Energy Research & Social Science 7 (2015) 99–107

Contents lists available at ScienceDirect

Energy Research & Social Science

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

Original research article

Fuel poverty, policy, and equity in New Zealand: The promise of prepayment metering

Kimberley Clare O'Sullivan*, Philippa L. Howden-Chapman, Geoffrey M. Fougere

He Kainga Oranga/Housing and Health Research Programme, Department of Public Health, Wellington, University of Otago, 23a Mein Street, Newtown, Wellington 6242, New Zealand

ARTICLE INFO

Article history:
Received 5 September 2014
Received in revised form 29 March 2015
Accepted 31 March 2015

Keywords:
Fuel poverty
Prepayment metering
Policy
Mixed methods research

ABSTRACT

Fuel poverty is a complex and pervasive policy problem, in part due to the difficulty of identifying households experiencing fuel poverty to target for remedial action. This paper explores the extent to which the use of prepayment metering for electricity can be used as a proxy for identifying fuel poor households. We hypothesised that as prepayment metering in New Zealand is typically used by low-income households, yet is a more expensive payment method; households using prepayment metering have constrained choices and are at higher risk of fuel poverty than the general population. To explore this question, we used information from multiphase mixed methods research on prepayment meter use, which included two postal surveys, complemented by data from an interview study, to explore three different methods of measuring fuel poverty. We conclude that as households using prepayment metering are experiencing greater levels of fuel poverty using all three measurements, prepayment metering can be used as a useful proxy for targeting remedial fuel poverty policy in New Zealand.

1. Introduction

Fuel poverty is a complex problem as it is caused by several contributing factors, including the thermal performance of the dwelling envelope and appliances, household income, and the price of energy [1,2]. A basic definition of fuel poverty is that a household is fuel poor if it cannot afford adequate household energy, including heating to World Health Organization recommended indoor temperatures (at least 18 °C), for a reasonable expenditure of household income. More specific definitions have also been used, most notably the required energy expenditure for a 10% household income threshold after housing costs in England (referred to hereafter as the Boardman definition) [1,2]. More recently England has updated its definition to a 'low income, high costs' model, where a household is in fuel poverty if the required energy expenditure is above the national median and would leave the household with an income below the poverty line (60% median) [3,4].

A key fuel poverty policy problem, even in England where required data on the thermal performance and energy requirements of individual dwellings is identifiable in the English House Condition Survey and Energy Performance Certificates, has been the translation of monitoring definitions into the identification of fuel poor households for targeting remedial policies [2,5]. Policies using blunt targeting, for example the English Winter Fuel Payment for those over 65, have been criticised for providing unnecessary support to households that do not require it, while leaving other groups such as low income families with young children at high risk of fuel poverty [2,5]. Some success using area level modelling to find pockets of fuel poverty in communities and target local remedial policies has been shown [6]. However, these techniques are sensitive to differing household composition, occupancy, income, and energy requirements and behaviours, which can cause otherwise similar households to experience divergent severity of fuel poverty [6,7].

In New Zealand, while fuel poverty is estimated to affect 25% of households [8], fuel poverty has not been officially defined, measured, or explicitly targeted, and its crucial effect on children is largely unrecognised [9]. Identifying households in, or at risk of fuel poverty, has to date been difficult due to insufficient information about the thermal performance and energy requirements of individual dwellings that could be provided through a scheme such as the Housing Warrant of Fitness currently under development [10]. In the local setting, more so than in other countries, electricity prices are an important driver of fuel poverty, with housing predominantly heated using electric resistance heating [8,11]. The use of heat pumps has increased among the general

* Corresponding author. Tel.: +64 13144802602.
E-mail address: kimberley.osullivan@otago.ac.nz (K.C. O'Sullivan).

http://dx.doi.org/10.1016/j.erss.2015.03.008
2214-6296/

population, however these more efficient heating devices are less commonly used among those purchasing electricity through prepayment metering [12].

Households that have been disconnected from electricity services for late or non-payment of electricity bills may only be offered electricity services again through using prepayment meters, a form of payment where the meter is credited in advance of electricity being used. There are many potential advantages to using prepayment metering, for example the increased ability to monitor and therefore control or reduce consumption, and budgetary management and avoidance of debt [13,14]. However, prepayment meters are not without disadvantages, such as increased transactional costs, including time and travel to outlets to purchase credit and increased pressure on households already experiencing financial hardship and other bill stress. Of particular concern are the inconvenient and potentially harmful outcomes of "self-disconnection",[1] or running out of credit and going without electricity, as well as "self-rationing" behaviours where householders ration their electricity use sometimes to extremes, even where self-disconnection may be avoided [9,15–17]. Self-rationing of energy involving restricting heating may leave householders exposed to unhealthily cold homes [12,18], which is a particular problem for New Zealand where homes are typically underheated [8,19].

Previously qualitative research indicated that prepayment metering posed specific problems for fuel poor households in New Zealand [20]. Key stakeholders suggested that lower income households are more likely to use prepayment metering, as did surveys of retailers offering prepayment metering undertaken by the previous regulatory body, the Electricity Commission [21,22]. These results were also supported by overseas evidence of problems associated with prepayment metering [16]. Despite these drawbacks, prepayment metering remains a popular payment method among consumers, who appreciate the feedback and sense of control over their budgets and electricity use it provides [16,17]. This evidence suggested that exploring prepayment metering, as a means of investigating the outcomes of fuel poverty among a specific and easily identifiable group, was warranted.

We undertook a multiphase mixed methods research programme to investigate the advantages and disadvantages of using prepayment metering to pay for electricity from a consumer perspective [23]. The results of each of the research phases have included a price comparison [24], a nationwide postal survey [9], a follow-up postal survey [12], an integration of survey datasets to explore outcomes specifically for prepayment households with children [9], and a study using in-depth interviews [17]. This paper provides a summary integration of these datasets to explore whether in the current absence of more specific data; the use of prepayment metering is a useful proxy for identifying fuel poor households.

2. Methods and results: estimating fuel poverty rates among prepayment meter users in New Zealand

The first survey dataset was from a primarily quantitative nationwide postal survey undertaken in 2010 with the support of three major electricity retailers in New Zealand, who provided an anonymised random sample to investigate the advantages and disadvantages of using prepayment metering from a consumer perspective [9]. The 2010 survey sample included a total of 768 customers, calculated presuming a response rate of 50% (384), providing adequate study power assuming 50% frequency of self-disconnection in the population. The final response rate for the 2010 survey, which included a rigorous protocol of repeat mailings, was 47.9%. Of the 359 respondents to the 2010 survey, 324 (90.2%) agreed to postal follow-up and were included in the 2011 sample. The 2011 survey, also fully described elsewhere, achieved a response rate of 61.0% using a similar protocol [12]. In both years respondents were offered a $20 supermarket voucher to thank them for completing the survey, which were sent by the researchers on receipt of the survey form.

Survey data for both years were entered into a Microsoft Access database and analysed using Epi Info version 3.4 (Center for Disease Control, Atlanta, GA). The uncorrected chi-squared test was used for significance testing, with an alpha level of ≤ 0.05. Compared to the general population (based on Census 2006 data), Māori and Pacific ethnicities were over-represented in the sample, home ownership and employment was lower, and there were fewer retirement age respondents [9].

A qualitative research phase followed in 2012, in which a series of semi-structured interviews were carried out with 12 individuals, either recruited through the survey or through a local family budgeting agency (see [17] for a full description). Interviews were undertaken in participants' homes, and participants were offered $25 supermarket vouchers for each interview in acknowledgement of their contribution to the study. Interviews were digitally recorded and fully transcribed, and analysed using qualitative descriptive methods that have been identified as useful for mixed methods studies [25–27]. The analysis was informed by the survey results and with a sociotechnical approach [28,29] to explore the influences of interactions with prepayment meters and an alternative in-home display device on household energy behaviours. Householders reporting sociotechnical interactions with prepayment meters were provided with increased feedback that influenced budgeting and management of household energy use. Unfortunately, this feedback encouraged householders experiencing severe hardship to take extreme measures when restricting their energy use, particularly with regards to insufficient use of heating. Despite this and other disadvantages, prepayment meters were perceived positively and were preferred to standard post-payment billing, as was also found in the surveys.

To investigate whether prepayment metering is a useful proxy for identifying households in fuel poverty, we undertook an integrative analysis using survey data and informed by the qualitative interviews to estimate fuel poverty rates among prepayment meter users using several of the questions asked of survey participants as indicators. Here we compare three types of estimated measures of fuel poverty: actual expenditure, required expenditure, and composite measure. For ease of reference we describe the methods and results of each estimate calculation together in the following sections.

2.1. Actual expenditure fuel poverty among prepayment meter users

At one end of the spectrum, using the reported annual expenditure on electricity as a percentage of household income, it is possible to calculate the number of households using prepayment metering that experience *actual expenditure* fuel poverty. However, actual energy expenditure has been shown to be a poor indicator of fuel poverty due to the energy and other expenditure self-rationing behaviours typical among fuel poor households [1,2,16,30–32]. Therefore it is likely to underestimate the number of households in fuel poverty if a 10% actual spend threshold is used. Also contributing an underestimate is that only electricity spending is included

[1] The term "self-disconnection" refers to the service being shut off when a prepayment meter runs out of credit. While the term problematically implies the consumer has agency to make a choice to disconnect, the term is widely used and understood so we use it here.

Table 1
Estimated actual expenditure fuel poverty rates using different income estimates and thresholds.

	Reported electricity expenditure as a percentage of reported gross annual household income			
Estimated income	≥5%	≥10%	≥15%	≥20%
High-range	32.3%	5.2%	1.5%	0.7%
Mid-point	45.4%	23.4%	10.8%	4.1%
Low-range	67.7%	40.5%	32.7%	31.2%

in the calculation. As the majority of the sample used electricity for heating hot water and cooking, not other sources of energy (natural gas, for example), the underestimate caused by only including electricity expenditure should be smaller in this group compared to the general population.

Respondents were asked to report gross annual household income in $20,000 brackets for the previous year from $0 through to above $100,001, and three income points within these brackets were used for these calculations. For example, if a respondent reported annual household income of $40,001–$60,000, the actual expenditure ratios were calculated using the high-range value of $60,000 as the annual household income figure, as well as the mid-point ($50,000) and low-range ($40,001) values. If a respondent reported annual household income of greater than or equal to $100,001, a figure of $120,000 was used as the high-range value. It should be noted that the income figures here have not been adjusted for housing costs (rent/mortgage/insurance, etc.) as these were not collected in the survey, which is likely to result in an underestimate of the number of households in fuel poverty at any given threshold.

We report here the number of households reporting annual electricity expenditure as a percentage of their gross annual household income thresholds (Table 1); the proportion of households spending greater than or equal to 5%, 10%, 15%, and 20% of household income. This is consistent with the approaches to defining and measuring fuel poverty used in both Scotland and Northern Ireland and follows the suggestion of Liddell and colleagues [33] to use a range of fuel poverty thresholds to better describe the phenomenon in the community. Respondents with missing data (those who reported that they did not know either their expenditure or income, or did not respond to either question) were excluded from this analysis. The number of respondents for this analysis was 269 (from 359 respondents), using data from the 2010 survey of prepayment users, which provides the largest, most nationally representative dataset available in New Zealand.

Due to the large income brackets used in the survey, the rates of estimated actual expenditure fuel poverty for each threshold are spread over a large range. However, the figures illustrate the extent to which decisions around thresholds can alter rates of fuel poverty. The figures help to explain why using a scale rather than using one threshold measurement to describe the phenomenon can provide a fuller picture of the number of households that may already be facing hardship or extreme hardship, through to those who are at risk of hardship in the event of a change in circumstances.

2.1.1. Households using prepayment metering experience greater estimated rates of actual expenditure fuel poverty than New Zealand households generally

Compared to the national population, the figures above indicate that prepayment meter users appear to be spending more on electricity as a percentage of total household income. According to the Household Expenditure Survey, New Zealand households in the lowest income decile spent 13.1% of their total average household income on total household energy in 2010, while households in the second lowest income decile spent 7.1% and households in the third lowest income decile spent 5.3%.[2] Comparatively, New Zealand households in the highest income decile spent just 1.6% of their total average household income on total household energy in 2010.

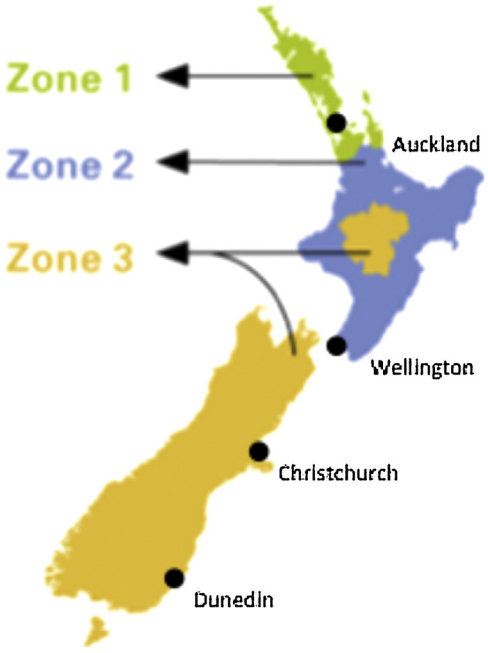

Fig. 1. Map of climate zones for building code insulation standards. (Retrieved from http://www.dbh.govt.nz/quick-energy-guide on 15 December 2014.)

In contrast, an estimated 23% of prepayment meter consumers spent greater than or equal to 10% of household total income on electricity in 2010, using the mid-point income estimate range. This roughly equates to prepayment metering households being around 1.8 times more likely to experience actual expenditure fuel poverty than New Zealand households in the lowest income decile. This figure does not include spending on other household fuels, although 12.8% of households using prepayment metering reported using gas cooking and 10.6% gas hot water heating. No questions were asked in 2010 to indicate what fuels were used for space heating, or how many households used solid fuels. This suggests that households using prepayment metering may be at even greater risk of experiencing actual expenditure fuel poverty than the general population.

2.2. Estimating rates of required energy expenditure fuel poverty among prepayment meter users

Another way of estimating fuel poverty rates is to use the approach set out by Lloyd, first described using prices from 2001 [34], and later updated with 2008 prices [8]. Lloyd calculated the required energy expenditure for adequate heating and energy use of a 100 m^2 house in three climatic zones across the country set out by the Department of Building and Housing and the New Zealand Standard 4218.2009 governing the required level of insulation for dwellings (Fig. 1).[3] Climate Zone 1 encompasses the top of the North Island, including the far north, Auckland and Manukau cities,

[2] These figures are based on Statistics New Zealand's data which are licensed by Statistics New Zealand for re-use under the Creative Commons Attribution-Noncommercial 3.0 New Zealand license.

[3] see Appendix B of NZS4218:2009, p32 https://law.resource.org/pub/nz/ibr/nzs.4218.2009.pdf – last accessed 13 July 2013.

and Thames Coromandel. Climate Zone 2 covers the rest of the North Island from the northern boundaries of the Waikato and Hauraki districts, excluding the central plateau. Climate Zone 3 includes the central plateau of the North Island, and the South Island.

Although Lloyd used 2008 electricity prices for standard billing, we have not updated these in order to be able to compare to his national estimates. It is likely that these calculations underestimate the rates of required energy expenditure fuel poverty among survey respondents, due to prepayment metering prices being more expensive than standard billing, electricity price rises and increases to other living costs since that time correspondent with a period of economic downturn. Lloyd also assumed that the dwelling sizes average 100 m^2 [8], which is lower than trends for new-build housing floor areas which had increased to 191 m^2 in 2006 [35] and may underestimate the number in fuel poverty. Another assumption from Lloyd's calculations is that space heating is provided by electric resistive heating, which may overestimate the number in fuel poverty where cheaper alternatives are used. This is particularly problematic with the recent increase in electric heat pump use nationwide.

The required household income range to avoid fuel poverty using a 10% threshold was then calculated based on the required electricity expenditure [8]. For example, a Climate Zone 1 house requires electricity expenditure of $2000–$2400, therefore the required household income range to avoid fuel poverty is $20,000–$24,000. For Climate Zone 2, the required electricity expenditure was $2900–$3900, with a required household income to avoid fuel poverty of $29,000–$39,000. Although Lloyd used the average of the estimates for the cities of Christchurch and Dunedin to calculate the required energy expenditure and household income for Climate Zone 3, in the estimates here we used the estimated figures from Dunedin city where the required electricity expenditure is $4100–$4750 and the required household income is $41,000–$47,500. The rationale for this was that where Climate Zone 3 covers the entire South Island and central plateau of the country, for the surveys, prepayment meter users in Christchurch city and the surrounding areas were excluded due to the September 2010 earthquake. Survey respondents classified as living in Climate Zone 3 were living in the deep south region (Dunedin, Mosgiel, Invercargill, Bluff, and Gore), and are most likely to have the required energy expenditure and therefore household income, similar to that estimated by Lloyd to be required in Dunedin city.

For the calculation of required energy expenditure fuel poverty for the survey respondents, the climatic zone of each respondent's address was assigned, and the mid-point figures of the assumed average required electricity expenditure and household income level estimated by Lloyd [8] was compared to the reported electricity expenditure and income level for each respondent. As household income was reported in $20,000 brackets, we use the simple assumption that households have the mid-point figure of the reported gross income bracket.

As in the previous estimate, respondents with missing data (those who reported that they did not know either their expenditure or income, or did not respond to either question) were excluded from this analysis. Two further respondents for whom address data were not provided were also excluded. The number of respondents for this analysis in 2010 was 267 (out of a total of 359 respondents from the survey). It is not clear what the effect of this dropout rate (around 26%) has on the estimated rate of fuel poverty.

It is useful to assess the expenditure and income patterns across the spectrum when considering fuel poverty [33,36,37]. Consistent with this, we report households in four electricity consumption categories here.

Respondents who reported both *lower electricity expenditure* than the mid-point of the range estimated to be required for adequate electricity services and a *lower household income level* than the mid-point of the range estimated to be required are considered *fuel poor and self-rationing*. These households numbered 46.1% of respondents, compared with the estimated figure of 25% New Zealand households in fuel poverty in 2008.

The 41.6% of respondents who reported *lower electricity expenditure* than that estimated to be required for adequate electricity services, but a *higher household income level* than that estimated to be required, are considered to be *self-rationing electricity*. It is not clear whether the circumstances of these households would allow for purchasing adequate electricity services, or whether they are self-rationing for financial reasons, for example to cope with rent or mortgage payments or to service other costs or debt. They may also be using other energy sources, such as gas or firewood. Therefore, the most conservative approach is to exclude these households from those defined as fuel poor under the 10% required expenditure threshold used in Lloyd's estimates.

Some respondents also reported higher electricity expenditure than that estimated as required for adequate electricity services. There were 1.9% of respondents who reported *higher electricity expenditure*, but *lower income levels* than those estimated to be required, and are described here as *fuel poor*. Together with the 46.1% who were fuel poor and self-rationing, this takes the total number of survey respondents in fuel poverty to 48.0% – almost double the national estimated rate.

Finally, those who reported both *higher electricity expenditure* and *higher income levels* than those estimated to be required, which may indicate the household is *over-consuming electricity*. There were a small number of households (10.5%) that were over-consuming electricity, although we use this term with some caution as this could also be an artefact of the limitations of the assumptions.

It is also interesting to assess the rates of fuel poverty across the climate zones (Table 2), as this gives some illustration of the geographic disparity of energy costs (not completely explained by temperature differences across the country) and fuel poverty in New Zealand [8,24]. Although the survey was designed to be a nationwide survey, there are far fewer respondents from Climate Zone 3. This is due in part to the exclusion of Christchurch and the surrounding areas following the major earthquakes in 2010 and 2011. Additionally, there were fewer areas in the South Island where prepayment metering was available and the population of the South Island is also lower than that of the North Island.

A total of 12.5% respondents were spending over the estimated required electricity expenditure mid-point [8]. Of those, 89.2% were living within Climate Zone 1, which typically experiences the mildest climates and has the lowest required electricity expenditure. Overcrowding is also a problem typical of poorer households particularly in the Auckland and Manukau regions, where the majority of respondents from Climate Zone 1 were living, so it is possible that the required electricity expenditure for these households is higher than that estimated by Lloyd, with electric hot water and cooking most commonly used among survey respondents. By the same token, household income may be higher where there are more working occupants, though the household expenses may also require a higher household income than estimated under Lloyd's assumptions. Of those 10.6% of respondents who were over-consuming electricity, 9.4% were residing in Climate Zone 1.

Lloyd estimated that in Auckland (Climate Zone 1) 14% of the city population were fuel poor in 2008, while in Wellington (Climate Zone 2) 24% were fuel poor and in Dunedin (comparable with prepayment meter users in Climate Zone 3) as many as 47% of households were fuel poor [8]. Among prepayment meter

Table 2
Estimated required expenditure fuel poverty among prepayment meter users compared by climate zone.

Climate zone	Electricity consumption categories			
	Fuel poor + self-rationing (low income, low expenditure)	Fuel poor (high expenditure, low income)	Self-rationing (low expenditure, high income)	Over-consuming electricity (high income, high expenditure)
1 (46.07% of total)	11.6%	1.5%	23.6%	9.4%
2 (40.45% of total)	27.3%	0.4%	12.0%	0.8%
3 (13.48% of total)	7.1%	0	6.0%	0.4%

consumers, 28.5% or approximately double the rate of households in Climate Zone 1 were estimated to be fuel poor. In Climate Zone 2, 68.5% of prepayment meter consumers or almost three times as many households were estimated to be fuel poor. Finally, in Climate Zone 3, 52.78% or just over half of prepayment meter consumers were estimated to be fuel poor, slightly higher than the estimated rate for other households.

2.2.1. Households using prepayment metering experience greater estimated rates of required energy expenditure fuel poverty than New Zealand households generally

Comparison with the estimates of fuel poverty among the total New Zealand population provided by Lloyd show that in every geographic region, prepayment meter users have higher estimated rates of fuel poverty. Nationally, households using prepayment metering are almost twice as likely as the general population to experience fuel poverty.

2.3. Using fuel poverty indicators to create a composite measure of fuel poverty among prepayment meter users

If fuel poverty is more broadly defined as an inability to afford sufficient household energy, the above measures do not appear to fully portray the extent of fuel poverty in the community. For example, only 48.0% of prepayment metering households are estimated to use the required electricity expenditure and therefore experience fuel poverty. But, a further 41.6% of households report spending *less* than the estimated required electricity expenditure, despite having more than the estimated required income to avoid fuel poverty, showing the extent to which self-rationing may occur. Overall, almost 88% of households using prepayment metering were spending less than the estimated required electricity expenditure needed to avoid fuel poverty.

Furthermore, the qualitative data from the interview study highlighted the severe self-rationing actions that some households undertook to avoid self-disconnection, although this was not always successful [17]. Thus, qualitative and subjective indicators from survey questionnaires can be employed in a composite measure to account for some self-rationing behaviour when considering the number of households that may be experiencing fuel poverty.

Healy and Clinch [38] first provided an alternative strategy for measuring fuel poverty using a mix of objective and subjective indicators of fuel poverty to create a composite measure, enabling comparison of the prevalence of fuel poverty in the European Union. Six indicators that reported measures of affordability, access to heating appliances and building quality were used to create a composite measure of fuel poverty. Assigning different weights to the indicators provided a range of scenarios to compare fuel poverty across the European Union [38]. Overall, the authors concluded that using the composite measure found lower levels of fuel poverty in England than using a 10% required expenditure threshold definition of fuel poverty.

Similar composite measures of fuel poverty using proxy indicators from the standardised European Union Statistics on Income and Living Conditions survey were recently used to update these figures by Thomson and Snell [39]. As in the earlier study, the authors found that fuel poverty was especially prevalent among southern and eastern European countries.

Although comparison to nationally collected data is not possible here, using the survey questions to create a composite measure of fuel poverty provides a fuller picture of the phenomenon among prepayment meter consumers. It can indicate which survey questions may be useful in future studies to measure fuel poverty within the general population.

2.3.1. 2010 survey composite measure of fuel poverty

Several of the survey questions from both the original 2010 survey and the 2011 follow-up survey could be used as indicators of fuel poverty to create a composite. We have selected indicators that relate to the key drivers of fuel poverty: financial constraint, adequacy and affordability of heating, and housing quality. Using two indicators that are compared to the estimated required thresholds for avoiding fuel poverty as calculated by Lloyd [8], we have also included some of the geographic elements, for example climate differences and pricing disparity, contributing to fuel poverty in New Zealand.

Healy and Clinch [38] used self-reports of being unable to pay utility bills on time as a subjective indicator of financial difficulty contributing to fuel poverty. However, the measures above showing that the majority of survey respondents are not purchasing adequate electricity to avoid fuel poverty, together with the descriptions of self-rationing from the qualitative interview study (see [17]) suggest that this may be a weak indicator among prepayment meter consumers in New Zealand. Only 14.9% of respondents in 2010 reported electricity expenditure above the lowest estimated required amount to avoid fuel poverty. Although 52.6% of respondents in 2010 reported having self-disconnected at least once in the past year, only 29.8% reported that the reason for their last self-disconnection was financial constraint. In 2010, 46.5% (and in 2011, 40.8%) of respondents reported being unable to pay any of their gas, telephone, or water bills in the past year. However, the majority of participants were not connected to mains gas, around three quarters did not have a water bill, as water was paid for through the council rates, and around one sixth did not have a home telephone due to the high cost of telecommunications services. Another indicator which could be used is the reported expenditure on electricity, compared to the estimated required expenditure for the corresponding climate zone as calculated by Lloyd [8]. This could indicate the use of electricity self-rationing by the household, which has been commonly found between both households experiencing and at risk of fuel poverty. However, Lloyd's figures are based on the assumption that electricity is the only fuel contributing to household energy, which may overestimate the number of those in fuel poverty. The majority of respondents reported spending below the lowest estimated electricity expenditure threshold required to avoid fuel poverty. For these reasons we have used

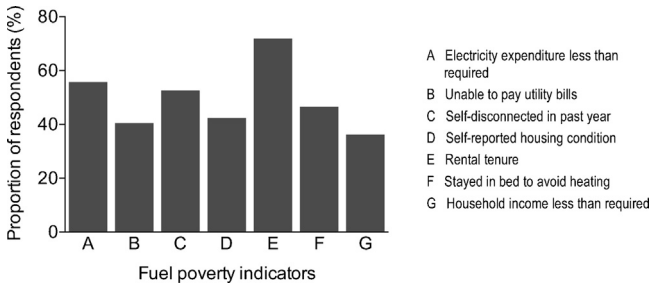

Fig. 2. Proportion of total respondents reporting fuel poverty indicators ($n = 359$).

the following to indicate financial constraints contributing to fuel poverty:

- have spent less than the mid-point of the estimated required electricity expenditure range for their climate zone (indicator A);
- have been unable to pay utility bills in the past year (indicator B);
- have self-disconnected in the past year (indicator C).

Healy and Clinch [38] used indicators from the European surveys that directly relate to housing quality and conditions that both indicate and contribute to fuel poverty: damp walls and/or floors, and rotten window frames. Although these specific indicators were not included in the prepayment surveys, two questions can be used to provide point towards housing quality which may be contributing to fuel poverty. Self-reported housing condition is used as a subjective indicator of housing quality, with positive responses including the categories very poor, poor, and average (as opposed to good or excellent), as it has been shown that tenants of typical low-income housing overestimate the quality of their housing compared to qualified building inspectors [40] (indicator D). Tenure is used as an objective indicator of housing condition, with rental properties counted as a positive indicator of fuel poverty (indicator E). Home ownership is not a perfect indicator of fuel poverty as it is more prevalent among older people who may have fixed incomes and inadequate occupancy contributing to the likelihood of fuel poverty. However, it has consistently been shown that private rental housing in New Zealand is of poorer quality than housing owned by the occupant [41,42]. Additionally, despite an ongoing programme of improvement, many state sector rental properties are also of insufficient thermal quality for occupants to avoid fuel poverty without additional heating [43,44].

In the absence of questions regarding the available heating sources in 2010 due to survey space constraints, we selected the question "Have you stayed in bed longer to save on heating costs?", with "have done a little" or "have done a lot" counted as positive responses, as a subjective indicator of cold indoor temperatures (indicator F). Heating practices and thermal comfort indicators of survey respondents were more fully explored in the follow-up survey in 2011, and these have been incorporated into a composite measure using the 2011 data in the following section.

Household income is a relatively easy measure to assess within the community, as opposed to the current difficulties with assessing housing quality, and can easily be compared to the estimated required household income thresholds in each climate zone as calculated by Lloyd [8]. For this reason, the final indicator used in the composite measure is having a household income less than the mid-point estimated required household income to avoid fuel poverty in the corresponding climate zone (indicator G).

For these calculations, each respondent was assessed for all seven indicators. Fig. 2 shows the proportion of positive responses to each indicator, using the total number of respondents ($n = 359$).

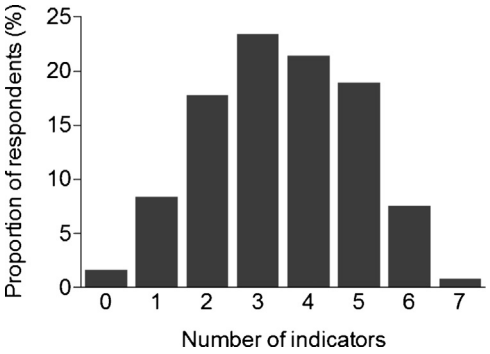

Fig. 3. Number of fuel poverty indicators reported using indicators A through G ($n = 359$).

Only 0.8% of respondents had all seven indicators, while using a threshold of three or more indicators, 72.1% of respondents experience fuel poverty (Fig. 3). Setting the threshold at four or more indicators finds 48.7% of respondents in fuel poverty. Although a threshold of four or more indicators more closely aligns with the estimated rate under the required electricity and household income model explored above, the threshold of three or more offers a rate of fuel poverty using the composite measure that is in between that for fuel poverty under Lloyd's assumptions and those who are fuel poor or electricity self-rationing (89.6%) under Lloyd's assumptions. A threshold of three or more indicators may therefore offer the most accurate estimate of households, who are potentially fuel poor in the sense that they are unable to afford sufficient energy, given the likely underestimate of fuel poverty under Lloyd's assumptions caused by relying on household income. This may be especially relevant when circumstances such as overcrowding lift the household income level, particularly in Climate Zone 1.

Indicator G is partly an indicator of financial constraint, which can also be assessed using indicators A, B, and C. It is also the only indicator which had sufficient missing data for the figures to be markedly different when respondents with missing data were excluded from the analysis. Therefore, it is also interesting to explore the rates of fuel poverty using only indicators A through F to make up the composite measure (Fig. 4). When only the six indicators A through F are used for the composite measure, 64.6% of respondents have a composite score of three or more indicators, while 41.5% have four or more indicators.

A large proportion of respondents were missing data from at least one indicator, with 30.9% missing data when seven indicators were used, although this was lower at 12.6% when only six indicators (A through F) were used. However, little difference in the

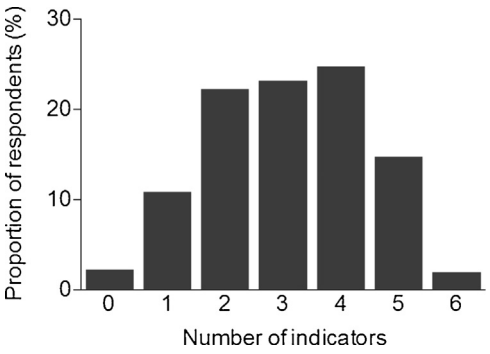

Fig. 4. Number of fuel poverty indicators reported using indicators A through F ($n = 359$).

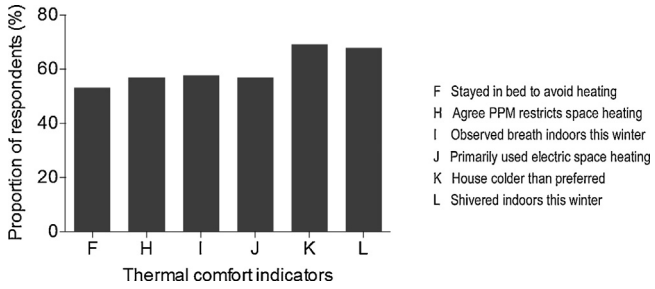

Fig. 5. Proportion of respondents reporting selected thermal comfort indicators in 2011 ($n = 192$).

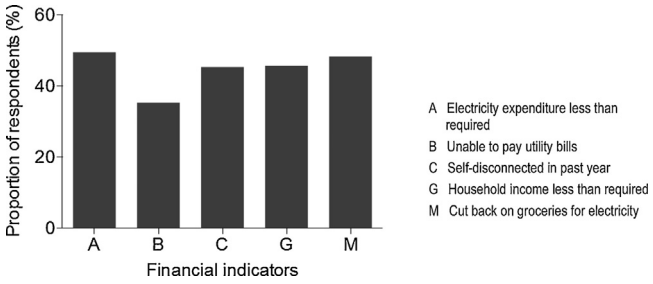

Fig. 6. Proportion of respondents reporting selected financial indicators in 2011 ($n = 192$).

proportion of those reporting any number of indicators is found when those with at least one piece of missing data were excluded.

2.3.2. 2011 survey composite measure of fuel poverty

The 2011 survey more fully explored heating practices and thermal comfort indicators among prepayment meter consumers. When compared to the one available thermal indicator used in 2010 taken from the General Social Survey (indicator F), staying in bed to avoid using space heating (53.1%), all thermal indicators from the follow-up survey had higher rates of positive responses (Fig. 5). Three indicators had only slightly higher positive responses: agreeing with the statement that prepayment metering encourages restriction of space heating (indicator H, 56.8%); having observed breath condensing indoors on at least one occasion this winter (indicator I, 57.8%); and using electric space heating as their primary heating source (indicator J, 56.8%). Having the house colder than occupants would have liked had the highest number of positive responses at 69.3% (indicator K), and 67.7% (indicator L) reported shivering indoors on at least one occasion this winter.

In future development of a questionnaire for a composite measure of fuel poverty, it may be more appropriate to use a less specific question than staying in bed to avoid using space heating to assess thermal comfort. The results above indicate that although some people did not use this particular practice they found their indoor temperatures insufficiently warm. As previously discussed, although shivering is a physiological response that occurs at different temperatures for different people, most people would agree that having indoor home temperatures cold enough that occupants experience shivering indoors reflects inadequate space heating. Having indoor temperatures colder than preferred is a more subjective indicator as personal preference for indoor temperature also varies, though using this indicator fits with the approach of using consensual measures of fuel poverty under a broader definition that places higher emphasis on qualitative indicators than the traditional 10% required expenditure threshold definition. For these reasons, in future development of composite questionnaire for measuring fuel poverty we suggest that shivering and colder than preferred temperatures be further investigated.

The follow-up survey also asked an additional question indicative of financial constraint to reflect the 'heat or eat' self-rationing phenomenon that has been found in earlier international studies: 'Do you cut back on grocery spending to afford electricity?' (indicator M). Fig. 6 compares responses to this indicator to the other indicators of financial constraint used in the composite measure developed from the 2010 survey.

It appears that self-rationing grocery expenses (indicator M, 48.4%) was more common among respondents than other self-rationing indicators such as utility bill stress (indicator B, 35.4%) or running out of prepayment meter credit in the previous 12 months (indicator C, 45.3%). It fell between the indicators of financial constraint taken as the mid-point of the estimated required

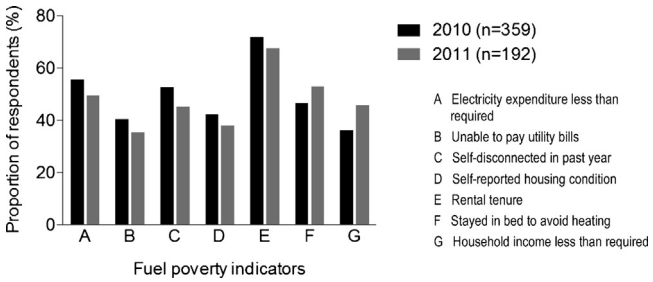

Fig. 7. Proportion of respondents reporting fuel poverty indicators A through G in 2010 and 2011.

electricity expenditure and household income ranges to avoid fuel poverty calculated by Lloyd (indicator A, 49.5% and indicator G, 45.8%, respectively). Therefore, it may also be useful to investigate using this indicator when developing a questionnaire to assess fuel poverty using a composite measure in the general population.

Comparing the results to the seven fuel poverty indicators from the 2010 and 2011 found broadly consistent results (Fig. 7), with slightly lower rates of composite measure fuel poverty among respondents to the follow-up survey (Figs. 8 and 9).

In 2011, using a composite measure made up of the seven indicators A through G, and a threshold of three or more indicators, 67.2% of respondents were fuel poor. When a threshold of four or more indicators is used, 58.9% of respondents were fuel poor.

Using a composite measure made up of the six indicators A through F (excluding having a household income less than the mid-point of the range estimated to be required to avoid fuel poverty in the corresponding climate zone), and a threshold of three or more indicators, 46.9% of respondents were fuel poor. Using a threshold of four or more indicators, 38.0% of respondents were fuel poor.

However, as previously discussed, there were some differences found among the groups of those who responded to the follow-up survey, those who consented to follow-up but did not respond, and

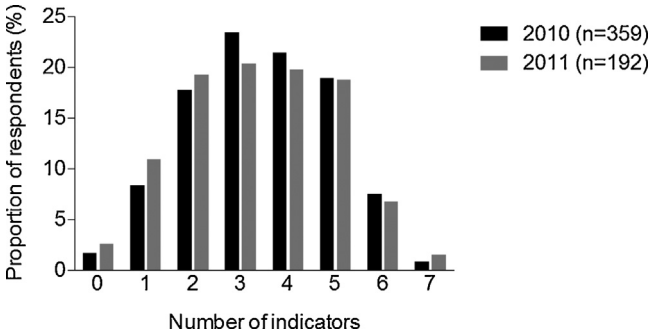

Fig. 8. Number of indicators reported by respondents in 2010 compared to 2011 using indicators A through G.

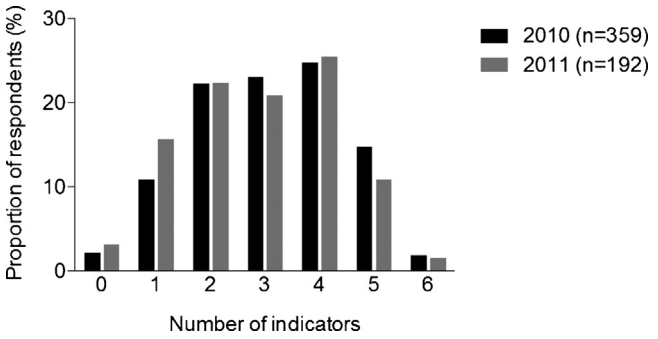

Fig. 9. Number of indicators reported by respondents in 2010 compared to 2011 using indicators A through F.

those who did not consent to follow-up. Therefore the 2010 figures are more likely to be nationally representative results of consumers using prepayment metering.

Based on these results we suggest that further development of a composite measure of fuel poverty includes at least three key indicator questions: "Is your house ever colder than you prefer during the winter months?" "Do you ever experience shivering inside during the winter months?" and "Do you ever cut back on grocery spending to afford electricity?" (described as K, L, and M here). Further exploration of a suitable indicator question of housing quality would be useful as these results suggest that rental tenure was a better indicator of self-reported housing quality, though use of rental tenure in a composite measure could falsely identify households in better quality rental housing as fuel poor.

2.3.3. Households using prepayment metering experience high rates of composite measure fuel poverty

While this exercise has shown that households using prepayment metering experience high rates of composite measure fuel poverty, this cannot be compared to a similar measure of the general population of New Zealand easily. Although the composite measures used are not directly equivalent, it is interesting to compare the figures of composite fuel poverty among prepayment metering with composite measures of fuel poverty in European countries. For example, Thomson and Snell's [39] most recent comparison of composite measure across the European Union used three indicators: ability to keep the home adequately warm; arrears on utility bills in last 12 months; and leaking roof, damp walls/floors/foundation, or rot in window frames or floor. Bulgaria had the highest rates of fuel poverty of all of the European Union countries under all of the composite measure scenarios used, ranging from 30.5 to 31.2% [39]. In contrast, very low rates of fuel poverty were found in Denmark, Finland, and Sweden, for example, in Denmark rates ranged from 2.7 to 4.8% [39]. Using the more conservative measure of having four or more indicators of fuel poverty, those using prepayment metering in New Zealand in 2010 had a composite rate of fuel poverty ranging from 41.5 to 48.8% (from six or seven indicators, respectively). Using a threshold of three or more indicators, rates ranged from 64.6 to 72.1%.

3. Discussion

Fuel poverty occupies the interdisciplinary space of energy policy that has been highlighted as a concern for *Energy Research and Social Science* [45,46]. Fuel poverty also requires an exploration of human–energy interactions at the individual and household level to uncover complicated behavioural habits and practices often overlooked in single-discipline studies, which can undermine the effectiveness of energy policies [47–49]. Taking a problem-focussed approach to fuel poverty, policy solutions to ameliorate fuel poverty must be flexible enough to adapt to the needs of populations at the household level [5,7].

We have shown through mixed methods research that prepayment metering poses specific problems for households experiencing, or at risk of, fuel poverty in New Zealand [9,12,17,24,50]. However, previously we have not known whether the use of prepayment metering could be used as a proxy for identifying the fuel poor, or to what extent those using prepayment metering in New Zealand can be classified as fuel poor. The findings show that despite the uncertainty introduced by the assumptions on which these calculations are based, households using prepayment metering are at greater risk of fuel poverty than the general population.

The three measures of fuel poverty explored here illustrate the extent to which different assumptions used to define and measure fuel poverty can affect the observed rates of fuel poverty in a population. Using the most rigid assumptions that actual expenditure reflects necessary energy use provide the lowest rates of fuel poverty. However, both the international evidence [1,2,16,30–32] and the findings from our research suggest that measuring actual expenditure fuel poverty does not truly reflect energy affordability among the population. If a quantitative definition of fuel poverty, as in the English definitions, is used, an estimated required expenditure and income threshold is more appropriate. However, without a current standardised measure of the quality and energy requirements of individual dwellings, measuring required expenditure fuel poverty must rely on estimates that use assumptions which may have significant effect sizes. If fuel poverty is more broadly defined, for example, as the inability to afford sufficient household energy, a composite measure of fuel poverty finds that households using prepayment metering may be at even greater risk.

Our research, together with evidence from both other countries and the local setting finds that both households experiencing, and at risk of fuel poverty, tend to self-ration household energy expenditure below required levels for adequate energy services, particularly when using prepayment metering [16,17]. These results suggest that using a composite measure is likely to better reflect a more valid experience of the phenomenon in the community setting. While we have focussed this research on those using prepayment metering, our previous qualitative study indicates that self-rationing behaviours are also present among low-income households using standard billing [20]. Therefore, development of a composite measure of fuel poverty to use across the entire population is likely to be beneficial for policy targeting.

These findings are reflective of the New Zealand situation where, relative to other countries, the housing thermal performance is poor, the cost of electricity and heating is high, and electricity governance light-handed. Even so, this research may provide useful insights for other jurisdictions where those using prepayment metering are typically have lower incomes and may be at risk of fuel poverty, for example Australia, England, North America, and South Africa [15,51–53]. In other countries, for example in Northern Ireland, discounted tariffs encourage the use of prepayment meters more widely across the population [54]. However, at present, targeting fuel poverty remediation to those using prepayment metering is a simple strategy which may help to reduce fuel poverty rates until better measurement and identification of fuel poor households is possible in New Zealand and abroad.

4. Conclusion and policy implications

In sum, all three measures of fuel poverty explored here support the hypothesis underpinning the multiphase mixed methods

research investigation and of this paper, that in New Zealand, households using prepayment metering experience higher rates of fuel poverty than the general population. Further, exploring the experiences of prepayment metering consumers has shed light on the experience of fuel poverty in New Zealand. Without accurate measurements of fuel poverty among the general population, it is difficult to ascertain exactly how much more at risk those using prepayment meters are. Nonetheless, these analyses support the conclusions from the individual research phases that better regulation and consumer protections could help to reduce fuel poverty in New Zealand. In the current policy vacuum, even crude targeting of policy actions, for example targeting present retrofitting subsidies to those using prepayment metering for electricity, could be useful to reduce fuel poverty.

Acknowledgements

The authors would like to thank all of the participants of the research who generously contributed their time. The research this paper draws from was funded by a FRST grant Adaption to Climate Change and Vulnerable Populations and the University of Otago. The authors would also like to thank Mercury Energy, Genesis Energy, and Contact Energy for their co-operation.

References

[1] Boardman B. Fuel poverty: from cold homes to affordable warmth. London: Belhaven Press; 1991.
[2] Boardman B. Fixing fuel poverty: challenges and solutions. London: Earthscan; 2010.
[3] Hills J. Getting the measure of fuel poverty: final report of the fuel poverty review. London, Centre for Analysis of Social Exclusion. CASE report 72; 2012. ISSN 1465-3001.
[4] Department of Energy and Climate Change. Fuel poverty: a framework for future action. London, The Stationery Office Limited on behalf of the Controller of Her Majesty's Stationery Office: Department of Energy and Climate Change; 2013.
[5] Boardman B. Fuel poverty synthesis: lessons learnt, actions needed. Energy Policy 2012;49(0):143–8.
[6] Fahmy E, Gordon D, Patsios D. Predicting fuel poverty at a small-area level in England. Energy Policy 2011;39(7):4370–7.
[7] Walker R, McKenzie P, Liddell C, Morris C. Estimating fuel poverty at household level: an integrated approach. Energy Build 2014;80(0):469–79.
[8] Howden-Chapman P, Viggers H, Chapman R, O'Sullivan K, Telfar Barnard L, Lloyd B. Tackling cold housing and fuel poverty in New Zealand: a review of policies, research, and health impacts. Energy Policy 2012;49:134–42.
[9] O'Sullivan KC, Howden-Chapman PL, Fougere GM, Hales S, Stanley J. Empowered? Examining self-disconnection in a postal survey of electricity prepayment meter consumers in New Zealand. Energy Policy 2013;52:277–87.
[10] Gillespie-Bennett J, Keall M, Howden-Chapman P, Baker M. Improving our nation's health, safety and energy efficiency through measuring and applying basic housing standards: Viewpoint article. N Z Med J 2013;126(1379).
[11] Howden-Chapman P, Viggers H, Chapman R, O'Dea D, Free S, O'Sullivan K. Warm homes: drivers of the demand for heating in the residential sector in New Zealand. Energy Policy 2009;37(9):3387–99.
[12] O'Sullivan KC, Howden-Chapman PL, Stanley J, Fougere GM. A follow-up postal survey of electricity prepayment meter users in New Zealand examining patterns of self-disconnection and heating practices; 2015 (under review).
[13] Coutard O, Guy S. STS and the city: politics and practices of hope. Sci Technol Hum Values 2007;32(6):713–34.
[14] Faruqui A, Sergici S, Sharif A. The impact of informational feedback on energy consumption – a survey of the experimental evidence. Energy 2010;35:1598–608.
[15] Sharam A. Second class customers: pre-payment meters, the fuel poor, and discrimination. North Melbourne: Energy Action Group; 2003.
[16] Boelman V, Downer K, Atkin B, Macgarty E. Pre-payment meter users & self-disconnection. London: RS Consulting; 2010 [research commissioned by Consumer Focus].
[17] O'Sullivan KC, Viggers HE, Howden-Chapman PL. The influence of electricity prepayment meter use on household energy behaviour. Sustain Cities Soc 2014;13:182–91.
[18] Buchanan K, Russo R, Anderson B. The question of energy reduction: the problem(s) with feedback. Energy Policy 2015;77(0):89–96.
[19] Isaacs N, Saville-Smith K, Camilleri M, Burrough L. Energy in New Zealand houses: comfort, physics and consumption. Build Res Inf 2010;38(5):470–80.
[20] O'Sullivan KC [Unpublished Master's Thesis] Gee my account is in credit! Qualitative component of the warm homes pilot study; 2008 http://ourarchive.otago.ac.nz/handle/10523/367
[21] Electricity Commission. Prepayment meter survey results. Wellington: Electricity Commission; 2007.
[22] Electricity Commission. Prepayment meter survey results. Wellington: Electricity Commission; 2008.
[23] O'Sullivan KC. Power and control: a multiphase mixed methods investigation of prepayment metering and fuel poverty in New Zealand. Wellington: Department of Public Health, University of Otago; 2013 [Ph.D. Thesis].
[24] O'Sullivan KC, Howden-Chapman P, Fougere G. Making the connection: the relationship between fuel poverty, electricity disconnection and prepayment metering. Energy Policy 2011;39:733–41.
[25] Sandelowski M. Combining qualitative and quantitative sampling, data collection, and analysis techniques in mixed-method studies. Res Nurs Health 2000;23(3):246–55.
[26] Neergaard MA, Olesen F, Andersen RS, Sondegaard J. Qualitative description – the poor cousin of health research? BMC Med Res Methodol 2009;9, http://dx.doi.org/10.1186/1471-2288-9-52.
[27] Sandelowski M. What's in a name? Qualitative description revisited. Res Nurs Health 2010;33(1):77–84.
[28] Guy S. Designing urban knowledge: competing perspectives on energy and buildings. Environ Plan C: Gov Policy 2006;24(5):645–59.
[29] Hinton E. Review of the literature relating to comfort practices and socio-technical systems. Working paper: Carbon, Control and Comfort: User-centred control systems for comfort, carbon saving and energy management (EP/G000395/1), Deliverable 3. London: King's College London; 2010.
[30] Consumer Focus Wales. Prepayment meters and self-disconnection: case studies in Wales. Cardiff: Consumer Focus Wales; 2010.
[31] Mummery H, Reilly H. Cutting back, cutting down, cutting off. Self-disconnection among prepayment meter users. London: Consumer Focus; 2010.
[32] Moore R. Definitions of fuel poverty: implications for policy. Energy Policy 2012;49:19–26.
[33] Liddell C, Morris C, McKenzie SJP, Rae G. Defining fuel poverty in Northern Ireland: a preliminary review. Coleraine, Northern Ireland: University of Ulster; 2011.
[34] Lloyd B. Fuel poverty in New Zealand. Soc Policy J N Z 2006;27:142–55.
[35] Statistics New Zealand. Severe crowding in New Zealand since 1921: a challenge to health and decency. Wellington: Statistics New Zealand; 2012.
[36] Liddell C, Morris C, McKenzie SJP, Rae G. Measuring and monitoring fuel poverty in the UK: national and regional perspectives. Energy Policy 2012;49:27–32.
[37] McChesney I. Fuel poverty in New Zealand – a public policy investigation. Welllington: Victoria University of Wellington; 2012.
[38] Healy JD, Clinch JP. Fuel poverty in Europe: a cross-country analysis using a new composite measurement. Environmental studies research series working paper. Dublin: Department of Environmental Studies; 2002.
[39] Thomson H, Snell C. Quantifying the prevalence of fuel poverty across the European Union. Energy Policy 2013;52:563–72.
[40] Howden-Chapman P, Matheson A, Crane J, Viggers H, Cunningham M, Blakely T, et al. Effect of insulating existing houses on health inequality: cluster randomised study in the community. Br Med J 2007;334:460–4.
[41] Buckett NR, Jones MS, Marston NJ. BRANZ 2010 house condition survey – condition comparison by tenure. Wellington Build Res Assoc N Z [BRANZ] 2011.
[42] Cunningham M. Surveying housing's effect on health. Build 2012;129:30–1.
[43] Lloyd CR, Callau MF, Bishop T, Smith IJ. The efficacy of an energy efficient upgrade program in New Zealand. Energy Build 2008;40(7):1228–39.
[44] Lloyd B, Callau M. Retrofit interventions to enable healthy living conditions in existing NZ houses. Wellington: Energy Efficiency and Conservation Authority; 2009.
[45] Sovacool BK. What are we doing here? Analyzing fifteen years of energy scholarship and proposing a social science research agenda. Energy Res Soc Sci 2014;1(0):1–29.
[46] Sovacool BK, Ryan SE, Stern PC, Janda K, Rochlin G, Spreng D, et al. Integrating social science in energy research. Energy Res Soc Sci 2015;6(0):95–9.
[47] Moezzi M, Janda KB. From if only to social potential in schemes to reduce building energy use. Energy Res Soc Sci 2014;1(0):30–40.
[48] Royston S. Dragon-breath and snow-melt: know-how, experience and heat flows in the home. Energy Res Soc Sci 2014;2(0):148–58.
[49] Stern PC. Individual and household interactions with energy systems: toward integrated understanding. Energy Res Soc Sci 2014;1(0):41–8.
[50] O'Sullivan KC, Howden-Chapman PL, Stanley J, Hales S. Kids in the cold: outcomes for households with children using prepayment metering for electricity. N Z Med J 2013;126(1371):71–81.
[51] Ruiters G. Developing or managing the poor: the complexities and contradictions of free basic electricity in South Africa (2000–2006). Afr Dev 2011;XXXVI(1):119–42.
[52] Brutscher P-B. Self-disconnection among pre-payment customers – a behavioural analysis. Electricity policy research group working paper 1207; 2012.
[53] Howat J, McLaughlin J. Rethinking prepaid utility service: customers at risk. Boston, MA: National Consumer Law Centre; 2012.
[54] Darby SJ. Metering: EU policy and implications for fuel poor households. Energy Policy 2012;49:98–106.