Measuring fuel poverty in France: which households are the most vulnerable?

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Abstract

Fuel poverty is a growing concern in France. Following the hike in energy prices that started in 2004, the problem of energy affordability for low-income households entered the political debate with the "Grenelle de l'environnement" in 2007. According to the standard UK definition (10% ratio) 3.4 million households were subject to fuel poverty in France in 2006. We question the way fuel poverty is currently measured and compare the impact of alternative measurement approaches on the extent and composition of fuel poverty in France. Then, we identify and characterize vulnerable households that are not ordinarily poor, but can be pushed into poverty because of their fuel bills. The incidence, depth and severity of poverty is measured with the Foster, Greer and Thorbecke indicator. Furthermore, econometric models are used to analyze which factors influence the probability of vulnerable households to fall into poverty. The study indicates that the proportion of fuel poor people and their characteristics differ significantly depending on the fuel poverty measure chosen. The econometric results show that the probability of falling into poverty is higher for those who are retired living alone, rent their home, use an individual boiler for heating, and cook with butane or propane.

Keywords: Fuel poverty, vulnerable households, poverty indicators, logit model

1. Introduction

Fuel poverty is commonly defined as the difficulty a household faces in maintaining an adequate level of warmth at a reasonable cost in their home (Boardman, 1991; Lewis, 1982). In France, the current fuel poverty policy was created in 2010 during the French environment roundtables called ‘‘Grenelle de l’environnement’’, under the law “Grenelle 2” n° 2010-788[1]. The law “Grenelle 2” defines the concept of energy precariousness. A person suffering from energy precariousness is *“anyone who encounters, in their home, particular difficulties in obtaining the energy required to meet their basic energy needs due to insufficient resources or housing conditions”.* The law has since been complemented by a more practical definition inspired by the United Kingdom[2]. According to the 2001 UK Fuel Poverty Strategy, a household is considered to be in fuel poverty if it needs to spend more than 10% of its total income before housing costs on fuel to heat its home to an acceptable level.

Fuel poverty is a serious problem from three main perspectives: poverty and reducing it; health and well-being; decreasing carbon emissions and saving energy (Hills, 2011). This type of poverty has several causes which are almost always combined: low-energy efficient housing, rising fuel prices, and low incomes (IEA, 2011; Rappel, 2011; Palmer *et al*., 2008). A key issue is the considerable overlap between fuel-poor households and those with low incomes. Using a widely adopted income poverty measure (60% median equivalised income threshold), Palmer *et al.* (2008) showed that nearly three quarters of the fuel poor in England in 2005 were also income poor. Moreover, from a definition point of view, many institutions and countries showed that those two concepts were inextricably linked. For instance, the WHECA (Warm Homes and Energy Conservation Act 2000) establishes that being on a “lower income” is a precondition to becoming a fuel-poor household. The Energy Act 2010, which introduces the concept of reducing both the extent and the depth of fuel poverty in the UK, defines fuel poverty as a dual issue, involving households on low incomes faced with unreasonable fuel costs. The French definition of energy precariousness clearly stipulates that the main drivers of fuel poverty are low income resources and domestic energy inefficiency.

There are numerous criticisms of the current official indicator (10% ratio approach), the main one being that it fails to capture all of the main drivers of fuel poverty (Hills, 2011). In fact, this ratio can capture households with high energy costs, but not all of these households are on low incomes. This is why significant numbers of households with relatively high incomes have been found to be fuel poor even though they should be able to absorb the cost of higher bills (Hills, 2011; Moore, 2012). By contrast, for households on low incomes, unreasonable fuel costs have to be traded with other essential expenditure. Such households can even be pushed into poverty because of energy costs without reaching the 10% ratio. Such anomalies occur because the measure is based on fuel costs expressed as a percentage of income regardless of the manner by which income is calculated.

Therefore, much debate focuses on how to measure fuel poverty given the potential difficulties in identifying one single indicator that will satisfactorily capture all of these issues. In order to target low-income households, fuel poverty can be studied from a perspective of poverty concern in general, using the after fuel cost poverty approach (Hills, 2011). This consists in measuring residual income (i.e. after housing and fuel costs) and comparing it to an income standard such as the poverty line (threshold of 60% of the national equivalised income level). There is a clear interest in establishing whether some households may be exposed to poverty because of high fuel costs. Hills (2011) has also proposed an alternative measurement framework focusing directly on the overlap of high costs and low income. This proposal contains two new indicators: the Low Income High Costs indicator measures the extent of the problem, and the fuel poverty gap indicator calculates its depth.

[1] Loi n° 2010-788 du 12 juillet 2010 portant sur l’engagement national pour l’environnement.
[2] This complementary energy precariousness measure is not included in the law.

Little empirical research has been undertaken on fuel poverty in France. Fuel poverty can be measured in a number of ways; therefore we analyze the impact of three different measurement approaches: the "*10% ratio approach*", "*the after fuel cost poverty approach*", and the "*Hills approach*" (Low Income High Costs indicator) on the extent of fuel poverty and the composition of the fuel poor households in France.

Then, we study another aspect of fuel poverty that has been covered less frequently in literature. That is, identifying households that are at risk of falling below the poverty line specifically because of high fuel costs. These households can be classified as vulnerable in the sense that they are *a priori* non-poor before the fuel bills but a marginal increase in energy prices is enough to make them slip below the threshold[3]. Such an approach allows us to identify the impact of high fuel costs on the margins of poverty. A specific policy targeting such households could be implemented to help them shift above the threshold and therefore reduce the extent of fuel poverty in France.

This paper attempts to provide some answers to the following questions: What is the scope of the three proposed fuel poverty measures? Which households are most vulnerable? What are the key factors that push vulnerable households into fuel poverty?

We conduct an income-based analysis in order to quantify and identify these vulnerable households. We use the Foster, Greer and Thorbecke (FGT) (1984) indicator to calculate the incidence, depth and severity of poverty and then estimate the logit and complementary log-log regression models to characterize vulnerable households that are pushed into poverty because of fuel costs. The database used for this study is the French housing survey "enquête logement 2006" (Insee, 2006). It is a detailed and representative survey that includes data on income and information on housing conditions.

This paper is organized as follows: Section 2 presents the three different fuel poverty measures and their impact on the extent and composition of the fuel poor in France. Section 3 describes the econometric methodology used for the vulnerability part of the study. Section 4 presents the econometric results. The final section concludes and sets out some policy implications.

2. Measuring fuel poverty in France

While there is a widespread agreement on the concept of fuel poverty, its measurement differs markedly, leading to significant implications in terms of the extent of fuel poverty and fuel-poor households characteristics.

2.1 Fuel poverty objective measures

- The *"10% ratio approach"*

The most common objective measure of fuel poverty is the 10% threshold, which means that households with a ratio in excess of 0.1 are classified as fuel poor.

[3] In this study the notion of "vulnerability" does not encompass a range of wellbeing and social issues, such as older people, the long-term sick and disabled people, etc. Vulnerable households are those for which the energy cost is the triggering poverty factor.

$$Fuel\ poverty\ = \frac{Required\ fuel\ costs}{Income} > 10\%$$

This indicator uses income before housing costs (BHC) and it is not equivalised (adjusted to household size and composition). The required fuel costs are estimated based on income data and modeled physical data relating to dwelling characteristics and energy efficiency. The advantage of focusing on required, rather than actual, fuel spending is that it takes under-consumption into account (Dubois, 2012; Fahmy, 2011). However, this measure is open to a number of criticisms (for a detailed description of the indicator's weaknesses, see Hills, 2011). Some of these criticisms relate to its intrinsic ratio form and some to the way income is calculated.

Firstly, using a ratio to determine the extent of fuel poverty does not include a cut off for households with high income. Therefore, a significant number of high-income households were found to be fuel poor with this measure (Hills, 2011; Moore, 2012). This is not in line with the definitions exposed in the introduction.

Secondly, income is not adjusted to account for households' different compositions and sizes. Therefore, it overestimates the incomes available to larger households to meet these domestic fuel needs. Empirical analyses suggest that income equivalence has a substantial effect on the social and demographic composition of the fuel poor (Fahmy, 2011).

Thirdly, experts argue that income should be measured after housing costs (AHC) to give a true picture of a household's disposal income and therefore the affordability of fuel bills, given that housing costs are usually met before other types of consumption (Hills, 2011; Moore, 2012). Housing costs are highly geographically variable, therefore, estimating incomes on a before housing cost (BHC) basis can produce misleading estimates of the extent and spatial distribution of fuel poverty.

- The *"after fuel cost poverty approach"*

In order to capture households on low income, we can use a broader measure of fuel poverty using traditional indicators from income poverty. Eurostat's definition of poverty risk refers to individuals living in households where the equivalised income is below the threshold of 60% of the national equivalised median income. Under this approach, households whose equivalised income after housing costs (HC) and fuel costs (FC) falls below the threshold are classified as fuel poor. This approach is presented by Hills (2011) and it is called *"after fuel cost poverty"* approach.

$$\begin{aligned} Fuel\ poverty = Equivalised\ (Income - HC - FC) \\ < 60\%\ (median\ equivalised\ income - HC - FC) \end{aligned}$$

This approach successfully identifies households that are in income poverty and whose situation is worsened by fuel costs. However, within this indicator nearly all households with very low income are classified as fuel poor regardless of their fuel requirement. This approach does not properly reflect the distinct nature of fuel poverty but rather gives insights to the broader concept of poverty.

- The *"Hills approach"*

The Hills report (2011) recommends adopting a new indicator of the extent of fuel poverty: the "Low Income-High costs" indicator (LIHC). This indicator captures households that have a combination of low income and relatively high costs by establishing two specific thresholds:

- ✓ The income threshold is the same as for the *"after fuel cost poverty approach"*. It is consistent with official poverty measurements;
- ✓ The energy cost threshold is based on the median required spending of all households.

Therefore, households that are below the conventional 60% of the median income poverty line and have fuel costs above the median level are classified as fuel poor.

This indicator is consistent with the definition of fuel poverty and improves our understanding of the phenomenon compared with the current measure. However, this approach will not give a precise identification of households that are pushed into poverty because of fuel costs. Moreover, fixing the energy cost threshold to the median is essentially arbitrary.

2.2 The extent and composition of fuel poverty under various approaches

We propose measuring the extent and composition of fuel poverty in France using the three approaches described above. However, as household composition and housing costs were a main criticism of the traditional 10% ratio measure, we will adjust gross income in the three approaches to take these two aspects into account. Moreover, it is easier to compare the indicators on the same basis. In all three approaches, gross income takes households' size and composition into account and is calculated after housing costs.

We assign to each member of the household an equivalent income value, calculated using the OECD equivalence scale. Economies of scale in housing and the consumption of goods and services are allowed for controlling household composition. Some existing literature underlines the potential asymmetry in the management of, and access to, household resources (Browning, Bourguignon, Chiappori and Lechene, 1994; Roy, 2005; Belleau and Proulx, 2010, 2011). Nevertheless, assuming that most households share and manage their income in a fair manner, we deflate the household resources by the number of consumption units in the household. We assign a value of 1 to the first household member, 0.5 to each additional adult member and 0.3 to each child under 14 years old. This method has the advantage of showing households' standards of living more precisely.

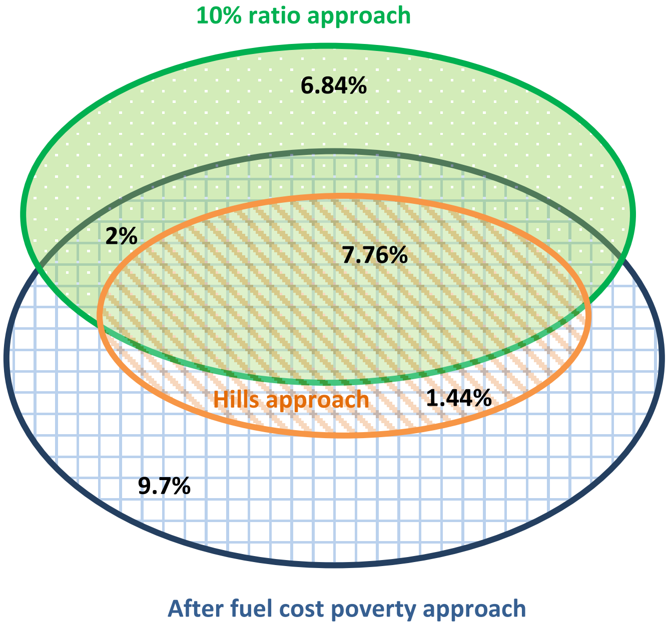
It is often used in income poverty measurements to deduct housing expenditure (mortgage payments or rents) from income and show the share of households under the poverty line (Hills, 2011, Moore, 2012). In fact, the amount households must spend is only ever an imperfect measure of the standard of living they can achieve, but for many things the same cash amount can translate into similar items in a shopping basket, meeting their needs in similar ways. The greatest exception to this is housing, because of the huge variations in rents and house prices across the country and the difficulty people would face in moving.

We have a choice of sources for income data as well as housing and energy expenditure. The only survey in which income data is available in combination with information on housing conditions and expenditure is the French housing survey "Enquête Logement 2006" conducted by the French National Institute of Statistics and Economic Studies (Insee, 2006). In 2006, the survey sample covered over 70,000 dwellings (about 60,000 in Metropolitan France and 10,000 in the overseas departments) and a total of 43,000 households responded to the survey. Data were collected using computer-assisted personal interviews. The survey includes more than 1000 variables related to the characteristics of the housing stock, the quality of the dwellings and the expenditure associated with housing.

Housing costs in the database include rents and mortgage payments minus housing allowance. For the *after fuel cost poverty* and *Hills* approaches, fuel costs are subtracted from income. In the French Housing Survey, fuel costs comprise water, electricity and other fuel expenses.

Figure 1 shows the extent of fuel poverty in France using the different measures of fuel poverty exposed above.

Figure 1: The extent of fuel poverty in France using different approaches



Source: Enquête Logement, authors' calculations
N = 40 136

Fuel poverty rates vary notably for the three measures. 16.6%[4] of the French population is considered as fuel poor according to the *10% ratio approach*; 20.9% according to the *after fuel cost poverty approach* and 9.2% according to the *Hills approach*. Within the 16.6% of fuel poor under the *10% ratio approach*, 6.84% are not exposed to poverty after housing and fuel costs under the *after fuel cost poverty approach*. Also, of the households that are found to be fuel poor under *the after fuel cost poverty approach*, 11.14% do not spend more than 10% of their income on energy expenses.

The above figure illustrates that the *10% ratio approach* includes households that do not necessarily have a low income and it also demonstrates that the rate of 10% is arbitrary because a household can still be poor with lower energy expenses. We found that among the households in the last decile group (10% of the population with the highest income), 1.15% were fuel poor under the *10% ratio approach*. Moreover, households' annual gross income is on average € 11681[5] for those who are poor according to the *after fuel cost poverty approach*, € 11,980 for those who are poor according to the *Hills approach* and € 14,128 for those who are poor according to the less restrictive *10% ratio approach*.

Also, according to *the after fuel cost approach* only 43% of the poor spend more than 10% of their gross income on paying the energy bill. For them, the energy bill represents almost 22% of gross income. For the 57% who do not reach the 10% ratio, energy expenses represent about 6% of gross income.

The *Hills approach* brings out both approaches as the thresholds used ensure that only households on very low incomes with very high fuel costs are considered as fuel poor.

[4] 6,84%+7,76%+2%

[5] Household annual gross income here is not deflated by the number of consumption units in the households

Under the *after fuel cost poverty approach*, we have calculated the extent of poverty with the poverty rate (headcount), but it is also possible to study the depth and severity of poverty using the poverty gap and square poverty gap indicator (Foster, Greer and Thorbecke, 1984) (see table 1). The poverty gap shows how far below the poverty line people are affected. This is an interesting indicator for ascertaining whether the situation improves, for instance, when the poor move closer to the poverty line, even when only a few of them cross it. The square poverty gap takes into account not only the distance separating the poor from the poverty line (the poverty gap), but also inequality among the poor. A higher burden is placed on those households furthest away from the poverty line.
The headcount, the poverty gap and the squared poverty gap are the three measures that can be obtained using the general formula of the Foster, Greer and Thorbecke indicator (FGT):

$$FGT_\alpha = \frac{1}{n}\sum_{i=1}^{q}\left(\frac{z-y_i}{z}\right)^\alpha$$

n is the population size, q is the number of poor (those with incomes at or below the poverty line z), y_i are individual incomes and α is a sensitivity parameter.
When α has a value of zero, we obtain the headcount, when α is equal to one, we obtain the poverty gap and when α is equal to two, we obtain the squared poverty gap.
In this *after fuel cost poverty approach*, three levels of income can be considered: gross income, gross income after housing costs, gross income after housing costs and fuel costs.

Table 1: Poverty rate, gap and severity

	Poverty rate	Poverty gap	Severity	Poverty line (euros per CU)	Mean income (euros per CU)	Mean income under the poverty line (euros per CU)	N
Gross Income	17.59%	0.05028	0.02316	9869.4	19631	7048.28	40136
Gross Income - housing costs	18.94%	0.06098	0.03083	8700.6	17607.53	5899.87	
Gross Income - (housing costs + energy cost)	20.90%	0.07273	0.03994	8215.14	16685	5356.58	

Using this approach we can see that housing and energy costs increase the exposure to poverty, as well as the poverty gap and the severity of poverty. If we do not take into consideration those expenses, 17.59% of the population is exposed to poverty before redistribution[6]. After housing and energy bills, almost 21% of the population is exposed. This increase in poverty is associated with more inequalities: mean gross income of poor households represents 35.9% of the mean gross income within the population[7], but mean

[6] According to the French Statistical Office (INSEE), the poverty rate, calculated after redistribution attained 13.1% in 2006. We calculate in this paper the poverty headcount using the gross income per consumption unit while official statistics provide poverty rate the net income per unit of consumption (after redistribution).
[7] 7048,28/19631=0,359

income after housing and energy costs represent 32.1% of the average. We can deduce that those expenditures weigh more heavily on poorer households.

Based on these three approaches, we can study the composition of fuel-poor households across different socio-economic and dwelling characteristics (appendix 1).

When looking at the professional categories of the heads of household, we note some differences between the approaches. Under *the after fuel cost poverty approach* a large proportion of the poor are active (40 % of the poor are employees or blue collar workers), whereas, in the two other approaches they are mainly inactive. Pensioners are more frequently energy poor. However, it appears that pensioners do not combine necessarily low incomes[8] with high energy expenses, but are probably faced with significant fuel costs compared to their standard of living. Under the *10% ratio* and the *Hills approaches* respectively 54% and 45% of the poor are pensioners, while under *the after fuel cost poverty approach*, which mainly targets low incomes, only 30% are pensioners. On average, pensioners represent 33% of the French population. They are consequently over-represented in the fuel poor population (according to the 10% and the Hill approaches).

We observe that the average head of household is 57 years old according to the *Hills measure* of fuel poverty, 60 years old according to the *10% ratio approach*, but only 50 years old under the *after fuel cost poverty approach*. This also explains why a greater proportion of individuals are widowed in the fuel-poor population targeted by the *Hills* and *10%* approaches (26% and 29% against 15% with the fuel poverty’s broader approach). When focusing on household composition more than marital status, we observe that the poor are mainly people living alone. The poor household composition seems to be more or less the same under the three approaches.

The fuel poor are mainly homeowners for the *10% ratio approach* and the *Hills approach* (respectively 66% and 53%) while under *the after fuel cost poverty approach* 63% of the fuel poor are tenants. This last approach includes a larger share of the population that was already income poor before housing and energy costs. It is therefore logical to find more tenants when using this approach. This is in line with literature on poverty in general, where the results show that the poorest are usually tenants (Insee, 2013). As the 10% ratio approach does not cut off low-income households, it is intuitive to find more homeowners than in the two other approaches. Moreover, as this approach includes a large portion of pensioners, it is consistent with the housing occupation status.

We find that 76% and 71% of the poor live in detached houses under the *10% ratio* and the *Hills approach* respectively, while under the *after fuel cost poverty approach* 54% of the poor live in an apartment. The fuel poor under the *10%* and *Hills approaches* are more likely to live in a detached house than the average population (on average, 58% of the population live in a detached house), while with the *after fuel cost* poor are more likely to live in an apartment than the average population (41%).

We observe that the majority of the fuel poor under the three approaches use an individual boiler as the main heating system in their house: 65% of the poor under the *10% ratio*, 60% under the *Hills approach,* and that the number is less significant under the *after fuel cost poverty approach* (38%). Those living in poverty under the three approaches also more frequently use butane and propane for cooking than the average population (about 40% against only 24% on average). In contrast, the average population more frequently uses

[8] In France, retirees enjoy in average a standard of living close to that of workers (Legendre, forthcoming).

electricity to cook (27%) than the fuel poor under all three approaches. Among the after fuel cost poor, only 12% use electricity, compared to 16% among the fuel poor with both of the other approaches.

In the French housing survey, one subjective indicator relates to why respondents feel cold in their home. The main reasons for feeling cold given by the fuel poor relate to housing quality. Of the three approaches, above 40% of the fuel poor declared that they suffered from cold due to poor insulation, and more than 30% due to insufficient heating installation. Moreover, one out of three households limit their heating consumption due to its cost. In the average population, 41% said they suffered from cold due to poor insulation, and 19% due to equipment breakdowns, compared to only around 13% for the poor population (under the three approaches). Statistics on feeling cold as a result of under-consumption of heating is particularly informative: while on average 21% of respondents declared that they suffered from the cold because of under-consumption, 36% of the fuel poor gave this reason under the *10% and Hill approaches*, and 29% among *the after fuel cost* poor. In other words, the fuel poor are constrained in their energy consumption, which might have a strong impact on their well-being.

The definition of fuel poverty indicators raises serious questions. First, pursuing a fuel poverty reduction policy requires precisely defining who the fuel-poor are. Which population is the most vulnerable? It is vital to identify these inhabitants *ex ante* in order to conduct an efficient policy. Secondly, policy makers need relevant indicators to measure the efficiency of their policy *ex post*. Therefore, reliable tools are needed. Depending on the fuel poverty indicators chosen, the targeted population will not be the same, and the results of the policy will change.

3. Econometric analysis

3.1 Vulnerable household sample

The objective is to target the groups in society that are most vulnerable to energy costs and at risk of falling into fuel poverty. Our starting point is the *after fuel cost poverty approach*. As we have seen, the main weakness of this approach is that of the 20.9 % of the fuel poor after housing and fuel costs, 17.6% were already poor based only on their income level. Therefore, this does not allow us to specifically study the nature of fuel poverty because these households are concerned with much broader poverty issues and energy bills only worsen their situation. To evaluate the vulnerability aspect of this problem, we chose a sample of households that were not poverty exposed before the fuel bill. Ultimately, households that became poor specifically and uniquely because of their fuel expenses represent 2.76% of our observations.

Targeting households that are pushed into poverty because of their fuel bills is important for understanding which type of household should be prioritized for support through fuel poverty reduction policies. The aim of the econometric analysis is to develop a model of the most influential demographic, socioeconomic and housing characteristics affecting the likelihood of a household falling into fuel poverty, for households that are not *a priori* poor.

3.2 Logit and Complementary log-log models

Logistic and complementary log-log regression models have been constructed to examine the factors that influence the probability of falling into fuel poverty in France.

Using logistics allows us to verify whether the patterns commonly seen across fuel poverty are actually associated with single characteristics or a combination of several characteristics. The advantage of the logit model is the direct relationship between the coefficients and the odds ratios, which provide pieces of information that are easy to interpret. By exponentiating the coefficients, we can determine the effect of each variable on the odds of a fuel-poor individual, compared to individuals possessing the baseline set of reference characteristics. An odd ratio is the ratio between the probability of "success" and the probability of "failure"[9].

Let Y_i denote a random variable representing a binary response. We define:

$$Y_i = \begin{cases} 1 \text{ if the individual is pushed into poverty because of the energy cost} \\ 0 \text{ otherwise} \end{cases}$$

The probability of being fuel poor $\pi_i$can be written as $\pi_i = P(Y_i = 1) = P(Y_i^* > \theta)$ with Y_i^* the latent response. The outcome depends on explanatory variables, so we estimate the following model:

$$Y_i^* = x\beta + \varepsilon$$

Where x is the vector of covariates and ε the error term.

Under this model, we have:

$$\pi_i = P(Y_i = 1) = F(x\beta)$$

We assume first that $F.$ follows a standard logistic distribution and estimate a logit regression model.

However, the positive outcome is quite rare in our sample (2.76% of 1). Therefore, we use a complementary log-log analysis as an alternative to the logit model to check the robustness of our results. The complementary log-log model is derived from the hypothesis that the error distribution (or distribution of Y_i^*) follows a log Weibull distribution. Unlike the logit analysis, the transformation is not symmetrical around 0: it is skewed to the right and therefore used when a positive outcome is rare.

3.3 Variables

The explanatory variables have been selected on the basis of existing literature on fuel poverty. First, we introduce socio-demographic and socio-economic variables. Literature shows that some households are more poverty exposed than others. Thus, we introduce variables that characterize housing conditions to be those often associated with difficulties in heating the home adequately and thermally insulating walls and roofs, etc. We select the variables in order to avoid any multicollinearity that might occur when some explanatory variables are highly correlated. Some variables, like for example "living in a detached house" and an "individual boiler" would provide redundant information.

- ✓ Household composition and activity status

Rather than marital status, we focus on household composition. Living alone is known to be associated with financial difficulties (Healy, 2003). We assume that compared to couples, those living without a partner are more likely to be exposed to fuel poverty. Moreover, being a

[9] Consequently, if the odd ratio is greater than 1, it expresses that there is a greater likelihood of success (dependant variable=1) than one of failure (dependant variable=0).

pensioner might also be linked with financial hardships: so we consider work status. Devalière (2009) found that pensioners exhibit high levels of fuel poverty in France. This piece of information is combined with the household composition.

Table 1 shows that households comprising retired and single people are far more likely to be fuel poor than other household types. 6.93% of pensioners living alone are below the poverty line. People living alone also on average face a deeper poverty than couples and they suffer from a more severe poverty than other subsamples. This statistic ties in with observations made in the previous section whereby a large proportion of the poor were living alone under the three approaches.

- ✓ Educational Attainment

Educational attainment is, in general, a good indicator of household income and social class. Poverty research has always demonstrated a strong link between low education levels and high levels of poverty and deprivation. 6.96% of people with no diploma experience fuel poverty while this proportion is less than 1% among those with an intermediate or a high educational level. The poverty gap and severity are also greater for individuals with no diploma.

- ✓ Housing tenure

Housing tenure is an important dynamic of fuel poverty (Whyley and Callender, 1997; Healy, 2003, Boardman, 2010, Devalière, 2011) since it gives households different levels of control concerning their home. Owner-occupiers are fully autonomous while tenants are more limited in their choices. However, homeowners also endure significantly higher financial burdens for their home maintenance. Descriptive statistics do not show large differences in poverty exposure between owner-occupiers and tenants, of whom respectively 2.84% and 2.62% are exposed, while the average poverty rate is 2.76% in the sample.

- ✓ Location

The climate zone in which the accommodation is located seems to have a strong influence on fuel poverty as it determines the temperature of homes, although this variable is rarely reported in literature. For example, in northern areas of France the poverty rate reaches 3.33%, which is higher than in the rest of the country.

- ✓ Heating system

We assume that the heating system used in a property has a strong influence on fuel poverty (Hills, 2012). Heating is the most important item of energy expenditure. It accounts for about 50% of the accommodation energy bill in France (ADEME, 2005).

- ✓ Energy used for cooking

Energy used for the cooking may also impact the exposure to fuel poverty: as for heating systems, collective energy sources like mains gas seem less expensive for households, while people using butane and propane bottles, whether combined with electricity or not, are more frequently poor.

- ✓ Age of property

We might expect the age of a property to have a significant influence on energy costs (Hills, 2012). Using a subjective measure of fuel poverty, Devalière (2011) showed that French households who reported suffering from cold lived more often in houses built before the first thermal regulation in 1974. The poverty rate reaches 3.67% for households whose property was built before 1949 and 2.50% for a property built between 1950 and 1975.

Table 1 Descriptive statistics of our sample

	Poverty rate	Poverty gap	Poverty severity
Couple of active people	0.86%	0.00052	0.00008
Retired couple	2.89%	0.00204	0.00025
Lone active	2.07%	0.00133	0.00016
Lone retired	6.93%	0.00562	0.00093
Have dependant children	1.78%	0.00091	0.00013
Homeowners	2.84%	0.00252	0.00043
Tenant	2.62%	0.00151	0.00019
No diploma	6.96%	0.00471	0.00059
Intermediate educational attainment	0.76%	0.00052	0.00007
High educational attainment	0.62%	0.00053	0.00009
Individual boiler Yes=1 No=1	3.73%	0.0029	0.00048
District heating Yes=1 No=1	0.68%	0.00048	0.00004
Collective boiler Yes=1 No=1	0.28%	0.00038	0.0001
Mixed heating (collective and individual heating) Yes=1 No=1	0.15%	0.00001	0
Individual electric heating (convectors) Yes=1 No=1	2.16%	0.00113	0.00012
Renewable energy Yes=1 No=1	0.48%	0.00073	0.00014
Housing constructed before 1949 Yes=1 No=1	3.67%	0.00269	0.00041
Housing constructed between 1950 and 1974 Yes=1 No=1	2.50%	0.00181	0.00025
Housing constructed after 1974 Yes=1 No=1	1.92%	0.00145	0.00027
Cooking with City gas cooking	2.36%	0.00159	0.00023
Cooking with butane and propane bottles	4.95%	0.0036	0.00058
Electricity cooking	1.19%	0.00073	0.00011
Gas and electricity cooking	1.17%	0.00082	0.0001
Cooking with electricity and butane and propane bottles	3.88%	0.00346	0.00059

Climate zone 1	3.33%	0.00241	0.00036
Climate zone 2	2.25%	0.0017	0.00025
Climate zone 3	3.34%	0.00231	0.0004
Climate zone 4	2.70%	0.00208	0.00037
Entire sample	2.76%	0.00203	0.00032
N		26531	

4. Econometric Results

Our models match the data correctly and the predictive power of the logit and complementary log log model is good (see table of results in appendix).

The results suggest that some household types are exposed to a higher fuel poverty risk. Living with a partner protects against this risk while living alone makes individuals more vulnerable. The odd ratio is particularly low for active couples, at 0.236, while it exceeds 1 for a retiree living alone (1,732). The more dependent children there are in a household, the higher the likelihood of fuel poverty. Single parent families, widows and widowers are consequently a high risk population. The marginal effect for a family composed of two active adults and two children remains below 1% (0.63%)[10]. However, marginal effects reach 3.07% for a pensioner living alone.

Being a homeowner and highly educated is associated with a lower exposure to fuel poverty. Their odd ratios reach respectively 0.557 and 0.418. On the contrary, a low level of education increases exposure to fuel poverty. A high level of education might correspond to increased awareness regarding home insulation and/or energy efficiency. Marginal effects calculated within a household whose risk is limited illustrate this result: i.e. 0.57% for a family (2 active adults and 2 children) whose head has been educated to the reference educational level. It reaches 1.57% in the absence of a diploma and 0.24% for a high educational level.

Our results show clearly that the type of heating system and the energy used for cooking are key factors to explain fuel poverty. An individual boiler is associated with a high probability of being fuel poor, while collective boilers and district heating systems seem to protect more against fuel poverty. Households that heat their home with an individual boiler have the highest odds of being fuel poor (nearly 1.8 times that of households using electric convectors). The marginal effects are significantly higher for those using an individual boiler. For instance, as shown in the appendix, the level is 3.69% for a homeowner retiree living alone and as much as 6.43% for a single-parent family. On the contrary, the marginal effect of using a district heating system is only 0.5% for a single-parent family, and 0.17% for a family with two children.

Cooking with butane and/or propane, whether mixed with electricity or not, increases the exposure to poverty, whereas using town gas stream (natural gas) and electricity from the grid reduces the exposure.

Finally, the age of the home and the climate zone also significantly impact exposure to fuel poverty. Only housing built after the first thermal regulation in 1974 is associated with a lower fuel poverty exposure. The odds of being fuel poor are lower compared to those living in a building constructed between 1950 and 1974: i.e. 0.783.

[10] When calculating the marginal effects, the other variables not mentioned are set at their average value or at their reference value.

5. Conclusion and policy implications

This paper estimates the scale of fuel poverty in France under diverse measures and identifies the vulnerable households at risk of falling into poverty only because of energy costs.

The three measurement approaches selected (the *10% approach,* the *Hills approach* and the *after fuel cost poverty approach*) led to contrasting results in terms of the extent of fuel poverty and the composition of the fuel poor.

Based on the results of the French housing survey (Insee, 2006), the results show that 16.6% of the French population is fuel poor under the *10% approach*, 20.9% under the *after fuel cost poverty approach* and 9.2% under the *Hills approach*. 7.76% of the population emerge as fuel poor according to the three approaches.

The approaches identify distinct types of fuel poor households. The *after fuel cost poverty approach,* which is a more global approach to poverty, mainly captures active individuals who are tenants and usually living alone in apartments, while the two other approaches, focusing more on energy expenditure, tend to target inactive retirees who own their homes and live in detached houses with individual boilers as their main heating systems using domestic fuel.

Furthermore, we conducted an income-based analysis in order to characterize the most vulnerable households. A renewed targeting of the fuel poor households was proposed in the empirical part of the paper. We identified those below the poverty line after the fuel bill and selected a sample of households that were not poverty exposed before the fuel bill. This enabled us to put a greater focus on individuals who fall into poverty solely as a result of energy costs. Logistic and complementary log-log models were used to analyze the impact of certain households and dwelling characteristics on the probability of falling into poverty. This detailed consideration of the characteristics is important in understanding which type of households should be prioritized for support through policies.

The study suggests that living alone is associated with a high probability of falling into fuel poverty. Moreover, retired people living alone are significantly exposed to fuel poverty. Being a homeowner and highly educated is associated with lower exposure to fuel poverty. The heating system equipment and the type of energy used for cooking are key elements that influence the probability of falling into fuel poverty. Using an individual boiler and cooking with butane/propane are associated with a high probability of being fuel poor, while collective boilers, district heating systems and cooking with city gas (natural gas) seem to protect against fuel poverty. Moreover, a home's low energy performance is a significant fuel poverty factor. Only housing built after 1974 (after the first thermal regulation in France) decreases the exposure to fuel poverty.

5.1 Policy implications

A policy targeting vulnerable individuals on the margin of poverty is essential to reduce the extent of fuel poverty in France. For the population identified in the econometric analysis, the cost of energy is the factor that triggers poverty. Therefore, a specific policy could be implemented to help households located just below the poverty line and help them shift above the threshold. However, we realize that the precise targeting of policy intervention involves trade offs associated with targeting support at one group of households over another. This means that the very poor households under *the after fuel cost poverty approach* (17.59% that were already poor only based on their income level) are not eligible for fuel poverty support policies. However, we consider that this section of the population could benefit from broader transfer policies to improve their standard of living. In this perspective, the government's role is to deliver an effective policy that focuses on the roots of fuel poverty and drives action to alleviate the problem in the long term.

Three broad types of policy are usually conducted to tackle fuel poverty: price-based, income-based and energy-efficiency improvement policies.

Price-based policy consists in reducing the price paid by households for energy. This type of policy is already applied in France, for example, through the social energy tariffs for low-income households[11], which have opened up the right to a reduction in electricity bills since 2005 and natural gas bills since 2008. At the end of 2012, more than 1.8 million French households benefitted from this measure. These aids are funded by all energy consumers. This policy would be expected to bring some households out of fuel poverty, reducing the headcount and the poverty gap. But there are limits to the application of this policy. The eligibility criteria are only based on households' income resources and not on fuel poverty indicators. In this analysis, we emphasize the fact that it is crucial to look closely at energy costs related to disposal income. Also, targeting the type of energy used, or the type of heating equipment, both of which are factors that determine fuel poverty, is not taken into account. Moreover, as these measures are funded by energy consumers, they can negatively impact vulnerable households in hardship situations that do not benefit from these measures. The debate on whether interventions should be funded by energy consumers or taxes is important. The tax-funded option would allow policy funding to be progressive and better protect vulnerable consumers.

Policies that increase income would lead to reduced levels of fuel poverty. However, income transfer for low-income households could be rationally spent on any other expenditure. In France, with housing allowances that tackle poverty in general, poorer households can also receive an income supplement to help them cover expenditure on energy and water. This type of policy does not specifically focus on fuel-poor and vulnerable households. Also, such payments would only have a one-off impact on fuel poverty unless repeated.

These curative measures are limited in scope and do not represent a sustainable answer to fuel poverty reduction in France. They do not address the root of the fuel poverty problem as they were not designed for fuel poor households. In addition, the amount of such aids is too small (about 10% of the total energy bill). If these types of measures are to be implemented in the short term, they should be supplemented by preventive policies that focus on improving the energy efficiency of housing.

The main focus of fuel poverty policies should be to reduce the energy consumption of housing in order to sustainably reduce vulnerable households' energy bills. This is in line with the "Grenelle de l'environnement" objective to reduce energy consumptions by 38% in the housing stock by 2020. To reach this target, the government has introduced several measures to incentivize energy-efficiency. The interest-free loan (L'éco-prêt à taux zéro) and the sustainable development tax credit (crédit d'impôt développement durable) are incentives to carry out renovation work or install efficient equipment. The first of these allows homeowners, without any income conditions, to borrow up to € 30,000 for renovation work in their main residence built before 1990. The second is for all households (tax payers, non-tax payers). They can deduct a percentage of their spending on energy efficiency improvements in their principal house from their taxable income (or receive a tax credit). These two tools aim to reduce energy consumption but as they do not focus on fuel poor households they are not well suited to reducing the extent of fuel poverty in France, especially because homeowners tend to be less fuel poverty exposed according to our empirical work. In many cases, fuel poor households have a borrower profile that is not reassuring for banks that provide interest-free

[11] Since December 2012 monthly income should not exceed € 967 for a single person

loans. These measures tend to benefit households with higher incomes. Similarly, accessing the sustainable development tax credit is difficult for low-income households that cannot usually afford to advance funds for renovation work.

We believe that if the policy maker clearly identifies those who are exposed specifically and uniquely because of fuel costs, it would be efficient in terms of fuel poverty reduction to provide them with incentives to save energy and carry out restoration works. This could take the form of aids for natural mains gas connection, subsidies for boiler replacements, etc. Fuel poor households can be occupied by owners, landlords or tenants, and therefore the policy should not be too restrictive, and could be in some cases unrelated to the home’s ownership.

5.2 Some limitations in our analysis are worth mentioning.

Our study is based on actual fuel expenditure because of a lack of data in France. Yet we cannot be sure that these costs are representative of an adequate level of well-being: would a household spend more to warm their dwelling if they could? We can assume so, because 29% to 36% of the fuel poor (depending on the definition) claim that they suffer from cold due to heating limitations.

We also propose taking an original approach to fuel poverty by distinguishing those who fall under the poverty line because of energy bills from those who were poor even before such expenditure. We cannot argue that the latter are not fuel poor, but we affirm that targeting them with fuel poverty measures might not be efficient, whereas it would be for the specific sample of people who fall into poverty because of the energy bill.

Despite its limitations, we believe that this study provides new insight into the impact of high fuel costs on people living at the margins of poverty in France, and proposes another method to efficiently target the most vulnerable households.

Appendix A Characteristics of the fuel poor under three different measures

Professional categories of the head of household

	Poor (after fuel cost poverty approach)	Poor (10% ratio approach)	Poor (Hills approach)	Population
Farmers	1%	2%	2%	1%
Shopkeepers, Craftspeople, entrepreneurs	4%	4%	4%	4%
Managers and profess. occupations	3%	2%	3%	12%
Intermediate occupations	8%	5%	6%	16%
Employees	19%	11%	14%	14%
Blue collar workers	21%	12%	16%	16%
Pensioners	30%	54%	45%	33%
Other inactive people	14%	10%	10%	4%
Total	100%	100%	100%	100%

Source: Enquête Logement 2006, authors' calculations

Household composition

	Poor (after fuel cost poverty approach)	Poor (10% ratio approach)	Poor (Hills approach)	Population
Person living alone	43%	49%	48%	33%
Multi-person households	4%	4%	3%	3%
Single parent with dependent children	12%	8%	10%	6%
Family (with or without children)	40%	40%	38%	58%

Source: Enquête Logement 2006, authors' calculations

Housing occupation status

	Poor (after fuel cost poverty approach)	Poor (10% ratio approach)	Poor (Hills approach)	Population
Homeowner (with or without mortgage)	32%	66%	53%	59%
Rent free	4%	5%	4%	4%
Tenant	63%	29%	43%	37%
Total	100%	100%	100%	

Source : Enquête Logement 2006, authors' calculations

Dwelling type

	Poor (after fuel cost poverty approach)	Poor (10% ratio approach)	Poor (Hills approach)	Population
Detached house	43%	76%	71%	58%
Flat	54%	22%	27%	41%
Room in a collective structure (seniors residence, group home)	1%	0%	0%	0%
Farm	0%	1%	0%	0%
Others	2%	1%	1%	1%
Total	100%	100%	100%	100%

Source: Enquête Logement 2006, authors' calculations

Heating system

	Poor (after fuel cost poverty approach)	Poor (10% ratio approach)	Poor (Hills approach)	Population
Individual boiler	38%	65%	60%	47%
District heating	2%	0%	0%	2%
Collective boiler	21%	4%	3%	16%
Mixed boiler (collective + individual heating)	1%	0%	0%	1%
Individual electric heating	30%	23%	27%	27%
None of the above	8%	8%	5%	6%
Total	100%	100%	100%	100%

Source: Enquête Logement 2006, authors' calculations

Energy type forindividual boiler

	Poor (after fuel cost poverty approach)	Poor (10% ratio approach)	Poor (Hills approach)	Population
Domestic fuel	25.15%	45.92%	36.35%	30.37%
City gas	62.86%	41.27%	52.87%	59.06%
Butane, propane	2.57%	7.14%	4.82%	3.90%
Coal	0.42%	0.46%	0.23%	0.32%
Wood	1.79%	2.70%	2.15%	2.19%
Electricity	5.73%	3.81%	5.19%	4.06%
Others	1.48%	0.00%	0.00%	0.10%
Total	100%	100%	100%	100%

Source : Enquête Logement 2006, authors' calculations

Energy used for cooking

	Poor (after fuel cost poverty approach)	Poor (10% ratio approach)	Poor (Hills approach)	Population
City gas	20%	21%	25%	25%
Butane Propane	43%	39%	38%	24%
Electricity	12%	16%	16%	27%
Electricity and City gas	5%	6%	7%	11%
Electricity and Butane	18%	17%	12%	12%
Other	2%	1%	1%	0%
	100%	100%	100%	100%

Source : Enquête Logement 2006, authors' calculations

% of respondents claiming to suffer from cold due to…

	Poor (after fuel cost poverty approach)	Poor (10% ratio approach)	Poor (Hills approach)	Population
Insufficient heating equipment	38%	30%	34%	32%
Equipment breakdown	12%	13%	13%	19%
Heating under-consumption	29%	36%	36%	21%
Poor insulation	45%	43%	47%	41%
Other reasons	7%	11%	8%	15%

Source: Enquête Logement 2006, authors' calculations

Appendix B Results of the estimates

	Logit		C log log
	Coefficients	Odds ratios	
Active couple Yes=1 No=0	-1.445***	0.236***	-1.409***
	(0.129)		(0.127)
Retired couple Yes=1 No=0	-0.327*	0.720*	-0.323*
	(0.149)		(0.146)
Active living alone Yes=1 No=0	-0.174	0.839	-0.169
	(0.127)		(0.124)
Retired living alone Yes=1 No=0	0.549***	1.732***	0.520***
	(0.118)		(0.113)
Number of children in the household	0.189***	1.209***	0.182***
	(0.046)		(0.0437)
Homeowner Yes=1 No=1	-0.584***	0.557***	-0.558***
	(0.094)		(0.090)
No diploma Yes=1 No=0	1.025***	2.787***	0.991***
	(0.154)		(0.150)
Level of diploma below A-level Yes=1 No=0	0.397**	1.488**	0.393**
	(0.143)		(0.141)
A level Yes=1 No=0	Ref.		Ref.
Intermediate educational level	-0.381	0.683	-0.373
	(0.221)		(0.219)
Master's degree Yes=1 No=0	-0.871***	0.418***	-0.862***
	(0.224)		(0.222)
Individual boiler Yes=1 No=0	0.586***	1.797***	0.567***
	(0.111)		(0.107)
District heating Yes=1 No=0	-1.495**	0.228**	-1.470**
	(0.518)		(0.514)
Collective boiler Yes=1 No=0	-1.933***	0.145***	-1.907***
	(0.283)		(0.281)
Mixed heating Yes=1 No=0	-0.981	0.375	-0.962
	(1.016)		(1.005)
Heating individual electric convectors Yes=1 No=1	Ref.		Ref.
Other type of heating system Yes=1 No=1	0.231	1.260	0.224
	(0.165)		(0.159)
Renewable energy Yes=1 No=1	-0.658	0.518	-0.658
	(0.524)		(0.514)
Cooking: city gas streams Yes=1 No=1	0.111	1.117	0.119
	(0.141)		(0.138)
Cooking: butane-propane Yes=1 No=1	0.891***	2.437***	0.867***
	(0.129)		(0.126)

Cooking: only electricity Yes=1 No=1	Ref.		Ref.
Cooking: electricity and city gas stream Yes=1 No=1	-0.544** (0.198)	0.580**	-0.525** (0.195)
Cooking: electricity and butane/propane Yes=1 No=1	0.621*** (0.152)	1.860***	0.609*** (0.148)
Cooking: other Yes=1 No=0	1.355** (0.498)	3.878***	1.300** (0.463)
Living area (m2)	0.0002 (0.001)	1.000	0.0002 (0.001)
Housing constructed before 1949 Yes=1 No=1	-0.025 (0.099)	0.975	-0.020 (0.095)
Housing constructed between 1950 and 1974 Yes=1 No=1	Ref.		Ref.
Housing constructed after 1974 Yes=1 No=1	-0.245* (0.114)	0.783*	-0.235* (0.110)
Climate zone 1 Yes=1 No=0	Ref.		Ref.
Climate zone 2 Yes=1 No=0	-0.220* (0.105)	0.802*	-0.207* (0.101)
Climate zone 3 Yes=1 No=0	-0.231 (0.120)	0.9793	-0.219 (0.116)
Climate zone 4 Yes=1 No=0	0.026 (0.118)	1.026	0.0271 (0.113)
Intercept	-3.835*** (0.238)	0.005***	-3.855*** (0.232)
N	26531		26531
LR chi2	882.52		881.88
Pseudo R2	0.1398		
R2 Mc Fadden	0.14		0.14
Comparison between predicted sample and sample frequencies (10 groups)	0K		
Correctly classified	97.44%		

Marginal effect for a retiree living alone, homeowner, according to each heating system

	Risk of falling below the fuel poverty line	Confidence Interval 95%	
		[	]
Individual boiler Yes=1 No=0	3,69%	2,21%	5,17%
District heating Yes=1 No=0	0,48%	0,01%	0,95%
Collective boiler Yes=1 No=0	0,31%	0,06%	0,55%
Mixed heating Yes=1 No=0	0,79%	0,00%	1,66%
Heating individual electric convectors Yes=1 No=1	2,09%	1,37%	2,81%
Renewable energy Yes=1 No=1	1,09%	0,00%	0,02%

Source: Enquête Logement 2006, authors' calculations

Key to reading: the marginal effects are calculated for a retiree, living alone, who is a homeowner with no children, the other variables being set at their reference value. A retiree living alone has a probability of 3.69% of falling into fuel poverty if he has an individual boiler, compared to other heating systems.

Marginal effect for a retiree living alone, who is not homeowner, according to each heating system

	Risk of falling below the fuel poverty line	Confidence Interval 95%	
		[	]
Individual boiler Yes=1 No=0	3.87%	2.15%	5.59%
District heating Yes=1 No=0	0.85%	0.00%	1.83%
Collective boiler Yes=1 No=0	0.55%	0.25%	0.85%
Mixed heating Yes=1 No=0	1.41%	0.00%	2.76%
Heating individual electric convectors Yes=1 No=1	3.68%	2.17%	5.18%
Renewable energy Yes=1 No=1	1.94%	0.00%	4.42%

Source : Enquête Logement 2006, authors' calculations

Key to reading: the marginal effects are calculated for a retiree, living alone, who is not homeowner and has no children, the other variables being set at their reference value. A retiree living alone has a probability of 3.87% of falling into fuel poverty if he has an individual boiler compared to other heating systems.

Marginal effect for a single parent family (1 active adult) with 1 child, who are not homeowners, according to each heating system

	Risk of falling below the fuel poverty line	Confidence Interval 95% [	]
Individual boiler Yes=1 No=0	6.43%	4.32%	8.54%
District heating Yes=1 No=0	0.50%	0.00%	1.02%
Collective boiler Yes=1 No=0	0.32%	0.10%	0.55%
Mixed heating Yes=1 No=0	0.83%	0.00%	1.83%
Heating individual electric convectors Yes=1 No=1	2.19%	1.26%	3.13%
Renewable energy Yes=1 No=1	1.15%	0.00%	2,47%

Source: Enquête Logement 2006, authors' calculations

Key to reading: the marginal effects are calculated for an active adult living with one child and who is not a homeowner, with the other variables being set at their reference value. This single-parent family has a probability of 6.43% of falling into fuel poverty if it has an individual boiler, compared to other heating systems.

Marginal effect for a family (active couple + 2 children) who do not own their home, according to each heating system

	Risk of falling below the fuel poverty line	Confidence Interval 95% [	]
Individual boiler Yes=1 No=0	1.35%	0.97%	1.73%
District heating Yes=1 No=0	0.17%	0.00%	0.34%
Collective boiler Yes=1 No=0	0.11%	0.00%	0.17%
Mixed heating Yes=1 No=0	0.28%	0.00%	0.54%
Heating individual electric convectors Yes=1 No=1	0.76%	0.44%	1.04%
Renewable energy Yes=1 No=1	0.39%	0.00%	0.86%

Source : Enquête Logement 2006, authors' calculations

Key to reading: the marginal effects are calculated for an active couple, living with 2 children and not homeowners, with the other variables being set at their reference value. This family has a probability of 1.35% of falling into fuel poverty if it has an individual boiler, compared to other heating systems.

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