Measuring Fuel Poverty: General Considerations and Application to German Household Data

Peter Heindl

ZEW

Zentrum für Europäische
Wirtschaftsforschung GmbH

Centre for European
Economic Research

Discussion Paper No. 13-046

Measuring Fuel Poverty:
General Considerations and Application
to German Household Data

Peter Heindl

Das Wichtigste in Kürze

Energiearmut könnte ein zunehmend ernstes Problem darstellen, falls die realen Preise für Energie marktbedingt oder durch politische Maßnahmen zur Treibhausgasvermeidung rasch ansteigen. Die Messung von Energiearmut beruht im Wesentlichen auf zwei weitgehend voneinander unabhängigen Bestandteilen. Zum einen muss eine angemessene Energiearmutsgrenze definiert werden. Dies ist eine weitgehend normative Frage. Zum anderen müssen passende Methoden zur Messung von Energiearmut (auf Basis einer Energiearmutsgrenze) ausgewählt werden. In diesem Arbeitspapier werden eine Reihe von Energiearmutsgrenzen auf Basis der bestehenden Literatur diskutiert und auf ihre Eignung zur Anwendung auf den Fall Deutschlands hin überprüft. Zudem werden Techniken zur Messung von Energiearmut vorgeschlagen. Auf Basis deutscher Haushaltsmikrodaten aus dem Sozio-ökonomischen Panel (SOEP) werden Ergebnisse für verschiedene Energiearmutsgrenzen generiert und gegeneinander abgewogen. Wie sich zeigt, kommt es bei der Anwendung verschiedener Energiearmutsgrenzen teilweise zu wesentlichen Unterschieden in der resultierenden Bewertung von Energiearmut. Die Wahl der Energiearmutsgrenze beeinflusst daher maßgeblich die resultierende Bewertung des Ausmaßes an Energiearmut und sollte mit Bedacht gewählt werden. Auch verschiedene Messtechniken können zu teils sehr unterschiedlichen Ergebnissen hinsichtlich der Armutsbewertung führen. Daher werden Möglichkeiten zur Messung von Energiearmut insbesondere mit Hinblick auf einen Vergleich verschiedener Haushaltstypen aufgezeigt und auf die verfügbaren Haushaltsmikrodaten angewendet.

Non-Technical Summary

Fuel poverty may become an increasingly severe problem in developed countries in cases when real prices for fossil fuels increase at high rates or when real energy prices increase due to policies for greenhouse gas abatement. Fuel poverty measurement consists of two largely independent parts, firstly, the definition of an adequate fuel poverty line, and secondly, the application of techniques to measure fuel poverty given some poverty line. This paper reviews options for the definition of fuel poverty lines as well as techniques for fuel poverty measurement. Based on household data from Germany, figures that would result from different fuel poverty lines are derived. Different fuel poverty lines partly yield highly different results with respect to which households are identified as fuel poor. Thus, the choice of the fuel poverty line matters decisively for the resulting fuel poverty assessment. Options for fuel poverty measurement and subgroup comparison in order to identify most vulnerable types of households are discussed in the light of the literature and based on applications to German household data.

Measuring Fuel Poverty
General Considerations and Application to German Household Data

Peter Heindl[1]

Centre for European Economic Research (ZEW), Mannheim, Germany

August 2013

Abstract: Fuel poverty may become an increasingly severe problem in developed countries in cases when real prices for fossil fuels increase at high rates or when real energy prices increase due to policies for greenhouse gas abatement. Fuel poverty measurement consists of two largely independent parts, firstly, the definition of an adequate fuel poverty line, and secondly, the application of techniques to measure fuel poverty given some poverty line. This paper reviews options for the definition of fuel poverty lines as well as techniques for fuel poverty measurement. Based on household data from Germany, figures that would result from different fuel poverty lines are derived. Different fuel poverty lines partly yield highly different results with respect to which households are identified as fuel poor. Thus, the choice of the fuel poverty line matters decisively for the resulting fuel poverty assessment. Options for fuel poverty measurement and subgroup comparison in order to identify most vulnerable types of households are discussed in the light of the literature and based on applications to German household data.

Keywords: Fuel Poverty; Energy Poverty; Poverty Measurement; Energiearmut

JEL-Classification: I32; Q28; Q48

1. Introduction

Direct residential consumption of energy, i.e. electricity, space heating and water heating, is an important part of overall household consumption and contributes to well-being and social participation, e.g. by supplying comfortable warmth or options to use appliances at home, like TV sets, computers, stoves, washing machines, and others. Residential energy demand is dependent on a number of variables, such as income, prices, preferences, and attitudes (Kriström, 2008). The elasticity of demand is lower in the short run compared to the long run, which goes back on "fixed assets" and limited options for increases in energy efficiency in the short run (Kriström, 2013). It was shown for Dutch households that the demand for space heating is highly dependent on the characteristics of dwellings while electricity consumption is mostly dependent on household characteristics and household composition (Brounen et al., 2012). For Dutch households it was also shown that changes in energy consumption are highly dependent on psychological variables rather than on household composition (Abrahamse and Steg, 2009). For the case of Norway, it was found that price sensitivity for residential energy consumption is higher for high-income households compared to low-income households (Nesbakken, 1999). For the case of Germany, it was shown that increases of energy efficiency in space heating are more pronounced in owner-occupied dwellings compared to rented dwellings (Rehdanz, 2007). The income of house owners is an important driver for energy retrofits in Germany, where house owners with lower incomes are less likely to invest in energy retrofits (Achtnicht and Madlener, 2012). Similar results were obtained for the case of Great Britain, where owner occupied households and renter households show different sensitivity to changes in fuel prices (Meier and Rehdanz, 2010). Overall, income (Nguyen-Van, 2010) [2] and prices (Reiss and White, 2008) determine residential energy demand and the price elasticity of demand (Reiss and White, 2005) but also human behaviour, or more general, household preferences matter decisively (Kriström, 2008; Reiss and White, 2008). Taking "non-price"

---

[2] Income affects overall energy consumption with increasing demand for increasing incomes (Nguyen-Van, 2010). On the households level, electricity demand is dependent on the household's appliances stock which is dependent on income according to Reiss and White (2005).

behavioural aspects of energy consumption in the design of energy efficiency policies into account can potentially have a strong impact on policy effectiveness (Allcott and Mullainathan, 2010).

Trends of increasing energy prices could be a threat for households with lower incomes. Price increases could go back on increases in the real prices of fossil fuels but also on price increases due to policies for greenhouse gas reduction, such as green taxes, subsidies, or costs of renewable energy promotion. The timeline in which increases in energy prices occur might be of particular importance with regard to fuel poverty because households need some time to adapt to price changes by increases in energy efficiency. This is reflected in a relatively low short-term price elasticity compared to the longer term (Kriström, 2013). In addition, households with lower income might find it hard to increase energy efficiency of the household because of budget constraints, e.g. to replace appliances or move to more energy-efficient dwellings. Taking the pace of price changes for energy services into account, the impact of environmentally motivated policies on energy prices might be of particular importance with respect to fuel poverty, either as a temporary or permanent issue, depending on the actual policy.

A case in point is the German energy transition. The federal government of Germany defined a number of policy targets that aim to reduce greenhouse gas emissions in Germany by 40 per cent until 2020[3]. A key policy is the German renewable energy feed-in tariff scheme (Erneuerbare-Energien-Gesetz, EEG) that offers subsidies for renewable energy carriers. While the scheme is very effective in promoting renewable energy[4], the resulting costs are considerable. Costs for renewable energy promotion are partly born by households and are directly passed through to the electricity bills. The costs for renewable energy promotion per consumed kilowatt hour (kWh) of electricity for households grew from EUR cent 0.41 in 2003 to EUR cent 5.277 in 2013. A three-person household consuming 3,500 kWh of electricity in 2013 faces costs of about EUR 185 in

---

[3] Please see BMWi (2012) and IEA (2013) for details on the German energy transition.
[4] The share of renewable energy carriers in gross electricity production in Germany was 20.3 per cent in 2011 and 12.1 per cent in final energy consumption (BMWi, 2012).

2013 that directly go back on renewable energy promotion. Costs are expected to further increase if the policy targets of the energy transition shall be achieved. Containment of costs for the energy transition becomes an increasingly important issue (IEA, 2013), inter alia, since there are tight links between GHG mitigation policies and poverty alleviation or avoidance (Ürge-Vorsatz and Tirado Herrero, 2012)[5], and because inequality and poverty are still an issue even in many developed countries (OECD, 2011), including Germany (BMAS, 2013). The strong increase in electricity prices in Germany led to a discussion on potential social drawbacks of the energy transition, e.g. by fuel poverty or "Energiearmut" as a result of strongly increasing prices, which has not been an issue in the public debate so far[6].

The aim of this paper is not to generate some particular figures on fuel poverty in Germany. Its aim is to provide a conceptual discussion on how fuel poverty could be defined and measured based on the literature and previous experiences regarding fuel poverty measurement, e.g. from the United Kingdom. While the term fuel poverty is used throughout this paper, it does not imply that a household is actual fuel poor or poor in general. The term should be interpreted in the sense that a household identified as fuel poor is potentially strongly impacted by the costs of energy services or alternatively can be regarded as a vulnerable energy consumer in accordance to the EU Commissions definition in the directives for the harmonization of European energy markets (CEER, 2012; EU, 2009a, 2009b).

The discussion on options for fuel poverty measurement consists of two steps. First, a fuel poverty line needs to be defined. Since any fuel poverty line is arbitrary in some sense, there is no technique available to identify an "optimal" fuel poverty line. The definition of a fuel poverty line is subject to public discussion on which poverty line is seen as reasonable and can be agreed on by the public. It might, however, be acceptable to require a fuel poverty line to identify those households that are

---

[5] On a global scale, this argument is related to the environmental kuznets curve discussion.
[6] A number of contributions to the fuel poverty discussion in Germany occurred early 2013, such as Goldhammer, Mans and Rivera, (2013). In Austria, the national energy regulation authority E-control contributed to the discussion (E-Control, 2013).

affected the most by the costs for energy services. As an application on household microdata from the German socio-economic panel (SOEP) will show, fuel poverty lines differ strongly in terms of which households are identified as fuel poor. A second aspect is related to the actual measurement of fuel poverty (once a fuel poverty line has been agreed). Based on the work of Watts (1968), Sen (1976), Kakwani (1980), Foster, Greer and Thorbecke (1984) and Atkinson (1987), there are well established concepts available that allow an assessment of poverty and the depth of poverty as well. Based on German microdata, a proposal is made how fuel poverty could potentially be measured in order to identify subgroups of households which are most vulnerable to increases in energy prices.

The paper is organized as follows. Section 2 provides a discussion on fuel poverty measurement in general and reviews the most important techniques available for fuel poverty measurement. Section 3 considers a number of potential fuel poverty lines based on the literature. In Section 4 different fuel poverty lines are applied to German household microdata in order to illustrate which types of households are identified as fuel poor by the different poverty lines, including an example of how fuel poverty could be measured in order to identify most vulnerable households or subgroups in the population. Section 5 concludes.

2. Concepts of Poverty Measurement

Poverty measurement in developed countries is often based on a poverty line that is determined relative to the median income of the overall population. In many countries, the poverty line is set to equal 60% of median income, which was 952 EUR in Germany in 2010 (BMAS, 2013, p. 461). The Worldbank proposed the absolute poverty line of one Dollar per day for least developed countries in its 1990 World Development Report[7]. The poverty line was updated to 1.25 Dollar in 2005 purchasing power parity. Although the 1.25 Dollar poverty line is an absolute one, it can be drawn

---

[7] For a discussion on the applicability and adequacy of a unique global poverty line such as the Dollar-per-day line see for example Banerjee and Duflo (2007).

from the national poverty lines of least developed countries that rely on considerations of basic needs and aspects of relative poverty as well (Ravallion et al., 2009; Ravallion et al., 1991).

Poverty measurement is sensitive to the choice of the poverty line that determines which persons or households are regarded as poor but also to the choice of poverty measure. The most intuitive poverty measure is the headcount-ratio, which equals the share of persons or households that fall below the poverty line relative to the overall population. While the headcount-ratio is an easy to interpret measure, it says nothing about the distribution of incomes below the poverty line. The poverty gap index takes the distance of incomes below the poverty line to the poverty line into account and therefore gives an indication of how much persons or households fall short of adequate income. Similar to the headcount-ratio, the poverty gap index gives limited information on the severity or depth of poverty within the group of the poor.

Sen (1976) proposed an axiomatic approach to poverty measurement with the propositions that given other things a) *a reduction of income of a person below the poverty line must increase the poverty measure* (monotonicity axiom) and b) *a pure transfer of income from a person below the poverty line to anyone who is richer must increase the poverty measure* (transfer axiom) Sen (1976, p.219). The transfer-sensitivity axiom further states that a poverty measure should be sensitive to transfers that take place between persons or households below the poverty line (Kakwani, 1980). It is possible to construct income transfers that leave the headcount-ratio and the poverty gap index unchanged (or even decrease the headcount-ratio) while the transfers violate the axioms proposed by Sen (1976) and Kakwani (1980). This includes cases where the headcount-ratio decreases, while the income of one or more persons below the poverty line is decreased, including the possibility that one or more persons are put into hardship[8].

---

[8] See Coudouel, Hentschel and Wodon (2002) for a broader, mostly non-technical discussion on the application of poverty measures.

Foster, Greer and Thorbecke (1984) (FGT) proposed a class of poverty measures in which the headcount-ratio and the poverty gap index is nested, but can be parameterized so that it gives higher weights to lower incomes below the poverty line, is decomposable over subgroups of a population (i.e. is additively decomposable with population share weights), and is one of the most comprehensive aggregated poverty measures (Zheng, 2002). The FGL poverty measure is given by

$$P_\alpha = \frac{1}{N} \sum_{i=1}^{q} \left(\frac{G_i}{z}\right)^\alpha, \tag{1}$$

where z is the poverty line, G_i is the poverty gap of person or household i, and N is the total number of the population with q persons or households falling below the poverty line. The poverty gap takes into account incomes below the poverty line $y_i < z$ so that

$$G_i = (z - y_i) \times I(y_i < z). \tag{2}$$

For $\alpha = 0$, P_α equals the headcount-ratio, for $\alpha = 1$, P_α equals the poverty gap index, and for $\alpha > 1$, incomes (below the poverty gap) are weighted, with increasing weights for lower incomes as α increases. As noted by Foster, Greer and Thorbecke (1984, p. 763) the FGT measure approaches a "Rawlsian" measure for $\alpha \to \infty$, which focuses on the position of the poorest household.

Since fuel poverty is a special aspect of poverty, fuel poverty measurement should be related to general poverty measurement in the sense that the interference of both types of poverty can be explained and compared. Fuel poverty measures should further satisfy the same axioms as general poverty measures. Most importantly, this implies that in addition to P_0 or P_1, measures $P_{\alpha>1}$ can be applied to account for the transfer axiom (Foster, Greer and Thorbecke, 1984. p. 763) originally proposed by Sen (1976). As proposed by Foster, Greer and Thorbecke (1984, p. 764), FGT class poverty measures of different order can be applied to compare several subgroups in the population,

which might be of particular appeal in the case of fuel poverty in order to identify groups of most vulnerable energy consumers[9].

It was proposed to use poverty measures beyond the headcount ratio for a better understanding of the depth of the problem (Atkinson, 1987; Foster, Greer and Thorbecke, 1984; Sen, 1976). Consequently, similar poverty measures can be applied in the case of fuel poverty measurement. As proposed by Hills (2012), the poverty gap measure (FGT measure P_1 with $\alpha = 1$) could be used. Based on the same reasons as for the case of general poverty measurement, it is possible to apply poverty measures of the FGT class with $\alpha > 1$ to account for the transfer axiom (Foster, Greer and Thorbecke, 1984; Sen, 1976). This could be the squared poverty gap index with $\alpha = 2$. In order to make the class of FGT poverty measures applicable to fuel poverty, some minor adjustments are necessary. The original FGT measure is dependent on the poverty gap, the difference of the poverty line and the available income of a household for households that fall below the poverty line. The poverty gap is a positive real number. This is necessary condition in order to obtain the properties of the FGT class poverty measures for α not being a positive even integer. Thus, FGT measures for fuel poverty can be calculated based on Equation (1) and a modified poverty gap definition for the case of fuel poverty (if there is a poverty line based on expenditures on energy services).

Definition: *The fuel poverty gap G_i is given by expenditures on energy services e_i of household i and a fuel poverty line z. The fuel poverty gap is the amount of money a household spends on energy services in excess to the fuel poverty line. It is a positive real number for households with expenditures above the fuel poverty line and zero otherwise.*

The fuel poverty gap is defined by

$$G_i = (e_i - z) \times I(e_i > z). \tag{3}$$

---

[9] Adequate protection of vulnerable consumers is demanded by the Directives of the European Commission concerning rules for the internal market in electricity (2009/72/EC) and gas (2009/73/EC).

Several types of fuel poverty gaps or hybrid fuel and income poverty gaps were proposed in the literature or applied in policy evaluation. The following section discusses options for the choice of the fuel poverty gap.

3. Fuel Poverty Definitions

Just as the 60% median income poverty line definition, fuel poverty lines are arbitrary in some aspects. Proposed definitions differ strongly in terms of robustness to changes in energy prices, incomes and in terms of data requirements. They also differ in their ability to capture differences in household energy needs that arise from different household sizes, income, or composition. Families with children, for example, require on average more living space than single persons or couples without children, which will increase the need and the costs of space heating and electricity as well. The energy efficiency of dwellings might correlate with the rent and overall housing costs and influences the expenditures for space heating or cooling, but is not perfectly observable. This is also an argument to use income after housing costs (AHC) to assess energy poverty (Moore, 2012). Apart of the question how to define a fuel poverty line, there are also a number of options how to measure income and the costs of energy services, e.g. whether to equalize income and (or) fuel costs, or how to capture the requirements of specific subgroups, such as families with children, lone parents, or elder people in an appropriate way. Several fuel poverty definitions have been proposed and used in the literature. Some definitions focus on fuel expenditures of households relative to income, such as the 10 per cent threshold, or the two times median/mean expenditure share poverty line. Other possible definitions could focus exclusively on expenditures for energy services of households relative to the median or mean expenditure of the overall population. Some approaches focus on the basic needs of different types of households based on minimum income standards (MIS) or on households with high (fuel) costs and low income (HCLI).

The 10% Threshold

In the UK, a 10% threshold of energy related expenditures relative to available income has been used to assess fuel poverty. The concept has also been applied for the case of Ireland (Healy and Clinch, 2004). According to the UK Fuel Poverty Strategy 2001, whose aim is to eliminate fuel poverty by 2016, a household is defined as fuel poor if it *"would need to spend at least 10% of its income in order to heat the house to an acceptable level of warmth"*. Apart of space heating, other energy services such as water heating, lights, appliances and cooking are considered (Moore, 2012, p. 29). Income is measured based on full income before housing costs (BHC), including housing benefits and on a non-equivalised scale, i.e. not adjusted for household size and composition (Hills, 2012, pp. 29-30; Moore, 2012). Energy Poverty in England is assessed based on data from the English Housing Survey and modelled utility bills of households. The 10 per cent threshold was criticised as being inappropriate since it relies on observations made more than twenty years ago by Boardman (1991)[10] and is highly sensitive to changes in energy prices (Moore, 2012). The UK government intends to change the official fuel poverty line and it was recommended to move away from the 10 per cent threshold by Hills (2012). Based on the 10 per cent threshold, 15 per cent of households in England where identified as fuel poor in 2011, 25 per cent in Scotland, 29 per cent in Wales, and 42 per cent in Northern Ireland (Department of Energy and Climate Change, 2013). Instead of the 10 per cent threshold, alternative shares of expenditures on energy services could be defined as fuel poverty line.

The Two Times Median and Two Times Median Expenditure Share Threshold

Originally, the 10% threshold represented the share of income spent on fuel services by the poorest 30% of households in the UK and about twice the median of expenditure on fuel services relative to the overall sample population in Boardman (1991) and according to Moore (2012). Earlier works that date back to the 1970s also applied the two times median concept (Liddell et al., 2012). The

---

[10] See Liddell, Morris, McKenzie, & Rae, (2012) for a review on fuel poverty in the United Kingdom.

twice the median concept identifies those households having unusually high expenditures on energy services. Since the median divides the distribution of expenditures on energy services in two parts, with 50% of households having higher (lower) expenditures than the median, the concept is relatively robust to extreme low or high observed values of expenditures in a sample. In this paper, the concept is applied to expenditures on energy services and the share of expenditures relative to income for comparison.

The Two Times Average and Two Times Average Expenditure Share Threshold

In a working paper of the EU Commission, the fuel poverty line was set equal to two times the average fuel expenditure share (relative to income) of all households in the sample population (EU, 2010). The concept is similar to the two times median approach. A major disadvantage of the two times average approach is that the average (arithmetic mean) is more sensitive to extreme values in a distribution. A clear advantage is that mean values are often available for aggregated data on energy related expenditures of households, while the median is not. The concept is applied to expenditures on energy services and the share of expenditures relative to income for comparison as in the case of the median approach described above.

The Minimum Income Standard (MIS) Approach

In some countries, such as Norway or Sweden, there are budget standards, which are defined to identify assistance needs for (poor) households. A minimum income standard (MIS) for Britain was proposed by Bradshaw et al. (2008). The MIS is defined as *"having what you need in order to have the opportunities and choices necessary to participate in society"* (Bradshaw et al., 2008, p. 1). Needs for different types of households where assessed based on "Blending" in Bradshaw et al. (2008), which takes into account the views of experts and the public in deriving and assessing income standards for different types of households and different types of goods and services. The MIS proposed for Britain augments the standard 60% of median income poverty assessment. As

shown in Bradshaw et al. (2008), the proposed MIS matches well to the 60% of median definition, but cast light on the needs of several subgroups, such as families with children, which have higher needs relative to other households. According to Moore (2012) income standards could be used to assess fuel poverty. A household would be subject to fuel poverty if the available income after housing and fuel costs is insufficient to meet the minimum income standard. While the MIS takes several subgroups of the population into account, it might fail to identify the needs of individual households in certain situations. The needs of a family with children might be highly different dependent on the age of a child e.g. because of costs for childcare or tuition fees. Also, for elder people, the costs for medical and healthcare will highly depend on the health status of a person which can change unexpectedly. For the case of Germany, social benefit rates (based on German law Sozialgesetzbuch II, also SGB II) could be interpreted as a MIS. Although SGB II rates differ conceptually from MIS as defined by Bradshaw et al. (2008), they represent what is regarded as reasonable income under basic security. From the perspective of public economics the SGB II rates could represent a MIS since labour supply would presumably be zero for households whose income from labour less housing costs and necessary expenses for energy services falls below SGB II rates[11]. In this case, fuel poverty could, on the margin, be a motivation for households with lower (labour) income, to decrease labour supply and receive SGB II benefits under which the cost for space heating and in some cases certain expenditures for electricity are taken over by the welfare agency.

The High Cost / Low Income (HCLI) Approach

A report commissioned by the British Department of Energy and Climate Change reviewed the definition of fuel poverty in the UK with a strong focus on how to measure fuel poverty (Hills, 2012). The Hills Report made the recommendation that *"the Government should change its*

---

[11] Under SGB II social security, housing costs and expenses for space heating and partly for water heating are directly taken over by the welfare agency. Thus, costs for those energy services could influence labour supply of households with incomes marginally above social benefit rates.

approach to fuel poverty measurement away from the current '10 per cent' ratio indicator" (Hills, 2012, p. 8). In the report a new approach for fuel poverty measurement was proposed. It is proposed that a household should be regarded to be fuel poor if they face fuel costs above the median level and is left (after expenditures on all energy services) with a remaining income below the poverty line of 60% median income after housing costs. It is further proposed to equivalise income (based on the OECD scale) as well as fuel costs (based on a specific fuel cost scale, see Table 1).

Table 1: Fuel cost equivalence scale as proposed by (Hills, 2012, p. 52)

Household type	Equivalence factor
Couple with dependent children	1.15
Couple without dependent children	1.00
Lone parent	0.94
Single person	0.82
Other multi-person household	1.07

Source: Hills (2012)

The definitions of fuel poverty lines discussed above differ in many aspects. While the 10 per cent, two times median, and two times average approach establishes a pure fuel poverty line, the MIS and HCLI are based on an income poverty line after expenditures for energy services are taken into account. Taking equivalised incomes into account offers the possibility to capture the requirements of different household types more adequately compared to non-equivalised income or when fuel poverty lines are used that ignore household incomes. Considering income after housing costs could further capture some aspects of energy efficiency of buildings but incur the risk of overweighting under-occupied dwellings or households with preferences (i.e. a willingness to pay) for larger dwellings. Table 2 summarises the most important properties of the different fuel poverty lines.

Table 2: Overview of fuel poverty lines and their properties

Type	Measurement	Properties	Equiv. Income
10%	Expenditure on energy services greater or equal to 10% of Income (or any other share).	HH specific poverty line dependent on HH income. Fuel poverty line.	No (optional)
2x median energy exp.	Expenditure on energy services greater or equal to 2x median expenditure (or any other factor).	Unique poverty line within sample, not dependent on income. Fuel poverty line.	Not applicable
2x median share	Share of energy expenditures relative to income greater or equal to 2x median share of expenditures in the sample	Unique poverty line within sample as ratio of median expenditures and income	Yes (optional no)
2x average energy exp.	Expenditure on energy services greater or equal to 2x average expenditure (or any other factor).	Unique poverty line within sample not dependent on income. Fuel poverty line.	Not applicable
2x average share	Share of energy expenditures relative to income greater or equal to 2x mean share of expenditures in the sample	Unique poverty line within sample as ratio of mean expenditures and income	Yes (optional no)
MIS based	Residual income after expenditure on energy services and housing costs less or equal the MIS (after housing costs and expenditure on energy services).	HH specific poverty line dependent on HH type and income. Income poverty line.	Yes
High cost / low income	Households that spend more than the median on all energy services and fall below the poverty line of 60% of median income after expenditures on energy services are subtracted from income.	HH specific poverty line dependent on HH type and income. Hybrid income and fuel poverty line.	Yes

4. Fuel Poverty in Germany: A Comparison of Poverty Lines

In this section, poverty measures are calculated for the case of Germany based on comprehensive household data from the German socio-economic panel (SOEP) and under consideration of different fuel poverty lines. The aim of this section is not to present some particular figures on fuel poverty in Germany, but to discuss the applicability of different fuel poverty lines based on household survey data from 2011, using the GSOEP28 dataset. The data reflect the situation in the year 2010. Since the SOEP dataset was used for the official poverty line assessment in Germany (BMAS, 2013) and contains a large number of socio-economic variables, the data nicely match the research question. After a brief data description, different fuel poverty lines are tested against each other, followed by a proposal how to identify households which are most vulnerable to fuel poverty or increasing energy costs in general.

4.1 Data Description

While for some fuel poverty measures, e.g. the two time median expenditure measure, the only information needed are household expenditures for energy services, other measures, such as the MIS or low income/high cost measure, require information on housing costs and income as well. To be consistent in comparing fuel poverty measures, a subsample of the GSOEP28 dataset is used for which all required data are available for 2011. The original full sample of n=12,290 observations in 2011 collapses to n=10,193 observations for which available household income, costs for electricity, space heating, and water heating, as well as housing costs are jointly available. Since costs for electricity where not available for 2,560 households that own property, their costs where generated by imputation (based on the predicted values of an OLS regression). Equivalised household incomes are generated based on the (new) OEDC equivalence scale that weights the first adult in a household by 1.0, each additional person in the household of age 15 or higher by 0.5, and each child aged 14 years or less by 0.3. Equivalisation of household incomes is the standard procedure to account for different household size and composition and is used by the German

statistical office. After equivalised income was generated, the mean equivalised income in the full sample is EUR 1,586, with 60% of mean income (the official poverty line) at EUR 952. The income distribution in the subsample of n=10,193 is similar to the original one with mean income EUR 1,556 and 60% of mean equal to 934 EUR. Costs for energy services consist of expenditures for electricity, heat, and water heating. Available income and equivalised income are distinguished by income before housing costs (BHC) and income after housing costs (AHC). Housing costs consist of mortgage or home loan interest, repayments and running additional charges in the case of property owners and rents and additional charges in the case of rented apartments or houses. An additional set of control variables is available, which are not needed to calculate fuel poverty measures, but could be used to identify subgroups of households. This includes the size of dwellings (square meters), the number of occupied rooms, the number of persons in the household, the type of household (single, couple, couple with children, lone parent, and others), the quality of dwelling (e.g. if it needs refurbishment), the age of buildings, further information on dwellings (e.g. if balcony is available), information since when a household lives in a dwelling, and information if a dwelling is let with rebate. The SOEP dataset also provides population share weights, which are used to weight the sample so that it properly reflects the overall population in Germany. Summary statistics are reported in Table 9 in the appendix.

As Figure 1 shows, about 25 per cent of households in the sample had expenditures for all energy services of more than 10 per cent of *non-equivalised* household income BHC. The mean expenditure share in 2011 was 8.2 per cent. Mean expenditure for electricity were EUR 66 or 3.2 per cent of non-equivalised income BHC. Mean expenditure for space heating were EUR 102 or 5.0 per cent of non-equivalised income BHC. The figures differ not too much from those in Neuhoff et al. (2012, 2013), where different data were used[12].

---

[12] Neuhoff et al. (2012, 2013) used German household data from the Federal Statistical Office (DEStatis), namely the "Einkommens- und Verbrauchsstichprobe".

A joint look at *equivalised income* and expenditures for energy services reveal that the share a household in the sample needs to spend on all energy services strongly depends on income in average. The poorest 10 per cent of households need to spend 19 per cent of equivalised income on energy services in median, while the richest 10 per cent of households have a cost share of 4.8 per cent in median. Energy consumption and energy expenditures do not increase at the same rate as equivalised household income. This gives a first indication that fuel poverty might be a predominant issue amongst households with low income or with energy needs above average, such as families, lone parents, or elder people. Average equivalised incomes and expenditure on all energy services are displayed in Figure 2 for all households in the sample and several subgroups.
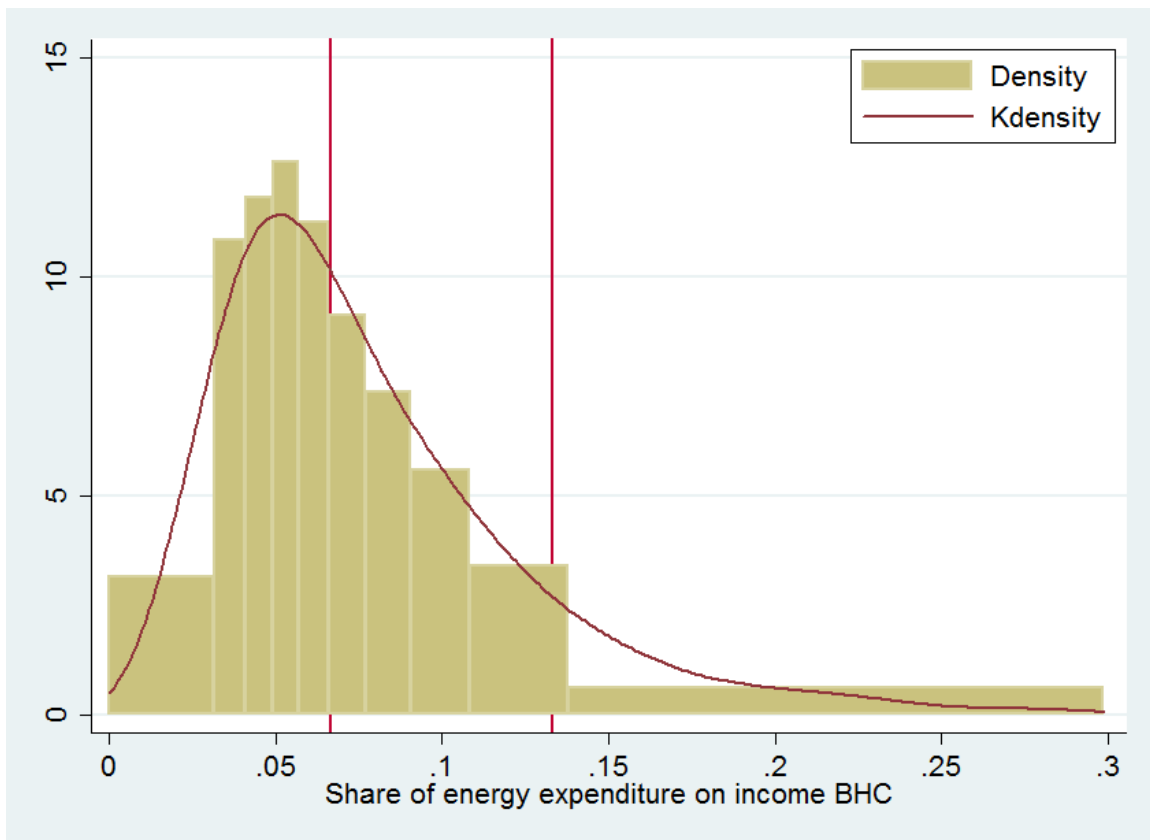

Figure 1: Density of the share of expenditures for all energy services relative to non-equivalized household income in the sample. Each bin represents 10% of the distribution. The vertical lines represent the mean and two times the median share of expenditure respectively.

4.2 A Comparison of Fuel Poverty Lines

Table 3 shows the results of a fuel poverty assessment based on German data from the SOEP 2011. Eight fuel poverty lines are considered. The 10% poverty line, where a household is identified as fuel poor if its expenditures on all energy services (space and water heating and electricity)[13] are higher or equal to ten per cent of non-equivalised household income. A similar fuel poverty line (based on modelled bills) has been used for the assessment of fuel poverty in the UK (Moore, 2012). The two times median expenditure poverty line considers a household as fuel poor if its expenditures are equal to or above the two times median expenditure in the sample. The two times mean expenditure poverty line takes the same approach with average expenditures in the sample. The two times median *share* of energy expenditure relative to income, that has been previously applied in the UK (Liddell et al., 2012), considers the share of expenditures relative to income rather than absolute expenditures. Also a two times mean expenditure *share* poverty line is considered following a working paper of the EU Commission (EU, 2010). Both the median and mean share concepts are applied using equivalized incomes in the application below. For the MIS poverty line, German welfare rates (SGBII rates) are taken as a minimum income standard. Although SGB II rates are no MIS as defined by Bradshaw et al. (2008), they reflect the actual least income available for households in Germany. SGB II rates are allocated dependent on household composition. The MIS can therefore be interpreted as an available minimum income on an equivalised scale (see appendix for details). The high cost/low income (HCLI) approach is motivated by Hills (2012). The poverty line is defined by two conditions. Firstly, a household must have expenditures on all energy services above the mean to be considered as potentially fuel poor. Secondly, a household qualifies as fuel poor if it is left with a residual income (after expenditures on energy services) below the official poverty line. The approach can be applied before housing

---

[13] While (Neuhoff et al., 2012, 2013) focus on electricity prices, it seems to be appropriate to assess fuel poverty based on expenses on all energy services to be consistent over time and to capture all changes in prices, including fossil fuels and policy driven price changes. Furthermore, space heating represents a basic need for German households for several month of the year and should thus be included in any fuel poverty assessments.

costs (BHC) and after housing costs (AHC). The poverty line must be adjusted accordingly and is set to EUR 952 before housing costs (BMAS, 2013) and to EUR 775 after housing costs based on SOEP data in 2011. Hills (2012) also suggested to equivalise energy expenditures according to household type (see Table 1). Expenditures on energy services are not equivalised in this paper to avoid an overweighting of specific household types and to allow for comparison with the official income poverty line.

As shown in Table 3, the share of households potentially subject to fuel poverty is rather high (25.1%) when the 10 per cent poverty line is applied. The figure is higher compared to England, where 15% of households fall under the 10 per cent threshold in 2011, similar to Scotland (25%), but lower compared to Wales (29%) and Northern Ireland (42%)[14] (Department of Energy and Climate Change, 2013, p. 19). The two times median expenditure and two times mean expenditure approach yield relatively low shares of fuel poor (4.6% and 2.9%). Those poverty lines clearly fail to capture poorer households. Average equivalised income in the group of fuel poor is very high when using these poverty lines while the share of households that fall below the official poverty line is low. In contrast, the 2x median and mean expenditure share poverty lines yield higher shares of fuel poor (11.2% and 4.9%). The MIS poverty line identifies 8.8% of households as subject to fuel poverty. Those households have the lowest average equivalised income (EUR 721) when compared to other poverty lines. About 90 per cent of fuel poor households under the MIS also fall below the income poverty line. The HCLI BHC poverty line identifies 10.5 per cent of households as fuel poor, with an average equivalised household income of EUR 907, which is close to the income poverty line of 952 EUR. 52 per cent of households that were identified as fuel poor by the HCLI BHC also fall under the official poverty line and fuel poor households have particularly high shares of expenditures on energy services relative to income with mean 26.3 per cent. The HCLI AHC

---

[14] The results for the UK are based on modeled bills while the results for Germany are based on household survey data from the SOEP. EUROSTAT data show that prices for gas where about the same in Germany and the UK in 2010 and 2011 (data nrg_pc_202), but electricity prices in Germany where about 10 EUR cent per kWh higher in Germany when compared to the UK for households consuming 2,500 to 5,000 kWh of electricity (data nrg_pc_204).

poverty line identifies 12.6 per cent of households as fuel poor and shows slightly different figures with regard to other indicators because of the different poverty line used for the fuel poverty assessment compared to the BHC poverty line. For the case of England, the HILC indicator identified a share of about 12 per cent of fuel poor (Department of Energy and Climate Change, 2013, p. 21), based on a slightly different methodology (equivalised energy expenditure and different income poverty line). Similar to the case of Germany, the HILC approach delivered a lower share of fuel poor in the case of England when compared to the 10 per cent approach. Average equivalised incomes and expenditures on all energy services are displayed in Figure 2, where different fuel poverty lines are compared.
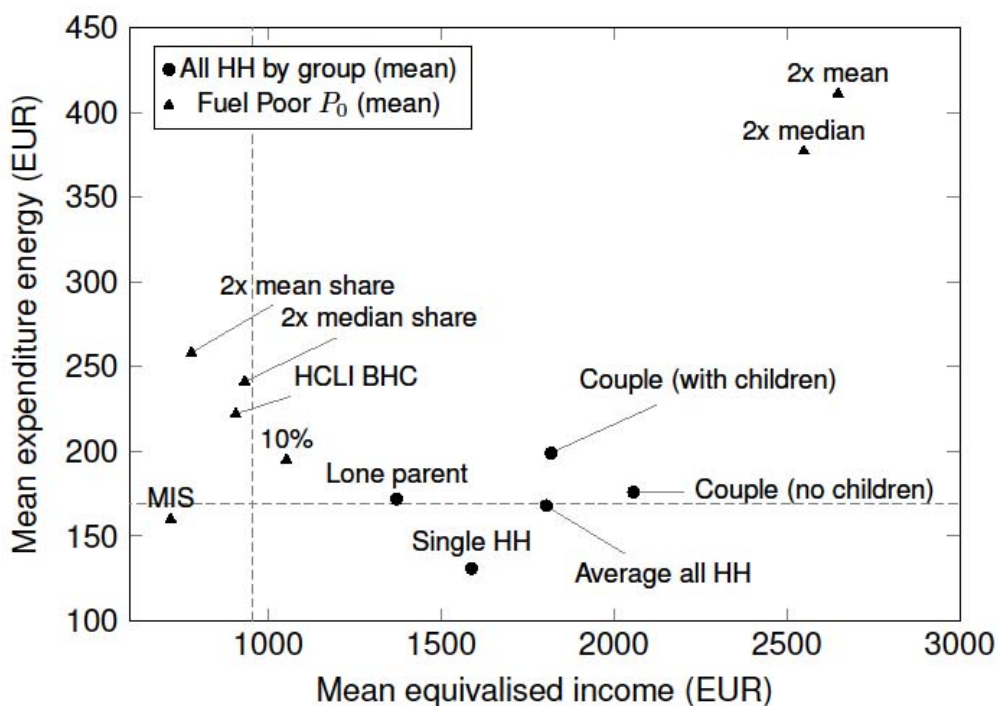

Figure 2: Mean of equivalised income and all expenditures on energy services in EUR for all households in the sample and several subgroups and within the groups of "fuel poor" evaluated based on different fuel poverty lines.

Table 3: Fuel poverty measures for Germany (2011)

Type	Share fuel poor in sample	Share of fuel poor (population weights)	Average equivalised Income of fuel poor (BHC)	Share of fuel poor below poverty line (952 EUR)	Average exp. on energy services of fuel poor (equiv. income)
10% NE BHC	25.1%	29.8%	1,054	45.7%	20.3%
2x median expenditure	4.6%	4.1%	2,549	8.1%	21.5%
2x median share of exp.	11.2	12.0%	933	58.2%	28.2%
2x mean expenditure	2.9%	2.4%	2,648	7.9%	22.1%
2x mean share of exp.	4.9%	5.4%	779	74.8%	36.5%
MIS (SGBII)	8.8%	9.9%	721	89.2%	25.0%
HCLI EI BHC	10.5%	11.1%	907	52.2%	26.3%
HCLI EI AHC	12.6%	13.7%	998	43.5%	24.5%

When the share of fuel poor is broken down to several subgroups for different fuel poverty lines, some conceptual differences of the fuel poverty lines are revealed (Table 4). The 10 per cent measure identifies single households as the most vulnerable type of households. This is in strong contrast to all of the remaining concepts. This is because the 10 per cent approach is based on non-equivalised income and neglects scale effects. The two times median and two times mean expenditure concepts identify other HH as most vulnerable household types, while the figures for lone parents are relatively low and similar to those for couples without children. The two times median share and two times mean share poverty lines both identify lone parents as most vulnerable household type. Also the MIS and HCLI identify lone parents and other households as most

vulnerable. Interestingly, MIS and HCLI differ strongly with regard to the figures for single HH and couple with children. While the MIS ranks single HH as the third most impacted group and figures for couples with children are relatively low, the HCLI (and the two times median share) ranks couples with children as a household type that is more frequently subject to fuel poverty compared to single HH or couples without children. This likely goes back on the definition of the MIS that is based on SGB II rates, in which specific allocation for children is available. This limits the applicability of SGB II rates as MIS for families that do not receive public assistance, i.e. in cases where equivalised household income is low for some reason.

Table 4: Share of fuel poor for different measures in subgroups (results with population share weights in parenthesis) in per cent

	Single HH n=3064	Couple no Children n=3722	Lone parent n=702	Couple with Children n=2553	Other HH n=152
10% NE BHC	41.3% (42.7)	18.1% (20.3)	38.5% (39.8)	12.1% (14.6)	25.7% (28.2)
2x median	1.6% (1.6)	4.6% (5.0)	5.4% (4.5)	7.9% (7.8)	7.9% (7.4)
2x median share of exp.	8.3% (8.9)	8.3% (9.5)	20.5% (22.4)	16.0% (18.5)	17.8% (20.3)
2x mean	0.8% (0.8)	2.7% (2.9)	3.8% (3.2)	4.9% (4.4)	7.9% (7.4)
2x mean share of exp.	3.4% (3.7)	3.5% (4.4)	10.8% (12.0)	7.2% (8.5)	5.3% (5.4)
MIS	12.6% (12.3)	4.7% (5.5)	18.4% (20.6)	7.1% (8.1)	16.4% (17.0)
HCLI EI BHC	7.4% (7.8)	8.1% (9.0)	20.7% (24.4)	14.6% (16.6)	16.4% (17.2)
HCLI EI AHC	9.6% (10.7)	8.8% (9.8)	25.2% (29.4)	17.8% (20.3)	19.1% (19.8)

Comparing the correlation of the different fuel poverty lines gives an indication about the proximity of the different fuel poverty lines (Table 5). The 10 per cent measure shows relatively high correlation to MIS, HCLI, and two times median/mean share but is not a perfect substitute. The two

times median and two times mean expenditure concepts show weak correlation to the remaining fuel poverty measures. The HCLI concept has a relatively high correlation to the 10 per cent measure, high correlation to the BHC and AHC concept, and median or mean share measure as well. For the MIS measure, correlation to most of the remaining measures, i.e. to the HCLI, is less pronounced than expected.

Table 5: Pairwise correlation of fuel poverty measures (Germany 2011, results with population share weights in parenthesis)

	10%	2x median exp.	2x median Share of exp.	2x mean exp.	2x mean Share of exp.	MIS	HCLI BHC	HCLI AHC
10%	1.0000							
2x median expenditure	0.1263*** (0.1132)	1.0000						
2x median share of exp.	0.5322*** (0.5033)	0.2344*** (0.2337)	1.0000					
2x mean expenditure	0.1032*** (0.0999)	0.7797*** (0.7539)	0.2058*** (0.2134)	1.0000				
2x mean share of exp.	0.3863*** (0.3599)	0.2134*** (0.2170)	0.6405*** (0.6465)	0.1949*** (0.2095)	1.0000			
MIS	0.4293*** (0.4348)	-0.0005 (0.0013)	0.4437*** (0.4639)	0.0030 (0.0026)	0.4332*** (0.4304)	1.0000		
HCLI BHC	0.4772*** (0.4464)	0.0649*** (0.0706)	0.6569*** (0.6570)	0.0526*** (0.0617)	0.5302*** (0.5270)	0.3137*** (0.3196)	1.0000	
HCLI AHC	0.4677*** (0.4525)	0.0871*** (0.1016)	0.6112*** (0.6026)	0.0610*** (0.0832)	0.4800*** (0.4752)	0.2956*** (0.2899)	0.8096*** (0.8022)	1.0000

*** Significance level < 0.01%

Poverty lines can be compared so that they would yield similar shares of households potentially subject to fuel poverty[15]. Since poverty lines as the 10 per cent or two times median expenditure approach are chosen arbitrarily, the comparison can also strengthen the intuition about what would be comparable shares of expenditure on energy services relative to fuel poverty lines that (in parts) rely on income poverty lines, such as the HCLI. Table 6 compares the per cent expenditure and median expenditure concept to the HCLI BHC fuel poverty line. A ten per cent expenditure share fuel poverty line, as previously applied in the UK, seems to be too restrictive for the case of Germany. A similar share of fuel poor as in the HCLI BHC would be obtained at a level of 14 per cent expenditure on all energy services relative to non-equivalised income. The 10 per cent poverty line would be equivalent to an income poverty line of EUR 1,480 in the HCLI BHC concept. This is far above the official poverty line of EUR 954. Also a fuel poverty line of 1.65 times median expenditures on all energy services would yield a similar share of fuel poor when compared to the HCLI BHC. The two times median expenditure approach would be equivalent to a EUR 690 income poverty line in the HCLI BHC approach, which is far below the official poverty line.

Table 6: In-sample sensitivity of fuel poverty lines (Germany 2011)

	10%	2x median expenditure	HCLI BHC
10% non-equiv. BHC	10%	18.5%	14%
2x median expenditure	1.3 x Median	2 x Median	1.65 x Median
HCLI BHC	1,480 EUR poverty line	690 EUR poverty line	954 EUR poverty line

The comparison of fuel poverty lines for the case of Germany showed that the different concepts identify a different number of households as fuel poor and different types of households as well (Table 3 to 5). The two times median expenditure and two times mean expenditure concepts fail to identify poor households (in terms of income) and captures some households with relatively high incomes that face high expenditures on all energy services for some reasons. The 10 per cent

---

[15] This does not imply that the same households are identified as fuel poor.

approach is chosen arbitrarily but could be modified so that it yields a similar share of fuel poor compared to the HCLI BHC approach when setting the fuel poverty line equal to 14 per cent of expenditure. However, the 14 per cent and HCLI would not identify the same households as fuel poor. The correlation between both approaches is about 50 per cent, with larger variance of incomes for the 14 per cent threshold compared to HCLI BHC, where the 14 per cent approach captures some wealthier households than the HCLI BHC. The MIS fuel poverty line that is based on German social benefit rates (SGB II) yields lower figures of fuel poverty than the HCLI, the 10 per cent, and median/mean share measures because of a relatively low poverty line implied by SGB II rates. Single HH are identified as the most vulnerable types of households when using MIS SGB II, which is in strong contrast to the remaining fuel poverty lines. Thus, SGB II rates seem to be inappropriate as MIS in this case, because of the design of SGB II rate allocation for different types of households. However, the use of MIS SGB II shows that there is indeed a risk that increasing expenditures on energy services might lead to a decrease in labour supply of poor households, i.e. since costs for space heating are fully born by the welfare agency. The HCLI poverty line is able to identify poorer households as potentially subject to fuel poverty by definition and rules out cases in which high expenditure on energy services is driven by high income and specific preferences. Surprisingly, the two times median expenditure share measure yields results which are similar to the HCLI approach with relatively high correlation of households identified as fuel poor.

4.3 Analysing Fuel Poverty: An Example

The FGT class poverty measure allows for subgroup comparison of $j = 1 \dots m$ groups with income vector y broken down to $y^{(1)}, \dots, y^{(m)}$ income vectors and subgroup population share weights n_j/n. A subgroup's contribution to total poverty is $(n_j/n)P_\alpha(y^{(j)}; z)$ and the percentage contribution of a subgroup to overall poverty is given by $100\,(n_j/n)(P_\alpha(y^{(j)}; z)/P_\alpha(y; z))$ (Foster, Greer and Thorbecke, 1984, pp. 763-764). Based on this, a detailed comparison of subgroups and their contribution to overall fuel poverty is possible, once a certain poverty line has been agreed on. The

example below assumes the HCLI BHC poverty line. Apart of the share of households subject to fuel poverty (P_0), the squared poverty gap index (P_2) is calculated to capture the depth of poverty within the groups. Each group's contribution to P_2 in absolute figures and per cent is calculated to compare the relative importance of a group for overall fuel poverty, which can deliver valuable information for "targeting" of policies for fuel poverty reduction. The measure P_α is comparable between subgroups, which allows an assessment of which group is the most vulnerable according to a certain P_α.

The results from subgroup comparison based on the HCLI BHC and the P_2 FGT measure are reported in Table 7. According to P_2, the groups of lone parents, other HH, and couples with children are households where fuel poverty is the "deepest"[16]. Because of the size of the groups of single HH and couples without children, their contribution to overall poverty is about 50%, although fuel poverty is not as "deep" as among the remaining groups. The contribution of the group of other HH and lone parents to overall poverty is relatively small with 2.3 per cent and 13.8 per cent respectively, while fuel poverty is relatively severe in these groups. If the government aims to reduce the share of overall "fuel poor" based on the P_0, it could be tempted to introduce policies that target the groups of households where fuel poverty is not very deep but which jointly contribute to a large amount to P_0, such as single HH or couples without children. If the objective is to reduce fuel poverty amongst those households which are most severely concerned, the targeting schedule would prefer lone parents and other households, followed by couples with children. Table 8 shows ranked targeting schedules based on different indicators of poverty. Dependent on which indicators are chosen to set up (targeted) policies for poverty reduction, the targeting schedule will look different. As the example has shown, policies that aim to minimise P_0 might fail to identify the most vulnerable households or those who are most concerned with fuel poverty. Therefore, the use of poverty measures with $\alpha > 1$ and disaggregation of the overall population in subgroups is

---

[16] For lone parents in Germany it was shown that their poverty risk is about two times higher when compared to other household types (IAB, 2009).

recommended in order to identify households most vulnerable to changes in energy prices or fuel poverty in general and to assess the impact of policies that aim to reduce fuel poverty over time.

Table 7: In-sample subgroup comparison based on the HCLI BHC measure

HH Group	n	fuel poor (per cent)	P2	Contribution to overall P2	Contribution P2 (per cent)	Eq-Income (Mean)
All HH	10,193	10.5 %	0.0130055	-	-	1,805
Single HH	3,064	7.4 %	0.0100215	0.0030124	23.2%	1,589
Couple (no children)	3,722	8.1 %	0.009164	0.0033463	25.7%	2,057
Lone Parent	702	20.7 %	0.0259932	0.0017902	13.8%	1,372
Couple (w. children)	2,553	14.6 %	0.0182137	0.0045619	35.1%	1,819
Other HH	152	16.5 %	0.019764	0.0002947	2.3%	1,760
Total	10,193	-	-	0.0130055	100 %	-

Table 8: Targeting schedule based on different fuel poverty indicators from the HCLI BHC measure

Rank	P0	P2	Contribution to P2	Eq-Income
1	Lone Parents	Lone Parents	Couple + Children	Lone Parents
2	Other HH	Other HH	Couple no Children	Single HH
3	Couple + Children	Couple + Children	Single HH	Other HH
4	Couple no Children	Single HH	Lone Parents	Couple + Children
5	Single HH	Couple no Children	Other HH	Couple no Children

5. Concluding Remarks

Throughout this paper a number of options for fuel poverty measurement and the definition of a fuel poverty line where discussed. The application of different fuel poverty lines on German microdata from the socio-economic panel showed that the poverty lines partly differ strongly with respect to which households are identified as fuel poor. This shows that the actual choice of the fuel poverty line matters decisively for the resulting fuel poverty assessment. Overall it appears that an *X* per cent poverty line is a rough measure of fuel poverty and fails to fully identify households which are less wealthy. As noted by Moore (2012), figures resulting from that fuel poverty line are highly sensitive to temporary changes in fuel prices, which is a clear disadvantage. Poverty lines, such as the *X* times median expenditure or *X* times mean expenditure approach, fully fail to identify poorer households. In contrast, the *X* times median/mean expenditure share measure identifies households with relatively low incomes and high fuel costs. Concepts like the "high cost/low income" (HCLI) poverty line, originally proposed by Hills (2012) or a "minimum income standard" offer high accuracy in identifying poorer households with high expenditure on energy services. They also show relatively strong correlation to the two times median expenditure share concept. While the HCLI can be applied to German data without any limitation, the MIS based on SGB II benefit rates seem to be less appropriate, i.e. because a poverty line below the official poverty line of 60 per cent median income would be implied by the SGB II rates. A strong feature of the HCLI is that the poverty line is directly related to the income poverty line of 60 per cent median income, which allows for some comparison with figures in income poverty, and contributes to a better understanding of complex fuel poverty patterns and related issues of justice (Walker and Day, 2012). Interestingly, fuel poverty augments income poverty assessments, i.e. in the case of the HCLI, since about half of households identified as fuel poor by the HCLI are not identified as income poor based on the income poverty line, but fall below the income poverty line after expenses on energy services. Overall, the two times median share poverty line and the HCLI

poverty line, which show comparably strong correlation, seem to be the most appropriate fuel poverty lines compared to the remaining options considered in this paper. In order to account for household composition, using equivalised income clearly is to prefer over non-equivalised income.

Once a fuel poverty line has been chosen, fuel poverty measurement can take place based on existing advanced techniques of poverty measurement, such as the class of poverty measure proposed by Foster, Greer and Thorbecke (1984). The FGT class poverty measures allow for subgroup comparison, which is an important tool in order to identify most vulnerable groups of households. The potentials of the FGT class poverty measure go far beyond the application presented in this paper and could be expanded to cover a regional comparison as well. Although poverty measurement often takes place based on the headcount ratio (P_0), as it is for example a central feature of the German income poverty assessment (BMAS, 2013), it is strongly recommended to go beyond the headcount ratio in fuel poverty measurement, e.g. by using the squared poverty gap index (P_2), to account for the transfer axiom (Foster, Greer and Thorbecke, 1984; Sen, 1976). The application of the squared poverty gap index would further help to identify potentially unwanted regressive effects of policies that aim to reduce fuel poverty over time. As a research perspective, the application of multidimensional poverty measures (Alkire and Foster, 2011) to the case of fuel poverty in developed countries, potentially jointly with aspects of income poverty, could be considered.

For the case of Germany, the socio-economic panel offers a rich dataset on households that includes a large number of socio-economic variables beyond income and energy expenditure. A second option, however, would be to assess fuel poverty based on household data from the German statistical office (Laufende Wirtschaftsrechnung and/or Einkommens- und Verbrauchsstichprobe), which likely offers even more accurate data on actual household expenditure on energy services and other categories. Since the aim of this paper was not to generate some particular figures on energy

poverty in Germany, but to discuss and compare different fuel poverty lines and options for fuel poverty measurement, this issue is left to further research.

References:

Abrahamse, W. and L. Steg (2009), 'How do socio-demographic and psychological factors relate to households' direct and indirect energy use and savings?', Journal of Economic Psychology 30(5), 711–720.

Achtnicht, M. and R. Madlener (2012), 'Factors Influencing German House Owners' Preferences on Energy Retrofits', ZEW Discussion Paper 12-042.

Alkire, S. and J. Foster (2011), 'Counting and multidimensional poverty measurement', Journal of Public Economics 95(7-8), 476–487.

Allcott, H. and S. Mullainathan (2010), 'Behavioral science and energy policy', Science 327(5970), 1204–1205.

Atkinson, A. B. (1987), 'On the Measurement of Poverty', Econometrica 55(4), 749–764.

Banerjee, A. V and E. Duflo (2007), 'The Economic Lives of the Poor', The Journal of Economic Perspectives 21(1), 141–167.

BMAS (2013), 'Lebenslagen in Deutschland', Bundesministerium für Arbeit und Soziales, Berlin.

BMWi (2012), 'First Monitoring Report "Energy of the future"', Bundesministerium für Wirtschaft und Technologie, Berlin.

Boardman, B. (1991), 'Fuel Poverty: From Cold Homes to Affordable Warmth', Belhaven Press, London.

Bradshaw, J., S. Middleton, A. Davis, N. Oldfield, N. Smith, L. Cusworth and J. Williams (2008), 'A Minimum Income Standard for Britain', Leicestershire, UK.

Brounen, D., N. Kok and J. M. Quigley (2012), 'Residential energy use and conservation: Economics and demographics', European Economic Review 56(5), 931–945.

CEER (2012), 'CEER Status Review of Customer and Retail Market Provisions from the 3rd Package as of 1 January 2012', CEER, Brussels.

Coudouel, A., J. S. Hentschel and Q. T. Wodon (2002), 'Poverty Measurement and Analysis', in Jeni Klugman (ed.), A Sourcebook for Poverty Reduction Strategies - Volume 1: Core Techniques and Cross-Cutting Issues (pp. 27–74), The World Bank, Washington D.C.

Department of Energy and Climate Change (2013), 'Annual Report on Fuel Poverty: Statistics 2013', London, UK.

E-Control (2013), 'Energiearmut in Österreich - Definitionen und Indikatoren', E-Control, Wien.

EU 'Directive 2009/72/EC of the European Parliament and of the Council of 13 July 2009 concerning common rules for the internal market in electricity and repealing Directive 2003/54/EC' (2009), Brussels.

EU 'Directive 2009/73/EC of the European Parliament and the Council of 13 July 2009 concerning common rules for the internal market in natural gas and repealing Directive 2003/55/EC' (2009), Brussels.

EU (2010), 'An Energy Policy for Consumers', European Commission Staff Working Paper No. 1407.

Foster, J., J. Greer and E. Thorbecke (1984), 'A Class of Decomposable Poverty Measures', Econometrica 52(3), 761–766.

Goldhammer, K., U. Mans and M. Rivera (2013), 'Beiträge zur sozialen Bilanzierung der Energiewende', IASS, Potsdam.

Healy, J. D. and J. P. Clinch (2004), 'Quantifying the severity of fuel poverty, its relationship with poor housing and reasons for non-investment in energy-saving measures in Ireland', Energy Policy 32(2), 207–220.

Hills, J. (2012), 'Getting the Measure of Fuel Poverty: Final Report of the Fuel Poverty Review', Centre for Analysis of Social Exclusion, London.

IAB (2009), 'Bedarfsgemeinschaften im SGB II: Warum Alleinerziehende es besonders schwer haben', IAB-Kurzbericht, Institut für Arbeitsmarkt und Berufsforschung, Nürnberg 12-2009.

IEA (2013), 'Energy Policies of IEA Countries: Germany 2013 Review', International Energy Agency, Paris.

Kakwani, N. (1980), 'On a Class of Poverty Measures', Econometrica 48(2), 437–446.

Kriström, B. (2013), 'Residential Energy Demand', Encyclopedia of Energy, Natural Resource, and Environmental Economics 1, 218–224.

Kriström, Bengt (2008), 'Residential Energy Demand', in Household Behaviour and the Environment: Reviewing the Evidence (pp. 97–115), OECD Publishing, Paris.

Liddell, C., C. Morris, S. J. P. McKenzie and G. Rae (2012), 'Measuring and monitoring fuel poverty in the UK: National and regional perspectives', Energy Policy 49, 27–32.

Meier, H. and K. Rehdanz (2010), 'Determinants of residential space heating expenditures in Great Britain', Energy Economics 32(5), 949–959.

Moore, R. (2012), 'Definitions of fuel poverty: Implications for policy', Energy Policy 49, 19–26.

Nesbakken, R. (1999), 'Price sensitivity of residential energy consumption in Norway', Energy Economics 21(6), 493–515.

Neuhoff, K., S. Bach, J. Diekmann, M. Beznoska and T. El-Laboudy (2012), 'Steigende EEG-Umlage: Unerwünschte Verteilungseffekte können vermindert werden', DIW Wochenbericht 41, 3–12.

Neuhoff, K., S. Bach, J. Diekmann, M. Beznoska and T. El-Laboudy (2013), 'Distributional Effects of Energy Transition: Impacts of Renewable Electricity Support in Germany', Economics of Energy & Environmental Policy, 2(1), 41-54.

Nguyen-Van, P. (2010), 'Energy consumption and income: A semiparametric panel data analysis', Energy Economics 32(3), 557–563.

OECD (2011), 'Divided We Stand: When Inequality Keeps Rising', OECD Publishing, Paris.

Ravallion, M., S. Chen and P. Sangraula (2009), 'Dollar a Day Revisited', The World Bank Economic Review 23(2), 163–184.

Ravallion, Martin, G. Datt and D. van de Walle (1991), 'Quantifying Absolute Poverty in the Developing World', Review of Income and Wealth 37(4), 345–361.

Rehdanz, K. (2007), 'Determinants of residential space heating expenditures in Germany', Energy Economics, 29(2) 167–182.

Reiss, P. C. and M. W. White (2005), 'Household Electricity Demand, Revisited', Review of Economic Studies 72(3), 853–883.

Reiss, P. C. and M. W. White (2008), 'What changes energy consumption? Prices and public pressures', The RAND Journal of Economics 39(3), 636–663.

Sen, A. (1976), 'Poverty: An Ordinal Approach to Measurement', Econometrica 44(2), 219–231.

Ürge-Vorsatz, D. and S. Tirado Herrero (2012), 'Building synergies between climate change mitigation and energy poverty alleviation', Energy Policy 49, 83–90.

Walker, G. and R. Day (2012), 'Fuel poverty as injustice: Integrating distribution, recognition and procedure in the struggle for affordable warmth', Energy Policy 49, 69–75.

Watts, H. (1968), 'An economic definition of poverty', In D. P. Moynihan (Ed.), On Understanding Poverty, Basic Books, New York.

Zheng, B. (2002), 'Aggregate Poverty Measures', Journal of Economic Surveys 11(2), 123–162.

Appendix: SGB II rates for MIS

The MIS was calculated on the household level for each individual household according to household composition and size. SGB II rates taken for MIS calculation were EUR 382 per month for the first adult person in the household, EUR 345 for the second adult person, EUR 289 for a dependent child greater 16 years, and EUR 255 for a dependent child less or equal to 16 years. Costs for electricity where subtracted from the SGBII rates to capture the non-energy related component of the SGBII rate based MIS. Subtraction is based on average costs for electricity of all households. A household is regarded as subject to fuel poverty if

$$P_{0,MIS} = \begin{cases} 1 \; if \; inc_{ahc} - c_{energ} - MIS \leq 0 \\ 0 \; if \; inc_{ahc} - c_{energ} - MIS > 0 \end{cases}.$$

Table 9: Summary statistics SOEP sample 2011, n=10,201, currency EUR 2010

Variable	Mean	Median	SD	Min.	Max.
HH Income	2762.99	2300,00	2020.98	70	55000
Equivalised HH income	1805.04	1555,56	1181.85	70	36666.67
Costs electricity	66.21	62.58	32.61	0	950
Costs heating	101.99	90.00	57.41	0	833.25
Overall energy costs	168.21	155.00	74.92	0	1100
Number of persons in HH	2.15	2	1.07	1	6
Dummy single HH	0.301	-	0.4585	0	1
Dummy couple no children	0.365	-	0.4814	0	1
Dummy lone parent	0.069	-	0.2532	0	1
Dummy couple with children	0.250	-	0.4333	0	1
Dummy other HH	0.015	-	0.1212	0	1