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## Fuel poverty in Scotland: Refining spatial resolution in the Scottish Fuel Poverty Indicator using a GIS-based multiple risk index

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# Fuel Poverty in Scotland: refining spatial resolution in the Scottish Fuel Poverty Indicator using a GIS based multiple risk index

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## Introduction

Traditionally fuel poverty has been measured using the accepted definition of the *'inability to obtain adequate energy services for 10% of household income'* (Boardman, 1991, p.201). More recently this definition has been questioned; Boardman herself has called for greater clarity regarding 'income' and 'adequate energy services' (Boardman, 2000, p.3). Fuel poverty's non-conformity to income based indicators can be seen in its prevalence in rural areas, in particular in Scotland, where limited access to the gas network, severe winters and low incomes create a *'significant fuel poverty burden'* (Illsley et al., 2007). Using the Scottish Government's definition of fuel poverty<sup>1</sup>, based on the Scottish Fuel Poverty Statement (The Scottish Executive, 2002), the 2004/5 Scottish house Condition Survey estimated that 328,000 households (15.5%) in Scotland live in fuel poverty. Further to this Communities Scotland calculate that *'for every 5% increase in fuel price, a further 30,000 households would become fuel poor'* (Cormack et al., 2004). With recent rises in fuel prices Energy Action Scotland bring the actual number of households in Scotland suffering from fuel poverty closer to 650,000 (Cormack et al., 2004)

In response to this position, Local Authorities in Scotland were charged under the Housing (Scotland) Act (2001) with the duty of setting out a fuel poverty strategy - measures to be taken to ensure, as far as reasonably practicable, that people do not live in fuel poverty within their area. In addition to this a target date was set for the complete eradication of fuel poverty in Scotland by November 2016, similar targets have been set throughout the rest of the UK. As

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<sup>1</sup> "A household is in fuel poverty if it would be required to spend more than 10% of its income (including Housing Benefit or Income Support for Mortgage Interest) on all household fuel use."

part of this, 'Fuel Poverty Proofing' of individual households is required whereby energy inefficient dwellings would be targeted by schemes that tackle fuel poverty such as Warm Deal and Central Heating Programme in Scotland, Warm Front in England, Warm Homes in Northern Ireland and the Home Energy Efficiency Scheme in Wales.

In order to effectively capture such dwellings however, a local authority must first of all know where to target its efforts. A tool is therefore required to predict areas where fuel poverty is likely to be prevalent, as the issue differs in many respects to general deprivation (Baker et al., 2003). Whilst an attempt was made to provide such a tool by Energy Action Scotland in 2003 through their Scottish Fuel Poverty Indicator, this was calculated at the Electoral Ward level and can be seen as problematic in terms of the ecological fallacy – small areas or houses which may lie in fuel poverty are 'masked' by the characteristics of the area in which they are situated (Changeworks, an Edinburgh based charity, will provide calculations at the output area level and has done so for various local councils in Scotland, however a 'mapped' index is not readily available on their website). Further to this, little information on 'local' housing stock was included. In such light, there is a need to look at alternative methodologies for predicting areas susceptible to fuel poverty in Scotland – incorporating both social aspects, in terms of identifying those groups of people most at risk, and physical aspects in terms of those buildings most prone to energy inefficiency. In addition, there is also a need to cost-effectively improve the spatial resolution at which fuel poverty can be predicted so as to ensure all potentially fuel poor households are identified.

This paper provides detail of the process undertaken in order to produce a fuel poverty indicator to cost-effectively meet the requirements of Stirling Council (Figure 1) in identifying areas susceptible to fuel poverty, through refinement of the Scottish Fuel Poverty Indicator. Stirling Council, with a population of around 86,212, comprises 35,508 households and displays a marked polarity in harbouring areas of both extreme affluence and deprivation.

Figure 1

### *The political agenda*

Whether or not a household experiences fuel poverty is determined by a number of social and physical factors in addition to broader political policy related to energy and housing. Social factors refer to the demographic make-up and subsequent income of the occupants of a particular household, whilst the physical factors refer to specific characteristics of the dwelling in which the householders reside - largely energy (in) efficiency and location. This interaction can be characterised in that where household income is sufficiently high it can accommodate the energy costs resulting from inadequate thermal insulation and inefficient heating systems (albeit wastefully); similarly where a dwelling meets extremely high standards in heating and insulation provision, energy charges may be manageable within a comparatively small budget (NEA, 2004). There is a general growing awareness of climate change (and the role energy efficiency plays) in both public and political arenas (Lorenzoni et al., In press and House of Commons, 2007) with organisations such as the Carbon Trust, established in 2001, aiming to accelerate *'the move to a low carbon economy'* (Carbon Trust, 2007). The relationship between climate change mitigation, energy efficiency and fuel poverty is currently being discussed, indeed the Climate Change and Sustainable Energy Act (2006) commits the government (England and Wales) to produce an energy measures report by August 2007. This report must contain information on actions that local authorities will take to improve energy efficiency, reduce greenhouse gas emissions, increase the levels of microgeneration (small scale production of heat/and or electricity as set out in the Energy Act 2004) and reduce the number of households living in fuel poverty. In Scotland fuel poverty was placed firmly on the agenda during the campaign for the 2007 Parliament Election with each of the main political parties providing a statement on the approach that they would take in order to tackle fuel poverty (EAS, 2007). The majority of the parties acknowledged the social, environmental and economic factors involved with the Green Party proposing the appointment of a Minister for Climate Change and Sustainable

Development, under whose remit fuel poverty would fall. At an individual level there is a widespread awareness of climate change ‘but limited behavioural response’ (Lorenzoni et al., In press, p.3). Research has however shown that along with recycling, energy efficiency in the home is one of the more common individual actions taken (Lorenzoni et al., In press). Closely linked to the issue of fuel poverty, reasons for this are more commonly cited as being financial or health related (DEFRA, 2002).

In both academia (Olsen, 2001, Rudge, 2006, Sommerville et al., 2000) and public policy (Department of Health, 1988, DTI and DEFRA, 2001) there is a growing interest in the relationship between housing and health and this is firmly recognised within the health inequalities agenda (Thomson et al., 2001). A plethora of government initiatives (such as Warm Deal, Promoting Winter Warmth and several government strategies such as Tackling Health Inequalities – a Programme for Action (DoH, 2003), the UK Fuel Poverty Strategy (DTI and DEFRA, 2001) and the National Service Framework for Older People, DoH, 2001)) relate to the increasing number of studies that have highlighted the relationship between fuel poverty and health (Cheshire, 2002). Whilst it is noted that demonstrating causal links between housing and health is problematic due to many confounding variables involved (Rudge, 2001) and the multidimensional nature of health (Shortt & Rugkåsa, 2007) low indoor temperatures have been linked with certain types of illness (Rudge, 2001). Research has found associations between cold housing and excess winter deaths (Eurowinter, 1997; Wilkinson et al., 1998), and cold and damp housing with respiratory illness (Collins, 2000; Hyndman, 1990) and impaired mental health (Khanom, 2000) damp housing and asthma specifically (Williamson et al., 1997)

### **Predicting Fuel Poverty**

Deprivation indices have been used extensively to explore the relationship between social deprivation and health and by all accounts they provide an adequate proxy for deprivation experienced within a small area (Adams et al., 2005, Niggebrugge et al., 2005). In the UK there

is a plethora of deprivation indices such as the Townsend index (Townsend et al., 1988), the Carstairs index (Carstairs and Morris, 1990) and the most recent Index of Multiple Deprivation (DETR, 2000). Bartley and Blane (1994) have called for researchers to consider the appropriateness of deprivation indices and to evaluate them in terms of the purpose for which they are being used and *'the validity of the assumptions about social and economic life that they embody'* (p.1479). Reflecting on the importance placed on housing within the Black Report, in particular on the 'materialist' or 'structural' explanations of poverty, Healy and Clinch (2002a) emphasise the role of economic and associated socio-structural factors in fuel poverty. They move on to employ a suite of 'consensual' indicators to derive a composite measure of fuel poverty that attempts to capture *'the wider elements of fuel poverty, such as social exclusion and material deprivation, as opposed to approaches based solely on home-heating expenditure or household temperature'* (Healy and Clinch, 2002b, p.10). Whilst we recognise the relationship between fuel poverty and the broader aspects of deprivation we would argue, in agreement with Boardman (1991), that fuel poverty is unique in that it is not adequately accounted for by such material/structural explanations of poverty measured at a composite level (the wealthy in large houses can also suffer) but rather requires us to consider a combination of social and physical dwelling factors. The aim of any fuel poverty indicator is to identify areas that should be targeted with housing improvements, and in order to do so effectively knowledge of the existing housing stock must be incorporated.

Pither and Moore (2006) recently carried out the first major review of fuel poverty indicators in the UK. Methods of predicting fuel poverty vary in scale from absolute indicators which assess the level of fuel poverty suffered by individual households through to Local Area Indicators and Surveys which measure the relative risk of fuel poor households living in an area (Pither and Moore, 2006). The financial costs of such indicators range from the comparatively expensive, yet absolute, process of performing an individual house assessment, to the comparatively inexpensive yet less accurate method of combining social variables from the census to determine which areas are relatively more likely to include fuel poor households.

An example of the individual household level fuel poverty estimator is the 'Affordable Warmth Index' which uses handheld pocket survey software to identify 'fuel poor' buildings '*...after a five minute doorstep assessment*' (Powergen - publicity brochure). Although such an index quantifies the risk of fuel poverty for individual households it does not solve the larger problem of identifying specific areas that councils should target for 'fuel poverty proofing'. In an ideal situation, detailed fuel poverty information could be gathered for all households using such indices or specific individual household surveys, however for reasons of expense and logistics this is highly impractical. Cost effective local area indicators are therefore employed to identify areas which may contain fuel poor households for further analysis and investment. From a policy and decision making point of view, such area based composite indicators have the ability to summarise complex or multi-dimensional issues, thus facilitating easier interpretation and ranking of areas in view of supporting a decision-making process (Nardo et al., 2005). In light of such benefits, fuel poverty can be seen to provide a highly appropriate example of just such a complex and multi-dimensional issue, therefore such local area indicators can be seen as a valuable tool in identifying areas susceptible to fuel poverty for dwelling improvements and investment.

Several methods of predicting fuel poverty at a local area level are currently used in the UK. One such example is the Centre for Sustainable Energy (CSE) Fuel Poverty Indicator (FPI). Developed by the CSE in conjunction with the University of Bristol, the FPI has recently been updated to predict fuel poverty at an output area level across the whole of England using census variables (from the 2001 census), the English House Condition Survey (EHCS) and postcode level housing data from RESIDATA that includes age of dwelling and property valuation (Fahmy and Gordon, 2007). Employing multivariate binary logistic regression analysis, predictors of fuel poverty were determined for two models, a Basic Income Model and a Full Income Model, emphasising the problems recognised in defining 'income'. As full methodology information was not available for the updated FPI from CSE at the time of our investigation we based our analysis on the first version (Baker et al., 2003) with the eight most important census



variable predictors of fuel poverty found by Baker et al. listed in Table 1. In relation to the strength of each predictor's odds ratio, a percentage of the number of households falling in each of these categories is then taken as being in fuel poverty and these percentages summed to give the total proportion of fuel poor households in each area.

Table 1

The Building Research Establishment (BRE) Housing Stock Modelling service similarly combines census data with findings from the EHCS in order to provide probability information of the level of fuel poverty in small areas. Pither and Moore (2006) note that the BRE model is also based on a smaller unit, the census output area, which allows data to be combined to a ward or local authority area. By contrast to such census based methodologies however, the National Energy Action Fuel Poverty Estimator estimates the level of fuel poverty at electoral ward level through combining domains from the government's Index of Multiple Deprivation (IMD).

The Scottish Fuel Poverty Indicator (SFPI), developed by Alembic Research for Energy Action Scotland, is calculated at the Electoral Ward level and uses, essentially unchanged (Pither and Moore, 2006) the same methodology as used by the CSE for their fuel poverty indicator.

Whilst such indices provide councils with an estimation of where they should effectively target their energy efficiency their design fails to acknowledge the importance of individual household characteristics. Unnecessary expenditure in identifying and combating fuel poverty can be avoided if the accuracy of local area indicators can be improved, with this depending on a number of factors (Pither and Moore, 2006). Of particular concern are the variables used to predict fuel poverty at the small area level which are often determined using national house condition survey data, leading to problems in accuracy if the housing stock in question differs significantly from that identified nationally (Pither and Moore, 2006). It is suggested that it may

be possible to increase the robustness of indicators through determination of predictors using the smallest, most relevant house condition survey sample (Pither and Moore, 2006).

Informed by findings of the Scottish House Condition Survey and using an entirely census based methodology, the SFPI lacks information on the specific energy efficiency characteristics of housing in different local authority areas – a problem exacerbated by ranking wards relative to Scotland as a whole, as opposed to within local authorities. In indicating fuel poverty at electoral ward level, the indicator also risks masking small pockets of fuel poverty in otherwise affluent wards. It has also been noted by Pither and Moore (2006) that the CSE have serious reservations about the adoption of their model in Scotland due to significant differences in housing, specifically the high proportion of older tenements in many Scottish towns and cities and the contrasts between urban and rural housing in Scotland. There is therefore a requirement for a methodology which refines the Scottish Fuel Poverty Indicator through the inclusion of information on energy efficiency and housing stock for individual local authorities, and in the spatial resolution at which predictions of fuel poverty can be made.

## **Methodology**

In this paper the 2002 CSE model is used as the basis for developing a refinement of the SFPI at a census output area level, representing a significant spatial refinement on the electoral ward level geography used to publish the original SFPI. Building upon this model and using a novel approach two components are included, a social component identifying population groups most at risk and a physical component identifying energy inefficient housing. The census variables used by Baker et al. (2003) (see Table 1) are used as a basis for determining those groups at risk of fuel poverty, however as the weightings placed on these indicators were developed from the 1996 EHCS they are not valid for this project. An alternative methodology was therefore identified to obtain fuel poverty risk scores in Principal Components Analysis (PCA).

PCA is a statistically robust method for data reduction and exploration (Salmond & Crampton, 2002) which has found widespread acceptance in producing composite indicators at a

variety of scales (Nardo et al., 2005). The purpose of PCA is to extract from a correlation matrix a smaller set of factors which capture the main axes of variation in the larger set of measures (Salmond & Crampton, 2002). PCA has been used extensively in the production of deprivation indices both in the UK and abroad (Nardo et al., 2005), significantly in the Scottish Index of Multiple Deprivation (Scottish Executive, 2004).

As previously identified fuel poverty arises through the interaction of social factors, through those groups most at risk, and physical factors, in the form of energy inefficient housing. Both factors therefore need to be represented in a fuel poverty indicator. Rudge (2001) integrated energy efficiency with census data in a fuel poverty indicator using a visual survey of relative percentages of building types and ages to correlate with standard SAP<sup>2</sup> ratings from the 1996 English House condition survey to form an energy efficiency score for each Enumeration District. Working from this approach the methodology used in this paper for developing a fuel poverty indicator is outlined in Figure 2. Central to this methodology is the collection of information on local housing stock energy efficiency in order to, where possible, weight the model toward the characteristics of the local area. A key conceptual construct behind this research is that the most appropriate fuel poverty indicator for an area is one that takes account of locally available data; therefore this methodology should remain flexible in terms of data availability. The use of GIS in providing a flexible environment in which all relevant information can be brought together and analysed is key.

Figure 2

### *Data Sources*

In constructing a fuel poverty indicator for Stirling Council it was necessary to ascertain local sources of housing information from relevant authorities. Through liaison with Stirling Council,

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<sup>2</sup> The Standard Assessment Procedure (SAP) is used by the government to determine the energy efficiency of a dwelling. Ratings range from 1 to 100 and the higher the SAP score, the more energy efficient the property. SAP ratings are based on the energy costs for space and water heating.

GIS datasets held by Housing Services were made available, opening up the possibility of mapping the location of almost 30,000 (85%) dwellings (private and public sector) in the council area in terms of property type and tenure. This data was then integrated with a GIS dataset obtained of current and previous local authority (public sector) housing from the council's integrated housing management system and referenced geographically using the council's corporate address gazetteer and housing services data. This location information was used to identify a final dataset that offered further variables of energy efficiency (year of construction and type of water heating) for a sample of 9,205 (26%) dwellings. In addition, the findings of a local house condition survey carried out in 2003 were made available to inform the weighting of dwelling variables. The methodology therefore combines the mapping of social factors at the output area scale and energy efficiency characteristics at an individual dwelling scale (for the 9,205 dwellings for which we had detailed information) (Figure 2). In order to map overall fuel poverty risk at different scales, a final output area fuel poverty 'score' is obtained from the social component PCA and attributed as a variable to any dwelling located within that output area, as a measure of the level of risk of potential inhabitants being groups at risk of fuel poverty. This score is then fed into a second PCA conducted for individual dwellings.

Based on the census variables chosen by Baker et al. (2003) (Table 1) for the CSE fuel poverty indicator (which in turn informs the Scottish Fuel Poverty Indicator), a set of census variables were chosen to represent the social factors of fuel poverty risk. Groups at risk of fuel poverty can easily be drawn from the census, however finding a measure of low income is more problematic. As income is not measured by the UK census, debate continues regarding the best indicator of low income (Baker et al., 2003; Rudge, 2001). The CSE indicator uses two census measures for low income - unemployment and lack of access to a car. Use of car ownership as a measure of low income however becomes problematic in the context of Stirling Council as a large rural area is included. The importance of owning a car increases with rurality therefore making it problematic as an indicator of deprivation (Higgs & White, 2000). In deciding on a proxy measure for low income therefore, it was decided upon consultation with Stirling Council

to use adults in Social Grade E (individuals aged over 16 on state benefit, unemployed and lowest grade workers), as this measure has been used as a proxy for low income in recent local deprivation indices constructed for the council to inform decision making, and encompasses those on low incomes in addition to those unemployed.

In addition to the work of Rudge (2001) and the CSE fuel poverty indicator, the findings of the 2002 Scottish house condition survey (SHCS) have also been taken into account in choosing census variables (Table 2). Due to the problematic nature of correlating fuel poor households with disability benefits uptake as identified by Cormack et al. (2004) in analysing the 2002 SHCS, along with the relatively low importance placed on this indicator by Baker et al. (2002) it was decided not to include households with a disabled person in the analysis. In addition private rented households were not included as tenure is included in the dwelling level indicator. Conversely, additional indicators used by Rudge (2001) were added in place – all pensioner households and single person households. Further to this average house size was included following consultation with Stirling Council. The council felt this to be an important variable due to the predominance of large, difficult to heat homes in the council area. The variables chosen to represent the social component of fuel poverty risk are therefore detailed in Table 2.

Table 2

### *Social component*

PCA determined that 3 components could explain 77% of the variance with a varimax rotated solution interpreted through both mapping and examination of relative loadings to determine the characteristics of each component (Table 3). Each component of the rotated solution could be interpreted to represent a dimension of fuel poverty risk in the data. Through data exploration afforded by the PCA results, it may be extrapolated that Stirling Council area has concentrations of single pensioners and people on low incomes (component 2) in certain output areas, with

single elderly people often at risk due to their concentration in areas that also have a high proportion of houses without central heating (component 3). Lone parents and single person households at risk of fuel poverty are also found together (component 1). In addition however, Stirling Council area also displays areas with concentrations of all-pensioner households living in large under-occupied housing (component 1). Although this second group of pensioners could be considered a fuel poverty risk, when mapped, they highlighted more affluent areas in the urban area which interfered with the model's ability to predict fuel poverty in relation to the previously described dimensions. This dimension could merit further research as a potential indicator of rural fuel poverty which is particularly difficult to address due to the high levels of owner occupation in rural areas and the aforementioned lack of access to the gas network.

Factor scores for the 3 components were obtained for each output area. These were then transformed in terms of scale (negative to positive), according to the interpretation of the components to represent fuel poverty and summed to give a combined fuel poverty score for each output area. This factor score sum was then used to rank output areas in terms of relative risk of fuel poverty. Output areas displaying large negative values were those most at risk of fuel poverty.

Table 3

#### *Individual dwelling component*

A separate analysis was performed on the energy efficiency data gathered at the individual dwelling level, representing a different scale to the social component. Table 4 outlines the variables and resulting coded values assigned, which were obtained for a sample of 9,205 previous and current local authority owned dwellings in Stirling Council area. In order to allow meaningful PCA on this data, it was necessary to code the data to reflect the relative energy efficiency impacts such variables are likely to have on a dwelling. These variable codings were informed both by findings of the 2002 Scottish house condition survey and a local house

condition survey carried out by Michael Howard Associates in 2003 on behalf of Stirling Council. Where possible the local house condition survey was used to inform coding so as to better reflect local housing characteristics. Variable codings therefore reflect odds ratios formed through logistic regression performed by Cormack et al. (2004) and average NHER<sup>3</sup> ratings (determined through survey of a sample of individual dwellings) as reported by the 2003 local house condition survey. In addition, the sum of output area risk factors was attributed to each dwelling for the output area it was located in, as an indicator of the likelihood of the inhabitants of a dwelling belonging to a group identified by the social component of the indicator as being at risk of fuel poverty.

#### Table 4 and 5

As with the social component, the sum of output area risk factors attributed those areas at risk of fuel poverty with the large negative values, while those areas least at risk were represented by the larger positive values. Through inclusion of this data in the dwelling level indicator, it was necessary to code variables according to the same scale, therefore coding reflects increased energy efficiency with increased values. For example, a value of 1 represents the relatively least energy efficient value (the value most likely to place the dwelling at risk of fuel poverty). Principal components analysis revealed that 3 components accounted for 63% of variance in the data with interpretation of these loadings summarised in Table 5. With these components representing separate dimensions of energy efficiency in housing, it was again decided to sum the factor scores obtained for each dwelling in order to obtain a single score by which dwellings could be ranked. By setting the model up to code variables in terms of energy efficiency (low to high), relatively energy inefficient dwellings at risk of fuel poverty can then be identified in those attributed large negative factor scores.

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<sup>3</sup> The National Home Energy Rating (NHER) is a measure of energy efficiency on a scale of 0 to 10, where 0 is the worst and 10 is the best. It is based on total fuel running costs for all uses of energy in the home per square metre

## Results and Discussion

Both the social component and the individual dwelling indicator were mapped on the basis of the fuel poverty risk score. Fuel poverty risk scores ranged from -8 (most at risk of fuel poverty) to +3 (least at risk of fuel poverty) for output areas, and -8 (most at risk of fuel poverty) to +5 (least at risk of fuel poverty) for dwellings. For mapping purposes, both output areas and dwellings were represented in deciles according to fuel poverty risk.

Figure 3a shows the currently available SFPI data mapped for all electoral wards in Stirling Council, while Figure 3b shows the current SFPI at its most refined useful scale showing the Raploch and Town centre electoral wards in Stirling city identified as being among those most at risk of fuel poverty. Figures 4a and 4b meanwhile show the social component output area indicator (devised in this study) for the same areas at the same scale. From the comparison of these figures, while these areas still display a concentration of output areas at risk of fuel poverty, a great deal more intricacy and subtlety can clearly be seen to exist in the relative risk of fuel poverty when mapped at output area level. Figure 5 shows a further magnification to the 1:5,000 scale where the individual dwelling indicator becomes useful in displaying the variations in fuel poverty risk between dwellings within those output areas identified using the social component alone as most at risk of fuel poverty. Figure 6 then shows magnification to the 1:1,000 scale at which the visualisation of individual dwellings using polygon outlines becomes useful to identify the physical characteristics of buildings in addition to their relative risk of fuel poverty.

When mapped, 10 of the 139 output areas in the top 2 deciles most at risk from fuel poverty in our social component index lay within wards classed by the Scottish Fuel Poverty Indicator as being 'at least risk from fuel poverty'. A further 53 output areas in our top 2 deciles most at risk from fuel poverty lay in wards classed by the Scottish Fuel Poverty Indicator as having a 'below average percentage of fuel poor households'. This represents the possibility of

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and takes account of specific details of the location. The average NHER rating for the country as a whole is between 4.0 and 4.5 (Michael Howard Associates, 2003)



around 3,150 households in fuel poverty within wards previously classed as having the least risk of containing fuel poverty.

When the sample of 9,205 dwellings were mapped as address points, 312 of the 1,871 dwellings in our top 2 deciles most at risk of fuel poverty at the dwelling level lay within output areas ranked in the top 2 deciles most at risk of fuel poverty in our social component index. The remaining 1,559 dwellings in the top 2 deciles most at risk of fuel poverty were therefore spread out in areas which would not have otherwise been highlighted as being at risk from fuel poverty. On inspection of the output areas highlighted as most at risk from fuel poverty, a range of different energy efficiency levels were also noticeable in dwellings

#### Figures 3 – 6

This result highlights the inaccuracies councils encounter when working with composite indicators at an aggregated scale, and the very real prospect of a ‘hidden’ geography of fuel poverty. Local authorities can improve the thermal efficiency of their housing stock through a variety of methods including central heating replacements, cavity wall filling, loft insulation, re-roofing and external cladding of non-traditional house types (Stirling Council, 2005). As stated previously, in order to direct such resources to areas of need, or more specifically to dwellings, local authorities must use some form of spatial indicator – this is clear. What is not clear is the appropriateness of scale. Can we adequately predict the prevalence of fuel poverty at anything other than the scale of the individual dwelling? The results presented here emphasise the dangers of ecological fallacy in the use of local area predictors of fuel poverty (including our own indicator at the output area level), and the generation of fuel poverty risk indices for relatively large spatial units demonstrated to mask smaller areas at risk of fuel poverty. The problems of ecological fallacy in predicting fuel poverty can therefore be reduced with reduction of the size of the spatial unit to which statistics are aggregated, however this solution is made still more

problematic in considering the size of the area for which assumptions about housing can be made (Pither and Moore, 2006). The difficulties encountered when aggregating any data to a specific spatial scale are ones faced by all researchers in the field and information on local housing stock energy efficiency is therefore key to the successful identification of such previously masked areas or dwellings susceptible to fuel poverty.

The ability to map fuel poverty risk (using individual dwelling data) onto individual dwelling can be seen as important in freeing any subsequent analysis from standard geographical units, thus for example allowing for the identification of individual dwellings likely to be at risk, and complete freedom in building up community profiles at any scale. Such information would not however be available for all local authorities, thus highlighting the importance of investigating locally available data on housing stock. Our collaboration with Stirling council was fruitful in terms of data but knowledge of similar datasets in other local authorities is limited. While providing a useful tool for the identification of dwellings which may be susceptible to fuel poverty through a combination of mitigating circumstances, this indicator is by no means intended to be an absolute measure of whether a dwelling is in fuel poverty or not, as this can only be determined through a detailed household survey and validation as identified by Pither and Moore (2006). Such surveys, in combination with strategies for raising awareness about measures to eradicate fuel poverty, would be seen as the next stage in tackling fuel poverty were a local council to undertake developing an indicator such as this. In discussion with Stirling Council, a potentially cost effective route for validation and ‘fine tuning’ was noted which would involve mapping the address points of clients applying to the council for advice on fuel poverty proofing grants and affordable warmth schemes (and the subsequent success rate in receiving funding) against the indicator. Unfortunately at the time of writing data recording mechanisms which would facilitate testing such a process were not in place, but could form the basis for further research should they become available.

It was noted during the course of this research that Energy Action Scotland have plans to release a refinement of the SFPI at census output area level to local authorities in Scotland,

however this is as yet unpublished and details regarding the methodology were unavailable. In working closely with a local authority, this research benefited from both the proactive GIS unit supporting Stirling Council, and a housing department keen to utilise GIS, in terms of obtaining files which georeferenced all housing data to allow for highly detailed mapping. Problems were however encountered in separate elements of the housing information being held by different departments, which required lengthy processes in manipulation and combination to be used. A lack of data held on the complete housing stock also meant that a sample of only 9,205 dwellings could be analysed, from a housing stock of over 30,000.

There is a push by the Scottish Executive for the inclusion of GIS to a greater degree in Local Authority operations, and the set up of a central Corporate Address Gazetteer by all Scottish Councils. If the maintenance of accurate and detailed information on the physical aspects of individual dwellings could be included within this framework (including the energy efficiency characteristics of any homes receiving individual energy assessments) then mechanisms could be put in place to effectively monitor progress of fuel poverty risk at a dwelling level on an ongoing basis. This was identified by Pither and Moore (2006) as beyond the scope of any local area fuel poverty indicator currently in use.

Given directives from the Scottish Executive for the eradication of fuel poverty in Scotland by 2016, local authorities are under increasing pressure to effectively and efficiently target those areas within their boundaries where this problem is prevalent in order to set about tackling it. This research therefore represents a step towards improving the accuracy with which areas and dwellings can be targeted, thus improving the efficiency of directing further action against fuel poverty. On a final note perhaps the most challenging aspect of fuel poverty is responding to rising energy prices in a liberalised market. Tackling this, predicting areas that may be affected most severely and treating the most difficult properties are statutory obligations and social responsibilities of a responsive government. Since affordable warmth is one of the four objectives of the government's energy policy, failure to address such fuel increases will

result in an escalation in the number of vulnerable households and severe challenges for fuel poverty policy throughout the UK.

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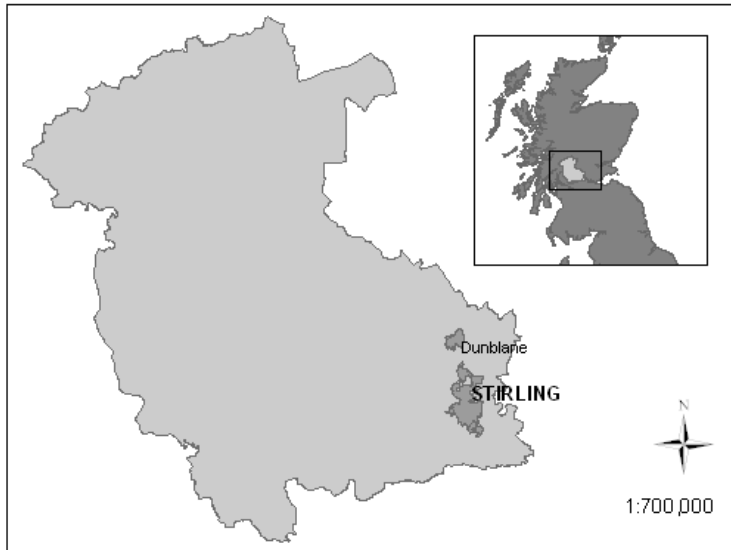
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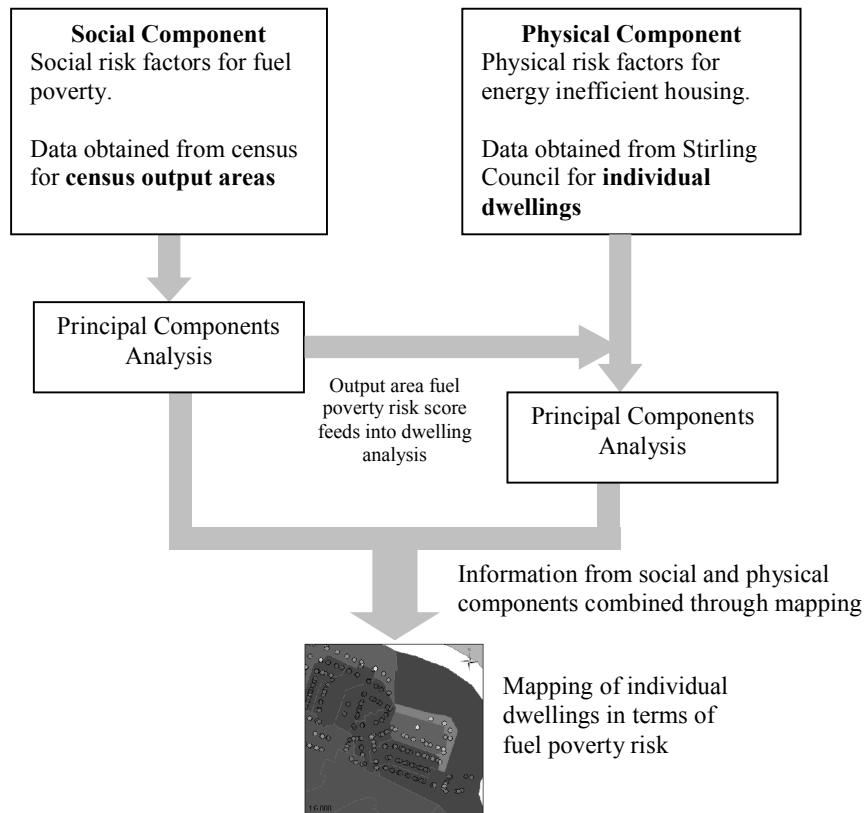
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**Figure 1**  
Location of study area

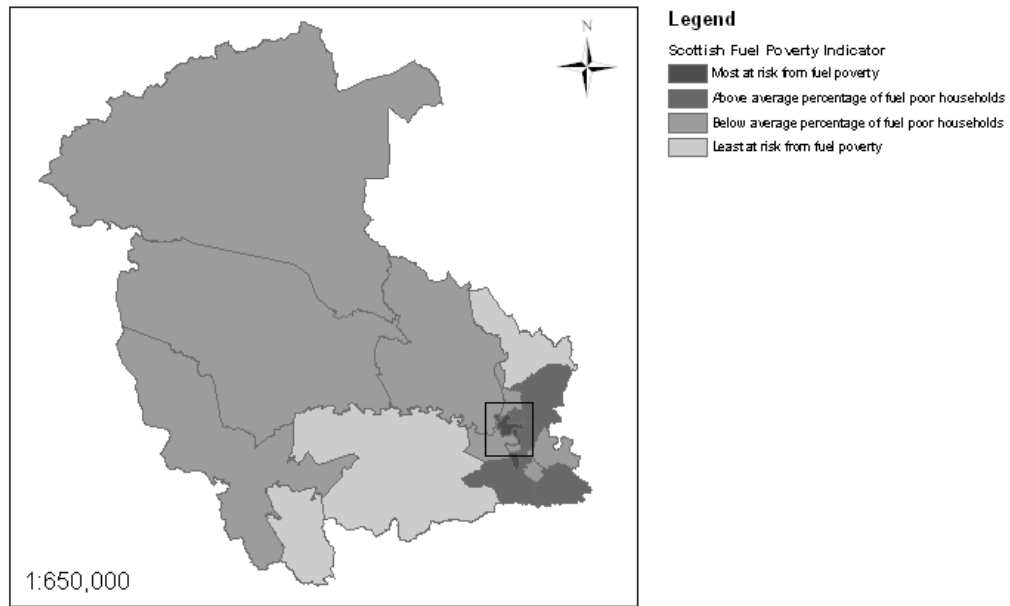


**Figure 2**  
Methodological Framework



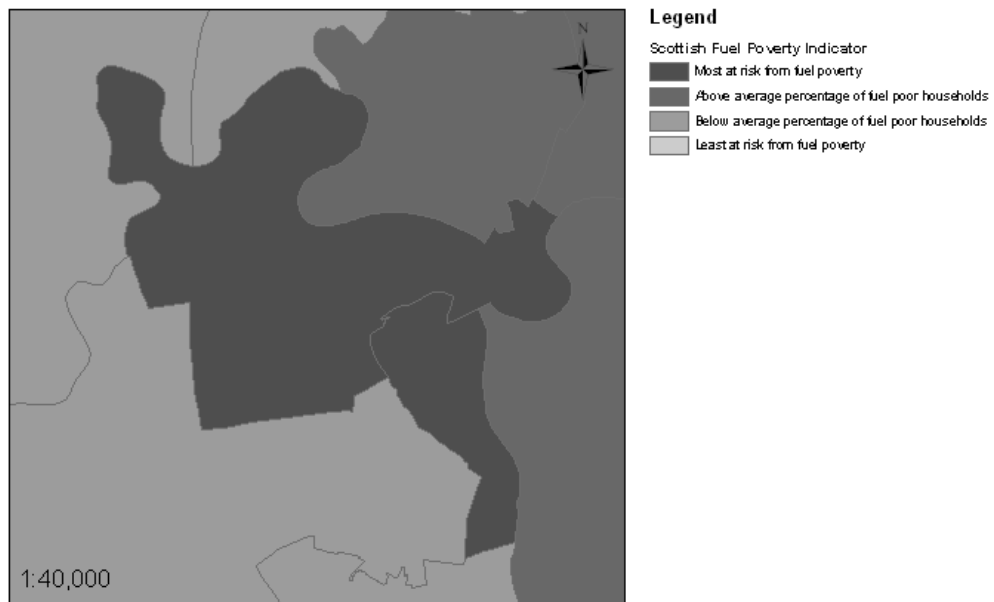
**Figure 3a**

Scottish Fuel Poverty Indicator, showing fuel poverty risk at electoral ward level for Stirling Council area. See figure 3b for insert.



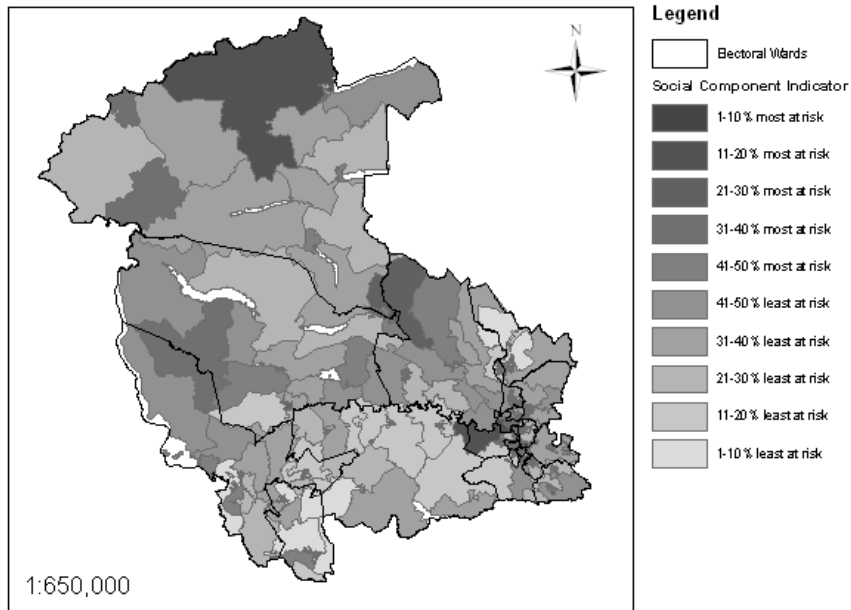
**Figure 3b**

Insert from figure 3a – Scottish fuel poverty indicator at most accurate usable scale



**Figure 4a**

Social Component / output area fuel poverty indicator, showing fuel poverty risk for Stirling Council area



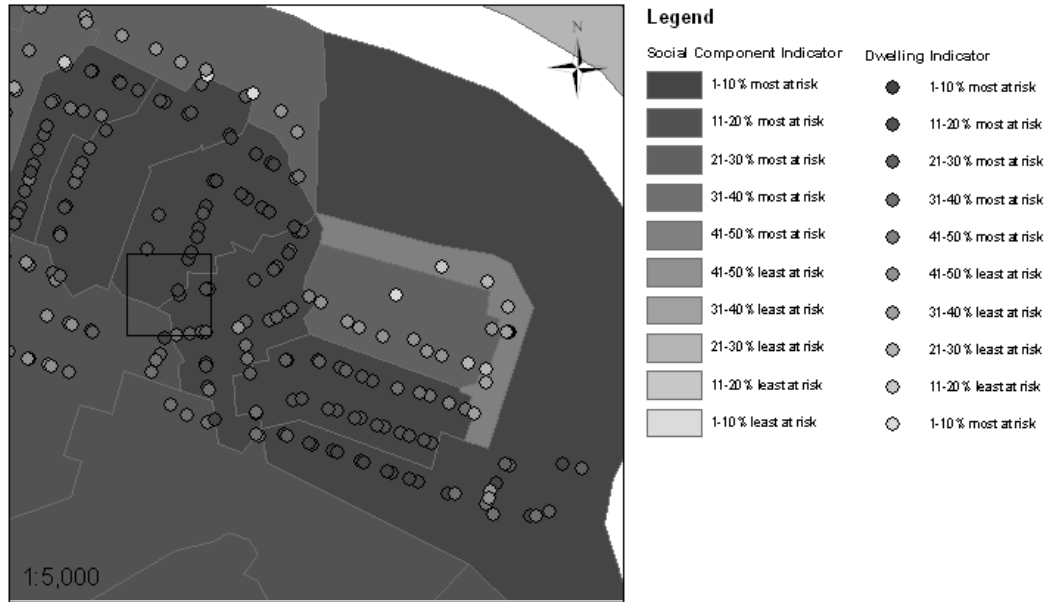
**Figure 4b**

Social Component / output area level indicator as viewed at same scale as Figure 3b. See Figure 5 for insert



**Figure 5**

Social component / output area indicator shown with dwelling level indicator superimposed. Here, dwellings are displayed as shaded point data. See Figure 6 for insert



**Figure 6**

Dwelling level indicator visualised as shaded polygon dwelling outlines, superimposed on social component / output area indicator. Note: Here the shading scale on the Social Component Indicator has been reversed to aid interpretation.



Table 1: Census variables used as predictors of fuel poverty in CSE fuel poverty indicator

Census variable
Unemployed households
Underoccupied households
Households with no access to a car
Households with no central heating
Single pensioner households
Lone parent households
Private renting households
Households including a disabled person

Source: Baker *et al* (2002)



**Table 2**

Census variables chosen to indicate risk of fuel poverty in social component

Variable	Comments
Persons in Social Grade E (Low Income proxy)	Proxy measure for low income. Although differing from the low income proxy used by Baker et al. (2002), this encompasses those on low incomes in addition to those unemployed.
Single Pensioner Households	Identified as the second most at risk household type by the 2002 SHCS (Cormack <i>et al.</i> , 2004). Also used by Baker <i>et al.</i> (2002) and Rudge (2000).
All Pensioner Households	Identified as the 4 <sup>th</sup> most at risk household type by the 2002 SHCS (Cormack et al., 2004). Also used by Baker et al. (2002) and Rudge (2000).
Single Person Households (not pensioners)	Identified by the 2002 SHCS as the group most at risk (Cormack et al., 2004).
Lone parent households with dependent children	Identified as the 3 <sup>rd</sup> most at risk household type by the 2002 SHCS (Cormack et al., 2004). Also used by Baker et al. (2002).
Households without Central Heating	Identified by Baker et al. (2002) and Cormack <i>et al.</i> (2004) as a risk of fuel poverty
Underoccupied housing	Identified by Baker et al. (2002) as a risk of fuel poverty
Average number of rooms per household	Included in conjunction with underoccupation to provide a measure of individuals living in large, underoccupied houses as, in consultation with the council, are thought may be prevalent in Stirling's owner-occupier dominated rural hinterland.

**Table 3**

Interpretation of Social Component / Output Area Indicator PCA explaining characteristics of fuel poverty

Component	Significant loadings	Interpretation
1	<p><u>Positive</u></p> <ul style="list-style-type: none"> <li>- All pensioner households (.749)</li> <li>- Average number of rooms per household (.598)</li> <li>- Underoccupied housing (.737)</li> </ul> <p><u>Negative</u></p> <ul style="list-style-type: none"> <li>- Lone parent households (-.762)</li> <li>- Single person households (not pensioners) (-.581)</li> </ul>	<p>Strong positive loadings highlight concentrations of older people living in large houses at the positive end of the scale, while strong negative loadings highlight single people and lone parents living in smaller homes at the negative end of the scale. This component can be seen as somewhat problematic as there are strong loadings at both ends of the scale, both of which could be related to fuel poverty risk.</p>
2	<p><u>Positive</u></p> <ul style="list-style-type: none"> <li>- Persons in social grade E (low income proxy) (.880)</li> <li>- Single pensioner households (.836)</li> </ul> <p><u>Negative</u></p> <ul style="list-style-type: none"> <li>- Average number of rooms per household (-.665)</li> <li>- Underoccupied housing (-.537)</li> </ul>	<p>Strong positive loadings highlight concentrations of single elderly people and individuals likely to have a low income living in smaller houses, while strong negative loadings highlight concentrations of large under-occupied homes. In this component, such large houses are however uncorrelated with a group at risk from fuel poverty and thus are more likely to show relatively affluent areas. In this component therefore, fuel poverty risk is highlighted by the positive end of the scale.</p>
3	<p><u>Positive</u></p> <ul style="list-style-type: none"> <li>- Households without central heating (.857)</li> <li>- Single pensioner households (.626)</li> </ul>	<p>Strong positive loadings highlight concentrations of elderly people living alone, without central heating. There are no strong negative loadings in this component, however the positive loadings here strongly suggest fuel poverty risk.</p>

**Table 4**

Variables and Coding for Principal Components Analysis of individual dwelling data

Variable	Values	SHCS fuel poverty risk odds	Value assigned for analysis
Tenure	Private Rented	Reference Category	1
	Owner Occupied	0.903	2
	Local Authority	0.610	3
Type of Water Heating	Coal	Reference Category	1
	Electricity	0.787	2
	Gas	0.271	3

Variable	Values	LHCS Average NHER rating	Value assigned for analysis
Property Type	Maisonette	3.3	1
	Flat	4.5	2
	End Terrace	4.5	2
	Semi-detached	4.6	3
	Detached	4.6	3
	Mid-terrace	5.3	4
Year of Construction	Pre-1919	3.7	1
	1975-82	4.3	2
	1919-29	4.7	3
	1950-63	4.7	3
	1930-49	4.8	4
	1964-74	4.8	4
	1983-90	5.3	5
	Post-1997	5.3	5
	1991-97	5.5	6
Location (Urban / Rural)	Rural	4.2	1
	Urban	4.8	2

Adapted from Cormack et al (2004), Michael Howard Associates (2003)

**Table 5**  
Individual dwelling components – characteristics of energy efficiency

Component	Loading	Interpretation
1	<u>Positive</u> – Property Type (+.589) – Output area sum of factors (+.756) <u>Negative</u> – Tenure (-.668)	Energy efficient property types, and output area factor score load strongly in a positive direction, and relative likelihood of energy efficiency in tenure loads significantly in the negative direction. We would look for the higher factor scores to highlight dwellings with greater energy efficiency. As high positive factor scores give energy efficient buildings, therefore at the other end of the scale (low/negative) are the energy inefficient buildings.
2	<u>Positive</u> – Type of water heating (+.820) – Location (urban/rural) (+.768)	This component relates strongly to type of water heating and urban / rural location. High positive factor scores will give energy efficient buildings, therefore at the other end of the scale (low/negative) are the energy inefficient buildings.
3	<u>Positive</u> – Year of construction (+.958)	Relates very strongly to energy efficiency in terms of the age of the dwelling The high positive factor scores give energy efficient buildings, therefore at the other end of the scale (low/negative) are the energy inefficient buildings.