Energy Research & Social Science 36 (2018) 79–93

Contents lists available at ScienceDirect

Energy Research & Social Science

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

Original research article

'Getting the measure of fuel poverty': The geography of fuel poverty indicators in England

Caitlin Robinson*, Stefan Bouzarovski, Sarah Lindley

Department of Geography, School of Education, Environment and Development, The University of Manchester, United Kingdom

ARTICLE INFO

Keywords:
Fuel poverty
Vulnerability
Indicators
Spatial analysis

ABSTRACT

Recognition of the negative impacts of fuel poverty, a lack of sufficient energy services in the home, has generated considerable interest in how the phenomenon can best be measured. Subsequently, the most well-known indicators deployed in policy-making, the established 10% indicator and the recent Low Income High Cost (LIHC) indicator, have generated considerable discussion and critique. One facet of the debate that remains unexplored is the effect of a change in indicator upon the spatial distribution of fuel poverty. Using spatial analyses we interrogate sub-regional estimates of the two indicators in England, where the LIHC indicator was first conceived. Three principle findings are discussed, enhancing understanding of the geographic features of fuel poverty as understood by each indicator. Firstly, the reduction in fuel poor households has disproportionately affected areas with lower housing costs. Secondly, there is a higher prevalence of fuel poverty in urban areas. Finally, the condition is more spatially heterogeneous with fewer 'hot-spots' and 'cold-spots'. As a result, each indicator captures different notions of what it means to be fuel poor, representing particular vulnerabilities, losses of wellbeing and injustices. This has implications for the targeting of limited alleviation resources and for alternative national contexts where the LIHC indicator might be deployed.

1. Introduction

In industrialised nations, interest in fuel poverty commonly stems from a concern about excess winter deaths and poor health due to cold homes [1]. In defining fuel poverty, emphasis has traditionally been placed on affordability, focusing upon the drivers of low incomes, domestic energy inefficiency and high energy prices [2]. This approach is often reflected in policy-making [3]. However, during the past three decades a burgeoning research agenda has become apparent, primarily within the social sciences, that draws attention to the multi-dimensionality of the phenomenon [4]. Here, fuel poverty is more broadly defined as an inability to attain the socially and materially necessitated domestic energy services that ensure the wellbeing of a household, allowing them to participate meaningfully in society [5]. Within this agenda, a stronger emphasis has been placed upon the considerable geographic component that influences whether a household is likely to fall into fuel poverty [6–8]. This reflects how fuel poverty varies between different locales, due to the uneven, and often distinctive, spatial distributions of contributing factors [6].

To date, interest in the geographical components of fuel poverty has rarely translated into national scale policy-making, with the exception of Northern Ireland (NI) where progress has been made in area-based targeting of fuel poor households [9]. This reflects a wider erosion of spatial policy-making over the last decade [10]. Instead, in the few geographic contexts in which the incidence of fuel poverty is measured, expenditure-based indicators are relied upon to provide a national estimate of households, with little attention given to the localised geographies of fuel poverty they succeed in creating [11,9].

Measurement of fuel poverty is perhaps most developed in England, where a review by Professor John Hills, 'Getting the measure of fuel poverty', has triggered the replacement of the former 10% indicator with a Low Income High Cost (LIHC) indicator [3]. Although not yet implemented elsewhere, the LIHC indicator has attracted considerable attention within different national contexts [12,7,13,14]. Valuable academic literature has explored the implications of the change in the measurement approach for the economic [15–17], social [15–18] and political [18] cleavages of the fuel poverty debate, however, the spatial dimension of the change has been overlooked.

The aim of this paper is to understand how the spatial distribution of fuel poverty using a LIHC indicator compares to that of the former 10%

Abbreviations: AHC, After Housing Costs; BEIS, Department for Business, Energy and Industrial Strategy; BHC, Before Housing Costs; DECC, Department for Energy and Climate Change; LA, local authority; LIHC, Low Income High Cost; LISA, Local Indicator of Spatial Association

* Corresponding author at: Quad D, Floor 1, Arthur Lewis Building, The University of Manchester, M13 9PL, United Kingdom.
E-mail address: caitlin.robinson@manchester.ac.uk (C. Robinson).

http://dx.doi.org/10.1016/j.erss.2017.09.035
Received 3 April 2017; Received in revised form 3 August 2017; Accepted 22 September 2017
Available online 09 November 2017

indicator, focusing upon England as a case study. In highlighting the difference in the geographic characteristics of fuel poverty as understood by each indicator, we provide insight into the way in which particular geographies are prioritised depending upon the measurement approach adopted. If, as is the case in England, these indicators are used to find the fuel poor and inform the targeting of alleviation measures, our findings offer further understanding of which households are most likely to benefit from the resources available. This is of considerable importance in an arena in which alleviation resources are often insubstantial given the scale of the problem [19]. Whilst the analysis focuses upon England, our results have wider implications for alternative national contexts in which the indicator might be deployed. More broadly, in achieving this aim we are concerned with the extent to which the increasing engagement of geographers and spatially-concerned scientists with energy studies has infiltrated into the governance of energy challenges, specifically fuel poverty.

The paper is structured as follows. In section two, we summarise findings from wider research concerning the spatial characteristics of fuel poverty before discussing in section three the concepts of socio-spatial vulnerability and justice that are increasingly mobilised. In section four, the 10% and LIHC fuel poverty indicators are outlined. The methods used to explore the spatial distribution of fuel poverty using each indicator are explained in section five, including various spatial statistics and cluster analyses. In section six, we discuss the results of these analyses, identifying key differences in the geographic characteristics of fuel poverty as understood by each indicator. The final section, section seven, offers conclusions and implications for policy. These policy implications are twofold. Firstly we consider the implications for policymakers using the LIHC indicator to find the fuel poor. Secondly, we reflect upon whether the use of either indicator alone is sufficient given the different geographies of fuel poverty that each prioritises.

2. The spatial characteristics of fuel poverty

Individuals and households move in and out of fuel poverty, whether due to a fluctuating need for energy seasonally, an unexpected bill or a change in circumstance. There are also households that find themselves trapped in persistent fuel poverty [20]. In spite of these temporal fluctuations, there are still underlying characteristics that enhance the likelihood of these households experiencing fuel poverty that have uneven spatial distributions. This includes spatially-based attributes that are directly coupled with geography, such as the material and infrastructural characterisation of an area, and those that lend their collective attribute to the space as a result of aggregation, for example, demographic characteristics [21].

Interest in the spatial distribution of fuel poverty ranges from a recognition that the condition is 'locally contingent' upon different national contexts ([77]: 282), to acknowledgment of the 'local realities' of fuel poverty within different neighbourhoods and households ([9]: 9). In quantifying fuel poverty across the European Union, Thomson and Snell [22] highlight its high prevalence in Southern Europe due to low thermal efficiency standards, despite a relatively mild climate. A high prevalence of fuel poverty in Eastern Europe is also recognised where post-socialist neoliberal reforms of economic and legal systems have led to energy price increases and reduced social welfare [5]. At a national-scale, Rudge [23] documents the difference between the British experience of fuel poverty and that of the rest of Europe, due primarily to the changeable climate and the historical legacy of poor quality housing. Even within the United Kingdom (UK) there exist significant disparities between the devolved nations (England, NI, Scotland and Wales) with a high prevalence outside England. For example, the cost of heating and lighting is greater in NI due to the colder climate and reliance on oil-fired heating [16]. Spatial variations also exist regionally in energy prices and exposure to particular climatic conditions [24].

At a more localised scale, the likelihood of experiencing fuel poverty varies between different household types and demographics and therefore also geographically, as households with similar characteristics tend to cluster in particular locales [7]. Varying characteristics mean that households require different levels of consumption and expenditure to achieve the same levels of comfort and wellbeing, characteristics that include age, income, employment, composition, health and ethnicity. For example, households with young children, pensioners or a member with a disability or long-term illness all have enhanced vulnerability due to an increased physiological need for energy services, amongst other factors [25–27]. In the UK, families with young children are more likely to live in urban or suburban areas, those with a disability or long-term illness are concentrated in urban areas or coastal communities and pensioners are more likely to live in rural and coastal communities [28].

It is also common within fuel poverty research for a distinction to be made between rural and urban areas [29,20]. Urban and rural households are embedded in differing wider systems of infrastructural provision and institutional arrangements [30,31]. Within these broad rural and urban typologies fragmentation of power networks has occurred and enclaves of well-connected consumers exist [31]. The radical economic liberalisation of infrastructure and markets in the energy sector since the 1980s has allowed for the 'unbundling' of infrastructures relating to energy transmission and for the 'bypassing' of less valued or powerful consumers and places. In cities, this has entrenched inequalities between those that are networked and connected, and those who are not. This inequality is often symbolised by the pre-payment meter, a means of paying for energy services that requires credit in advance, often used in low income households more likely to accrue debt [31,32]. In rural areas that are expensive to supply, cross-subsidies from more lucrative urban areas have been dismantled resulting in reliance upon expensive fuel types (primarily oil) in isolated households not connected to the gas network [31]. This lack of access to cheaper fuels also extends to flats in high density urban areas [20]. In addition to networked infrastructure, the housing stock, a complex arrangement of materials and technologies of varying efficiency, also varies spatially. Inner-city areas are often characterised by inefficient pre-1917 terraced housing [23] whilst rural areas tend to be associated with older, solid wall properties [20]. Urban neighbourhoods also have a disproportionate number of inefficient properties in the private rented sector in which tenants lack housing rights [33] and access to retrofitting schemes [34]. In rural areas there is a higher concentration of under-occupancy leaving some smaller households in disproportionately large properties that require excessive heating to maintain adequate warmth [35].

Austerity policies implemented by governments across Europe and the United States, particularly in the wake of the Financial Crisis in 2008, have led to geographically concentrated cuts to welfare, cuts that can enhance the likelihood of households experiencing fuel poverty. For example, in England, the erosion of incomes, local services and infrastructure provision has disproportionately impacted less prosperous local authorities (LA) that have a high reliance upon welfare, many of which are former industrial or mining areas [36]. From 2009 to 2016 the most deprived tenth of LA experienced spending cuts of 28% per capita compared to the least deprived tenth that cut spending by just 16% [37].

3. Socio-spatial vulnerability and justice

Much of the recent focus upon the spatial characteristics of fuel poverty has stemmed from literature that mobilises the concept of social vulnerability [6,38,4] and increasingly justice [7,39]. Each concept highlights the uneven spatial distribution of factors known to enhance the likelihood of a household falling into fuel poverty.

Social vulnerability can be understood as the degree of susceptibility within a household to a stress that is not sufficiently

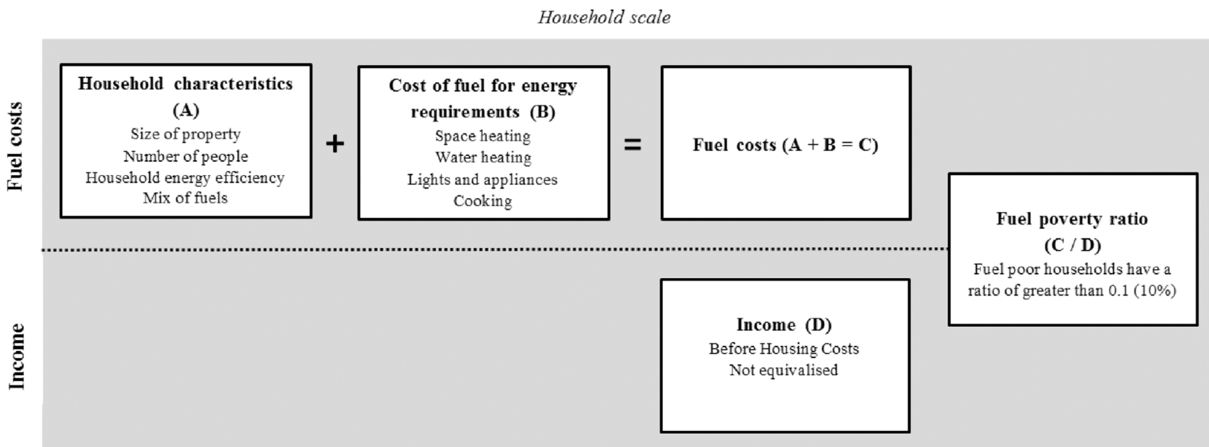

Fig. 1. Summary of 10% fuel poverty indicator.

counterbalanced by their capacity to resist the negative impacts associated, and to maintain their well-being [40]. The concept draws attention to a range of personal, social, cultural, material, technical and political characteristics, to understand the likelihood of a household experiencing these negative outcomes [41]. Social vulnerability is spatially variable, with particular vulnerabilities manifesting in certain locations. Thus, when combined with 'aspects of place' ([42]: 7), socio-spatial vulnerability results is a geographical expression of the likelihood of a loss of wellbeing in the household. Specifically concerning vulnerability to fuel poverty, Bouzarovski and Petrova [6] recognise the uneven spatial distribution of a range of dimensions that increase the likelihood of a household being unable to access sufficient energy services: affordability, access, energy efficiency, needs, the flexibility to meet these needs, and energy-related practices. Middlemiss and Gillard [4] also identify six vulnerability challenges derived from a bottom up approach: quality of dwelling fabric, energy costs and supply issues, stability of household income, tenancy relations, social relations and ill health.

In addition, justice debates are increasingly central to discussions of fuel poverty [43,38,44,39] as the phenomenon can be considered to threaten 'modern notions of equity, justice and fairness' ([44]: 362). Walker and Day [39] offer a framework that challenges existing, normative conceptualisations of what renders a household fuel poor using three interconnected justice concepts: distribution, recognition and procedure. The framework confronts the 'institutionalised exclusion, social culture of misrecognition and current distribution patterns' ([45]: 518) associated with fuel poverty. Increasingly, research that mobilises a justice framing recognises the importance of spatial differences in the material and socio-economic inequalities that give rise to fuel poverty [11]. For example, Walker et al. [46] explores the unequal distribution of energy efficiency measures across NI using a justice framework.

Despite this interest in the spatial characteristics of fuel poverty, the measurement of the phenomenon that underpins the limited examples of national fuel poverty policy relies primarily upon expenditure-based indicators and national-scale estimates of fuel poor households. Little attention has been given to the localised geographies of fuel poverty as understood by these indicators.

4. Measuring and monitoring fuel poverty

A handful of countries make a significant effort to define and measure fuel poverty (primarily the UK, Ireland and France) and where measurements exist they tend to be expenditure-based. Definition and measurement of the phenomenon is perhaps most developed in the UK where fuel poverty has received considerable political attention for several decades [2]. A recent review of the measurement of fuel poverty by Hills [3] recommended that the former 10% indicator, the most widely accepted indicator of fuel poverty, be replaced by a LIHC indicator [3]. Currently, each devolved administration in the UK is individually responsible for the measurement of fuel poverty and only England has adopted the LIHC indicator in the wake of the review. However, the Scottish Fuel Poverty Strategic Working Group discusses the indicator as part of recommendations that will lead to a new definition and statutory target for fuel poverty [47]. Additionally, researchers have engaged with the LIHC indicator in various national contexts in which there is considerable overlap with the UK in terms of the drivers of fuel poverty. This includes Poland [12], France [13], the Czech Republic, [7] and Hungary [7].

The spatial analysis within this paper focuses upon the distribution of fuel poverty using the indicators in England, given that this is the only national context in which the LIHC indicator currently informs policy-making [3]. In England, the measurement and alleviation of fuel poverty is the responsibility of the recently created Department for Business, Energy and Industrial Strategy (BEIS), formerly the Department for Energy and Climate Change (DECC). Here, the 10% and LIHC indicator use the same definition from the Warm Homes and Energy Conservation Act (2000) defining a person in fuel poverty as living on a lower income in a home which cannot be kept warm at reasonable cost.

Using the 10% indicator, members of a household are fuel poor if 'they are required to spend more than 10% of their income to maintain an adequate standard of warmth' ([48]: 8) (Fig. 1). The indicator uses a ratio of modelled fuel costs and a Before Housing Costs (BHC) measure of income. Modelled fuel costs are derived from energy price and a modelled consumption figure that includes data about property size, the number of people in the household, the property's energy efficiency and the fuel mix. Fuel poor households are those with a ratio of greater than 1:10 (10%).

The 10% indicator is an absolute measure of fuel poverty and has been challenged as it does not respond to variations in income or energy efficiency improvements [15], thus exaggerating the impact of the considerable fuel prices rises in recent years [17]. Hills suggests that 'flaws in the [10% indicator] have distorted policy choices, [and] misrepresented the problem' (). As a result, relatively well-off households in inefficient properties are identified as fuel poor [49] and the number of fuel poor households changes rapidly [15].

The LIHC indicator that has subsequently been introduced is calculated using a combination of a national income threshold and fuel cost threshold [48,3]. A household is fuel poor if it exceeds both thresholds (Fig. 2). The fuel cost threshold is a weighted median of the fuel costs of all households, equivalised according to the number of people in a property. This average fuel cost value for the different household size categories is the assumed cost of achieving an adequate level of comfort in each case. The threshold is the same for all households of equivalent size, with half exceeding the fuel cost threshold and

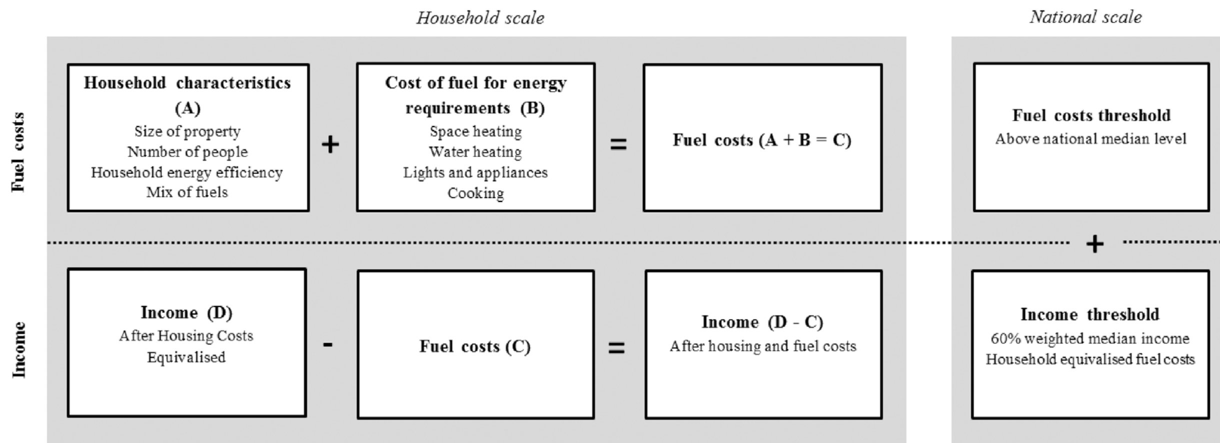

Fig. 2. Summary of LIHC fuel poverty indicator.

therefore being considered 'high cost'. The income threshold is calculated as 60% of the weighted national median for income After Housing Costs (AHC) are accounted for; the government definition of relative poverty. The income figure for each household is also equivalised to account for the number of people in the household. This figure is combined with the equivalised fuel costs of the household. The income threshold is therefore higher for those that require a greater level of income to meet larger fuel bills.

The LIHC indicator has also been the subject of critique. The indicator uses a measure of those who earn 60% of median income to define poverty in combination with median fuel costs (rather than 60% of median fuel costs) [15]. This approach excludes some low-income, single person households [49,46]. Moore [17] considers the LIHC indicator to obscure increases in energy price, as its introduction has led to a fall in fuel poor households, in spite of considerable increases in energy prices during the same period. This significant reduction in fuel poverty has been described by some as an attempt to move the goalposts in order to justify missing targets for the eradication of fuel poverty, that was a target in all households by 2016 [38]. Middlemiss [18] identifies that the LIHC indicator prioritises energy efficiency as a solution to fuel povertydistracting from other drivers, such as the wider failure of the energy market to provide an affordable, and appropriate energy supply to homes. Whilst considering the LIHC indicator an improvement upon the 10% indicator, Koh et al. regards it as 'highly economic and technological indicator' ([50]: 7).

Fahmy et al. recognise that the 'spatial distribution of fuel poverty [also] varies considerably depending upon the specific definition and measurement approach adopted' ([51]: 4371) leading to the over and under-estimation of fuel poverty [16]. To date, there is no evidence pertaining to how the geography of fuel poverty differs using the new LIHC indicator compared to the former 10% indicator. Seemingly the interest in the spatial distribution of fuel poverty within wider research is somewhat divorced from government efforts to measure fuel poverty. To fill this research gap we use quantitative, geospatial analyses that, in comparison to a qualitative approach, allow for comparison of the spatial distribution of fuel poverty according to different indicators nationally, regionally and at the neighbourhood scale.

5. Methods

5.1. Datasets

To explore the spatial distribution of fuel poverty indicators in England, our analysis utilises quantitative data at the scale of the Region and the Lower Super Output Area (LSOA). In England there are 9 regions that represent the highest tier of sub-national division. For the reporting of small area statistics there are 32,844 LSOAs that represent 1000–3000 individuals, or 400–1200 households [52]. In adopting our methodological approach we acknowledge the issue of ecological fallacy, representing populations using aggregated data that can conceal considerable socio-spatial variations in the incidence of fuel poverty within each neighbourhood. This is a particularly pertinent issue given the concern of the analysis with differing representations of the multidimensional condition of fuel poverty by different indicators. However, LSOA scale is considered appropriate as this is the highest resolution at which the dataset is available, and the scale at which the government propose to target the fuel poor in this national context [53].

Two sub-regional datasets are used, estimates of fuel poverty produced by the former government DECC and the urban-rural classification produced by Defra.

For 2012, the year in which the LIHC indicator was introduced, sub-regional fuel poverty estimates at the LSOA scale are available for the 10% and LIHC indicators [54]. The estimates are based upon national data from the English Housing Survey [53]. These datasets are not considered robust at very low level geographies and it is recommended that they be used to highlight general patterns in the spatial distribution of fuel poverty but not to identify individual LSOA with a particularly high percentage of fuel poor households [53]. For reference, estimates of the percentage of fuel poor households for both indicators are mapped in Figs. 3 and 4. A relative scale is used, deciles, providing a means of comparing how the percentage of households that are considered fuel poor in each LSOA varies across England. It is therefore possible to rank each LSOA relative to others with regards to the percentage of fuel poor households according to each indicator, e.g. LSOA in the top or bottom 10%. In both cases the LSOA in the top decile exhibit a large range in the proportion of households experiencing fuel poverty.

In addition to the fuel poverty estimates, a Urban-Rural Classification dataset from 2011, that distinguishes between rural and urban areas, provides insight into the geographical features associated with the fuel poverty indicators [55] (Fig. 5). The classification defines rural areas as those outside settlements with more than 10,000 residents [56]. Each LSOA is assigned to one of eight settlement types (Table 1).

5.2. Geospatial methods

Various statistical and geospatial techniques explore the relationship between the 10% and LIHC sub-regional fuel poverty estimates and the urban-rural classification dataset. The fuel poverty estimates are also overlaid to investigate the difference between the two. These analyses are carried out using the Statistical Package for Social Science and the outputs mapped using ArcGIS 10.2.

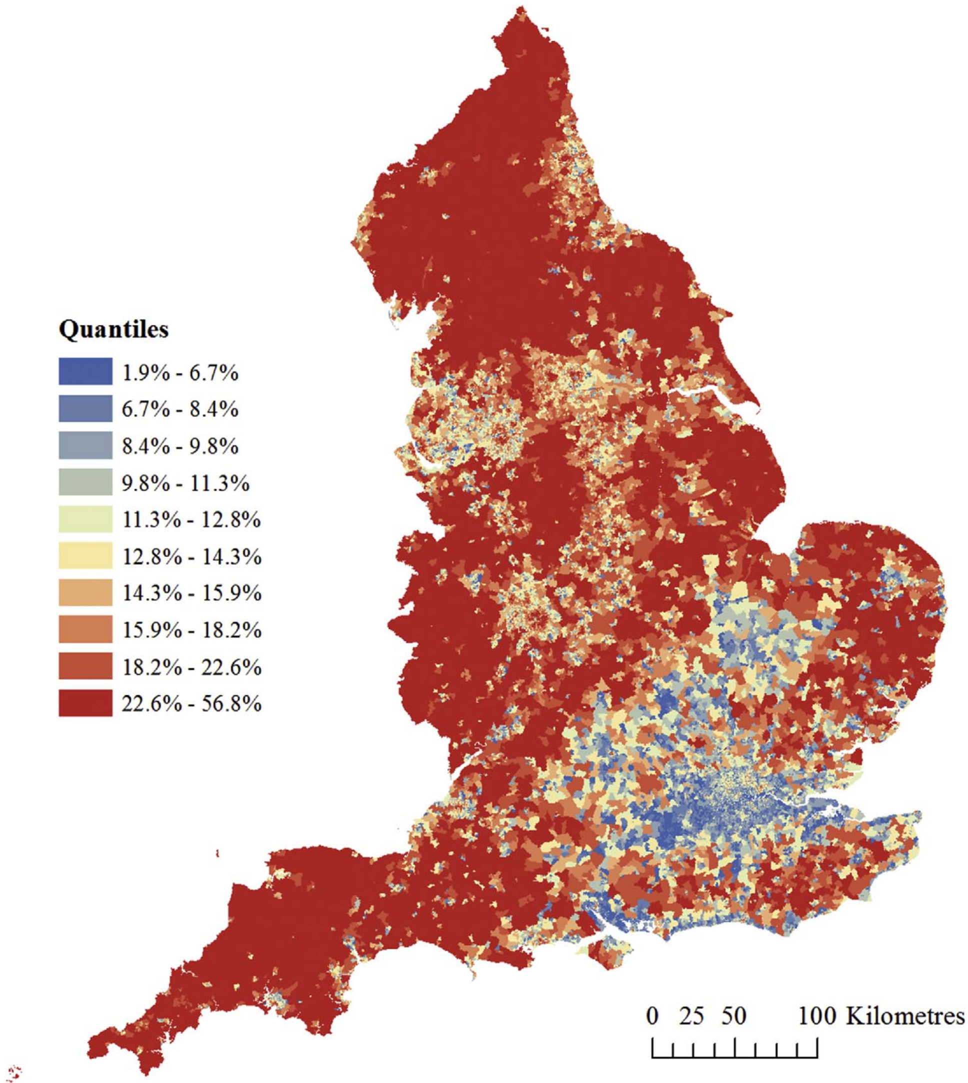

Fig. 3. Relative percentage of fuel poor households using 10% indicator for LSOA.
Data source: DECC [54], ONS [52].

In addition, a Local Indicator of Spatial Association (LISA) a type of cluster analysis identifies local patterns of association, reflecting a tendency for nearby locations to cluster together [57]. Examples of the successful application of cluster analyses exist in the fields of social vulnerability [58] and energy geographies [59]. The cluster analysis is particularly useful given the recommendation not to identify individual LSOA as having a high percentage of fuel poor households.

The LISA uses LSOA population-weighted centroids, a single reference point within each area that represents the spatial distribution of the population [60]. Using a Local Moran's I statistic, clusters of population weighted centroids that have high (hot spots) or low (cold spots) values are identified [57], in this instance clusters of LSOA with a high or low percentage of fuel poor households (Table 2). The analysis also allows for identification of outliers, where a high value is surrounded by low values or vice versa. These clusters and outliers are statistically significant for a 95% confidence level. A spatial weights matrix conceptualises the spatial relationship for the cluster analysis using a distance feature of K nearest neighbours, setting the number of neighbours to 8 [61]. This is due to the varied spatial distribution of LSOA across England. LSOA in urban areas tend to be smaller, thus the scale of analysis is more important than fixing a number of neighbours.

6. The spatial distribution of fuel poverty indicators in England

The results show three spatial patterns associated with the shift from a 10% indicator to a LIHC indicator in England: a spatially-concentrated reduction in the fuel poor, a higher prevalence of fuel poverty in urban areas and a more spatially heterogeneous fuel poor. These are explored further in the following analysis.

6.1. Low Income, High Cost: A spatially-concentrated reduction in the fuel poor

The introduction of a LIHC indicator has resulted in a considerable reduction in fuel poverty with 771,014 fewer households considered fuel poor compared to the former 10% indicator [54]. This represents a difference of 13.79% of households experiencing fuel poverty using the 10% indicator compared to 10.49% of households using the LIHC indicator. However, this national statistic hides spatial variations in the reduction in fuel poverty. Relative reductions have been experienced more acutely in particular regions and neighbourhoods, whilst some locations have experienced an increase in fuel poverty, despite a reduction nationally. As it is not appropriate to use LSOA scale fuel poverty estimates to identify individual fuel poor LSOA, regional estimates are analysed.

The introduction of the LIHC indicator has had significant implications for the concentration of fuel poor households across different regions (Table 3). Using the 10% indicator, the East Midlands (17.8%), North East (17.8%) and Yorkshire and The Humber (17.4%) have the highest percentage of fuel poor households. Using the LIHC indicator,

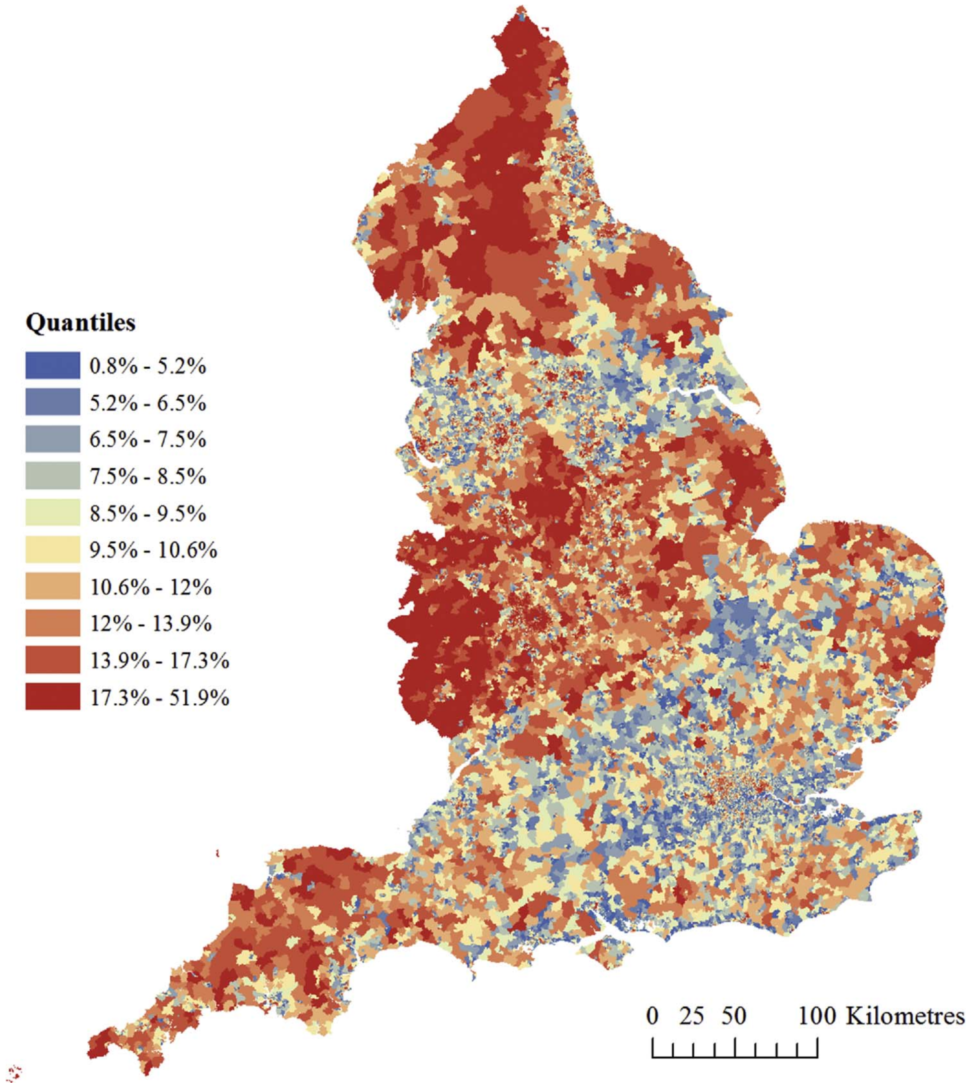

Fig. 4. Relative percentage of fuel poor households using LIHC indicator for LSOA.
Data sources: DECC [54], ONS [52].

the West Midlands has the highest percentage of fuel poor households (15.2%) followed by the East Midlands (13.2%). For both indicators, the region with the lowest percentage of fuel poor households is the South East, 8.9% for the 10% indicator and 7.8% for the LIHC indicator.

The difference in the percentage of fuel poor households (Fig. 6) between the two indicators is most significant in the South West region where 7% fewer households are fuel poor using the LIHC indicator compared to the 10% indicator. Meanwhile, the North East and Yorkshire and The Humber have also experienced significant reductions in fuel poor households, −6.1% and −6.4% respectively. The smallest reductions in fuel poor households are concentrated in London (−0.5%), the South East (−1.1%) and the West Midlands (−1.4%). This represents a transfer in relative fuel poverty towards these regions.

One likely explanation of the relative transfer of fuel poverty towards the South East and London is the difference in methods used to calculate income. The 10% indicator uses a BHC income measure that includes all housing costs, including rent and mortgage payments [48]. However, unlike the Households Below Average Income statistic that measures the percentage of people living in low-income households, the BHC income measure in the 10% indicator excludes certain benefit payments (Housing Benefit and Support for Mortgage Interest). Concerning income poverty, a BHC measure of income is often deemed most appropriate as it is argued that people who pay more for housing are likely to benefit from the increased standard of the accommodation [63]. However, when measuring fuel poverty, a BHC definition of income is less helpful as the phenomenon is dependent upon disposable income available after housing costs are met [17]. Subsequently, the LIHC indicator uses a measure of AHC income. Mortgage and rent payments are deducted from the full income of each household [3,48]. The understanding of income within the LIHC indicator demonstrates a concern with how much money a household has available to spend upon essential utility bills, food, transportation etc. after their housing costs are met, better reflecting the financial flexibility of a household.

There are considerable regional disparities in housing costs across England [64]. The housing market in London and the South East is distinct from much of the country, characterised by high demand for property, an acute need for housing and significant disparity in affordability between renting and home ownership [65]. Fig. 7 displays the ratio of house prices to earnings for each region in 2012 [64] demonstrating the considerable difference between London and the South East compared to other regions, in particular the North and the Midlands. London has a ratio of 8.6 compared to a ratio of 5.1 in the North East. By excluding housing costs from the measurement of income, the percentage of fuel poor households using the LIHC indicator is likely to be higher in areas with a higher house price to earnings ratio, explaining the transfer of relative fuel poverty to the South East and London. Whilst outside the scope of this paper, it is interesting to note that this spatial distribution could be enhanced significantly in future. This ratio increases to 11.3 for London in 2015 compared to the North East which has a value of 5.2.

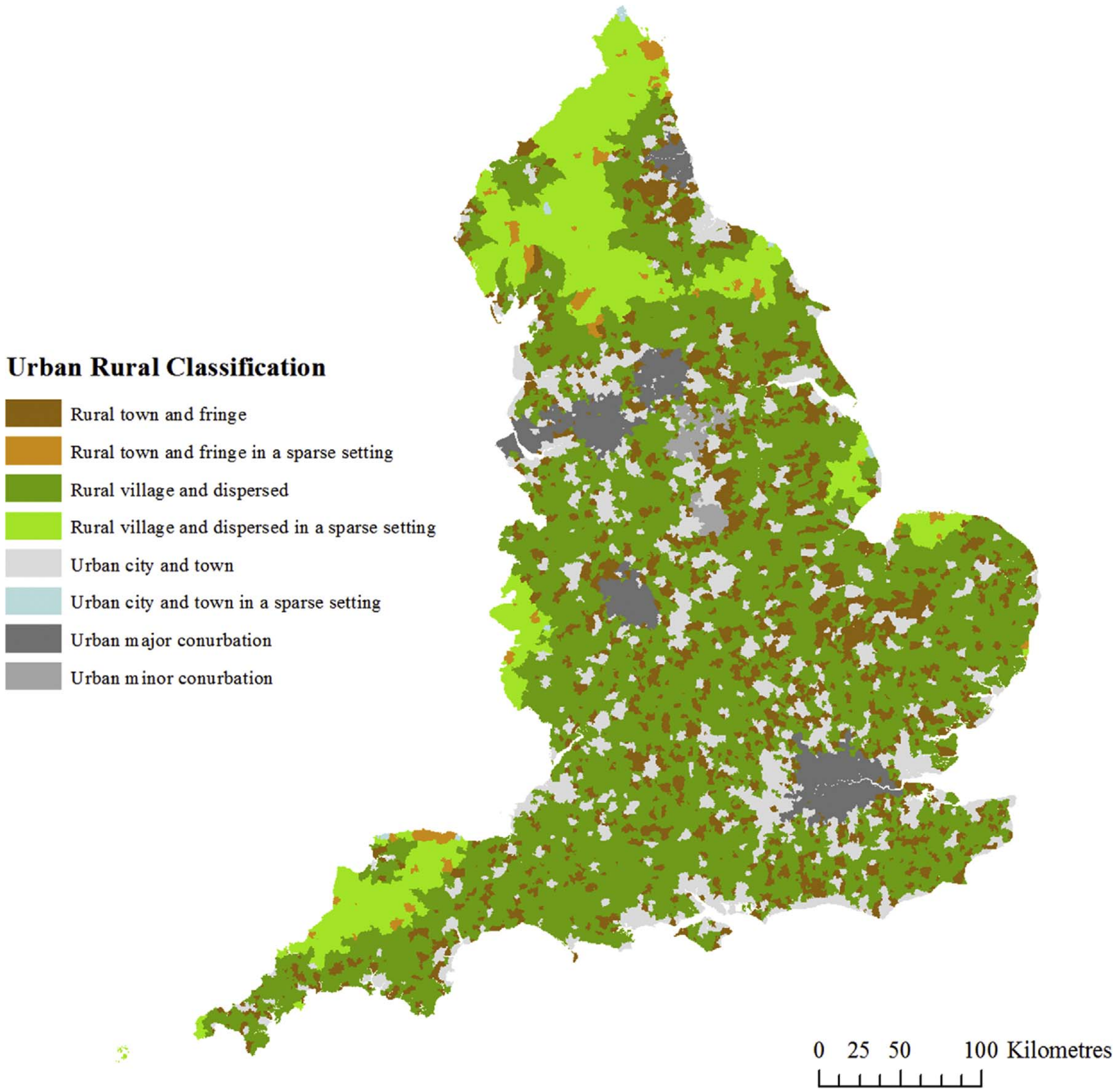

Fig. 5. Urban-Rural Classification for LSOA.
Data source: Defra [55], ONS [52].

Table 1
Distribution of LSOA between urban and rural classifications.
Data source: Bibby and Brindley [56]

Classification		Frequency (%)	LSOA (count)
Urban	Major conurbation	33.2%	11,523
Urban	Minor conurbation	3.5%	1208
Urban	City and town	45.3%	15,724
Urban	City and town in sparse setting	0.3%	94
Rural	Town and fringe	9.2%	3189
Rural	Town and fringe in sparse setting	0.6%	197
Rural	Village and dispersed	7.2%	2490
Rural	Village and dispersed in sparse setting	0.9%	328

Table 2
Typology of Local Moran's I clusters and outliers.

Feature	Description	Local Moran's I (z-score)
High–High Cluster	Cluster or 'hot spot' of high values due to the local association of LSOA with a high percentage of fuel poor households	> 0
High-Low Outlier	Outlier in which a high value is surrounded primarily by low values	< 0
Low High Outlier	Outlier in which a low value is surrounded by primarily high values	< 0
Low–Low Cluster	Cluster or 'cold' spot of low values due to the local association of LSOA with a low percentage of fuel poverty	> 0

Exploration of the differing income calculation methods does not explain some important spatial patterns that have been discussed. Firstly, the relative transfer of fuel poor households to the West Midlands. Secondly, the considerable reduction in fuel poor households in the South West, despite a relatively high house price to earnings ratio. These patterns are discussed in the following section that explores the higher prevalence of fuel poverty in urban areas using the LIHC indicator.

6.2. *Low Income, High Cost: An urban phenomenon*

Despite a considerable reduction in fuel poverty in England as a whole using the LIHC indicator, examination of the difference between urban and rural LSOAs reveals that this is primarily a reduction in rural fuel poverty (Figs. 8 and 9). Using the 10% indicator, rural areas are more likely to be fuel poor [66,67]. However, on average rural LSOA

Table 3
Regional breakdown of fuel poor households.
Data source: DECC [62]

Region	Households (count)	10% indicator (count)	10% indicator (%)	LIHC indicator (count)	LIHC indicator (%)	Difference (%)	Difference (count)
East of England	2394,681	278,142	11.6	206,319	8.6	−4.4	−89,186
East Midlands	1,935,410	345,203	17.8	256,017	13.2	−2.9	−71,823
London	3114,62	296,165	9.5	276,782	8.9	−0.46	−19,383
North East	1,109,018	197,889	17.8	128,971	11.6	−6.11	−68,918
North West	2,976,114	467,214	15.7	335,344	11.3	−4.34	−131,870
South East	3,552,475	315,568	8.9	276,860	7.8	−1.05	−38,708
South West	2335,218	384,853	16.5	217,210	9.3	−7	−167,643
West Midlands	2,242,988	373,783	16.7	340,226	15.2	−1.35	−33,557
Yorkshire	2,274,473	394,776	17.4	224,850	10.8	−6.4	−149,926

have experienced an 8.1% decrease in fuel poor households using the LIHC indicator. Meanwhile there has been no reduction on average of fuel poor households in urban LSOA.

This contrast is more considerable when broken down by Urban-Rural Classification type (Table 4). LSOA classified as *'Rural- Village or dispersed'* and '*Rural – Village or dispersed in sparse setting'* have experienced significant decreases in the percentage of fuel poor households relative to other classifications, −11.8% and −22% respectively. Meanwhile, '*Urban – Major Conurbation'* have experienced a relatively minor reduction in fuel poor households (−1.7%). The '*Urban – Minor Conurbation'* is the only classification to have an increase in fuel poor households using the LIHC indicator (+0.7%).

The disparity between urban and rural areas reflects the spatial concentration of reductions in fuel poverty using a LIHC indicator in particular regions (Section 6.1.) The relative increase in fuel poor households has been concentrated in cities in the West Midlands, the

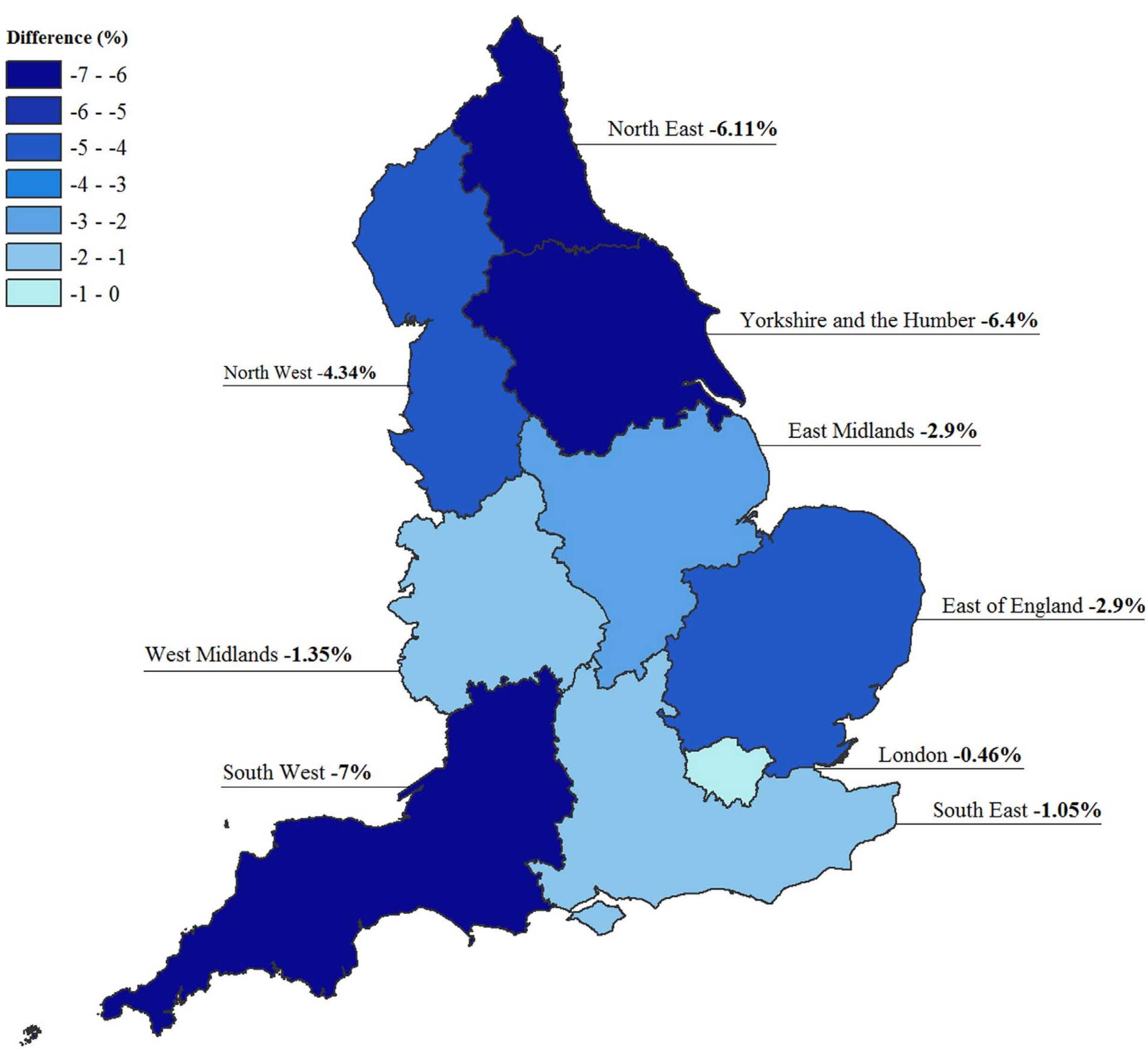

Fig. 6. Difference between the percentage fuel poor households using the 10% and LIHC indicators for regions.
Data source: DECC [54], ONS [52].

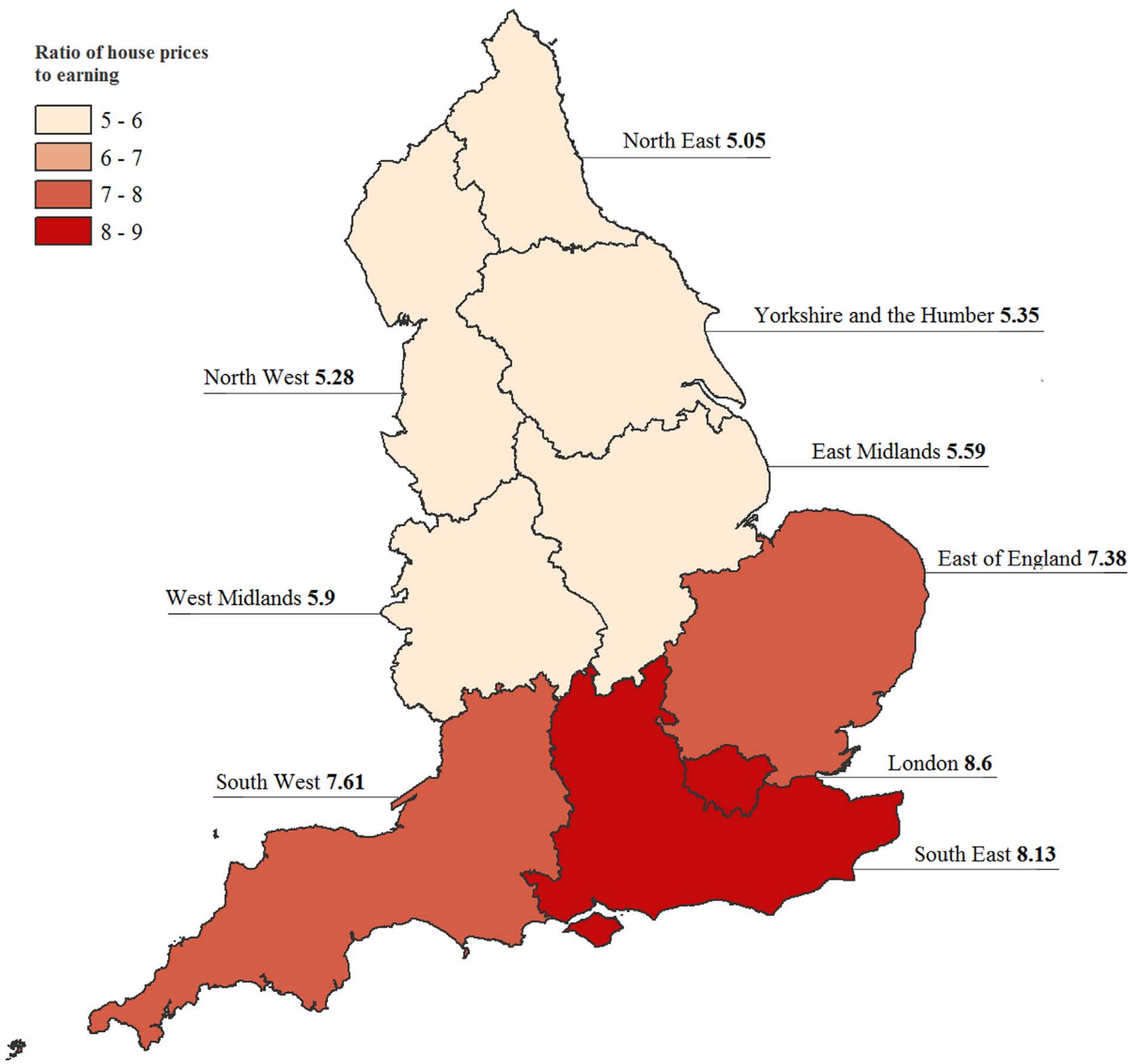

Fig. 7. Ratio of house prices to earnings for regions in 2012.
Data source: DCLG [64], ONS [52].

South East and London (Fig. 9). The decrease in fuel poor households has been concentrated in regions with a higher percentage of rural LSOA, including the South West. Relative to their rural counterparts, urban LSOA are higher density and tend to be more socially homogenous [68].

The transfer of relative fuel poverty from LSOA classified as rural to those classified as urban can be attributed in part to the indicator design and the emphasis placed upon particular drivers of fuel poverty. Using the 10% indicator, energy price is one of the main determinants of the incidence of fuel poverty. Analysis by Roberts et al. [20] of fuel poverty using the 10% indicator finds the rural fuel poor to be more vulnerable to energy price increases relative to their urban counterparts, attributed to a lack of access to a range of fuel types and inefficient housing stock. The 10% indicator is an absolute measure and uses a 10% threshold of income spent on fuel, over which a household is considered fuel poor [48]. As such, it exaggerates the impact of the considerable price rises that have occurred in recent years [17]. In contrast, using the relative LIHC indicator the percentage of fuel poor households has remained steady despite considerable increases in energy price [48]. Access to affordable energy supplies, and thus the driver of energy price, is a particularly significant vulnerability factor with regards to fuel poverty in off-the-grid rural areas that rely upon expensive fuel types [29,67,20]. The 10% indicator is therefore more likely than the LIHC indicator to represent these socio-spatial vulnerabilities. This partly explains the higher prevalence of fuel poor households in urban LSOA using the LIHC indicator compared to the 10% indicator.

The use of equivalisation also contributes to the relatively urban characterisation of fuel poverty using an LIHC indicator. Equivalisation adjusts household incomes based upon different demands for resources, considering household size and composition. The 10% indicator does not equivalise incomes, however, the LIHC indicator equivalises income and fuel costs. Thus, the LIHC indicator reflects how larger households require more energy and tend to have less disposable income than smaller households. As a result, the LIHC indicator is less likely than the 10% indicator to recognise households that are under-occupied as fuel poor [35,67] and is critiqued for under representing households that are smaller, particularly pensioners [17,46]. Data obtained from the latest Census (2011) that includes information about under-occupancy of households (with one or more spare bedrooms), suggests that under-occupancy is most common in owner-occupied homes that are prevalent in rural areas [69]. Those homes that are overcrowded (with one or more bedrooms too few) tend to have dependent children, or be

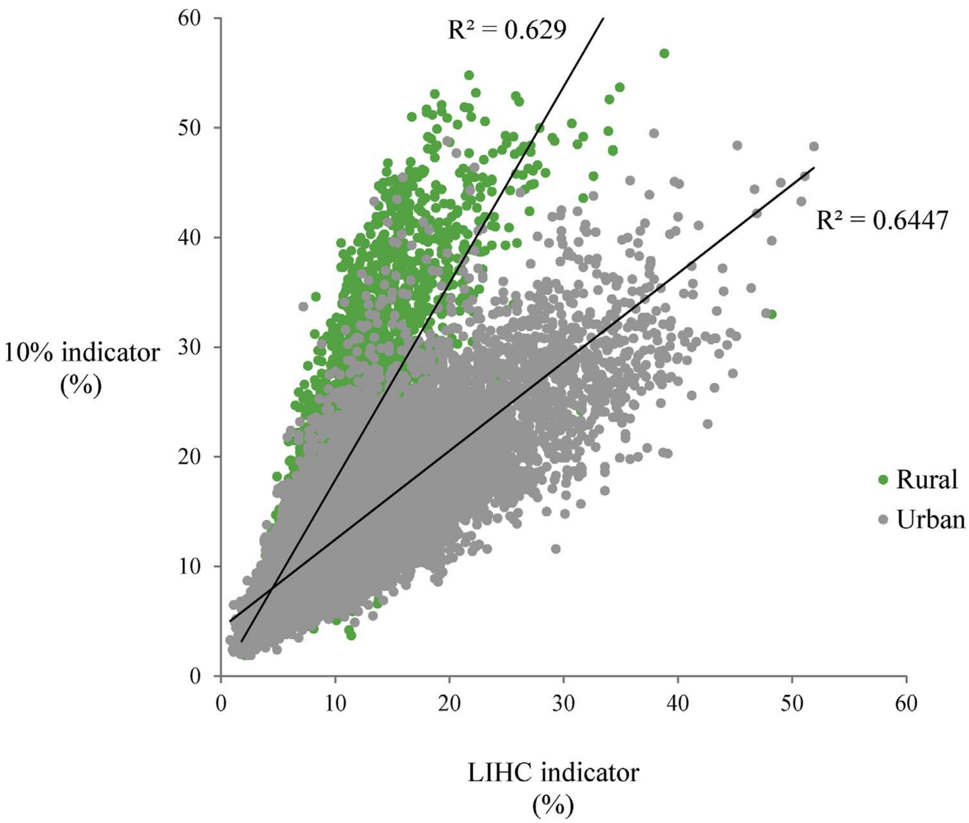

Fig. 8. Relationship between the percentage of fuel poor households using the 10% and LIHC indicators for rural and urban LSOA.
Data source: DECC [54], Defra [55].

privately or socially rented [70], demographics that are concentrated in urban areas in England [69]. Furthermore, this overcrowding of households is most common in London (11.3%) and the West Midlands (4.5%) [70], both regions that have a relatively higher prevalence of fuel poor households using a LIHC indicator compared to a 10% indicator.

In addition to equivalisation, the difference in the calculation of incomes regarding the inclusion of housing costs also contributes towards the relatively urban nature of fuel poverty using the LIHC indicator (explored further in Section 6.1). According to the English Housing Survey, households in London on average spend 25% of their income on housing costs, higher than other urban areas (19%) and rural areas (17%) [71].

6.3. Low income High cost: a spatially heterogeneous fuel poor

The outcomes of the LISA cluster analyses for each fuel poverty indicator are displayed in Table 5, Figs. 10 and 11. These figures demonstrate within which areas spatial clusters of LSOA with high or low percentages of fuel poor households are found, 'hot-spots' or 'cold-spots' of fuel poverty. They also help to identify which LSOA are not statistically significant using the cluster analysis, where there is considerable diversity in the incidence of fuel poverty between LSOA and thus local spatial association is not identified.

Using the 10% indicator cluster analysis (Fig. 10) there is a significant contrast between the regions of the South East and London and the rest of England (Section 6.1). Large numbers of LSOA form *low–low clusters*, with a statistically significant low percentage of fuel poor households (N = 4615). Only a handful of *low–low clusters* are found in the North, the Midlands and the South West, in the wealthier suburbs of major urban conurbations. By comparison, the South East, London and parts of the East of England are primarily *low–low clusters*. In fact, the region of London has only *low–low clusters*. For the 10% indicator there are high numbers of *high–high clusters* that have a statistically significant high percentage of fuel poor households (N = 3733). These *high–high clusters* are concentrated in the North, Midlands and South West in both cities and rural areas.

In contrast to that of the 10% indicator, the spatial distribution of the LIHC indicator has more diverse and spatially heterogeneous clusters of high and low fuel poverty (Fig. 11). Using the LIHC indicator there are large numbers of LSOA that form significant *high–high clusters* of fuel poor households, a similar number to the 10% indicator (N = 3680). Also similar is that many of the *high–high clusters* of fuel poor households are found in urban conurbations of the North, the Midlands, and swathes of the West Midlands, close to the Welsh Borders. However, the distinction between the South East and London, and the rest of England, is less stark. Whilst *low–low clusters* are still concentrated in these regions, there are fewer *low–low clusters* using the LIHC indicator compared to the 10% indicator (N = 2582). Several *high–high clusters* are found in the West and East of London. In large subsections of the LIHC indicator cluster analysis, no statistically significant clusters or outliers of LSOA are identified, for example, in the South West. This implies that there is negative spatial autocorrelation between the LSOA in these areas and therefore high spatial heterogeneity. Meanwhile, in larger city regions *low-high outliers* exist within *high–high clusters* of fuel poor households (and in the case of London *low–low clusters*). Thus in contrast to the 10% indicator, fuel poverty is more spatially heterogeneous using the LIHC indicator.

The spatial pattern in the cluster analysis for the 10% indicator reflects a regional division in England between an affluent 'south' and a relatively depressed 'north', characterised by socio-economic inequality, that is well documented within wider literature concerned with deprivation [72]. Martin [73] argues that the phenomenon is largely the result of a concentration of economic, financial and political power in London and the South East. This contrast between the north and south is particularly pronounced using the 10% indicator, compared to the LIHC indicator, due to the use of an AHC measure of income.

In addition, the 10% fuel poverty indicator is an absolute measure of fuel poverty whilst the LIHC indicator is a relative measure of fuel

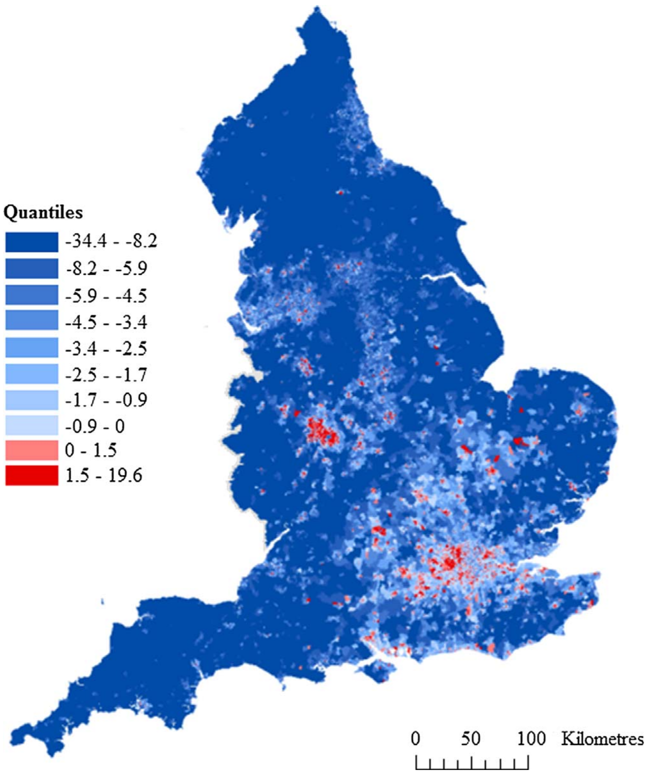

Fig. 9. Percentage difference between the proportions of fuel poor households identified using the LIHC indicator compared to the 10% indicator.
Data source: DECC [54], ONS [52].

poverty [62] (discussed in Section 6.2). Using an absolute measure it is technically feasible for every household to be fuel poor, something that is virtually impossible using the relative LIHC indicator [3]. This is reflected in the considerable increase in the percentage of fuel poor households using the 10% indicator in response to significant energy prices increases since the mid-2000s. An absolute measure of fuel poverty, that places considerable emphasis upon on a single fuel poverty driver, energy price, is likely to yield a more binary, and less heterogeneous, spatial distribution of fuel poverty.

6.4. *Summary of the spatial distribution of fuel poverty indicators*

Our analysis demonstrates that considerable differences exist between the spatial distribution of fuel poverty using each indicator, despite both the 10% and LIHC indicators being underpinned by the same definition (Table 6). Using a LIHC indicator there is a spatially-concentrated reduction in fuel poor households compared to the 10% indicator. The LSOAs with high proportions of fuel poor households according to the LIHC indicator are more likely to be urban and have higher housing costs, and are more spatially heterogeneous when compared to households identified as fuel poor by the 10% indicator.

Table 5
LSOA counts and mean Local Moran's I z-scores for clusters and outliers.

	10% indicator		LIHC indicator	
Cluster and outlier	LSOA (count)	Mean z-score (p-value)	LSOA (count)	Mean z-score (p-value)
High-high cluster	3733	+8.03 (< 0.05)	3680	+11.5 (< 0.05)
High-low outlier	111	×3.04 (< 0.05)	30	−2.58 (< 0.05)
Low-High outlier	49	×2.77 (< 0.05)	87	−2.92 (< 0.05)
Low-Low cluster	4615	+3.15 (< 0.05)	2582	+2.97 (< 0.05)

7. Conclusions and implications for policy

The aim of our analysis was to understand how the spatial distribution of fuel poverty differs using a LIHC indicator compared to the former 10% indicator. We demonstrate how exploration of the spatial distribution of the indicators used to monitor and measure fuel poverty can offer new and interesting insights into the dimensions of fuel poverty that are prioritised by each indicator. Many of these patterns only become visible when exploring the geographic characteristics of fuel poverty using each indicator at the neighbourhood scale.

As expressed earlier in the paper, our findings, although focused upon England, are relevant to other national contexts where similar challenges of fuel poverty exist. However, in applying these results to alternative national contexts it may also be necessary to consider how these spatial distributions could differ slightly given the localised challenges of fuel poverty. Even within the devolved administrations in the UK, the factors that contribute to fuel poverty differ, for example, a high dependency upon expensive oil boilers for heating in homes makes a considerable contribution towards the condition in NI [9,16]. This is supported by analysis of the applicability of the LIHC indicator to the French context that identifies some differences in who is considered fuel poor by the indicator compared to England [13].

Given the results of the spatial analyses, we conclude with a set of three policy recommendations if policy-makers or practitioners are to succeed in addressing fuel poverty as understood by the LIHC indicator. These recommendations are followed by a series of more general observations that question the suitability of using a single indicator for the measurement of fuel poverty, given the considerable variations in the spatial distribution of fuel poverty yielded by different indicators in our analysis.

Firstly, a trade-off between a household's ability to 'heat-or-eat' is well documented in fuel poverty literature and media representations of the phenomenon. However, the spatial analysis draws attention to a further trade-off when using a LIHC indicator, in which the cost of housing also reduces the income that a household has available to

Table 4
Percentage of fuel poor households using 10% and LIHC indicators according to the Urban-Rural Classification.
Data source: Bibby and Brindley [56], 2015, DECC [62]

Classification	Class frequency	LSOA (count)	10 indicator (%)	LIHC indicator (%)	Mean diff. (%)
Urban: Major conurbation	33.7%	11,523	12.9	11.2	−1.7
Urban: Minor conurbation	3.5%	1208	17.1	12.3	+0.7
Urban: City and town	45.3%	15,724	12.3	9.7	−2.5
Urban: City and town (sparse)	0.3%	94	18.5	11.6	−7.0
Rural: Town and fringe	9.2%	3189	13.7	8.7	−5.0
Rural: Town and fringe (sparse)	0.6%	197	19.6	11.2	−8.4
Rural: Village and dispersed	7.2%	2490	23.6	11.8	−11.8
Rural: Village and dispersed (sparse)	0.9%	328	38.8	16.8	−22.0

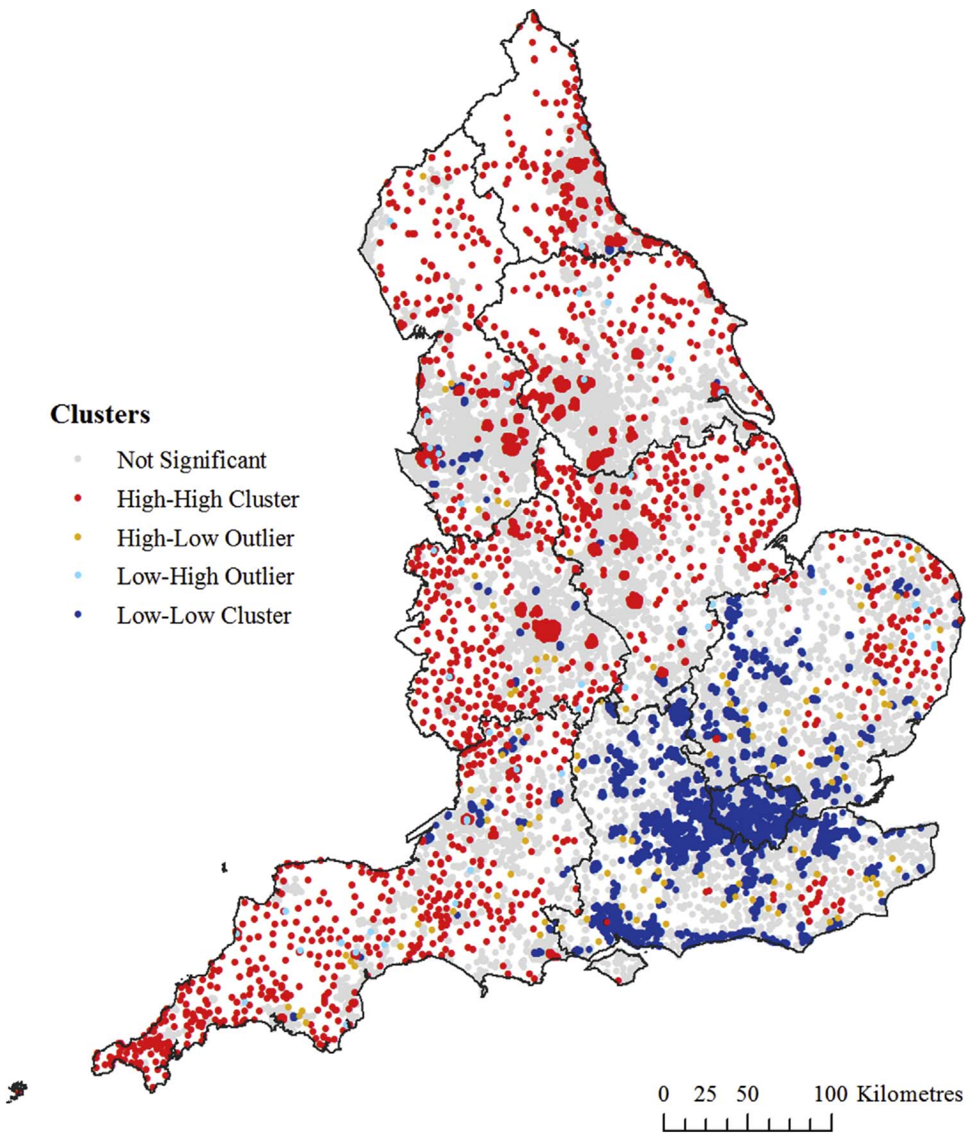

Fig. 10. Cluster and outlier analysis (Local Moran's I) of percentage of fuel poor households using 10% indicator.
Data source: DECC [54], ONS [60].

spend upon energy services. Middlemiss [18] recognises how, counterintuitively, fuel poverty tends to be dealt with separately from more general considerations of poverty and housing, as part of the energy policy domain rather than the welfare policy domain. This demonstrates a need to address related issues such as access to affordable housing, the provision of social housing and the rights of private tenants simultaneously with fuel poverty policy as these issues are inextricably linked to a household's ability to access appropriate domestic energy services.

Secondly, the higher prevalence of fuel poverty in urban areas using the LIHC indicator suggests a need for a greater awareness of those socio-spatial vulnerabilities commonly associated with inner-city areas. One socio-spatial characteristic that often distinguishes rural areas from urban areas is the built environment. In the UK, building regulations regarding a minimum standard of insulation were only enforced from 1976 [74]. Subsequently, urban areas are often characterised by a high concentration of Victorian terraced housing that have inefficient construction features, including solid walls and single glazing [75]. Examples of characteristics of the urban, built environment that enhance energy poverty also exist in other contexts, for example, in poor quality housing stock in cities in Eastern and Central Europe [5]. In addition, certain inner-city areas tend to have a relatively high concentration of low income families and private renters, groups characterised as vulnerable to fuel poverty [33]. In using the LIHC indicator to target the fuel poor, these groups may, to some extent, be reprioritise with regards to fuel poverty policies. For example, currently in the UK a universal Winter Fuel Payment is paid to all pensioners regardless of income, representing the single largest expenditure in terms of fuel poverty alleviation. The effectiveness of this payment in tackling fuel poverty as understood by the LIHC indicator could be reconsidered given that the payment targets a group whose vulnerability tends to be characterised by dimensions associated with rurality, including a lack of access to the gas network, a tendency to live in solid-walled properties and underoccupancy within the home [67]. The need for a greater focus upon socio-spatial vulnerabilities commonly associated with urban areas could be beneficial in terms of effective targeting of fuel poor households. The spatial concentration of social disadvantage in urban areas makes targeting easier, compared to spatially heterogeneous rural populations that are dispersed over a larger area [68], a benefit also acknowledged by Walker et al. [24].

Thirdly, the greater spatial heterogeneity of the fuel poor using the LIHC indicator compared with the 10% indicator suggests that it may be necessary to consider a more localised approach in targeting policy. Our analysis suggests that this is more of a priority when understanding fuel poverty using a LIHC indicator rather than a 10% indicator. A localised approach to targeting should reach beyond universal policies at

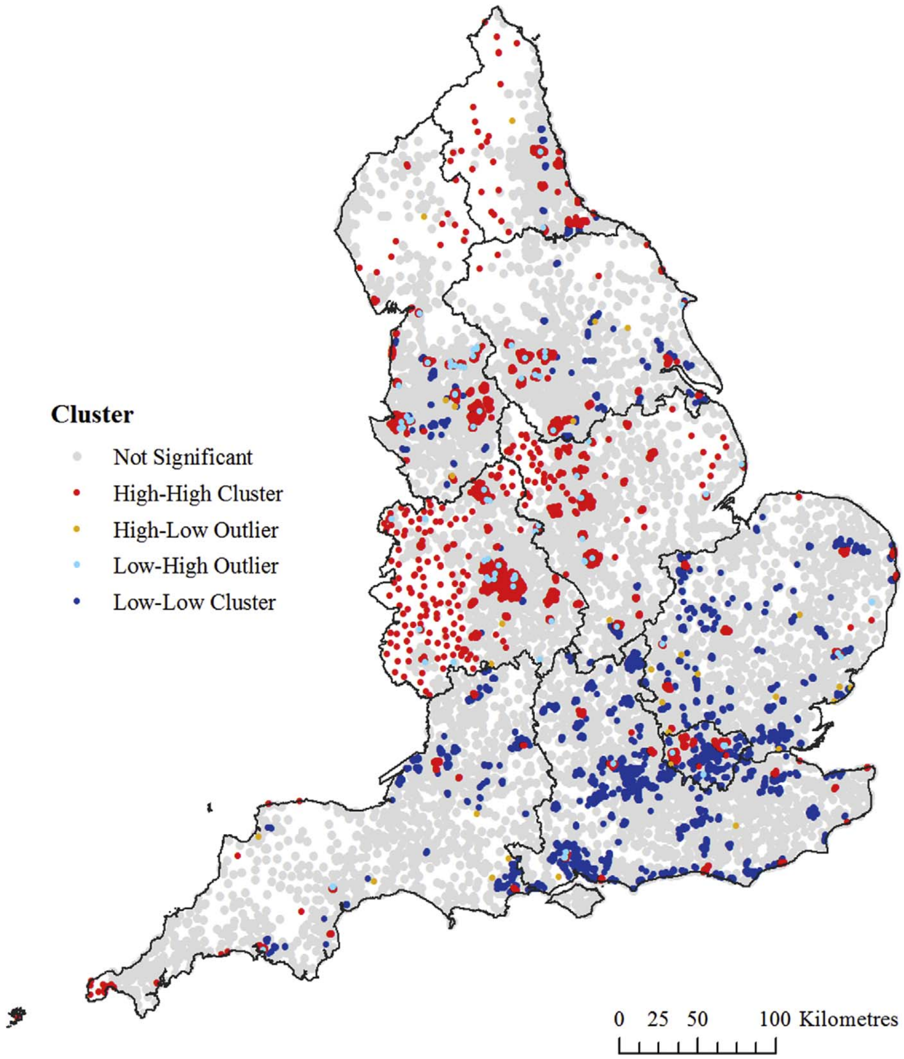

Fig. 11. Cluster and outlier analysis (Local Moran's I) of percentage of fuel poor households using LIHC indicator. Data source: DECC [54], ONS [60].

Table 6
Summary of relative spatial typologies for 10% and LIHC fuel poverty indicators.

	10% indicator	LIHC indicator
Area classification	More likely to be rural	More likely to be urban
Neighbourhood size	Larger	Smaller
Density of households	Less dense	More dense
Spatial heterogeneity	Less spatially heterogeneous	More spatially heterogeneous

the national or regional scale, for example the LA or city region, to account for spatial heterogeneity in the likelihood of experiencing fuel poverty between different neighbourhoods [16]. Area-based targeting is an example of such a localised approach that has been considered in relation to fuel poverty [51,24]. Area-based policies have been successful in targeting of energy efficiency measures for the alleviation of fuel poverty in NI [46].

In addition to these three policy recommendations for using the LIHC indicator to target the fuel poor, the spatial differences identified between the two indicators are also potentially disruptive to policy-making. We recognise that both the 10% and LIHC indicators investigated rely upon a relatively narrow, economic-focused understanding of fuel poverty as their starting point. However, the 10% indicator places considerable emphasis upon energy price as a driver of fuel poverty compared to the LIHC indicator that prioritises a relative understanding of the income a household has available to spend upon fuel. As a result, each indicator captures different notions of what it means to be fuel poor, representing particular socio-spatial vulnerabilities, losses of wellbeing, potential injustices and geographies of fuel poverty. Depending upon the measurement approach selected, different indicators prioritise different facets of the fuel poverty debate.

Subsequently, neither the 10% indicator nor the LIHC indicator succeeds in representing the highly geographic or multi-dimensional of fuel poverty recognised within wider research [6,11,4]. In designing an indicator, there is an inevitable need to balance both its theoretical underpinning and its practical reality [76], however, our analysis leads us to question whether a single indicator (particularly expenditure focused) can adequately represent the complex socio-spatial distribution of fuel poverty. This requires further exploration including spatial analyses of the relationship between the fuel poverty indicators and wider socio-spatial vulnerabilities.

When using an expenditure-based indicator careful consideration should be given to whether the chosen indicator represents the particular fuel poverty challenges that typify a region or neighbourhood, before it is used to target policy measures, or that characterise a particular national context, before it is adopted elsewhere. Expenditure-based measure may need to be used in combination with other spatially-constituted measurement approaches that account for the localised nuances of the condition of fuel poverty.

Funding

This work was supported by the Engineering and Physical Sciences Research Council (EPSRC) Power Networks Centre for Doctoral Training at the University of Manchester [grant number EP/L016141/1, 2016]. Stefan Bouzarovski is a Visiting professor at the Department of Geography, University of Bergen; and an External Professor at the Institute of Geography, University of Gdansk. Part of the research leading to this paper has received funding from the European Research Council (ERC) under the European Union's Seventh Framework Programme (FP7/2007–2013)/ERC grant agreement number [313478].

References

[1] J.D. Healy, Excess winter mortality in Europe: a cross country analysis identifying key risk factors? J. Epidemiol. Commun. Health 57 (10) (2003) 784–789.
[2] B. Boardman, Fuel Poverty: From Cold Homes to Affordable Warmth, Pinter Pub Ltd, 1991.
[3] J. Hills, Fuel Poverty: The Problem and Its Measurement, CASE, London, 2011.
[4] L. Middlemiss, R. Gillard, Fuel poverty from the bottom-up: characterising household energy vulnerability through the lived experience of the fuel poor, Energy Res. Soc. Sci. 6 (2015) 146–154.
[5] S. Buzar, Energy Poverty in Eastern Europe: Hidden Geographies of Deprivation, Ashgate Publishing, Ltd, 2007.
[6] S. Bouzarovski, S. Petrova, A global perspective on domestic energy deprivation: overcoming the energy poverty-fuel poverty binary, Energy Res. Soc. Sci. 10 (2015) 31–40.
[7] S. Bouzarovski, S. Tirado Herrero, Geographies of injustice: the socio-spatial determinants of energy poverty in Poland, the Czech Republic and Hungary, Post-Commun. Econ. (2017) 1–24.
[8] M.J. Pasqualetti, M.A. Brown, Ancient discipline, modern concern: geographers in the field of energy and society, Energy Res. Soc. Sci. 1 (2014) 122–133.
[9] C. Liddell, C. Morris, P. McKenzie, G. Rae, Defining Fuel Poverty in Northern Ireland: A Preliminary Review, Ulster University, 2011.
[10] C. Wong, M. Baker, B. Webb, S. Hincks, A. Schulze-Baing, Mapping policies and programmes: the use of GIS to communicate spatial relationships in England, Environ. Plan. B 42 (6) (2015) 1020–1039.
[11] S. Bouzarovski, N. Simcock, Spatializing energy justice, Energy Policy 107 (2017) 640–648.
[12] A. Miazga, D. Owczarek, It's Cold Inside-energy Poverty in Poland (No. 16/2015), (2015).
[13] I. Imbert, P. Nogues, M. Sevenet, Same but different: on the applicability of fuel poverty indicators across countries—insights from France, Energy Res. Soc. Sci. 15 (2016) 75–85.
[14] B. Legendre, O. Ricci, Measuring fuel poverty in France: which households are the most fuel vulnerable? Energy Econ. 49 (2015) 620–628.
[15] B. Boardman, Fuel poverty synthesis: lesson learnt, actions needed, Energy Policy 49 (2012) 143–148.
[16] C. Liddell, C. Morris, S.J.P. McKenzie, G. Rae, Measuring and monitoring fuel poverty in the UK: national and regional perspectives, Energy Policy 49 (2012) 27–32.
[17] R. Moore, Definitions of fuel poverty: implications for policy, Energy Policy 49 (2012) 19–26.
[18] L. Middlemiss, A critical analysis of the new politics of fuel poverty in England, Crit. Soc. Pol. 37 (3) (2016) 425–443 (0261018316674851).
[19] A. Jansz, P. Guertler, The Impact on the Fuel Poor of the Reduction in Fuel Poverty Budgets in England, The Association for the Conservation of Energy, 2012.
[20] D. Roberts, E. Vera-Toscano, E. Phimister, Fuel poverty in the UK: is there a difference between rural and urban areas? Energy Policy 87 (2015) 216–223.
[21] G. Galster, On the nature of neighbourhood, Urban Stud. 38 (12) (2001) 2111–2124.
[22] H. Thomson, C. Snell, Quantifying the prevalence of fuel poverty across the European Union, Energy Policy 52 (2013) 563–572.
[23] J. Rudge, Coal fires, fresh air and the hardy British: a historical view of domestic energy efficiency and thermal comfort in Britain, Energy Policy 49 (2012) 6–11.
[24] R. Walker, P. McKenzie, C. Liddell, C. Morris, Area-based targeting of fuel poverty in Northern Ireland: an evidenced-based approach, Appl. Geogr. 34 (2012) 639–649.
[25] R. Chard, G. Walker, Living with fuel poverty in older age: coping strategies and their problematic implications, Energy Res. Soc. Sci. 18 (2016) 62–70.
[26] C. Liddell, The Impact of Fuel Poverty on Children, Save The Children, Belfast, 2008.
[27] C. Snell, M. Bevan, H. Thomson, Justice, fuel poverty and disabled people in England, Energy Res. Soc. Sci. 10 (2015) 123–132.
[28] Office for National Statistics, Neighbourhood Statistics, (2011) [online] http://www.neighbourhood.statistics.gov.uk/dissemination/ (Accessed 31 March 2017).
[29] W. Baker, V. White, I. Preston, Quantifying Rural Fuel Poverty, Centre for Sustainable Energy, 2008.
[30] O. Coutard (Ed.), The Governance of Large Technical Systems, Routledge, 2002.
[31] S. Graham, S. Marvin, Cherry picking and social dumping: utilities in the 1990, Util. Policy 4 (2) (1994) 113–119.
[32] K.C. O'Sullivan, P.L. Howden-Chapman, G. Fougere, Making the connection: the relationship between fuel poverty, electricity disconnection, and prepayment metering, Energy Policy 39 (2) (2011) 733–741.
[33] A.R. Ambrose, Improving energy efficiency in private rented housing: why don't landlords act? Indoor Built Environ. 24 (7) (2015) 913–924.
[34] F. Fylan, D. Glew, M. Smith, D. Johnston, M. Brooke-Peat, D. Miles-Shenton, et al., Reflections on retrofits: overcoming barriers to energy efficiency among the fuel poor in the United Kingdom, Energy Res. Soc. Sci. 21 (2016) 190–198.
[35] J.D. Healy, J.P. Clinch, Fuel poverty: thermal comfort and occupancy: results of a national household-survey in Ireland, Appl. Energy 73 (3) (2002) 329–343.
[36] J. Pearce, Commentary, Environ. Plan. A 45 (9) (2013) 2030–2045.
[37] Department for Communities and Local Government, Local Authority Revenue Expenditure and Financing England, (2016) [online] https://www.gov.uk/government/statistics/local-authority-revenue-expenditure-and-financing-england-2016-to-2017-budget (Accessed 24 July 2017).
[38] S.M. Hall, S. Hards, H. Bulkeley, New approaches to energy: equity, justice and vulnerability. Introduction to the special issue, Int. J. Justice Sustain. 18 (4) (2013) 413–421.
[39] G. Walker, R. Day, Fuel poverty as injustice: integrating distribution, recognition and procedure in the struggle for affordable warmth, Energy Policy 49 (2012) 69–75.
[40] K. Allen, Vulnerability reduction and the community-based approach, in: M. Pelling (Ed.), Natural Disasters and Development in a Globalizing World, 2003.
[41] S.L. Cutter, B.J. Boruff, W.L. Shirley, Social vulnerability to environmental hazards, Soc. Sci. Q. 84 (2) (2003) 242–261.
[42] S. Lindley, J. O'Neill, J. Kandeh, N. Lawson, R. Christian, M. O'Neill, Climate Change, Justice and Vulnerability, York, Joseph Rowntree Foundation, 2011.
[43] K. Bickerstaff, G. Walker, H. Bulkeley (Eds.), Energy Justice in a Changing Climate: Social Equity and Low-carbon Energy, Zed Books Ltd, 2013.
[44] B.K. Sovacool, Fuel poverty, affordability, and energy justice in England: policy insights from the Warm Front Program, Energy 93 (2015) 361–371.
[45] D. Schlosberg, Reconceiving environmental justice: global movements and political theories, Environ. Polit. 13 (3) (2004) 517–540.
[46] R. Walker, C. Liddell, P. McKenzie, C. Morris, S. Lagdon, Fuel poverty in Northern Ireland: humanizing the plight of vulnerable households, Energy Res. Soc. Sci. 4 (2014) 89–99.
[47] Scottish Government, A Scotland Without Fuel Poverty is a Fairer Scotland, Scottish Government, 2016.
[48] Department for Energy and Climate Change, Annual Fuel Poverty Statistics Report 2014, (2014) [online] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/319280/Fuel_Poverty_Report_Final.pdf (Accessed 21 November 2016).
[49] L.K. Middlemiss, R. Gillard, "How Can You Live like That?": Energy Vulnerability and the Dynamic Experience of Fuel Poverty in the UK, (2014).
[50] S.C.L. Koh, R. Marchand, A. Genovese, A. Brennan, Fuel Poverty: Perspectives from the Front Line. Centre for Energy, Environment and Sustainability, Sheffield, 2012.
[51] E. Fahmy, D. Gordon, D. Patsios, Predicting fuel poverty at a small-area level in England, Energy Policy 39 (7) (2011) 4370–4377.
[52] Office for National Statistics, Census Boundary Data, (2011) [online] https://census.ukdataservice.ac.uk/use-data/guides/boundary-data (Accessed 31 March 2017).
[53] Department for Energy and Climate Change, Sub-regional Fuel Poverty 2016 Statistical Methodology, (2016) [online] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/533073/Fuel_poverty_sub_regional_methodology_2016.pdf (Accessed 29 March 2017).
[54] Department for Energy and Climate Change, Fuel Poverty Sub-regional Statistics: 2012, (2014) [online] https://www.gov.uk/government/collections/fuel-poverty-sub-regional-statistics (Accessed 29 November 2016).
[55] Department for Environment, Food and Rural Affairs, 2011 Rural Urban Classification, (2016) [online] https://www.gov.uk/government/collections/rural-urban-classification (Accessed 21 November 2016).
[56] P. Bibby, P. Brindley, Urban and Rural Area Definitions Methodology, Office for National Statistics, 2013.
[57] L. Anselin, Local indicators of spatial association −LISA, Geogr. Anal. 27 (2) (1995) 93–115.
[58] S.L. Cutter, L. Barnes, M. Berry, C. Burton, E. Evans, E. Tate, J. Webb, A place-based model for understanding community resilience to natural disasters, Glob. Environ. Change 18 (4) (2008) 598–606.
[59] T.J. Chatterton, J. Anable, J. Barnes, G. Yeboah, Mapping household direct energy consumption in the United Kingdom to provide a new perspective on energy justice, Energy Res. Soc. Sci. 18 (2016) 71–87.
[60] Office for National Statistics, LSOA Population Weighted Centroids, (2011) [online] http://geoportal.statistics.gov.uk/datasets/b7c49538f0464f748dd7137247bbc41c_0 (Accessed 29 November 2016).
[61] L.A. Waller, C.A. Gotway, Spatial clusters of health events: point data for cases and controls, Appl. Spat. Stat. Public Health Data (2004) 155–199.
[62] Department for Energy and Climate Change, Cutting the Cost of Keeping Warm—A Fuel Poverty Strategy for England, (2015) [online] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/408644/cutting_the_cost_of_keeping_warm.pdf (Accessed 1 December 2016).
[63] Department of Work and Pensions, Households Below Average Income (HBAI) Methodology, (2015) [online] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/530905/households-below-average-income-quality-methodology-2014-2015.pdf (Accessed 24 November 2016).
[64] Department for Communities and Local Government, Housing Market and House Prices, (2012) [online] https://www.gov.uk/government/statistical-data-sets

(Accessed 25 November 2016).
[65] B. Harrison, J. Wilson, J. Johnson, Changes to Affordable Housing in London and Implications for Delivery, Joseph Rowntree Foundation, 2012.
[66] Department for Environment, Food and Rural Affairs, Fuel, Energy and Fuel Poverty in Rural Areas, (2013) [online] https://www.gov.uk/government/statistics/fuel-energy-and-fuel-poverty-in-rural-areas (Accessed 25 August 2016).
[67] S. Roberts, Energy, equity and the future of the fuel poor, Energy Policy 36 (12) (2008) 4471–4474.
[68] P. Commins, Poverty and social exclusion in rural areas: characteristics, processes and research issues, Sociol. Ruralis 44 (1) (2004) 60–75.
[69] Office for National Statistics, 2011 Census Analysis Comparing Rural and Urban Areas of England and Wales, (2013) [online] http://webarchive.nationalarchives.gov.uk/20160105160709/http://www.ons.gov.uk/ons/dcp171776_337939.pdf (Accessed 29 November 2016).
[70] Office for National Statistics, 2011 Census Analysis − Overcrowding and Under-occupation in England and Wales, (2014) [online] http://webarchive.nationalarchives.gov.uk/20160105160709/http://www.ons.gov.uk/ons/rel/census/2011-census-analysis/overcrowding-and-under-occupation-in-england-and-wales/sty-household-occupancy-and-overcrowding.html (Accessed 29 November 2016).
[71] Department for Communities and Local Government, English Housing Survey: Annual Report on England's Households 2013–14, (2015) [online] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/461439/EHS_Households_2013-14.pdf (Accessed 10 February 2017).
[72] A.R. Baker, M. Billinge, Geographies of England: the North-South Divide, Material and Imagined, Cambridge University Press, 2004.
[73] R. Martin, The contemporary debate over the North-South divide: images and realities of regional inequality in late twentieth-century Britain, in: A.R. Baker, M. Billinge (Eds.), Geographies of England: the North-South Divide, Material and Imagined, vol. 37, Cambridge University Press, 2004Chapter 2.
[74] M. Dowson, A. Poole, D. Harrison, G. Susman, Domestic UK retrofit challenge: barriers: incentives and current performance leading into the Green Deal, Energy Policy 50 (2012) 294–305.
[75] C. Foulds, J. Powell, Using the Homes Energy Efficiency Database as a research resource for residential insulation improvements, Energy Policy 69 (2014) 57–72.
[76] C. Wong, Indicators for Urban and Regional Planning: The Interplay of Policy and Methods, Routledge, London, 2006.
[77] S. Bouzarovski, Energy poverty in the European Union: landscapes of vulnerability, Wiley Interdisciplinary Reviews: Energy and Environment 3 (3) (2014) 276–289.