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The determinants of domestic energy consumption in France: Energy modes, habitat, households and life cycles

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ABSTRACT

This article explores the question of domestic energy consumption. It concentrates on the example of France and using micro-data from the 2002 and 2006 National Housing Surveys conducted by INSEE (National Institute of Statistics and Economic Studies). The empirical analysis is divided into three stages: the first verifies the correspondences between modes of energy consumption, household profiles and housing profiles, in order to classify consumer mode types; the second looks at the stabilities and variations over time of each of these types; the last seeks to identify the causes of these changes. The findings reveal sharp divergences between the factors affecting global consumption, consumption per m^2 and per person. These variations can be explained by the impact of the demographic characteristics of households, residential mobility and life cycles. Therefore, these findings demonstrate the flexibility over time of domestic energy consumption, which is still too often approached as a static variable solely associated with building characteristics. They need to be taken further through a longitudinal and multidisciplinary approach to energy consumption patterns.

1. Introduction

According to the International Energy Agency's 2013 reference scenario, by the year 2040, 14% of worldwide energy consumption will come from households, an increase of 57% compared with the 2010 rate. The residential sector is thus responsible for a large proportion of energy consumption. In France, for example, it is the second largest source of final consumption, at 46 million tonnes of oil equivalent (Mtoe) in 2012, just behind the transport sector (49 Mtoe, approximately 30% of final energy consumption).[1] Far from being governed by the energy efficiency of buildings alone, residential consumption largely reflects the domestic energy practices of households. This fact explains the increasing and interrelated interest of researchers and governments in understanding the determinants of domestic energy use in order to develop measures to rationalise consumption [1–4].

However, studies (and regulations) on this issue remain very techno-centric and the thematic frameworks of research into the energy consumption of buildings have changed little since the 1970s, despite the genuine advances that have taken place in construction techniques. Whatever the (economic or engineering) methods employed [5] the models relating to energy consumption and demand draw on a set of variables relating – amongst other things – to the properties of buildings, the price of energy, household incomes, the number of household electrical appliances, or climate (indoor temperature). For their part, certain economists stand out for their interest in more macro factors, such as inflation [6]. The great weakness of these models, however, is that they ignore consumer lifestyles, and therefore the energy use patterns of households, even when they take into account their socio-demographic characteristics [7]. In this respect, they overlook the leeway people have in their specific relations to energy consumption, and therefore treat the consumption patterns of users as governed purely by supply. While this perspective is undoubtedly relevant, it is also partial in the sense that it reduces the individual to a mere energy consumer subject to the economic rationales of

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producers (of buildings and energy). However, attempts to include socio-demographic variables reveal results in which the age of individuals and household size emerge as decisive variables in understanding domestic consumption processes [8].[2]

Over the past few years, empirical studies on residential energy consumption have received considerable attention. A growing literature has focused on exploring the determinants of residential energy consumption using different bottom-up statistical approach [7,9–12].

Valnezuela et al. [4] used a quantile regression model to examine predictors of household energy consumption among single-family residences in a Texas urban area. Their results indicate potential opportunities to lower consumption among the highest energy-consumption households including those with pools, with no central cooling, with people working from home, those built on pier/post foundation, and those that are renter-occupied. They found that: households in larger housing units consumed less energy per square meter than smaller housing units, married households consumed less energy per square meter than not married households, as the number of adults increases energy per square meter also increases, etc.

Recently Belaïd [13] used a bottom-up statistical approach to tease out the impacts of various factors on the domestic energy consumption in France across different population groups using data from the most recent National Housing Survey. The multivariate analysis has led to identify four main consumption typologies. Results revealed that energy prices were the most important factors determining domestic energy consumption. In addition, the study showed that occupant characteristics significantly affect domestic energy use. Thus, results call for combine all efforts, multiple strategies and smart policies, to incorporate household and consumption behaviours in managing domestic energy consumption.

Therefore, by shifting the focus to the energy behaviour of individuals or groups, sociological, anthropological and geographical approaches reveal the importance of residential practices and lifestyles in better understanding energy consumption processes [15–20].

Going beyond the analysis of individual behaviours fashionable in the 1980s and 1990s, the most current research tackles energy consumption as a set of practices that can only be identified through crosscutting approaches [21]. From this perspective, energy demand becomes a social construction structured by norms and conventions [22–25]. Beyond building-related factors, occupant behaviour plays a not insignificant role in the intensity of energy consumption in residential buildings. It remains the case that these two dimensions are rarely brought together in research on energy consumption.

That is the essential goal of this article, which seeks to study the effect of household characteristics on the modes and intensities of French domestic energy consumption. Using a national approach, we will endeavour to understand if there are links between the types of habitat occupied (houses, apartment buildings, residential sectors), the characteristics of residents and the energy combinations used. More specifically, the aim is to understand whether socio-demographic factors affect the typological profiles of domestic energy consumers, and whether the latter have a direct impact on the intensity of and trends in consumption. The findings reveal the decisive role of the socio-demographic characteristics of households, of their residential mobility and of their life cycle on domestic consumption. They thus demonstrate the flexibility over time of domestic consumption, which is still too often approached as a static variable solely associated with the characteristics of buildings.

[2] The final report of the Energy Transports Habitat Environment Localisations (ETHEL) project thus notes that “one of the major obstacles to a steady reduction in the consumption of energy for heating lies in the expansion of the areas heated”. For example, living space per person in France increased from 31m^2 in 1984 to 37m^2 in 2002, because of the rise of detached houses as a proportion of new housing and a fall in the average size of households. Once children have left home, many older households occupy dwellings with a high occupancy cost (areas to be heated), which no longer correspond to their need for living space [14].

2. Data and methods

The approach taken in this article is to link – from a socio-demographic point of view – the technical performances of buildings and the residential behaviours of inhabitants. This approach has been applied using methods of quantitative analysis based on the secondary processing of existing national surveys: the surveys on the housing conditions of French households (ENL) conducted by INSEE in 2002 (32,000 households) and in 2006 (31,000 households). These contain very detailed information on the characteristics of dwellings (size, amenities, number of rooms, renovation, etc.) and of buildings, as well as of housing occupants. However, they also have the advantage of including a large section on “dwelling amenities and energy used”.

Part of this information was initially used to construct summary indicators for the type of domestic energy used by households, combined with the intensity of consumption (from high to low). These indicators were then applied to the characteristics of the households, the buildings and the dwellings, on the assumption that the types of energy used at home reflect particular household and dwelling structures. The empirical analysis is divided into three stages: the first seeks to verify the correspondences between the combined use of domestic energy, the household profiles and the dwelling profiles, in order to establish consumer mode typologies. The second looks at the stabilities and variations over time of consumption in each of these types, endeavouring to distinguish between the role of household characteristics (consumption per head) and of dwellings (consumption per m^2) in these intensities. The final stage seeks to identify the causes of these changes, notably by introducing a life-cycle based analysis.

In the first step, in order to obtain a typology of consumers based on the combinations of energy types used by French households, a multiple correspondence analysis (MCA) and a hierarchical cluster analysis (HCA) were conducted. MCA is a generalisation of factorial correspondence analysis to multivariate cases [26]. The distances calculated between the different households within the factorial axis space is used to classify the closest individuals and merge them, at each successive stage, using a proximity criterion called Ward's minimum-variance method.

In the second phase, in order to analyse the morphological, social and demographic determinants of domestic energy consumption, we employed a logistic regression in which the variable to be explained is low energy consumption per person and per m^2, and the explanatory variables are the socio-demographic characteristics of the households and of their habitat. Finally, in the third and last stage, for the analysis of household consumption on a life-cycle basis, the age of the reference person was combined with household size. In this way, we identify the major life cycles of households, assuming linear family development (without separation, death or divorce). We then obtain four snapshots of life-cycle stages, meaning that we observe these stages from a transversal perspective on a given date, rather than from a longitudinal perspective.

3. Results

3.1. First stage: a typology of domestic energy consumers in France

In order to construct a typology of energy consumers, we began with the combinations of energy types used by French households in 2002, in order to be able to conduct a trend analysis by comparison with the housing survey conducted in 2006. Independently of their specific uses, we chose to consider the combinations of domestic uses of six types of energy: electricity, gas, oil, propane gas, wood, coal and district heating. The intensities and uses of these different forms of energy can be very variable: for example, oil is generally a fuel used for heating, mains gas for heating and cooking, and propane solely for cooking. Combining them can nevertheless make sense and distinguish users socially, for example when a household only has electricity in the