Measuring fuel poverty in tropical territories: A latent class model

Dorothée Charlier, Bérangère Legendre, Olivia Ricci

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Abstract

Fuel poverty in tropical territories cannot be defined and measured using traditional indicators based on heating issues (expenditure, restriction or the sensation of cold inside houses). We propose a new framework for the identification of fuel-poor households by referring to Amartya Sen's Capability Approach. To accurately assess fuel poverty in tropical areas using observable objective characteristics of decent, safe and healthy dwellings, we use the latent class model (LCM) methodology. This approach allows us to categorize households as fuel poor or non-fuel poor. It is also possible to extend further by considering the multi-dimensional phenomenon of fuel poverty. Using three classes, we can underline a scale of fuel poverty severity with a new class of vulnerable households. Restricting fuel poverty in tropical areas to a binary phenomenon leads to the neglect of the complexity of energy deprivation.

Keywords: fuel poverty, tropical islands, latent class model, capabilities approach

JEL codes: D12, C35, O12, Q41, R21

1. Introduction

Fuel poverty in developed countries is a complex phenomenon resulting from a combination of the following three main factors: low income, low-energy efficient housing and high energy prices (EPEE, 2006; Devalière, 2007; Palmer *et al*., 2008). These issues are quite different from

those identified in developing countries, where energy poverty usually describes situations in which people have inadequate access to modern energy sources. Bouzarovski and Petrova (2015) emphasized that the term "fuel poverty" is generally used in northern and colder countries, while in less developed countries, the term "energy poverty" is preferred and encompasses broader issues (infrastructure, electrification, education and health concerns).

Fuel poverty is often defined in Europe as a situation in which household members are unable to adequately heat their homes or meet other required energy services at affordable costs. In Scotland, Wales and Ireland, fuel poverty is officially defined as having to spend more than 10% of income on fuel use to maintain a satisfactory indoor level of warmth[1]. In France, this type of heating issue also has an increased importance. Many definitions include a heating issue as a main component of fuel poverty. Devalière (2007) proposed the following definition: "one who encounters a social, economic and environmental vulnerability which prevents him from heating himself appropriately and/or paying his energy bills". The Pelletier report also highlights this issue (De Quero and Lapostolet, 2009). A household member is considered to experience fuel poverty if he/she "has difficulty in heating their home because of the inadequacy of their resources and housing conditions."

On the one hand, in developed countries, fuel poverty is mainly related to the poor energy efficiency of housing and cold winter issues. However, on the other hand, among people living in developing countries, energy poverty concerns energy deprivation and the lack of adequate facilities. The populations in these countries face the absence of networks, which are a prerequisite for economic development. A better access to energy is therefore a key element of improving well-being (Pachauri et al., 2004). Energy poverty is strongly linked with poverty, especially consumption based measure of poverty: households do not have even a choice of

[1] The satisfactory heating regime recommended by the World Health Organization is 23°C in the living room and 18°C in the other rooms, which should be maintained for 16 of every 24 hours in households with older people or people with disabilities or chronic illness and 21°C in the living room and 18°C in the other rooms for nine of every 24 hours (or 16 of 24 hours over the weekend) in other households.

energy consumption level or electrical equipment to make. They do not have a physical access to electrical grid, nor physical access to markets where they could buy electrical equipment (Pachauri et al., 2004). Climatic issues are not central in energy poverty. However, according to Mohr (2018), "*more research is needed to understand predictors of fuel poverty and contrasts between cool and warm climates*"

At the crossroads of these issues, in some territories, access to energy does not seem particularly problematic, except for in the case of a major climatic event, but housing may be of poor quality. Indeed, some tropical territories have quite good energy networks; by definition, these territories do not experience winter cold but suffer from domestic energy deprivation (OREC, 2018). The geographic (islands), climatic (tropical), and socio-economic contexts in those territories induce a use of energy services that differs from that in temperate latitudes.

We focus in this paper on the French overseas territories (Guadeloupe, Martinique, Reunion Island and Guyana), which perfectly illustrate the gap between both approaches of the issue. These overseas territories are located far from mainland France. These territories, except for Guyana, are also characterized by their insularity. However, Guyana is isolated from the remainder of South America by its location between the Atlantic Ocean and Amazonia.

The climate in Guadeloupe, Martinique and Reunion Island is tropical maritime. The temperature differences between the summer and winter are low. Winter is the dry season, and summer is the wet season. In Guyana, the climate is similar but more equatorial. The temperatures slightly vary during the year. Precipitation is abundant during the summer. However, the following climatic characteristics are rather similar across the four territories: hot temperature, very mild and humidity.

The standards of living are also significantly low in these territories. For instance, in Guadeloupe, the mean disposable income per month reaches 780 €, and 50% of the population aged older than 15 years is inactive (OREC, 2018). Monetary poverty is more important in

these territories than in mainland France. In 2015, 40% of the population of Reunion Island lived under the poverty line compared to 14% of the population in mainland France (INSEE, 2018). Moreover, the prices of basic necessities are sometimes much higher (up to 35% for fuels) compared to those in mainland France (La Documentation Française, 2009). In this context, a household's energy budget may be significant. Although these territories are not developing economies, they often suffer from multidimensional precariousness (OREC, 2018). Consequently, energy is not considered a primary/basic need by household members, who adopt coping strategies and restrict their energy service consumption (OREC, 2018).

Within this context, tropical territories cannot be characterized by the current well-known fuel poverty or energy poverty issues. The phenomenon in tropical territories cannot be defined and measured by traditional indicators based on heating issues (expenditure, restriction or the sensation of cold inside houses). Moreover, indicators based on fuel expenditures and income relative to acceptable thresholds (Boardman, 1991, Hills *et al.*, 2010, Hills, 2011, 2012) can overestimate fuel-poor households given the higher rate of monetary poverty in these territories. These traditional indicators seem limited in capturing the complex and multidimensional characteristics of fuel poverty in tropical territories.

Consequently, a better understanding of the fuel poverty phenomenon in tropical territories complemented by a quantified evaluation seems necessary and original. Approaching this phenomenon in tropical areas requires overcoming the gap between the following approaches: fuel and energy poverty. Similar to Bouzarovski and Petrova (2015), we believe that in addition to heating issues, fuel and energy poverty should focus on all domestic energy services, including cooling, water heating, and cooking, as well as the hygiene, safety and sanitation of dwellings. Fuel expenditure-based indicators and definitions should capture the broader idea of

energy “services” rather than simply “fuel” or even “energy”. The concept of “services” captures notions of utility and adequacy rather than energy consumption (Sovacool, 2011).

Recent research (Day, *et al.*, 2016) focused on the notion of energy poverty from a capabilities approach based on the pioneer work conducted by Amartya Sen and Martha Nussbaum (Nussbaum, 2003; Nussbaum, 2011; Nussbaumer, *et al.*, 2012; Sen, 1979; Sen, 1999; Sen, 2003; Sen, 2004; Sen, 2012). The capability approach developed by Sen considers human life a set of "doings and beings" named “*functionings”*. Functionings vary from escaping morbidity and being adequately nourished to being integrated into a social community, achieving self-respect and receiving recognition for one’s work. Sen describes functionings as a personal achievement, i.e., what a person manages to accomplish or be. The capability of a person is a derived notion that reflects the combination of functionings and the freedom to choose a way of living. Therefore, according to Sen, poverty can be understood as a deprivation in the capability to achieve crucial and valued functionings. This concept of capability deprivation can be applied to energy poverty because it allows a richer comprehension of the phenomenon. Day *et al*. (2016) conceptualized the relationship among energy, energy services and capabilities to propose a definition of energy poverty based on the capabilities framework. According to these authors, domestic energy is obtained from different sources (biomass, solar energy, and gas) and provides services (lighting, refrigeration, etc.). These energy services enable people to wash clothes and store and prepare food. The authors call these daily actions *secondary capabilities*. Secondary capabilities are prerequisites required to access so-called *basic capabilities* (functionings), such as being in good health, having social respect, etc. Therefore, the authors defined energy poverty as *"an inability to realize essential capabilities as a direct or indirect result of insufficient access to affordable, reliable and safe energy services, and*

*taking into account available reasonable alternative means of realizing these capabilities" (*Day *et al., 2016).*

In this article, we use the common term "fuel poverty" to describe energy deprivation in tropical territories as we consider this term less specific than the term energy poverty. As fuel poverty in tropical areas has never been defined or measured, our objective is to study fuel poverty as a latent phenomenon that, by definition, we cannot observe. However, the literature offers different paths to theoretically approach the observable characteristics of fuel poverty.

Therefore, we rely on the capabilities theoretical framework developed by Sen and the conceptualizing work performed by Day *et al*. (2016) to identify the fuel poor in tropical territories with an innovative methodology.

To accurately assess fuel poverty in tropical areas, using observable objective characteristics, we use a latent class model (LCM) (Greene and Hansher, 2003). Assuming that objective multivariate variables describing a set of capabilities are observed, we link these variables to the following latent variable: fuel poverty in tropical areas. This methodology allows us to categorize households as fuel poor or non-fuel poor. As the main results extend the common bi-dimension phenomena, we show that defining three categories of energy-deprived people is better than defining people as only fuel poor and non-fuel poor. The most deprived represent approximately 12% of the population, while 32% of the population is expected to belong to the non-fuel poor class. An intermediate class encompassing 56% of the population represents vulnerable households that could easily be impacted by an exogenous shock. Restricting fuel poverty in tropical areas to a binary phenomenon leads to the neglect of the complexity of energy deprivation.

Our paper provides the following three key contributions to this field of research: we propose the first characterization of fuel poverty in tropical areas, we use an original methodology that has never been used to identify fuel poor households and we allow policy makers to identify a target group of households that is a top priority in fighting fuel poverty.

The paper is organized as follows. In section 2, we describe the data and variables. The class latent methodology is presented in section 3. Section 4 presents the results, and section 5 offers some concluding remarks.

2. Observable characteristics of fuel poverty in tropical areas: capabilities, data and variables

2.1 Capabilities

In the capability framework, energy demand can be interpreted as a services access demand. As underlined by Day, *et al*. (2016), households aspire to use energy services, such as cooking, lighting and cooling(Sovacool, *et al.*, 2014), more than they demand electricity or gas. Thus, a "*capability"* is the expression of the freedoms offered by the consumption of energy services. Practical Actions (2010) outlines the following basic energy services: lighting, cooking, water heating, space heating, cooling, information and communication, and earning a living.

Lighting avoids the loss of many productive hours during the night. Cooking and water heating are strongly linked to different issues, such as the possibility of cooking nutritious food and washing oneself and the opportunity to limit deforestation and climate change from a more global perspective. Space heating enables the control of thermal comfort in cold regions, while cooling is important for lengthening the lifespan of food and maintaining spaces at reasonable temperatures in countries with hot climates. Information and communication refer to social and

economic relationships to alleviate poverty. Finally, global energy access could enable a person to earn a living.

The classification of basic energy services by Practical Action and the conceptualized relationship among energy, energy services and capabilities by *Day et al.* (2016) helps us identify items that could be observable characteristics of fuel poverty in tropical areas. Moreover, the OREC (2018) technical report provides a profile of fuel-poor households living in Guadeloupe. The report shows that equipment, such as air conditioners and water systems, account for a large share of domestic energy consumption that can affect the most economically fragile households. However, some houses without air conditioners and electric water heaters also face high electricity bills, which can be explained by ageing equipment and energy-consuming practices due to the lack of device-specific technical knowledge. The presence of a cooling system remains marginal in traditional houses (wooden walls without thermal insulation and sheet metal roof construction). This type of dwelling induces significant energy losses and is an aggravating factor of high final energy consumption. Access to hot water is a preoccupation in overseas departments. Many households do not have any hot water. Even if the lack of hot water systems does not have sanitary consequences due to warm outdoor temperatures, people should have the choice of access. In rented houses, homeowners often decide to not provide hot water to tenants.

Domestic hot water, air conditioning and building insulation represent a significant proportion of over-consumption. These factors cannot be considered the only factors of fuel poverty in overseas departments because their diffusion only partially affects the most vulnerable populations. The OREC report (2018) also shows that it is important to integrate energy insecurity, safety and building conditions as drivers of fuel poverty in Guadeloupe.

The building quality has a direct impact on the quality of a house. Poor quality is mostly due to moisture, dampness and holes. Buildings that are very damp or very dry can have significant

impacts on the occupants' health. This fact has been well established in many reports, including those published by the World Health Organization (2009). Furthermore, electricity installations in overseas departments are sometimes homemade, illegal and dangerous. Household members connect their houses to electricity poles. Regardless of whether they are installed before or after metres, electrical installations may pose risks to users if they are not up to standard. "Homemade" and/or ageing facilities are often involved in fires . OREC (2018) also underlines the role of lighting. Lighting is not the most energy-intensive consuming item, but energy-saving margins can be achieved through better information regarding equipment and practices. Finally, some households in overseas departments do not use modern cooking equipment, which is important because indoor air pollution from the use of solid fuels leads to a high number of deaths per year according to the World Health Organization. Providing clean access to energy for cooking is a challenge in eliminating fuel poverty (Rao, *et al.* (2013); (World Bank, 2013).

Considering the literature described above and to cover all dimensions of fuel poverty, the following capabilities are analysed to characterize fuel poverty in tropical areas: lighting efficiency, security of electricity installations, access to clean energy for cooking, access to water heating, quality of building insulation and access to a cooling system.

2.2 Data

Our study is based on the 2013 French housing survey (INSEE, 2013). The purpose of the housing survey was to describe households' housing conditions and expenditures. This survey also includes a detailed description of the quality of the dwellings. Based on the survey, we have information regarding the following four French overseas departments: Guadeloupe, Martinique, Reunion Island and Guyana. To ensure consistency with the literature, we chose

the following variables, which are consistent with the capabilities presented in the previous section:

-Water heating: information about water access is available. It is possible to determine whether households have only hot water or cold water or whether there is no access.

-Quality of building insulation: regarding the quality of building insulation, we consider components of the building quality, moisture and holes in the roof. A building is well insulated if there is no moisture and no holes.

-Cooling: whether a household has a cooling system is known.

-Lighting: there is no direct information about the number of lights available in a dwelling. However, it is possible to determine whether there is sufficient brightness in a house. A good level of brightness leads to less energy consumption per day in terms of lighting.

-Electricity: information regarding the quality of the installation is available, and we introduce a dummy variable that indicates whether the electrical installation is protected.

-Cooking: based on the information in the database, the main fuel used for cooking (fossil fuels or solid fuels) is known.

For our study, additional information is available in the database to control drivers that influence fuel poverty. Even if the standard measures of fuel poverty are not relevant in this study, fuel poverty still refers to a multidimensional concept that includes the socioeconomic situation of a household according to the income level, the characteristics of the dwelling, including energy efficiency, and the energy access conditions generally reflected in energy prices. Within the same country, regional differences in climate, different socioeconomic characteristics (cost of living), and cultural factors necessarily influence the phenomenon of fuel poverty. Income elasticity is positively related to energy consumption in most studies, which is consistent with the "normal good status" of energy consumption as follows: income

elasticity often lies between 0.01 and 0.15. Positive elasticity may mainly involve the purchase of more energy-efficient appliances, which could result in lower energy consumption (Alberini and Filippini, 2011; Bakaloglou and Charlier, 2018; Bernard, *et al.*, 2011; Cayla, *et al.*, 2011; Damette, *et al.*, 2018; Dubin and McFadden, 1984; Labandeira, *et al.*, 2006; Nesbakken, 2001; Parti and Parti, 1980; Santamouris, *et al.*, 2007). Recently, new studies have shown that households react differently to residential energy price fluctuations as follows: fuel-poor households have the highest income elasticity (Charlier and Kahouli, 2019). A high education level increases the probability of being non-fuel poor (Chaton and Lacroix, 2018). Empirical research also underlines the effect of tenure status on fuel poverty as follows: renting households have a higher likelihood of experiencing fuel poverty (Davis, 2010; Poruschi and Ambrey, 2018). Tenants do not have full control of their heating consumption compared to owners (Healy and Clinch, 2004). Numerous studies also show that a poor energy efficiency dwelling is a main driver of fuel poverty (Boardman, 2010; Hills, 2011; Mohr, 2018). Experiencing mould and/or moisture problems in homes is a driver of fuel-poverty severity. Using French data, Legendre and Ricci (2015) show that the probability of being fuel poor is higher among single persons in rented properties with inefficient roof insulation. Compared to living in an apartment, living in a single detached house increases the probability of remaining in fuel poverty (Chaton and Lacroix, 2018). These results have been confirmed in France with the empirical fuel poverty study conducted by Belaïd (2018).

Therefore, we need to control for these characteristics to determine a fuel-poor profile and the probability of living in a dwelling with poor energy services. Income, occupant status, family composition, urban area, and type of home (period of construction and type of dwelling) have to be introduced in the study. The final sample contains 5686 observations. The summary statistics of the variables included in the model are presented in Table 1.

In general, the capabilities in Guadeloupe, Martinique and Reunion Island are better than those in Guyana. The use of cooling systems in Guadeloupe is more important than that in other overseas departments. In Guyana, more households use wood and do not have a cooking system. Households include tenants with children, and those with high education levels live in rural areas. The most recent housing stock is on Reunion Island.

Table 1: Summary statistics

Category	Variables	Whole sample		Guadeloupe		Martinique		Guyana		Reunion Island	
		Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
Space heating and building insulation	No problem with roof holes or moisture	0.461	0.499	0.464	0.499	0.467	0.499	0.339	0.474	0.508	0.500
Cooling	Presence of a cooling system	0.301	0.459	0.463	0.499	0.240	0.427	0.342	0.475	0.209	0.407
Water heating	Hot water supply	0.721	0.448	0.720	0.449	0.641	0.480	0.417	0.493	0.900	0.300
	Cold water supply only	0.258	0.438	0.271	0.445	0.353	0.478	0.478	0.500	0.099	0.299
	No supply of water	0.020	0.141	0.009	0.094	0.005	0.074	0.105	0.307	0.001	0.035
Cooking	Butane/propane	0.624	0.485	0.777	0.417	0.481	0.500	0.675	0.469	0.583	0.493
	Electricity	0.279	0.449	0.182	0.386	0.418	0.493	0.252	0.434	0.273	0.446
	Wood	0.084	0.277	0.024	0.155	0.093	0.291	0.034	0.182	0.140	0.347
	Other fuels	0.008	0.087	0.007	0.081	0.005	0.069	0.028	0.166	0.001	0.035
	No cooking system	0.006	0.079	0.010	0.100	0.003	0.058	0.011	0.103	0.003	0.057
Electricity	Protected electrical installation	0.850	0.357	0.845	0.362	0.841	0.365	0.781	0.414	0.889	0.315
Lighting	Good brightness level in the house	0.922	0.268	0.952	0.215	0.916	0.278	0.892	0.311	0.919	0.273
Other predictive variables	Income	19608	18168	19398	17288	19968	16134	20327	22140	19229	18062
	Homeowner	0.551	0.497	0.607	0.489	0.566	0.496	0.441	0.497	0.549	0.498
	No children	0.580	0.494	0.642	0.480	0.678	0.468	0.477	0.500	0.521	0.500
	Diploma superior to a bachelors + 2 years	0.178	0.383	0.184	0.388	0.167	0.373	0.184	0.387	0.178	0.383
	City with more 50,000 inhabitants	0.701	0.458	0.762	0.426	0.682	0.466	0.570	0.495	0.724	0.447
	Constructed after 1999	0.273	0.446	0.282	0.450	0.214	0.410	0.247	0.432	0.314	0.464
	Individual housing unit	0.740	0.439	0.762	0.426	0.710	0.454	0.728	0.445	0.748	0.434
	Observations	6586		1675		1470		1024		2417	

Note: A table of the correlations among the variables is available upon request

3. A latent class model defining fuel poverty in tropical areas

3.1 Latent class model versus other approaches

To identify household profiles, several methods, including a multidimensional analysis, cluster analysis (Fizaine and Kahouli, 2019) and regression analysis (Charlier and Legendre, 2019; Masuma, 2013; Thomson and Snell, 2013)(Belaïd, 2018; Waddams Price, *et al.*, 2007), can be used. A regression analysis is often used to identify the drivers of fuel poverty. Generally, in the economic literature, the drivers of fuel poverty are mostly identified using a conventional binary definition of fuel poverty, such as the Low Income High Cost Indicator (LIHC) or the effort rate (Boardman, 1991; Hills, 2011), which is not possible in our case because no objective measures of fuel poverty exist. Moreover, commonly in the social sciences, multiple indicators can be used to describe a phenomenon instead of a single measure of an outcome of interest. As mentioned in their report, according to Thomson and Bouzarovski (2018),*"Energy poverty is a multi-dimensional concept that is not easily captured by a single indicator"*. Energy poverty should be measured by a composite indicator (Llera-Sastresa, *et al.*, 2017)(Charlier and Legendre, 2019). Using regression methods to analyse a composite indicator that does not currently have a formal definition in tropical areas does not seem appropriate.

Multidimensional and cluster analyses, such as Latent Class Model (LCM), are used to identify profiles and create groups, but compared to LCM, cluster analysis presents several disadvantages. First, most cluster analyses are based on the subjective distance between variables (k-means clustering and similarity). Second, the choice of the number of clusters is often subjective and biased due to the lack of objective criteria (Ketchen and Shook, 1996). Indeed, Ketchen and Shook (1996) argue that cluster analyses often produce group profiles that are not meaningful considering that the number and nature of the clusters are based on the researchers' hypothesis. Third, cluster analyses can be more difficult to perform with missing

data and large sample datasets. Finally, cluster analyses are not appropriate for analysing large range variables; these variables tend to skew the results if they are given more weight, and standardization can have adverse effects (Ketchen and Shook, 1996).

In such a context, LCM offers a "model-based clustering" approach derived from the clustering approach that uses a probabilistic model to describe the distribution of the data. In this model, it is assumed that the population consists of a number of subpopulations and that in each of population, the variables have a different multivariate probability density function. Therefore, instead of finding profiles using some arbitrary distance measure as in cluster analysis, the LCM describes the distribution of the data and assesses the probabilities that certain households are members of certain latent classes. In contrast to clustering, using a statistical model also allows for the assessment of the goodness of fit. Assuming a latent structure determining the structure of the data exists, LCM is more appropriate than clustering, which only measures some similarities. Finally, using latent class methods, we can determine the weight of each variable that contributes to the phenomenon and, thus, identify the priority attributes that could be targeted; thus, we believe that this approach can enlighten policy decision makers.

3.2 Model

In their seminal work, Lazarsfeld and Henry first proposed a latent structure analysis in 1968 (Lazarsfeld and Henry, 1968), and a latent class analysis was a subdomain of this analysis. A latent class analysis is a measurement model in which the observations can be categorized into latent classes (Goodman, 2002). The latent variable is discrete and unobservable. The latent class model includes 1) a measurement model relating the observed variables (also called indicators or manifest variables) to the underlying latent variable and 2) a structural model characterizing the distribution of the latent variable and the impact of its antecedent variables (Masyn, 2013).

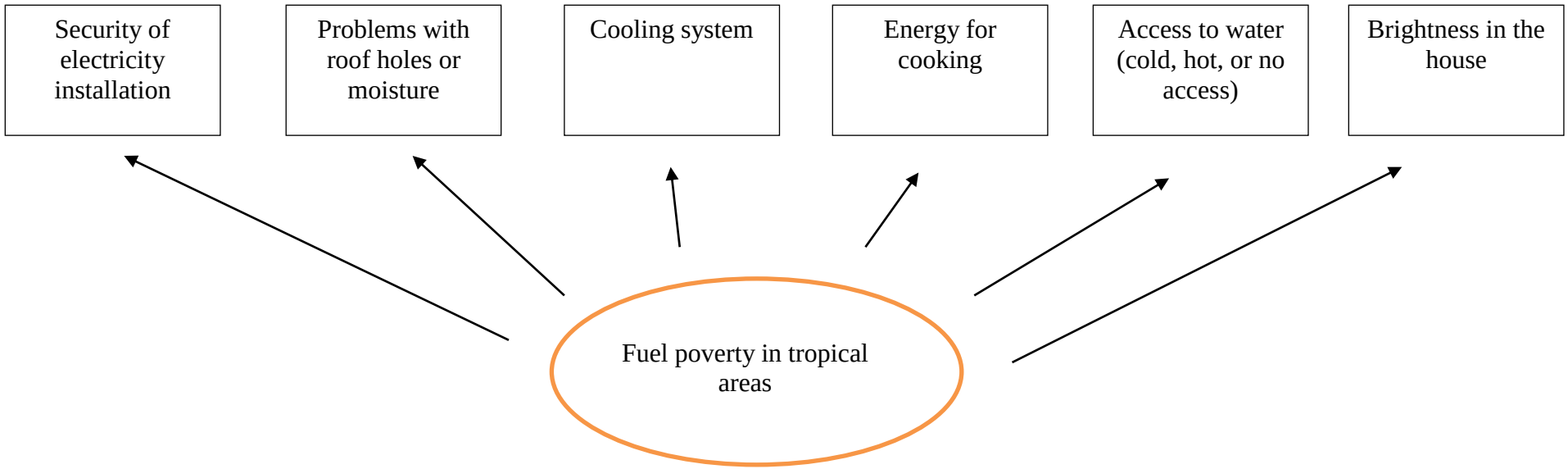
Fuel poverty in tropical areas has never been defined or measured. Consequently, this phenomenon is a good candidate as a latent variable. We assume that fuel poverty in tropical areas is a binary latent variable (i.e., typically poor and non-poor in the literature). Both identified classes are mutually exclusive and exhaustive as follows: each individual has membership in exactly one category, i.e., he is either fuel poor or non-fuel poor. The latent classes pertain to the latent heterogeneity that varies with the manifest variables.

As a first step, we are interested in building an unconditional model with only manifest variables to explain the belonging to a latent class. Consequently, we use the following observable characteristics assumed to be symptoms of this phenomenon: basic needs (Practical Actions, 2010), which are approximated by housing characteristics, and some household attributes commonly considered determinants in analyses of fuel poverty as presented in the previous section. The theoretical framework of capabilities (Sen, 1979) allows us to theoretically identify the model. The basic needs identified in the literature and fuel poverty in tropical areas are indeed strongly linked, allowing latent class *homogeneity* and latent class *separation* (Collins and Lanza, 2009).

Conditional or *local independence* is assumed (Masyn, 2013), implying that class membership explains all covariance among the manifest variables. The number and nature of the latent classes is set based on a set of associations among the observed variables.

Figure 1 represents the measurement model with the manifest variables resulting from latent class membership using diagramming conventions (Muthén and Muthén, 1998-2011).

Figure 1: Path diagram of unconditional LCM of fuel poverty in tropical areas



We sort individuals into a set of Q classes, namely, two classes in the present case. The logit model of discrete choice allows us to define the class to which each household belongs. Each household i as observed in T_i situations faces J_i alternatives as follows:

$$P_{it|q}(j) = Prob(y_{it} = j|class = q) = \frac{exp\left(x'_{it,j}\beta_q\right)}{\sum_{j=1}^{J_i} exp\left(x'_{it,j}\beta_q\right)} \text{ with } q = 1,2$$

y_{it} denotes an assignment to the fuel-poor class. The T_i situations are assumed to be independent given the class assignment. We define the contribution of household i to the likelihood as the joint probability of $y_i = [y_{i1}, y_{i2}, \dots, y_{iT}]$ as follows:

$$P_{i|q} = \prod_{t=1}^{T_i} P_{it|q}$$

H_{iq} is the probability that individual i belongs to class q

$$H_{iq} = \frac{exp\left(z'_i\theta_q\right)}{\sum_{q=1}^{Q} exp\left(z'_i\theta_q\right)}$$

$$q = 1, \dots, Q \; and \; Q = 2$$

$$\theta_Q = 0$$

z_i represents a set of observable attributes or manifest variables that contribute to determining class membership named the "risk factor" by Roeder, *et al.* (1999). We denote P_i as the likelihood of individual i as follows:

$$P_i = \sum_{q=1}^{Q} H_{iq} P_{i|q}$$

The log likelihood is as follows:

$$\ln L = \sum_{i=1}^{N} \ln P_i = \sum_{i=1}^{N} \ln \left[\sum_{q=1}^{Q} H_{iq} \left(\prod_{t=1}^{T_i} P_{it|q} \right) \right]$$

This issue is usual in maximum likelihood estimation (Greene, 2002). Using the parameter estimates of θ_q, the class probabilities ($\widehat{H}_{iq}$) can be obtained using Bayes Theorem as follows:

$$\widehat{H}_{q|i} = \frac{\hat{P}_{i|q}\widehat{H}_{iq}}{\sum_{q=1}^{Q}\hat{P}_{i|q}\widehat{H}_{iq}}$$

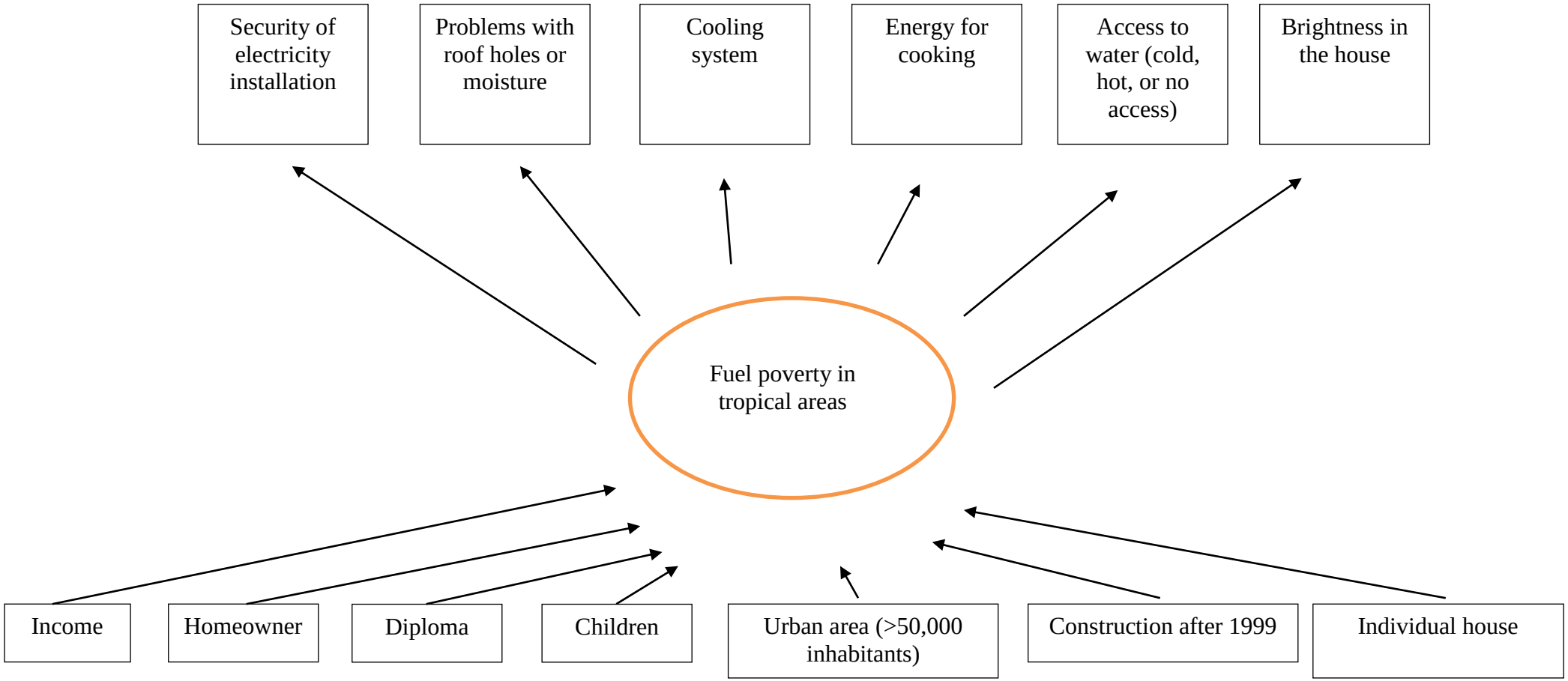
$\widehat{H}_{iq}$ denotes the household-specific estimate of the class probability given its estimated characteristic probabilities, which differs from the unconditional class probability used in the log likelihood function.

The maximum value of $\widehat{H}_{iq}$provides an empirical estimator of the latent class to which a household belongs. Then, we can obtain estimates of the household-specific parameter vector as follows:

$$\hat{\beta}_i = \sum_{q=1}^{Q}\widehat{H}_{q|i}\hat{\beta}_q$$

The second step involves the construction of a structural model to characterize the causal link between households' attributes and class membership. This model allows us to characterize the distribution of the latent variable. Covariates *M* are introduced to the mass probabilities, i.e., to the model of the distribution of latent variable *Q*, via a multinomial logit model. The main interests are the discrete latent variable, which is measured through the manifest variables, and how this latent variable depends on the covariates; subsequently, the covariates directly affect the probability of belonging to a given class. Thus, the regression coefficient means indicate the effect of an increase in a unit of the *m*-th covariate on the logit of belonging to class *q* with respect to the reference class (e.g., class 1). Figure 2 represents the complete model (including the measurement model and structural model).

Figure 2: Path diagram of the complete LCM of fuel poverty in tropical areas (measurement and structural models)



4. Results

Here, we present the results of a binary class model of fuel poverty in tropical climate to identify the fuel poor and non-fuel poor. First, we present the results of the measurement model (Table 3). Second, we present the results of the structural model (Table 4). Then, we report the class-specific marginal means of each variable (Table 5). Because the measurement model includes logistic regressions, these means are actually the predicted probabilities.

We can estimate the probabilities of being in each class. This analysis indicates that 54% of individuals are expected to be fuel poor (class 1), which can be relatively high in terms of households concerned. This class represents the statistical majority of the population living in French overseas territories. Fuel poverty can be characterized as a "normal" or "typical" situation, which can be considered substantial.

Table 3: Estimated coefficients in the binary logit model of Q latent classes

	Class 1 Fuel poor		Class 2 Non-fuel poor	
	Margin	Std. Err.	Margin	Std. Err.
0.Problems with roof holes or moisture				
1.No problems with roof holes or moisture	-0.807	(0.0713)***	0.572	(0.0519)***
0.No cooling system				
1.Cooling system	-2.256[a]	(0.0972)***	0.121	(0.0789)***
1.Butane/propane for cooking				
2.Electricity for cooking	-1.469	(0.0626)***	-0.241	(0.0562)***
3.Wood for cooking	-1.867	(0.0663)***	-2.281	(0.1209)***
4.Other fuels for cooking	-4.107	(0.1688)***	-5.205	(0.4149)***
5.No cooking system	-4.323	(0.1856)***	-5.325	(0.4254)***
1.Hot water supply				
2.Cold water supply	-0.242	(0.0667)***	-2,636	(0.1377)***
3.No water	-2.660	(0.1254)***	-8.463	(2.4262)***
0.Unprotectedelectrical installation				
1.Protected electrical installation	1.020	(0.0737)***	4.157	(0.2356)***
0.Low level of brightness in the house				
1.Good level of brightness in the house	2.062	(0.0676)***	3,259	(0.1185)***
Observations	6,586			

Robust standard errors are presented in the parentheses; *** p<0.01, ** p<0.05, * p<0.1

Note: [a]The probability of being in class 1 decreases if households have a cooling system compared to those without a cooling system.

Table 4: Results of predictive variables – base outcome: Class 1- fuel poor

	Coef.	Std. Err.
	No fuel poor	
Income (log-transformed)	1.923836	(0.1869)***
Homeowner	0.6650276	(0.1380)***
Diploma superior to a bachelors + 2 years	1.47552	(0.2121)***
No children	-0.563759	(0.1187)***
City with more than 50,000 inhabitants	0.5739866	(0.1159)***
Constructed after 1999	1.186008	(0.1288)***
Individual housing unit	-0.5854034	(0.1566)***

Robust standard errors are presented in the parentheses; *** p<0.01, ** p<0.05, * p<0.1
Note: The regression coefficient means measure the effect of an increase of one percent of the *m*-th covariate (such as income) on the logit of belonging to class2 with respect to the reference class (e.g., class 1).

In general, according to Table 3, our categories, which are chosen as capabilities, all significantly explain the probability of belonging to the fuel poor and non-fuel poor classes. Based on this table, we only interpret the sign and statistical effect of each coefficient compared to the base outcome as a probability of being in the class considered. For example, having no roof holes or moisture compared to having roof holes or moisture significantly decreases the probability of belonging to the category of fuel poor. In general, in the non-fuel poor class (Table 4), we find high-income households and family homeowner households living in collective housing units constructed after 1999. The opposite results are found to explain the probability of being in the fuel poor classes. These results are consistent with the literature related to fuel poverty (ONPE 2014). Indeed, even in tropical climates, fuel poverty is mainly characterized by low income and tenant households (Charlier and Kahouli, 2019; Davis, 2010; Poruschi and Ambrey, 2018). A high education level also increases the probability of being nom-fuel poor, which is consistent with the literature (Chaton and Lacroix, 2018).

Furthermore, regarding the predicted probabilities (Table 5), the first column of this table reports the probabilities of being fuel poor. Experiencing mould and/or moisture problems in homes is a driver of fuel poverty, which is consistent with previous findings (Boardman, 2010; Hills, 2011; Mohr, 2018). In this class, the probability of having a problem with roof holes or

moisture is 0.70. The probability of not having a cooling system is 0.90. This final manifest variable is the main attribute explaining the probability of being fuel poor. Generally, in the fuel poor class, there are households with poor living conditions, e.g., a higher use of wood and no cooking system, compared to the non-fuel poor (1.2% versus 0.3%, respectively). In addition, most households use cold water (42.3%). Furthermore, 26.5% of households have no protected installation. These results are interesting because they underline the profile differences in fuel poverty between northern countries and tropical islands. For instance, in a northern country, access to hot water and protected electrical installation are not questionable. However, in the same country, such as France in our case, the same phenomenon, i.e., fuel poverty, cannot be measured in the same way in metropolitan areas and overseas departments, underlining the necessity to identify another way to identify the fuel poor and non-fuel poor. Our methodology addresses this need.

Table 5: Class-specific marginal means or predicted probability

	Class 1 Fuel poor		Class 2 Non-fuel poor	
	Margin	Std. Err.	Margin	Std. Err.
0.Problems with roof holes or moisture	0.692	0.015	0.361	0.012
1.No problems with roof holes or moisture	0.308	0.015	0.639	0.012
0.No cooling system	0.896	0.009	0.470	0.020
1.Cooling system	0.104	0.009	0.530	0.020
1.Butane/propane for cooking	0.707	0.009	0.527	0.012
2.Electricity for cooking	0.163	0.009	0.414	0.014
3.Wood for cooking	0.109	0.006	0.054	0.006
4.Other fuels for cooking	0.012	0.002	0.003	0.001
5.No cooking system	0.009	0.002	0.003	0.001
1.Hot water supply	0.539	0.017	0.933	0.009
2.Cold water supply	0.423	0.015	0.067	0.009
3.No water	0.038	0.004	0.000	0.000
0.Unprotectedelectrical installation	0.265	0.014	0.015	0.004
1.Protected electrical installation	0.735	0.014	0.985	0.004
0.Low level of brightness in the house	0.113	0.007	0.037	0.004
1.Good level of brightness in the house	0.887	0.007	0.963	0.004
Observations	5686			

Recent studies raise the issue of the intensity of fuel poverty (Charlier and Legendre, 2019) and its composite dimension (Llera-Sastresa, *et al.*, 2017)(Charlier and Legendre, 2019)(Thomson

and Bouzarovski, 2018). This question implies that fuel poverty should not be measured as a binary phenomenon but rather as a phenomenon with a continuous distribution of intensity or at least more than 2 categories. Here, our method allows us to extend further in the analysis and consider an additional class. As previously mentioned in section 3.1, this is one of the many advantages of LCM and could allow us to achieve a more detailed and discriminating level of analysis. In such a context, fuel poverty should not be defined as a binary dimension but as a phenomenon with multi-dimensions, which is very interesting since it allows us to explore whether a class of vulnerable households appears and switch households to this class. In particular, it is possible to determine whether households considered non-poor with a binary measure are actually vulnerable. This intuition is consistent with (Charlier and Legendre, 2019) as follows: a scale of fuel poverty offers a more detailed analysis of the phenomenon and avoids exposure to threshold effects.

First, we aimed to confirm our assumption in a methodological way. In a latent class analysis, models with different numbers of classes are often compared. Following Goodman (2002), we compare models including two and three latent classes. We compare both models using AIC and BIC criteria (see Table 6). Smaller AIC and BIC values are better. We prefer a model with 3 classes as the three-class model has the smallest AIC and BIC values.

Table 6: Comparison of models

		AIC	BIC	LL	df
Model 1	2 classes	44203.67	44393.87	-22073.84	28
Model 2	3 classes	43471.39	43783.85	-21689.69	46

Thus, in a contextual way, the results show the importance of considering 3 classes, which is interesting regarding the definition of fuel poverty.

In total, 12% of individuals are expected to be fuel poor (class 1), 56% of individuals are expected to be vulnerable to fuel poverty (class 2) and 32% of individuals are expected to be non-fuel poor (class 3). This result shows that a large share of the fuel poor (previously class 1) fall in the second class, which is also the case for some households who previously belonged to class 3 and currently belong to class 2 (12%). Vulnerable becomes the majority class.

Thus, regarding public policies, policy makers should first target the most deprived households (in class 1) and obtain information regarding who is vulnerable. With three classes, we can underline a scale of fuel poverty severity. Restricting fuel poverty in tropical areas to a binary phenomenon could lead to the neglect of the complexity of energy deprivation.

The results of the estimated coefficients and predictive variables are presented in appendix A-1. We also present the results of the class-specific marginal means in Table 7.

Table 7: Class-specific marginal means or predicted probability with 3 classes

	Class 1 Fuel poor		Class 2 Fuel vulnerable households		Class 3 Non-fuel poor	
	Margin	Std. Err.	Margin	Std. Err.	Margin	Std. Err.
0.Problems with roof holes or moisture	0.915	0.020	0.569	0.017	0.342	0.014
1.No problems with roof holes or moisture	0.085	0.020	0.431	0.017	0.658	0.014
0.No cooling system	0.965	0.019	0.822	0.013	0.381	0.018
1.Cooling system	0.035	0.019	0.178	0.013	0.619	0.018
1.Butane/propane for cooking	0.715	0.021	0.684	0.010	0.483	0.014
2.Electricity for cooking	0.084	0.018	0.213	0.009	0.469	0.017
3.Wood for cooking	0.153	0.019	0.091	0.007	0.044	0.008
4.Other fuels for cooking	0.032	0.007	0.005	0.002	0.003	0.002
5.No cooking system	0.017	0.006	0.007	0.002	0.001	0.002
1.Hot water supply	0.296	0.044	0.681	0.015	0.955	0.008
2.Cold water supply	0.546	0.029	0.318	0.015	0.044	0.008
3.No water	0.158	0.028	0.001	0.002	0.002	0.001
0.Unprotectedelectrical installation	0.762	0.043	0.092	0.018	0.019	0.005
1.Protected electrical installation	0.238	0.043	0.908	0.018	0.981	0.005
0.Low level of brightness in the house	0.211	0.021	0.071	0.006	0.039	0.005
1.Good level of brightness in the house	0.789	0.021	0.929	0.006	0.961	0.005
Observations	5686					

These results are interesting because our assumption is confirmed. The new intermediate class shows a median profile. These households have good brightness levels inside and mostly

protected electrical installation. In general, there are poor building insulations and cooling systems. These last variables are the two main manifest variables explaining the probability of being fuel poor. There are also numerous uses of propane for cooking (21.3%) compared to the other classes. We cannot consider these households fuel poor, but we can consider them vulnerable to fuel poverty if their situation deteriorates in the future, e.g., through exogenous shock. Considering this new finding, it is possible to draw a profile of the households in each class. The members of fuel-poor households have a lower income than those of households that are non-fuel poor, do not have education diplomas or children, and live in old individual housing units located in rural areas. In the vulnerable class, we find homeowners with a high education level living in recently built buildings. However, these households face poor energy efficiency conditions in their dwelling. These households live mostly in dwellings with roof holes or moisture and no cooling system. In the case that their socio-economic situation deteriorates, these households can fall into a fuel poverty situation.

Table 8: Profile of the households in each latent class

	Class 1: fuel-poor households	Class 2: fuel vulnerable households	Class 3: households that are not fuel poor
Items or capabilities	Problems with roof holes or moisture No cooling system Wood cooking or no cooking system Cold water supply or no water access Unprotected electrical installation Low brightness in the house	Problems with roof holes or moisture No cooling system Propane used for cooking Electricity used for cooking Hot water or cold water supply Protected electrical installation Good brightness level in the house	No problems with roof holes or moisture Cooling system Propane used for cooking Hot water supply Protected electrical installation Good brightness level in the house
Socio-demographic characteristics	Low income Tenants No education No children Living in rural areas Old buildings Individual housing units	Medium income Homeowners High education level No children Living in a large city Recently built houses Collective buildings	High income Homeowners High education level Families with children Living in a large city Recently built houses Collective buildings

To prove the consistency of our results, in appendix A.2, we provide additional materials. The same estimations are conducted for each overseas department separately using the same variables. Indeed, to test the robustness of the method, the class-specific marginal means were calculated using the same set of observable attributes for each overseas territory. The results of the estimation again show the existence of the following three classes: fuel-poor households, vulnerable households and households that are not fuel poor. According to the local specificities, the proportion of the fuel poor is not completely the same as that in the whole estimation. However, the results of the estimation again show the existence of the following three classes: fuel-poor households, vulnerable households and households that are not fuel poor. This result is interesting and can be considered a tool for policy makers. Indeed, using the LCM enables policy makers to stress the main variables characterizing the probability of being in fuel poverty in each territory. If it is possible to identify those who are fuel poor within a whole sample using observable attributes, it is also possible for a community using local data to adapt policies for people who suffer the most. For example, in Guadeloupe, Martinique and Reunion island, the main tool for fighting fuel poverty is providing cooling systems. In Guyana, the quality of brightness should receive priority. Providing cold water is also a good tool for fighting fuel poverty in this territory. Finally, using LCM, the profile can be adjusted over time (if data are available) and does not depend on constant threshold measurement.

5. Conclusion

Recently, energy deprivation has been studied extensively. In developed countries, fuel poverty is often defined as a situation in which households are unable to adequately heat their homes or meet other required energy services at affordable costs. In developing countries, energy poverty usually describes situations in which people have inadequate access to energy. We contribute to this growing literature by exploring energy deprivation in tropical overseas areas in which the

usual distinction between energy poverty and fuel poverty is no longer relevant. The energy deprivation suffered by people living in developing countries highlights access issues, and fuel poverty mainly encompasses issues linked to wintry cold conditions in Europe. However, while some tropical developed territories have good energy networks and do not experience winter cold, they still suffer from domestic energy deprivation. No definition or measure exists to understand the phenomenon in tropical overseas areas. We applied the Sen capability theoretical framework to select observable objective characteristics of a decent, safe and healthy dwelling. The capability approach focuses on the ability to achieve crucial and valued functionings, which describe an achievement of a person. This concept of capability deprivation can be applied to fuel poverty because it allows a better comprehension of the phenomenon.

Assuming that objective multivariate variables describing a set of capabilities are observed, we linked these variables to the following latent variable: fuel poverty in tropical areas. Then, the LCM methodology was used to carry out this research. Lighting, electricity security, cooking, water heating, quality of building insulation and cooling are criteria *capabilities* used to characterize fuel poverty in tropical areas. Based on these items, we first constructed binary classes of fuel poverty.

We identified the characteristics common to people belonging to the most energy-deprived class, i.e., "fuel poor". Facing problems with roof holes or moisture increases the probability of belonging to this class by 70%. Having access to only cold water increases the probability by 43%, and having no running water increases the probability by approximately 3.8%.

In contrast, having a cooling system increases the probability of belonging to the “non-fuel poor” class by 53%. We further our analyses by extending the common bi-dimension phenomena, and our results show that defining three categories of energy-deprived people is better than defining individuals as only fuel poor and non-fuel poor. The most deprived

represent approximately 12% of the population, while 32% of the population is expected to belong to the non-fuel poor class (class 3). An intermediate class encompassing 56% of the population represents vulnerable households that could easily be impacted by an exogenous shock. Households belonging to the intermediate and non-fuel-poor classes share the following common features: on average, most households have access to hot water or protected electric installation. In contrast, vulnerable households, i.e., the intermediate class, remain exposed to roof holes or moisture and have no cooling systems. We conclude that restricting fuel poverty in tropical areas to a binary phenomenon leads to the neglect of the complexity of energy deprivation. Regarding policy recommendations, policy makers should first focus on providing cooling systems to fight fuel poverty. Moreover, using LMC, it is possible to identify the fuel poor in not only a sample but also a community using observable attributes. Thus, using local data could allow policy makers to adapt policies for people who suffer the most. This method is also flexible because it allows the government to adapt policies overtime without using a constant threshold measurement.

Finally, this research is clearly innovative as it proposes the application of capabilities to construct a categorization of the fuel poor and non-fuel poor rather than applying an existing definition that does not apply in tropical areas. Similar to previous studies, we ultimately divided the population into more than two groups and conclude that energy deprivation is much more complex and multidimensional than a binary phenomenon, implying that fuel poverty can be measured with different degrees of exposure.

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Appendix

A.1 Results of the three latent classes

Table A.1.1: Estimated coefficients in the multinomial logit model of Q latent classes

	Class 1 Fuel poor		Class 2 Vulnerable households		Class 3 Non-fuel poor	
	Margin	Std. Err.	Margin	Std. Err.	Margin	Std. Err.
0.Problems with roof holes or moisture			base outcome			
1.No problems with roof holes or moisture	-2.373	(0.251)***	-0.277	(0.068)***	0.652	(0.062)***
0.No cooling system			base outcome			
1.Cooling system	-3.321[a]	(0.555)***	-1.532	(0.086)***	0.486	(0.077)***
1.Butane/propane for cooking			base outcome			
2.Electricity for cooking	-2.139	(0.231)***	-1.166	(0.055)***	-0.030	(0.064)***
3.Wood for cooking	-1.545	(0.141)***	-2.013	(0.080)***	-2.397	(0.178)***
4.Other fuels for cooking	-3.122	(0.242)***	-4.940	(0.325)***	-4.993	(0.486)***
5.No cooking system	-3.742	(0.334)***	-4.564	(0.256)***	-6.735	(2.966)***
1.Hot water supply			base outcome			
2.Cold water supply	0.612	(0.192)***	-0.761	(0.069)***	-3.081	(0.180)***
3.No water	-0.630	(0.303)***	-6.206	(1.162)***	-6.376	(0.670)***
0.Unprotectedelectrical installation			base outcome			
1.Protected electrical installation	-1.162	(0.235)***	2.289	(0.210)***	3.958	(0.266)***
0.Low level of brightness in the house			base outcome			
1.Good level of brightness in the house	1.318	(0.128)***	2.573	(0.092)***	3.200	(0.142)***

Robust standard errors are presented in the parentheses; *** p<0.01, ** p<0.05, * p<0.1
Note: [a] The probability of being in class 1 decreases if households have a cooling system compared to not having a cooling system.

Table A.1.2: Results of the predictive variables – base outcome: Class 1- fuel poor

	Coef.	Std. Err.	Coef.	Std. Err.
	Class 2		Class 3	
Income (log-transformed)	0.225	(0.033)***	3.336	(0.354)***
Homeowner	0.084	(0.151)	1.026	(0.221)***
Diploma superior to a bachelors + 2 years	1.252	(0.466)***	2.314	(0.463)***
No children	0.111	(0.139)	-0.817	(0.231)***
City with more than 50,000 inhabitants	1.035	(0.157)***	1.069	(0.217)***
Constructed after 1999	0.419	(0.219)***	1.627	(0.207)***
Individual housing unit	-1.406	(0.241)***	-1.917	(0.286)***

Robust standard errors are presented in the parentheses; *** p<0.01, ** p<0.05, * p<0.1
Note: The regression coefficient means measure the effect of an increase of one percent in the *m*-th covariate (such as income) on the logit of belonging to class2with respect to the reference class (e.g., class 1).

A.2 Results of the three classes according to each overseas department

Table A.2.1: Class-specific marginal means or predicted probability by overseas departments

	Guadeloupe			**Martinique**			**Guyana**			**Reunion Island**		
	Latent class marginal means											
	Class 1*	Class 2	Class 3	Class 1	Class 2	Class 3	Class 1	Class 2	Class 3	Class 1	Class 2	Class 3
0.Problems with roof holes or moisture	0.873	0.560	0.355	0.785	0.519	0.297	0.907	0.703	0.515	0.625	0.594	0.304
1.No problems with roof holes or moisture	0.127	0.440	0.645	0.215	0.481	0.703	0.093	0.297	0.485	0.375	0.406	0.696
0.No cooling system	0.971	0.653	0.178	0.902	0.919	0.318	0.985	0.817	0.349	0.943	0.925	0.559
1.Cooling system	0.029	0.347	0.822	0.098	0.081	0.682	0.015	0.183	0.651	0.057	0.075	0.441
1.Network gas for cooking	0.803	0.842	0.667	0.610	0.532	0.252	0.773	0.761	0.540	0.722	0.596	0.478
2.Propane for cooking	0.062	0.129	0.313	0.256	0.365	0.685	0.000	0.172	0.443	0.271	0.085	0.457
3.Electricity for cooking	0.087	0.014	0.013	0.113	0.098	0.063	0.193	0.000	0.008	0.001	0.312	0.065
4.Wood for cooking	0.028	0.001	0.006	0.009	0.005	0.000	0.027	0.045	0.010	0.000	0.003	0.000
5.No cooking	0.020	0.014	0.000	0.013	0.000	0.000	0.007	0.022	0.000	0.006	0.004	0.001
1.Hot water supply	0.284	0.668	0.983	0.436	0.597	0.939	0.001	0.195	0.832	0.823	0.850	1.000
2.Cold water supply	0.662	0.332	0.013	0.544	0.403	0.061	0.376	0.795	0.166	0.172	0.150	0.000
3.No water	0.054	0.000	0.003	0.020	0.000	0.000	0.623	0.009	0.002	0.005	0.000	0.000
0.Unprotectedelectrical installation	0.604	0.099	0.047	0.528	0.025	0.018	0.730	0.216	0.014	0.068	0.247	0.009
1.Protected electrical installation	0.396	0.901	0.953	0.472	0.975	0.982	0.270	0.784	0.986	0.932	0.753	0.991
0.Poor brightness in the house	0.128	0.039	0.029	0.154	0.076	0.027	0.244	0.103	0.060	0.127	0.089	0.043
1.Good level of brightness in the house	0.872	0.961	0.971	0.846	0.924	0.973	0.756	0.897	0.940	0.873	0.911	0.957
	Latent class marginal probabilities											
% of individuals in class 1		0.145**			0.269**			0.162**			0.252**	
		0.514			0.475			0.442			0.369	
		0.341			0.257			0.397			0.379	

Notes:
*Class 1 Fuel poor, Class 2 Vulnerable households, Class 3 non-fuel poor.
**For example, people belonging to the fuel-poor class are more numerous in Reunion Island and Martinique (26.9% and 25.2%, respectively) than in Guyana or Guadeloupe (16.2% and 14.5%, respectively). However, in Guyana and Guadeloupe, a high number of people in the fuel-poor class who meet all fuel poverty standards have insulation problems, no modern cooking systems or unprotected electrical installation.

The classes are consistent in each overseas department (see Table A.1.1 in Appendix), demonstrating the robustness of the method chosen.