your health is: Excellent, Very Good, Good, Fair or Poor?", with SAH ranking from one (for excellent health) to five (for poor health). Despite its limitations as a self-reported health measure, SAH is considered as a strong predictor of mortality (Jylhä, 2009). It has been shown, however, that physical conditions reflected more on peoples' evaluation of their SAH than their mental health state (Powdthavee and Van Den Berg, 2011).

Our disability measures were collected at UKHLS Waves 8–12. Respondents were asked about the presence of any long-standing physical or mental impairment, illness or disability; a dichotomous variable is created and set equal to one for those facing any long-standing illness or disability, and zero otherwise. The exact wording of the disability question in UKHLS is: "Do you have any long-standing physical or mental impairment, illness or disability?"; this reflects the standard definition when identifying people with disabilities in surveys for the UK population (DWP, 2023). We also examined as separate outcomes specific functional difficulties, related to moving objects and memory and concentration, that are asked as follow-up questions to the main question about long-standing illness or disability. These functional

[7] Since the qualification for *LENRES* is based on whether individuals are classified as experiencing disadvantage in any one of the utilised binary components, there is no implicit weighting of the elements in the definition. Weighting one part more than another would have no effect on whether or not a household is classified as low energy price resilient; instead, measures of the depth or severity of resilience, for example exploring how many components of *LENRES* are experienced by the individual, will be affected, but these measures are not explored in our study.

[8] Fig. A1 in the Appendix shows that the proportion of the households with low levels of resilience to be around 25% each year between 2016 and 2021.

[9] Our sample covers the period up to and including April 2022. Hence, at present, we are only able to observe the initial impact of the energy price crisis.

Table 2
Cross-tabulations (percentages) of indicators of low energy and thermal affordability (*LEA*) and low energy and financial solvency (*LES*) used to measure low energy price resilience *LENRES* (cells B, C and D).

	LES = No	LES = Yes	Total
LEA = No	(A) 75.13%	(B) 4.98%	80.11%
	(n= 75,764)	(n=5,027)	(n=80,790)
LEA = Yes	(C) 14.95%	(D) 4.94%	19.89%
	(n= 15,075)	(n=4,983)	(n=20,058)
Total	90.07%	9.93%	100%
	(n=90,839)	(n=10,009)	(N=100,848)

Notes: Results are weighted using longitudinal sample weights on the pooled sample (UKHLS wave 8-12). Correlation coefficient = 0.249. N = 100,848.

difficulties are selected on the basis of existing research on the potential adverse effect of cold exposure on cognitive performance (Falla et al., 2021), especially memory and processing speed, and on manual performance (Ray et al., 2019).

In terms of our well-being measures, we use an overall life satisfaction measure which is collected longitudinally for every wave between UKHLS Waves 8 and 12. Our life satisfaction measures range between one (completely satisfied) and seven (completely dissatisfied), reflecting responses about people's overall life satisfaction. Typically, the life satisfaction measures are less prone to short-term changes, aiming to reflect people's overall cognitive well-being as opposed to emotional/psychological affect (Diener et al., 1985; Luhmann, 2017; Powdthavee and Van Den Berg, 2011).

The GHQ-12 is a widely used measure of non-psychotic psychological distress (Bowling, 1991; Goldberg et al., 1997). The twelve dimensions of GHQ are: span concentration, loss of sleep, playing a useful role, ability to make decisions, coping under strain, overcoming difficulties, enjoying activities, facing problems, feeling depressed/unhappy, confidence, feeling worthless, and general happiness. Respondents answer questions along these twelve dimensions on a four-category scale ('not at all', 'no more than usual', 'rather more than usual' and 'much more than usual'). For our analysis, we employ the Likert scoring method – a summation of all the responses to the GHQ questions, ranging from 0 (least distressed) to 36 (most distressed). This allows us to treat GHQ-12 as a pseudo-continuous measure in our analysis (e.g., Davillas et al., 2016; Davillas and Jones, 2021). We also employ each of these twelve dimensions as separate outcomes coded as one for the two categories indicating the most depressed states, while the remaining two categories, reflecting better mental health, are coded as zero. GHQ measures are considered as a shorter-term measure of well-being that typically aims to capture affect unlike our measure of overall life satisfaction (Powdthavee and Van Den Berg, 2011).

Overall, this rich set of health, disability and well-being outcomes allows us to explore the association between *LENRES* and both short-term and more affect-related measures, as well as more long-standing health and wellbeing outcomes. A full description of the set of health, disability and wellbeing outcomes for adults used in our models, along with their mean values, can be found in the appendix (Table A2).

3.2.2. Children living in the household

Our data also utilises the UKHLS youth questionnaire — a self-completion questionnaire for young people aged 10 to 16 living in the household, which is completed if a young person's parent or carer has given permission. Like the adult analysis, we draw upon the UKHLS Waves 8–12 longitudinal data and focus on children's overall health and overall satisfaction with their life. The young people's data is matched to household-level variables via their mother's personal identifier. After accounting for missing data, we rely on the UKHLS' panel of 8457 young individuals (aged 10 to 16), living in the same household as the adult participating between Wave 8 (January 2016 – May 2018) and Wave 12 (January 2020 – May 2022).

We employ a 5-point variable capturing the young respondents' evaluation of their own general health ranging between (1) excellent and (5) poor (*YHEALTH*). This is mainly a self-assessed health measure administered in a self-completion mode as: "In general, would you say your health is: excellent, very good, good, fair or poor". The overall children's wellbeing is captured by a 7-point scale variable capturing how children feel about their life as a whole; higher values reflecting worse levels of life satisfaction. Details on the health and wellbeing outcomes for children along with their mean values can be found in the appendix (Table A3).

These measures allow us to explore the extent to which the association between low energy price resilience and health and wellbeing outcomes is extended to children living in the household over and above their association with adults' outcomes. Finding evidence of an association between low energy price resilience of the household and adverse health and wellbeing consequences for children is of particular interest, not least because this is a period of rapid change and development; indeed, a large body of evidence suggests that the foundations for lifelong health and wellbeing are set during this important period of life (Handa et al., 2023).

3.3. Covariates

Our analysis exploring the socio-economic and demographic correlates of *LENRES* controls for a standard set of covariates expected to be associated with household energy price resilience. It should be explicitly noted that the full set of covariates described below (time variant and invariant variables) are used in the pooled econometric models; the time invariant covariates are omitted from our fixed-effects panel models, captured as part of the time-invariant unobserved heterogeneity.

We account for age (*AGE*), gender (*MALE*) and ethnicity (*WHITE, BLACK, ASIAN*, and *OTHER*). Moreover, we control for household composition, specifically an indicator for a single parent household (*LONEPARENT*), and housing tenure (a 4-category variable; *OWNER, MORTGAGE, SOCIAL_RENTER*, and *PRIVATE_RENTER*). Household size (*HHSIZE*) and its squared term (*HHSIZE2)* are accounted for to capture non-linear associations with our resilience outcome variables. We also control for energy payment by PPM (*PREPAYMENT*).

Labour force status is included, using a five-category variable (*EMPLOYED, UNEMPLOYED, RETIRED, STUDENT,* and *OTHER_JOBSTATUS*). We further account for a dichotomous education variable capturing respondents without A-levels or a degree (*NODEGREE* vs *ALEVEL_DEGREE*). We also account for a long-lasting illness or disability dichotomous variable (*DISABILITY*). Regional effects are captured using regional dummies (the nine government office regions of England, Northern Ireland, Scotland, and Wales), and an indicator of rurality (*RURAL* vs *URBAN*). Finally, we control for survey wave, year and month of interview time effects. Mean values and definitions of the explanatory variables used in the analysis are presented in the appendix (Table A4).

The same set of covariates (unless otherwise stated) are used in our subsequent analysis exploring the association of our energy price reliance measures with a wide set of health, disability and wellbeing outcomes. These covariates are assumed to be correlated with our energy price resilience measures and they are also main socio-economic correlates of the health, disability, and wellbeing outcomes (e.g., Davillas and Pudney, 2020a; Fuchs, 2004). Thus, our models allow us to estimate the association of low energy price resilience with our health, disability and wellbeing outcomes net of any potential confounding effects from this set of observed covariates.

3.4. Econometric analysis

To explore the social and economic characteristics associated with low energy price resilience, we regress our set of covariates on the *LENRES* indicator, using the following linear probability model specification:

$$LENRES_{it} = X_{it}^{'}\beta + \omega_t + \mu_r + \alpha_i + \varepsilon_{it} \quad (1)$$

where $LENRES_{it}$ represents the dichotomous outcome of low energy price resilience for individual *i* at wave *t*. The vector X_{it} contains our set of socioeconomic and demographic covariates, with β representing the vector of regression coefficients to be estimated; α_i denotes the time-invariant unobserved fixed effect. ω_t is the vector of wave and month indicators, and a year-on-year trend, capturing the seasonality in $LENRES_{it}$. μ_r captures regional and urban/rural location effects. Finally, ε_{it} denotes the idiosyncratic error term. Eq. 1 is estimated using pooled OLS and fixed effects models.

In the subsequent analysis, we explore whether our measure of low energy price resilience is associated with our set of health, disability and wellbeing outcomes for adults and children living in the household. We proceed by using the following general linear specification:

$$Y_{it} = \text{LENRES}_{it} + X_{it}^{'}\beta + \omega_t + \mu_r + \alpha_i + \varepsilon_{it} \quad (2)$$

where Y_{it} stands for the vector of health, disability and wellbeing outcomes of interest, while all remaining vectors are defined analogously to Eq. 1. Pooled OLS and fixed effects models, respecting the panel nature of the data, are used to estimate Eq. 2. Our fixed effects models eliminate time-invariant unobserved heterogeneity and, thus, our results are not affected by potential unobserved time-invariant factors that are correlated with both energy price resilience measures and our health, disability, and wellbeing outcomes, at the individual level. It should be also noted that linear probability models are used for the analysis of dichotomous outcome variables.

4. Results

4.1. Exploring the socio-economic and demographics of low energy price resilience

Our results on the socio-economic and demographic characteristics associated with *LENRES*[10] are presented in Table 3 (column 1). This table presents the regression coefficients of the time-varying covariates estimated using fixed effect linear probability models that eliminate time-invariant unobserved heterogeneity.[11]

Accounting for time invariant unobserved heterogeneity, we find that relying on PPMs as a fuel payment method has a positive and statistically significant association with *LENRES*; those using PPMs experience a 4.6 percentage points higher probability of *LENRES* compared to other payment methods. We also observe a statistically significant association between labour market status and *LENRES*. For example, being unemployed or retired is positively associated with *LENRES* – 24.6 point and 13.2 percentage point higher probability respectively – compared to the baseline category of being employed. Moreover, respondents who experience long-lasting health or disability experience a 1.6 percentage points (ppt) higher probability of *LENRES*.

We also find housing tenure to have a positive and systematic association with *LENRES*. Compared to individuals who own their home, all other tenure types are associated with a lower probability of energy resilience. For example, individuals renting in the private sector exhibit a higher probability of low energy price resilience (9.7 ppt) than those with mortgages (4.2 ppt), compared to the reference group of owners. In addition, our findings reveal single parent households to be positively associated with low levels of resilience, with a 10 ppt higher probability of *LENRES* than other household compositions.

Household size has a U-shaped association with *LENRES*; relatively small and relatively large households both appear to be associated with a higher probability of low energy price resilience. In addition, the association with low energy price resilience is increasing with the size of the property (captured by the number of bedrooms). It is worth noting

Table 3
Fixed effects OLS regressions of *LENRES*.

	(1)	(2)
Dependent variable	LENRES	LENRES
NOSAVINGS		0.081***
		(0.009)
CANNOTSAVE		0.034***
		(0.007)
PPM	0.046***	0.045***
	(0.014)	(0.014)
AGE	−0.008	−0.008
	(0.008)	(0.009)
UNEMPLOYED	0.246***	0.239***
	(0.015)	(0.015)
STUDENT	−0.028	−0.030
	(0.017)	(0.017)
RETIRED	0.132***	0.130***
	(0.012)	(0.012)
OTHER_JOBSTATUS	0.136***	0.133***
	(0.011)	(0.011)
DISABILITY	0.016***	0.016***
	(0.005)	(0.005)
SINGLEPARENT	0.100***	0.100***
	(0.022)	(0.022)
HHSIZE	−0.119***	−0.118***
	(0.014)	(0.014)
HHSIZE2	0.014***	0.014***
	(0.002)	(0.002)
NBEDS	0.015**	0.015**
	(0.006)	(0.006)
MORTGAGE	0.042***	0.040***
	(0.009)	(0.009)
SRS	0.097***	0.093***
	(0.023)	(0.023)
PRS	0.068***	0.065***
	(0.017)	(0.017)
RURAL	0.014	0.013
	(0.016)	(0.016)
Regional effects	Y	Y
Time effects	Y	Y
N	100,848	100,848

Notes: All model specifications also account for a set of regional, wave and month indicators, as well as a time trend (results not presented here). Column 2 adds controls for savings. All statistics are weighted using survey weights. Robust standard errors clustered at individual level in parentheses. Pooled linear probability model results can be found in the appendix (Table A5).
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

[10] As a robustness check we run all our regressions using a modified version of the LENRES and LEA variable where the 10% measure was replaced by the LIHC index. This approach has generated qualitatively similar results to the ones reported and discussed below.

[11] Pooled OLS estimates are presented in the appendix (Table A5, Column 1). Overall, the observed differences in the magnitude of the estimates between the OLS and the fixed effects models highlight the role of time-invariant unobserved heterogeneity.

that this finding is conditional on holding the household size constant, hence similar sized households living in larger (and potentially more inefficient) properties appear at greater risk of *LENRES*.[12]

In subsequent analysis, we explore whether the preceding results hold whilst controlling for the household's ability to make regular savings and/or have access to savings. This draws upon the FCA's definition of low financial resilience, which deems adults to have low financial resilience if, for example, they have a limited capacity to withstand financial shocks due to low or erratic incomes or savings. A comprehensive investigation of these issues is however impeded by the fact that UKHLS collect data that could potentially proxy for low or erratic savings only on an inconsistent basis (i.e., at specific waves).

In order to explore the influence of saving behaviour, we nonetheless utilise two variables contained in UKHLS at specific waves. The first dichotomous variable, collected at Waves 8, 10 and 12, takes the value of one if the household is unable to make regular savings of £10/month or more for rainy days or retirement, and zero otherwise (*CANNOTSAVE*).[13] Our second variable, collected at Waves 8 and 10, is set equal to one if the individual does not have any savings, and zero otherwise (*NOSAVINGS*). Due to the infrequent collection of these variables, we approximate savings behaviour by carrying forward the values for each individual across the panel (i.e., from Wave 8 to 12).[14] Hence the results in column 2 of Table 3 should be interpreted with some caution.

The fixed effects estimates presented in Table 3 (Column 2) reveals a positive association between the savings proxies and low energy price resilience.[15] We also note that our results about the socio-demographic correlates of low energy price resilience (after accounting for unobserved heterogeneity) remain almost identical to those obtained without controlling for savings behaviour (Table 3, Column 1 vs Column 2). Assuming that measurement errors in our savings variables play a limited role, these results suggest that the association between savings behaviour and our composite *LENRES* measure is independent from the role of all other variables included in our models, upon removing individual time-invariant heterogeneity.

4.2. Exploring the low energy price resilience channels

We also explore the socio-economic and demographic characteristics associated with the two channels of low energy price resilience, i.e. low energy and thermal affordability (*LEA*) and low energy and financial solvency (*LES*). Again, we estimate linear probability models (pooled and fixed effects) using *LEA* and *LES* respectively as the dependent variable in the specification outlined in Eq. 1. The fixed effects results for *LEA* and *LES* are displayed in Table 4.[16]

Employment status is also systematically associated with both *LEA* and *LES*; for example, the unemployed are more likely to be associated with both *LEA* and *LES* as opposed to the employed/self-employed respondents (reference category). Disability seems also to be associated with *LES*. These findings may not be surprising given the deprivation and financial vulnerability hazards associated with unemployment or long-standing health impairments. Similar to our results for the composite *LENRES* measure, household size appears to have a U-shaped association with both *LEA* and *LES*. Conversely, holding household size constant, the number of bedrooms remains systematically associated with *LEA* but not with *LES*. Similarly, single parents, compared to the reference group of 'all other household compositions', appear only associated with lower levels of affordability (*LEA*).

Compared to individuals who own their home, those with mortgages face systematically higher probabilities of both *LEA* and *LES*. Moreover, consistent with lower levels of energy efficiency in the rented sector, the *LEA* component appears to be a route to low energy price resilience for those renting in the private or social sector (versus the homeowner reference group).

Households paying for energy using a PPM appear to be associated with systematically higher probability of experiencing *LEA*, but this is

Table 4
Fixed effects linear probability regressions for the two LENRES channels– low energy and thermal affordability (LEA) and low energy and financial solvency (LES).

Dependent variable	LEA	LES
PPM	0.070***	−0.003
	(0.015)	(0.013)
AGE	−0.008	−0.002
	(0.009)	(0.006)
UNEMPLOYED	0.231***	0.107***
	(0.015)	(0.013)
STUDENT	−0.003	−0.024
	(0.018)	(0.015)
RETIRED	0.137***	0.002
	(0.012)	(0.007)
OTHER_JOBSTATUS	0.125***	0.053***
	(0.011)	(0.010)
DISABILITY	0.007	0.014***
	(0.005)	(0.004)
SINGLEPARENT	0.131***	0.020
	(0.023)	(0.021)
HHSIZE	−0.127***	−0.035***
	(0.014)	(0.011)
HHSIZE2	0.013***	0.006***
	(0.002)	(0.002)
NBEDS	0.021***	0.001
	(0.006)	(0.004)
MORTGAGE	0.042***	0.013**
	(0.009)	(0.006)
SRS	0.105***	0.003
	(0.025)	(0.018)
PRS	0.084***	−0.003
	(0.017)	(0.012)
RURAL	0.020	−0.001
	(0.015)	(0.010)
Regional effects	Y	Y
Time effects	Y	Y
N	100,848	100,848

Notes: All model specifications also account for a set of regional, wave and month indicators, as well as a time trend (results not presented here).
Robust standard errors clustered at individual level in parentheses.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

[12] It is worthwhile noting that the pooled linear probability model's results (Appendix, Table A5, Column 1) highlight the presence of positive associations between *LENRES* and being female (vs male), not obtaining educational qualifications (vs GCSEs or above), and being of black, mixed or other ethnicities (vs white). However, we are unable to test the robustness of these specific associations in the case of our fixed effects regressions, as they are time invariant covariates.

[13] The household is only asked this question if they have children living at home (aged 0–15) or no children (if there is no member of pensionable age).

[14] The aim of the UKHLS question on whether respondents have enough money to make regular savings of £10/month or more is to proxy the level of material deprivation at the household level for each member. The set of saving behaviour variables used in our analysis and their wording is employed in several large-scale surveys, e.g. the Family Resources Survey, and by the Department for Work and Pensions (HM Government, 2023). There is enough variation in our sample as far as these variables are concerned; for example, about 15% of our sample are unable to make regular savings of £10 a month or more (Table A4, Appendix). Given the data availability, we believe that both variables are proxies of people's capacity to withstand financial shocks (which could be related to increased energy prices) due to low or even absence of any savings.

[15] Pooled OLS estimates are presented in the Appendix (Table A5, Column 2).

[16] For brevity, the pooled OLS estimates are available upon request.

Table 5
Fixed effects linear regressions of self-assessed health (SAH), long-term illness and disability measures on LENRES (Panel A) and its underlying components – low energy and thermal affordability (LEA) and low energy and financial solvency (LES) (Panel B).

Specifications	(1)	(2)	(3)	(4)
Dependent variable	SAH	LTSD	Moving objects	Memory and Concentration
Panel A.				
LENRES	0.020***	0.015***	0.009**	0.010***
	(0.009)	(0.005)	(0.004)	(0.003)
Controls	Y	Y	Y	Y
Regional effects	Y	Y	Y	Y
Time effects	Y	Y	Y	Y
Panel B.				
LEA	−0.009	0.005	0.002	0.008**
	(0.010)	(0.005)	(0.004)	(0.003)
LES	0.112***	0.026***	0.018***	0.016***
	(0.014)	(0.007)	(0.006)	(0.005)
Controls	Y	Y	Y	Y
Regional effects	Y	Y	Y	Y
Time effects	Y	Y	Y	Y

Notes: Controls include socioeconomic, demographic characteristics, and regional/time effects (the DISABILITY covariate is omitted in these models) All statistics are weighted using sample weights. Robust standard errors clustered at individual level in parentheses. Sample size for estimations (1) is 99,109 due to item missingness in SAH and for estimations (2)–(4) is 100,848.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

not the case for *LES*. This reflects the fact that PPMs often result in higher energy costs and lower levels of affordability, while they may protect customers from energy solvency issues through their pay-as-you-go mechanism.

4.3. Low energy price resilience, health, disability, and wellbeing outcomes

Overall, our fixed effects models (Table 5, Panel A) show consistent associations between *LENRES* and our set of general health and long-standing disability measures. After accounting for time invariant unobserved heterogeneity, these results suggest that *LENRES* is systematically associated with worse self-assessed health and disability outcomes. Specifically, we find that low energy price resilience is associated with higher SAH values, suggesting worse health statuses (Column 1); SAH is a general health measure that often mostly reflects people's evaluation on their physical health. There is also a positive and systematic association between *LENRES* and long-standing disability measures (Column 2); this positive association is particularly evident in the case of our measures of specific functional difficulties, such as moving objects (Column 3) and memory and concentration (Column 4). The presence of a systematic association between *LENRES* and long-term measures of people's functioning, such as our disability measures, is a critical policy concern, in light of the relatively high levels of disability in the UK and their significant social and economic ramifications (e.g., Pudney et al., 2011; Jones, 2016; Davillas and Pudney, 2020b).

Table 6 (Panel A) presents our results on the association between *LENRES* and our overall wellbeing measure as well as measures of psychological distress. After taking into account unobserved heterogeneity, *LENRES* is associated with higher values of the life satisfaction measure suggesting worse levels of life satisfaction (Column 1). It is also evident that *LENRES* is strongly correlated with worse levels of psychological distress (GHQ measure, Column 2), and worse outcomes for *all* of the

Table 6
Fixed effects linear regressions of wellbeing outcomes on the composite low energy price resilience measure (LENRES; Panel A) and its underlying components (low energy and thermal affordability (LEA) and low energy and financial solvency (LES); Panel B).

Specifications	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Dependent variable	Life Satisfaction	GHQ-12	Concentration	Sleep	Useful	Decision making	Under strain	Overcome difficulties	Enjoy activities	Problem solving	Confidence	Depressed	Self-worth	Happiness
Panel A.														
LENRES	0.172***	0.375***	0.024***	0.036***	0.024***	0.022***	0.037***	0.043***	0.024***	0.034***	0.036***	0.033***	0.029***	0.034***
	(0.017)	(0.038)	(0.005)	(0.005)	(0.005)	(0.004)	(0.005)	(0.005)	(0.006)	(0.005)	(0.006)	(0.005)	(0.004)	(0.005)
Controls	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Regional effects	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Time effects	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Panel B.														
LEA	0.038**	0.082**	0.004	0.009	−0.002	0.005	0.004	0.015***	0.004	0.010**	0.007	0.010*	0.010**	0.006
	(0.018)	(0.042)	(0.006)	(0.006)	(0.005)	(0.005)	(0.006)	(0.005)	(0.006)	(0.005)	(0.006)	(0.005)	(0.004)	(0.005)
LES	0.492***	1.155***	0.085***	0.105***	0.087***	0.062***	0.119***	0.120***	0.086***	0.099***	0.120***	0.092***	0.079***	0.099***
	(0.028)	(0.071)	(0.009)	(0.009)	(0.009)	(0.008)	(0.010)	(0.009)	(0.010)	(0.009)	(0.010)	(0.009)	(0.008)	(0.009)
Controls	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Regional effects	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Time effects	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

Notes: Controls include socioeconomic, demographic characteristics, and regional/time effects. All statistics are weighted using sample weights.
Robust standard errors clustered at individual level in parentheses.
Sample size for all models is 98457.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

individual elements of our GHQ-12 psychological distress measure (Columns 3 to 14).[17] Overall, the results from Table 6 show that *LENRES* is strongly associated not only with measures that capture people's cognitive long-run overall wellbeing, as reflected by our life satisfaction outcome, but also with more affect outcomes captured in our GHQ-12 measures of psychological and emotional distress (Powdthavee and Van Den Berg, 2011).

For the main analysis of our study, in the case of dichotomous outcomes we use (pooled and fixed effects) linear probability models. Sensitivity analysis also shows that our results are robust to the use of probit models.[18] Moreover, our conclusions remain unchanged when using random effects probit models, and as expected, the marginal effects from these random effects models fall between the pooled and fixed effects OLS estimates.[19]

While our fixed effects models account for time-invariant unobserved heterogeneity, it may be the case that time-varying unobserved heterogeneity may influence our estimates, resulting in omitted variables biases. Although we do not aim for causal interpretations and analysis in this study, we employed the Oster's (2019) bounding approach as a robustness check. The bounding approach considers concomitant movements in coefficients and the coefficient of determination (R^2) across models in order to assess the influence of omitted variables. We conservatively assume that the observed variables have equal importance to those unobserved. We also set the maximum for the R^2 to 1.3 times its overall value in the fixed effects estimations. The bound estimates produced by Oster's approach are not only non-zero (i.e., zero is not included within the estimated lower and upper bounds of our *LENRES* coefficients) but also, they are practically identical to the fixed effects results (hence, the results are not presented for brevity and are available upon request). Overall, the Oster's bounding approach indicates that our results appear robust to omitted variable biases.

In a subsequent analysis (Tables 5–6, Panel B) we explore the relative contribution of the two components underpinning our composite measure of low energy price resilience (*LENRES*). More specifically, through estimating fixed effects models that include both the low energy and thermal affordability (*LEA*) and low energy and financial solvency (*LES*) dichotomous variables, we explore the relative role of each pathway in the observed association between low energy price resilience and our set of health, disability, and wellbeing outcomes.

Overall, we found that the associations between all our outcomes with the composite *LENRES* are primarily driven by the low energy and financial solvency (*LES*) component. For example, Table 5 shows that the positive associations of *LENRES* with SAH and disability (Panel A) are driven largely by the low energy and financial solvency (*LES*) component (Panel B). Turning to the specific disability indicators, we found that these associations are underpinned more strongly by *LES*, except for memory and concentration, which is also associated with *LEA* at the 5% significance level (Panel B, Column 4).

Similarly, the role of the energy and thermal affordability (*LEA*) component appears less pronounced for our wellbeing outcomes compared to *LES*; indeed, there are fewer cases that show strong associations (statistically significant at the 5% level) between *LEA* and our wellbeing outcomes (specifically, only in five out of fourteen outcomes of our analysis we found strong associations with the *LEA* component; Table 6, Panel B).

4.4. *Children's health and wellbeing outcomes*

In this subsection, we explore whether living in a home with low energy price resilience is associated with the wellbeing and/or health of children. Unlike our models for adults, only a limited set of variables are collected in the UKHLS in each wave of the longitudinal survey of young people. We control for children's age, number of close friends, perceptions on the importance of doing well in GCSE's, desire to proceed to higher education, whether they smoke, drink alcohol, belong to a social website, or regularly eat meals with their family. It is worthwhile noting that we found adult (mother's) individual socio-economic and demographic characteristics to yield neither robust nor statistically significant associations in the young people's fixed effects regressions. Hence, we employ mother's mental health as the only adult-individual variable in these regressions.[20] No time invariant characteristics (e.g., ethnicity, gender) are included as control variables in our fixed effects models of the association between low energy price resilience and children's health and wellbeing outcomes.

The results from the fixed effects models presented in Table 7 show that our composite measure of low household energy price resilience is only systematically associated with young people's life satisfaction measures rather than with general health.[21] Given that low energy price resilience at home is not associated with children's self-assessed health, at least as far as general health is considered, there may also be no relevant inequality of opportunity for their later life outcomes arising from health impairments during childhood – a period in which children experience circumstances beyond their control.

Table 7
Fixed effects linear regressions of measures of young people's health and wellbeing on LENRES (Panel A) and its components – low energy and thermal affordability (LEA) and low energy and financial solvency (LES) (Panel B).

Specifications	(1)	(2)
Dependent variable	Health	Life Satisfaction
Panel A.		
LENRES	0.033	0.101**
	(0.032)	(0.048)
Controls	Y	Y
Regional effects	Y	Y
Time effects	Y	Y
Panel B.		
LEA	0.040	0.111**
	(0.034)	(0.051)
LES	−0.070	0.060
	(0.042)	(0.054)
Controls	Y	Y
Regional effects	Y	Y
Time effects	Y	Y

Notes: Controls include socioeconomic, demographic characteristics, and regional/time effects.
Robust standard errors clustered at individual level in parentheses.
Sample size for all estimations is 8547.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

[17] As a robustness check, we utilised the SF12 mental health functioning measure to further test the LENRES association and its underlying channels. Our main analysis results are generally confirmed as we found a clear negative association between *LENRES* and mental health functioning capturing by the natural log of the SF12 mental health component. Moreover, in line with our results in Table 6, the observed association is more so driven by the energy and financial solvency component. For brevity these results are available upon request.

[18] Marginal effects from the pooled probit models versus the corresponding coefficients from the pooled linear probability models are available in the appendix, Tables A6–A7.

[19] These results are available upon request.

[20] Descriptions and mean values for all variables used in our young people analysis can be found in the appendix (Table A3). In addition, we control for the same set of time and regional effects specified in Eq. 1.

[21] The fixed effects (Oster) bounded results for life satisfaction do not contain zero and therefore provide further support to our conclusions (results available upon request).

Looking closely at the components underpinning these results, Panel B reveals that the households facing low energy and thermal affordability (*LEA*) issues, rather than low energy and financial solvency (*LES*) difficulties, are associated with deleterious life satisfaction outcomes for young people. This is in stark contrast to the situation of adults, for whom we find *LES* to generally be the key channel associated with our set of health and wellbeing outcomes.

5. Conclusions

The unexpected and substantial increase in energy prices observed across Europe following developments of the war in Ukraine has heightened Governments' and civil society's concerns about potential impact of these price increases on consumers, and especially on the most vulnerable. As financial and other policy interventions enacted at the start of the energy crisis are reduced or completely removed, it is important to reflect on the recent experience of high energy price volatility to assess the ability of different households to withstand, and adapt to, sudden and significant increase in prices.

Our paper contributes to the literature on energy resilience by shifting the focus from the supply-side's infrequent and time-limited disruptions to the consumer's required adjustments in response to unexpected and sustained increases in energy prices. We also extend the range of tools available for policy intervention, by providing a new quantifiable measure of resilience for residential households, which is based mainly on demand-side considerations and which we define as *energy price resilience*. This measure and its two components (energy and financial affordability and energy and financial solvency) have been used in our empirical analysis of the socio-economic and demographic factors likely to be associated with energy price resilience. We also investigate the association between energy price resilience measures and a wide set of health, disability, and wellbeing outcomes.

Based on our composite measure of energy price resilience we find that about a quarter of individuals in the UK have experienced a challenging situation of either energy related affordability or energy related solvency or both, during the period 2016–2022. We find a positive association of low energy price resilience and both a variety of factors including (i) the use of pre-payment energy payment methods, most prevalent among vulnerble households (Burlinson et al., 2023) (ii) a household's lack of access to savings (iii) unemployment. The importance of these factors is consistent when we look either at the aggregate measure of energy price resilience or its two components (energy affordability and solvency). We also find that living in rented accommodation and retirement are only associated with energy affordability.

Our results show that, after accounting for time-invariant unobserved heterogeneity, low energy price resilience is generally associated with worse health, disability, and wellbeing outcomes for all household members; however, these associations tend to be different between the energy affordability and energy solvency channel for adults. Specifically, our analysis shows that low energy price resilience is associated with *both* measures that proxy cognitive long-run overall wellbeing and affect measures capturing psychological and emotional distress.. In comparison, the results for children show that low energy resilience is only systematically associated with life satisfaction measures. Indeed, the lack of association between *LENRES* at home and children's general health may be encouraging, as this might indicate limited inequality of opportunity for later life outcomes.

Looking at the channels of low energy price resilience in adults, we find that the association between low resilience and our set of health, disability and wellbeing outcomes is mostly attributable to the energy and financial solvency channel, as opposed to the energy and thermal affordability component. On the other hand, the association between low energy price resilience of the household and children's overall cognitive well-being proxied by life satisfaction measures appears to be driven by the energy and thermal affordability channel. Bringing these results together, our findings suggest that children's wellbeing may be at greater risk when households face energy affordability challenges, which might imply that adults try to protect their children from these challenges, may do so to the potential detriment of their own health.

One limitation of our work is related to the lack of availability of more detailed data on energy consumption but also on the households' financial situation, saving behaviour and access to credit; this may limit our ability to fully assess the changes in energy consumption patterns during the energy crisis and their impact on the households' financial situation. It is also important to note that our empirical analysis does not cover the peak of the energy crisis period (the winter 2022–23); thus, the results from our analysis may underestimate the association between low energy price resilience and the deleterious outcomes, as during the peak of the energy crisis significant financial pressures were most likely to be felt by vulnerable households (despite the relevant government's mitigating measures).

In addition, despite controlling for time effects in the analysis, and while our Oster's bounding approach suggests that our results are robust to unobserved factors, it should be noted here that the associations established in this work are not of a causal nature due to potential endogeneity attributable to time varying unobserved heterogeneity.

Despite these limitations, we are able to offer some conclusions and recommendations based on the key results. The reaction of most Governments to the significant increases in energy prices in the winter of 2022 has been characterised by a desire to act swiftly to protect the majority of energy consumers. Given the potentially conflicting objectives of energy affordability and environmental sustainability, policy interventions which protect most consumers from price shocks will reduce households' sensitivity to such price signals. This is particularly concerning if those consumers who can afford to pay for energy do not adjust their consumptions patterns as a reaction to price signals because of the availability of universal and unconditional financial support.

Moreover, when considering vulnerable consumers, who are the focus of our analysis, the results presented in this study help to characterise the profile of the individuals and households who are more likely to be exposed to significant challenges resulting from high energy price crises. We would argue, that given the cost of supporting all individuals in society for future increases in price, tailored interventions, targeted at the most vulnerable in society, may need to be implemented. We believe that policy interventions which use our definition of energy price resilience, more clearly identify vulnerable individuals compared to the traditional fuel poverty measures. In particular, our evidence relating to the energy and financial solvency dimension of resilience could inform policymakers' interventions currently being considered, including the possible introduction of social tariffs (NEA, 2022), the levelling of costs across payment methods or the review of fixed costs (known as standing charges) – which are subject to consultation by Ofgem (Office for Gas and Electricity Markets (Ofgem), 2023b) and continue to be demanded by charities concerned about vulnerable households (Age UK, 2024).

Looking beyond the current crisis in energy markets, our proposed measure of energy price resilience would allow policymakers to define long term and consistent policy interventions, based on broader eligibility criteria than most of the current support schemes for vulnerable consumers. Overall, the associations between energy price resilience and health, disability, and wellbeing outcomes within households reveal the possibility that appropriate interventions in the energy sector could be linked to wider societal health and wellbeing benefits.

CRediT authorship contribution statement

Andrew Burlinson: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Software, Writing – original draft, Writing – review & editing. **Apostolos Davillas:** Conceptualization, Formal analysis, Investigation, Methodology, Software, Writing – original draft, Writing – review & editing. **Monica Giulietti:** Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Writing – original draft, Writing – review & editing. **Catherine Waddams Price:** Conceptualization, Formal analysis, Funding acquisition, Investigation, Writing – original draft, Writing – review & editing.

Declaration of competing interest

None.

Acknowledgements

The research was undertaken as part of the UK Energy Research Centre research programme. Funded by the UK Research and Innovation Energy programme under grant number EP/SO29575/1. Understanding Society is an initiative funded by the Economic and Social Research Council and various Government Departments, with scientific leadership by the Institute for Social and Economic Research, University of Essex, and survey delivery by NatCen Social Research and Kantar Public. The research data are distributed by the UK Data Service. The funders, data creators and UK Data Service have no responsibility for the contents of this paper. We thank participants at workshops, seminars and conferences hosted by NEA, Ofgem, Public Policy Exchange and the Centre for Competition Policy, Matthew Copeland and Matthew Scott for their thoughtful and useful comments. We would like to thank the guest editor and two anonymous referees for their insightful comments.

Appendix A. Appendix

Table A1
Composition of the LENRES measure.

Due to…	Population share (%)	LENRES share (%)
all 4 components	0.39	1.57
“inadequate heating” (only)	1.71	6.87
“10% of income spent of energy” (only)	12.57	50.48
“financial difficulties” (only)	2.88	11.57
“behind on bills” (only)	1.48	5.94
overlap across the components	5.87	23.57
Total	**24.9**	**100**

Notes: UKHLS Wave 8–12 (Jan 2016-May 2022) data. All statistics are weighted using sample weights.

Table A2
Health, disability and wellbeing outcomes for adults: definitions and mean values.

Variable	*Definition*	*Mean*
Self-assessed health		
	In general, would you say your health is: (1) excellent, (2) very good, (3) good, (4) fair, (5) poor.	*2.754*
N		*99,109*
Long term health and disability impairments		
LTSD	*1 if individual has a long-standing physical or mental impairment, illness or disability; 0 otherwise*	*0.302*
LTSD ()	*If you have a long-standing health problem, do you have substantial difficulties with…*	
Moving objects	*1 lifting, carrying or moving objects; 0 otherwise*	*0.139*
Memory and concentration	*1 memory or ability to concentrate, learn or understand; 0 otherwise*	*0.049*
N		*100,848*
Wellbeing measures		
Life satisfaction	*Satisfied with life overall: 1 (completely satisfied) to 7 (completely dissatisfied)*	*5.179*
GHQ-12	*Subjective wellbeing (caseness): 0 (the least distressed) to 12 (the most distressed)*	*1.893*
GHQ ()	*How you have been feeling over the last few weeks…*	
Concentration	*Have you recently been able to concentrate on whatever you're doing? 1 if much less or less than usual; 0 of better than or same as usual*	*0.176*
Sleep	*Have you recently lost much sleep over worry? 1 if much more or rather more than usual; 0 if not at all or no more than usual*	*0.166*
Useful	*Have you recently felt that you were playing a useful part in things? 1 if much less or less than usual; 0 if more so or same as usual*	*0.153*
Decision-making	*Have you recently felt capable of making decisions about things? 1 if much less capable or less so; 0 if more so or same as usual*	*0.098*
Under strain	*Have you recently felt constantly under strain? 1 if much more or rather more than usual; 0 if not at all or no more than usual*	*0.223*
Overcome difficulties	*Have you recently felt you couldn't overcome your difficulties? 1 if much more or rather more than usual; 0 if not at all or no more than usual*	*0.142*
Enjoy Activities	*Have you recently been able to enjoy your normal day-to-day activities? 1 if much less or less than usual; 0 if more so or same as usual*	*0.200*
Problem solving	*Have you recently been able to face up to problems? 1 if much less able or less so; 0 if more so or same as usual*	*0.110*
Confidence	*Have you recently been losing confidence in yourself? 1 if much more or rather more than usual; 0 if not at all or no more than usual*	*0.208*
Depressed	*Have you recently been feeling unhappy or depressed? 1 if much more or rather more than usual; 0 if not at all or no more than usual*	*0.166*
Self-worth	*Have you recently been thinking of yourself as a worthless person? 1 if much more or rather more than usual; 0 if not at all or no more than usual*	*0.094*
Happiness	*Have you recently been feeling reasonably happy, all things considered? 1 if much less or less so than usual; 0 if more so or about the same as usual*	*0.158*
N		*98,457*

Notes: UKHLS Wave 8–12 (Jan/2016-May/2022) data.
All statistics are weighted using sample weights.

Table A3
Children's general health and wellbeing outcomes as well as control variables for the relevant regression models: definitions and mean values.

Variable	*Definition*	*Mean*
Health and wellbeing outcomes		
Life satisfaction	*Satisfied with life as a whole: 1 (completely satisfied) to 7 (completely dissatisfied)*	*2.274*
Health	*Overall health is 1 (excellent) to 7 (poor)*	*2.139*
Controls		
Age	*Age in years*	*12.554*
Friends	*Number of close friends*	*9.103*
GCSEs, very important (reference)	*1 if individual thinks GCSE's or equivalents are very important; 0 otherwise*	*0.729*
GCSEs, important	*1 if individual thinks GCSE's or equivalents are important; 0 otherwise*	*0.244*
GCSEs, not very important	*1 if individual thinks GCSE's or equivalents are not very important; 0 otherwise*	*0.019*
GCSEs, not at all important	*1 if individual thinks GCSE's or equivalents are not at all important; 0 otherwise*	*0.009*
Yes, to higher education (reference)	*1 if individual would not like to go on to do further full-time education at a college or university; 0 otherwise*	*0.626*
No, to higher education	*1 if individual would not like to go on to do further full-time education at a college nor university; 0 otherwise*	*0.065*
Missing, higher education	*1 if missing; 0 otherwise*	*0.309*
Smoked (reference)	*1 if individual has smoked cigarettes at all; 0 otherwise*	*0.049*
Never smoked	*1 if individual has never smoked cigarettes; 0 otherwise*	*0.951*
Yes, to alcohol (reference)	*1 if individual has had an alcoholic drink; 0 otherwise YES/NO*	*0.240*
No, to alcohol	*1 if individual has never had an alcoholic drink; 0 otherwise YES/NO*	*0.760*
Yes, to social media (reference)	*1 if individual does belong to a social website (e.g., facebook); 0 otherwise*	*0.818*
No, to social media	*1 if individual does not belong to a social website (e.g., facebook); 0 otherwise*	*0.182*
No family meals (reference)	*1 if individual had no evening meals with family in the past week; 0 otherwise*	*0.060*
1–2 family meals	*1 if individual had 1–2 evening meals with family in the past week; 0 otherwise*	*0.171*
3–5 family meals	*1 if individual had 3–5 evening meals with family in the past week; 0 otherwise*	*0.266*
6–7 family meals	*1 if individual had 6–7 evening meals with family in the past week; 0 otherwise*	*0.503*

Notes: UKHLS Wave 8–12 (Jan/2016-May/2022) data.

Table A4
Control variable definitions and mean values for adults.

Variable	*Definition*	*Mean*
FIXEDOTHER (reference)	*1 if energy payment is standard credit or direct debit; 0 otherwise*	*0.873*
PPM	*1 if energy payment method is prepayment; 0 otherwise*	*0.127*
AGE	*Age in years*	*51.990*
FEMALE (reference)	*1 if female; 0 otherwise*	*0.536*
MALE	*1 if male; 0 otherwise*	*0.464*
WHITE (reference)	*1 if white; 0 otherwise*	*0.923*
BLACK	*1 if black; 0 otherwise*	*0.018*
ASIAN	*1 if asian; 0 otherwise*	*0.041*
OTHER_ETHNICITY	*1 if other; 0 otherwise*	*0.018*
ALEVEL_DEGREE (reference)	*1 if A-level/Degree qualification or equivalent; 0 otherwise*	*0.817*
NODEGREE	*1 if no qualifications/or basic qualifications; 0 otherwise*	*0.183*
EMPLOYED (reference)	*1 if employed or self-employed; 0 otherwise*	*0.527*
UNEMPLOYED	*1 if unemployed; 0 otherwise*	*0.040*
RETIRED	*1 if retired; 0 otherwise*	*0.297*
STUDENT	*1 if full-time student; 0 otherwise*	*0.045*
OTHER_JOBSTATUS	*1 if other economic activity; 0 otherwise*	*0.137*
NO-DISABILITY (reference)	*1 if not in long-term illness/disability; 0 otherwise*	*0.697*
DISABILITY	*1 if experience long-term illness/disability; 0 otherwise*	*0.302*
NO-SINGLEPARENT (reference)	*1 if not a single parent household; 0 otherwise*	*0.971*
SINGLEPARENT	*1 if single parent household; 0 otherwise*	*0.029*
HHSIZE	*Household size*	*2.668*
NBEDS	*Number of bedrooms*	*3.013*
OWNER (reference)	*1 if owns accommodation; 0 otherwise.*	*0.389*
MORTGAGE	*1 if owns accommodation with mortgage; 0 otherwise*	*0.328*
SRS	*1 if rents social accommodation; 0 otherwise.*	*0.180*
PRS	*1 if privately rents accommodation; 0 otherwise*	*0.103*
URBAN (reference)	*1 if living in urban area; 0 otherwise*	*0.748*
RURAL	*1 if living in a rural area; 0 otherwise*	*0.252*
Regions		
NEAST (reference)	*1 if respondent lives in the North East of England; 0 otherwise*	*0.047*
NWEST	*1 if respondent lives in the North West of England; 0 otherwise*	*0.108*
YORKSHIRE	*1 if respondent lives in Yorkshire and Humberside; 0 otherwise*	*0.089*
EMIDLANDS	*1 if respondent lives in the East Midlands; 0 otherwise*	*0.081*
WMIDLANDS	*1 if respondent lives in the West Midlands, 0 otherwise*	*0.087*
EAST	*1 if respondent lives in the East of England, 0 otherwise*	*0.098*
LONDON	*1 if respondent lives in London, 0 otherwise*	*0.101*
SEAST	*1 if respondent lives in the South East of England, 0 otherwise*	*0.136*
SWEST	*1 if respondent lives in the South West of England, 0 otherwise*	*0.089*
WALES	*1 if respondent lives in the Wales, 0 otherwise*	*0.048*
SCOTLAND	*1 if respondent lives in the Scotland, 0 otherwise*	*0.087*

(*continued on next page*)

Table A4 (*continued*)

Variable	*Definition*	*Mean*
Savings behaviour		
Ability to save		
CANSAVE (reference)	*1 if the household does have enough money to make regular savings of £10/month or more for rainy days or retirement; and 0 otherwise.*	*0.851*
CANNOTSAVE	*1 if the household does not have enough money to make regular savings of £10/month or more for rainy days or retirement; and 0 otherwise.*	*0.149*
Existing savings		
SAVINGS (reference)	*1 if the individual does have any savings; and 0 otherwise*	*0.468*
NOSAVINGS	*1 if the individual does not have any savings; and 0 otherwise*	*0.532*
N		100,848

Notes: UKHLS Wave 8–12 (Jan/2016-May/2022) data.
All statistics are weighted using sample weights.

Table A5
Pooled linear probability models of *LENRES*.

	(1)	(2)
Dependent variable	LENRES	LENRES
NOSAVINGS		0.203***
		(0.008)
CANNOTSAVE		0.098***
		(0.004)
PPM	0.175***	0.139***
	(0.010)	(0.010)
AGE	0.000	0.000
	(0.000)	(0.000)
MALE	−0.015***	−0.012***
	(0.005)	(0.004)
BLACK	0.140***	0.128***
	(0.021)	(0.019)
ASIAN	0.096***	0.090***
	(0.012)	(0.011)
OTHER_ETHNICITY	0.060***	0.042**
	(0.021)	(0.019)
NODEGREE	0.060***	0.056***
	(0.008)	(0.007)
UNEMPLOYED	0.327***	0.278***
	(0.014)	(0.013)
STUDENT	−0.046***	−0.037***
	(0.015)	(0.014)
RETIRED	0.037***	0.045***
	(0.007)	(0.007)
OTHER_JOBSTATUS	0.172***	0.136***
	(0.010)	(0.009)
DISABILITY	0.047***	0.035***
	(0.005)	(0.005)
SINGLEPARENT	0.194***	0.156***
	(0.016)	(0.015)
HHSIZE	−0.076***	−0.080***
	(0.007)	(0.006)
HHSIZE2	0.011***	0.010***
	(0.001)	(0.001)
NBEDS	0.007**	0.011***
	(0.003)	(0.003)
MORTGAGE	0.022***	0.017***
	(0.006)	(0.005)
SRS	0.159***	0.119***
	(0.010)	(0.009)
PRS	0.164***	0.135***
	(0.010)	(0.010)
RURAL	0.035***	0.036***
	(0.005)	(0.005)
Regional effects	Y	Y
Time effects	Y	Y
N	100,848	100,848

Notes: All model specifications also account for a set of regional, wave and month indicators, as well as a time trend (results not presented here). Column 2 adds controls for savings. All statistics are weighted using survey weights.
Robust standard errors clustered at individual level in parentheses.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table A6
Pooled linear probability regression models (Panel A) and marginal effects from the corresponding pooled probit models (Panel B) of disability measures on LENRES.

	(1)	(2)	(3)
Dependent variable	LTSD	Moving objects	Memory and concentration
Panel A. Pooled linear probability models			
LENRES	0.053***	0.027***	0.019***
	(0.006)	(0.005)	(0.003)
Controls	Y	Y	Y
Regional effects	Y	Y	Y
Time effects	Y	Y	Y
Panel B. Pooled probit models: marginal effects			
LENRES	0.057***	0.026***	0.014***
	(0.006)	(0.004)	(0.002)
Controls	Y	Y	Y
Regional effects	Y	Y	Y
Time effects	Y	Y	Y

Notes: The same set of control variables as those in Table 5 (main text) are accounted for in these models.
All statistics are weighted using sample weights. Robust standard errors clustered at individual level in parentheses.
Sample size for all estimations is 100,848.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table A7
Pooled linear probability regression models (Panel A) and marginal effects from the corresponding pooled probit models (Panel B) of wellbeing outcomes on LENRES.

Specifications	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Dependent variable	Concentration	Sleep	Useful	Decision making	Under strain	Overcome difficulties	Enjoy activities	Problem solving	Confidence	Depressed	Self- worth	Happiness
Panel A. Pooled linear probability models												
LENRES	0.050***	0.072***	0.055***	0.047***	0.077***	0.076***	0.055***	0.065***	0.074***	0.064***	0.053***	0.065***
	(0.005)	(0.005)	(0.005)	(0.004)	(0.005)	(0.005)	(0.005)	(0.004)	(0.005)	(0.005)	(0.004)	(0.005)
Controls	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Regional effects	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Time effects	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Panel B. Pooled probit models: marginal effects												
LENRES	0.045***	0.064***	0.048***	0.040***	0.071***	0.065***	0.050***	0.054***	0.067***	0.056***	0.043***	0.057***
	(0.004)	(0.004)	(0.004)	(0.003)	(0.005)	(0.004)	(0.004)	(0.003)	(0.004)	(0.004)	(0.003)	(0.004)
Controls	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Regional effects	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Time effects	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

Notes: The same set of control variables as those in Table 6 (main text) are accounted for in these models. Robust standard errors clustered at individual level in parentheses.
Sample size for all models is 98,457.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

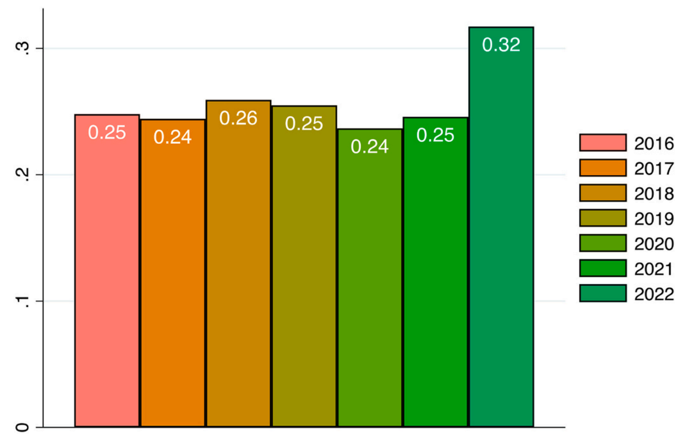

Fig. A1. Proportion of households with low energy price resilience (LENRES) over time.
Notes: All statistics are weighted using sample weights.

Appendix B. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.eneco.2024.107414.

References

Abi Ghanem, D., Mander, S., Gough, C., 2016. "I think we need to get a better generator": household resilience to disruption to power supply during storm events. Energy Policy 92, 171–180.
Age UK, 2024. New Age UK Analysis Shows an Energy Social Tariff Would Have Lifted 2.2 Million Households out of Fuel Poverty this Winter, London.
Anderson, W., White, V., Finney, A., 2012. Coping with low incomes and cold homes. Energy Policy 49, 40–52.
Awaworyi Churchill, S., Smyth, R., 2021. Energy poverty and health: panel data evidence from Australia. Energy Econ. 97.
Boardman, B., 1991. Fuel Poverty: From Cold Homes to Affordable Warmth. Belhaven Press, London, United Kingdom.
Bolton, P., Stewart, I., 2024. Domestic Energy Prices. House of Commons Library Research Briefing, p. 9491.
Bowling, A., 1991. Measuring Health: A Review of Quality of Life Measurement Scales. Open University Press, Milton Keynes, Bucks, p. 1991.
Burlinson, A., Giulietti, M., Law, C., Liu, H.H., 2021. Fuel poverty and financial distress. Energy Econ. 102, 105464.
Burlinson, A., Davillas, A., Law, C., 2023. Pay (for it) as you go: prepaid energy meters and the heat-or-eat dilemma. Soc. Sci. Med. 315, 115498.
Citizens Advice, 2023. Kept in the Dark: The Urgent Need for Action on Prepayment Meters. Citizens Advice, London, United Kingdom.
Citizens Advice, 2024. Shock Proof: Breaking the Cycle of Winter Energy Crises. Citizens Advice, London, United Kingdom.
Clifford Talbot, 2023. Energy Prices [online] Available at: https://www.cliffordtalbot.co.uk/energy-prices/. Accessed 4th December 2023.
Contoyannis, P., Jones, A.M., 2004. Socio-economic status, health and lifestyle. J. Health Econ. 23, 965–995.
Contoyannis, P., Jones, A.M., Rice, N., 2004. The dynamics of health in the British household panel survey. J. Appl. Econ. 19, 473–503.
Currie, J., Duque, V., Garfinkel, I., 2015. The great recession and mothers' health. Econ. J. 125, F311–F346.
Davillas, A., Jones, A.M., 2021. The first wave of the COVID-19 pandemic and its impact on socioeconomic inequality in psychological distress in the UK. Health Econ. 30, 1668–1683.
Davillas, A., Pudney, S., 2020a. Biomarkers as precursors of disability. Econ. Hum. Biol. 36, 100814.
Davillas, A., Pudney, S., 2020b. Biomarkers, disability and health care demand. Econ. Hum. Biol. 39, 100929.
Davillas, A., Benzeval, M., Kumari, M., 2016. Association of adiposity and mental health functioning across the lifespan: findings from understanding society (the UK household longitudinal study). PLoS One 11 (2), e0148561.
Davillas, A., Burlinson, A., Liu, H.H., 2022. Getting warmer: fuel poverty, objective and subjective health and well-being. Energy Econ. 106, 105794.
Deller, D., Waddams Price, C., 2018. Fairness in Retail Energy Markets? Centre for Competition Policy and UK Energy Research Centre.
Deller, D., Turner, G., Waddams Price, C., 2021. Energy poverty indicators: inconsistencies, implications, and where next? Energy Econ. 103, 105551.

Department for Energy Security and Net Zero (DESNZ), 2023a. Annual Fuel Poverty Statistics in England 2023 (2022 Data), February. HM Government, London, United Kingdom.
Department for Energy Security and Net Zero (DESNZ), 2023b. Fuel Poverty Methodology Handbook (Low Income Low Energy Efficiency), February. HM Government, London, United Kingdom.
Department for Work and Pensions (DWP), 2023. Making Disability Data Work for you: A Community Data Toolkit (Part 1). HM Government, London, United Kingdom.
Diener, E., Emmons, R.A., Larsen, R.J., Griffin, S., 1985. The satisfaction with life scale. J. Pers. Assess. 49 (1), 71–75.
Falla, M., Micarelli, A., Hüfner, K., Strapazzon, G., 2021. The effect of cold exposure on cognitive performance in healthy adults: a systematic review. Int. J. Environ. Res. Public Health 18 (18), 9725.
Financial Conduct Authority (FCA), 2017. Understanding the Financial Lives of UK Adults: Findings from the FCA's Financial Lives Survey 2017. FCA, London, United Kingdom.
Financial Conduct Authority (FCA), 2021. Financial Lives 2020 Survey: The Impact of Coronavirus. FCA, London, United Kingdom.
Financial Conduct Authority (FCA), 2022. Financial Lives 2022 Survey: Insights on Vulnerability and Financial Resilience Relevant to the Rising Cost of Living. FCA, London, United Kingdom.
Fuchs, V.R., 2004. Reflections on the socio-economic correlates of health. J. Health Econ. 23 (4), 653–661.
Gilbertson, J., Stevens, M., Stiell, B., Thorogood, N., 2006. Home is where the hearth is: Grant recipients' views of England's home energy efficiency scheme (warm front). Soc. Sci. Med. 63, 946–956.
Gilbertson, J., Grimsley, M., Green, G., 2012. Psychosocial routes from housing investment to health: evidence from England's home energy efficiency scheme. Energy Policy 49, 122–133.
Goldberg, D.P., Gater, R., Sartorius, N., Ustun, T., Piccinelli, M., Gureje, O., et al., 1997. The validity of two versions of the GHQ in the WHO study of mental illness in general health care. Psychol. Med. 27 (01), 191–197.
Grey, C.N.B., Schmieder-Gaite, T., Jiang, S., Nascimento, C., Poortinga, W., 2017. Cold homes, fuel poverty and energy efficiency improvements: a longitudinal focus group approach. Indoor Built Environ. 26, 902–913.
Guan, Y., Yan, J., Shan, Y., et al., 2023. Burden of the global energy price crisis on households. Nat. Energy 8, 304–316.
Gupta, R., Bruce-Konuah, A., Howard, A., 2019. Achieving energy resilience through smart storage of solar electricity at dwelling and community level. Energ. Build. 195, 1–15.
Handa, S., Pereira, A., Holmqvist, G., 2023. The rapid decline of happiness: exploring life satisfaction among young people across the world. Appl. Res. Qual. Life 18, 1549–1579.
Hansard, 2023. Energy Social Tariffs. Volume 741: debated on Thursday 23 November 2023. https://hansard.parliament.uk/Commons/2023-11-23/debates/EC36E16E-A09D-42C1-A3C5-88C30FAC2A0D/EnergySocialTariffs accessed 5th December 2023.
Harrington, B.E., Heyman, B., Merleau-Ponty, N., Stockton, H., Ritchie, N., Heyman, A., 2005. Keeping warm and staying well: findings from the qualitative arm of the warm homes project. Health Soc. Care Commun. 13 (3), 259–267.
Hasselqvist, H., Renström, S., Strömberg, H., Håkansson, M., 2022. Household energy resilience: shifting perspectives to reveal opportunities for renewable energy futures in affluent contexts. Energy Res. Soc. Sci. 88, 102498.
Hills, J., 2011. Fuel poverty: the problem and its measurement. In: Centre for Analysis of Social Exclusion, CASE Report 69: London, United Kingdom.
Hills, J., 2012. Getting the measure of fuel poverty: Final report of the fuel poverty review. In: Centre for Analysis of Social Exclusion, CASE Report 72: London, United Kingdom.
HM Government, 2022. The Autumn Statement. HM Government, London, United Kingdom.
HM Government, 2023. Poverty in the UK: Statistics. HM Government, London, United Kingdom.
International Energy Agency (IEA), 2022a. Global energy crisis. IEA, Paris, France.
International Energy Agency (IEA), 2022b. Electricity Market Report. IEA, Paris, France.
Johnson, R.C., 2010. The health returns of education policies from preschool to high school and beyond. Am. Econ. Rev. 100, 188–194.
Jones, M., 2016. Disability and Labor Market Outcomes. IZA World of Labor, p. 253.
Jylhä, M., 2009. What is self-rated health and why does it predict mortality? Towards a unified conceptual model. Soc. Sci. Med. 69 (3), 307–316.
Kahouli, S., 2020. An economic approach to the study of the relationship between housing hazards and health: the case of residential fuel poverty in France. Energy Econ. 85.
Llorca, M., Rodriguez-Alvarez, A., Jamasb, T., 2020. Objective vs. subjective fuel poverty and self-assessed health. Energy Econ. 87, 104736.
Luhmann, M., Specht, J., 2017. The development of subjective well-being. In: Personality development across the lifespan, pp. 197–218.
Marmot Review Team, 2011. The health impacts of cold homes and fuel poverty. In: Friends of the Earth and the Marmot Review Team.
Marmot Review Team, 2022. Fuel Poverty, Cold Homes and Health Inequalities. Institute of Health Equity, London.
Middlemiss, L., 2022. Who is vulnerable to energy poverty in the global north, and what is their experience? WIREs Energy Environ. 11 (6), e455.
Munyanyi, M.E., Mintah, K., Baako, K.T., 2021. Energy-related deprivation and housing tenure transitions. Energy Econ. 98.
National Energy Action (NEA), 2022. Solving the Cost of Living Crisis: The Case for a New Social Tariff in the Energy Market. NEA, Newcastle-Upon-Tyne, United Kingdom.
Office for Gas and Electricity Markets (Ofgem), 2021. Energy Network Indicators. Ofgem, London, United Kingdom.
Office for Gas and Electricity Markets (Ofgem), 2023a. Wholesale Market Indicators. Ofgem, London, United Kingdom.
Office for Gas and Electricity Markets (Ofgem), 2023b. Ofgem Opens Up Conversation on Energy Standing Charges, Ahead of Winter. Ofgem, London, United Kingdom.
Office for National Statistics (ONS), 2023. RPI All Items Index Jan 1987=100 [Online]. Available at: https://www.ons.gov.uk/economy/inflationandpriceindices/timeseries/chaw/mm23.
Oster, E., 2019. Unobservable selection and coefficient stability: theory and evidence. J. Bus. Econ. Stat. 37, 187–204.
Powdthavee, N., Van Den Berg, B., 2011. Putting different price tags on the same health condition: re-evaluating the well-being valuation approach. J. Health Econ. 30 (5), 1032–1043.
Public Health England, 2014. Minimum Home Temperature Thresholds for Health in Winter: A Systematic Literature Review. PHE, London, United Kingdom.
Pudney, S.E., Skew, A., Taylor, M.P., 2011. The Economic Impacts of Leaving Employment for Health-Related Reasons. University of Essex, Institute for Social and Economic Research Technical Report.
Ray, M., King, M., Carnahan, H., 2019. A review of cold exposure and manual performance: implications for safety, training and performance. Saf. Sci. 115, 1–11.
Roege, P.E., Collier, Z.A., Mancillas, J., McDonagh, J.A., Linkov, I., 2014. Metrics for energy resilience. Energy Policy 72, 249–256.
Thomson, H., Petticrew, M., Morrison, D., 2001. Health effects of housing improvement: systematic review of intervention studies. Br. Med. J. 323, 187–190.
University of Essex, Institute for Social and Economic Research, 2022. Understanding Society: Waves 1–12, 2009–2021 and Harmonised BHPS: Waves 1–18, 1991–2009. [data collection]. 17th Edition. UK Data Service. SN: 6614. https://doi.org/10.5255/UKDA-SN-6614-16.