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Determinants of Households' Space Heating type and Expenditures in Italy

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ABSTRACT: In Italy, several policy measures have been implemented in order to increase energy efficiency and reduce carbon emissions especially concerning the household sector. However, in order to design and implement these policy measures efficiently, it is necessary to get a better understanding of the factors influencing household energy behavior. In this paper, by using disaggregated data from the 2009 Italian Household Budget Survey, we firstly identify the factors which have a strong effect on the choice of a specific fuel by using a multinomial logit model taking into account the heterogeneity of households in the Italian regions. Secondly, we focus on the analysis of the determinants of space heating expenditure bearing in mind the possible influence of the choice of fuel on energy consumption. Finally, by using the results of the multinomial logit model we examine the implications of a simulated scenario concerning tax incentives for energy efficiency improvement. Many of the variables concerning the socio-economic characteristics of households(i.e. family income and type of family) and the characteristics of the dwellings (i.e. year of construction) prove to be important determinants of the choice of space heating technologies and of energy consumption. Altogether, our results help to identify the determinants of household heating behaviour in Italy. Designing and developing target oriented policy measures focusing on specific determinants will help policy makers to achieve the main objectives of Italy's energy policy which are to increase energy efficiency and lower energy consumption thus reducing carbon emissions.

Key words: Energy consumption, Environmental policies, Household budget data, Household energy behaviour

INTRODUCTION

Optimization of energy consumption and consequent environmental concerns have been widely considered recently (Quesada-Rubio *et al.*, 2011; Zeinolabedin *et al.*, 2011; Wang *et al.*, 2011; Cui *et al.*, 2011; Montero Lorenzo *et al.*, 2011; Alipour *et al.*, 2011; Chianese *et al.*, 2012; Barrera *et al.*, 2012) Over the last ten years the final consumption of energy by households in Italy has decreased slightly (Eurostat 2010b). However households are responsible for a significant share of the total consumption which reached about a quarter (23.7 %) of Italy's final energy consumption in 2009. The largest energy-using activity in households is space heating, which accounted for around 70% of the total energy consumption of households in 2008 (EEA, 2011) and produced 13.2 % of the total CO_2 emissions in that year (Eurostat 2010a). Household energy conservation, which represents one of the key aspects of sustainability issues, can be addressed through a combination of national or local environmental policies and the citizens' awareness and consciousness of their important rolein reducing energy consumption. In order to promote a more efficient use of energy in the residential sector, local governmentscan adopt a range of policies and programs, such as economic incentives (*e.g.* energy/ carbon taxation, energy conservation grants, financial incentives to improve the energy efficiency of homes through insulation and to promote the installation of more efficient heating appliances).To support the programs, local governments can also develop targeted information campaigns thus increasing the citizens' awareness of energy problems and their knowledge about possibilities for reducing them. However, Italian households are a rather disparate group with considerable variety in the type of space heating applied and its intensity of use across the Italian regions. Nevertheless, there are fewer studies aimed at analysing the determinants of Italian household energy consumption than in other European countries. To our best knowledge only Carraro et al. (2011) explored these aspects for Italy.

The aim of this paper is to provide policy makers with detailed information concerning the factors

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influencing households' fuel choice and consumption in order to design and implement more effective energy-saving policies. By taking into account the various "contextual" factors which can affect the fuel choice and its intensity of use, such as the geographic and climatic conditions and the socio-economic context, the proposed micro-level analysis can improve the understanding of household energy behavior and of the impact on fuel choice of an energy efficiency policy.By using disaggregated household budget data for the year 2009 collected by the Italian National Statistical Institute, we will analyse the Italian households' behaviour towards energy consumption for space heating with a threefold perspective. Firstly, we will identify the factors which have the greatest impact on the choice of a specific fuel by using a multinomial logit model which allows us to highlight whether there are differences between households choosing most polluting fuels (such as coal and oil) and those choosing more eco-friendly space heating systems (such as solar panels and natural gas). Choosing gas instead of coal or oil, for instance, can be a potential first step to lower $CO2$ emissions since natural gas has a lower emission factor than oil products and it produces only 60% as much $CO2$ per unit of energy as coal (Mondéjar-Jiménez *et al.*, 2010). Then we will investigatewhether there are geographic differences in the determinants of fuel choice.Secondly, we will focus on the analysis of the determinants of energy consumption for the chosen fuel after correcting for the selection bias as the choice of space heating fuel and its intensity of use may be related.In particular, a multinomial logit model is used to describe the selection process, which is modelled as having five possible outcomes, grouped according to the fuel use. The selection bias correction terms, obtained from the multinomial logit model, which captures the fact that fuel choice is the first stage of energy consumption, are included in the energy consumption regression models to correct for the correlation of errors between the two decisions. Thirdly, we will use the results of the multinomial logit model to predict the implications of a simulated number of thermal retrofit investments through tax incentives. Since existing homes represent the greatest opportunity for efficiency improvements, our aim is to explore what role an increased effectiveness of tax support instrument could play in encouraging households to switch to an inherently less polluting fuel, such as natural gas, thus reducing $CO2$ emissions.

The remainder of the paper is organized as follows. Several sources were used with the aim of constructing a reliable data set in order to estimate the determinants of fuel choice and fuel consumption in Italy. The Household Budget Survey (HBS) carried out by the ISTAT represents our primary source of data. The 2009 survey,which considers a sample of 23,006 households representative of all Italian households,was very suitable for our study since it enabled us to obtain detailed information regarding the socio-economic characteristics of the families and their dwellings together with their choice in terms of fuel used for heating purposes. We referred to additional sources of data in order to include variables related to the place of residence (such as geographic location, heating degree days, the percentage of green spaces managed by public institutions) and information regarding the specific type of heating fuel. In particular, the indicator concerning green spaces (in square meters) managed by public institutions at regional level per inhabitant for the year 2009, the percentage of energy consumption covered by renewable energy sources (year 2009) and the percentage of the resident population living in municipalities supplied with methane gas were obtained by ISTAT (ISTAT, 2012). Data on heating degree days (HDDs) which account for the differences in climate among the Italian regionswere taken from Eurostat. HDDs represents an indicator deriving from measurements of the outside air temperatures which reflects the demand for energy needed to heat a home or business in a specific region. Information concerning the prices of various fuels was obtained from the Chambers of commerce of the regional capital in each region.As the units of various fuels differ, the price of each type of fuel was converted in a common unit considering a Tonnage of Oil Equivalent (TOE) in order to make appropriate comparisons.Data on the number of retrofits for improving energy efficiency of existing buildings, relative to the populationliving in each region, were obtained by the Italian National Agency for new technologies, Energy and sustainable economic development (ENEA, 2010).

In Italy over three quarters (76.8%) of the households use natural gas from municipal pipelines as fuel for space heating, while 8.8% use LPG gas cylinders or gas in external apparels. Only 5.5% of the total households use gas, oil or other liquid fuels while about 3% of the households use electricity or solar panels.However it is worth noting that the choice of fuels depends on the geographical position of the households and the availability of fuels. In fact, at regional level there is a completely different situation regarding the offer of natural gas with the lowest value for Sardinia where the construction of the pipeline necessary for transporting the methane gas to the households is still underway,while the highest values were found for Lazio and Emilia Romagna in which the whole regional population resides in municipalities supplied with methane gas.Therefore, the variable *gas network* – which refers to the percentage of the resident population in a region living in municipalities supplied with methane gas – was taken into account when estimating the models, but it was not significant for explaining the choice of household fuel and heating expenses. Concerning the use of the various fuels,Lombardy and Tuscany showed the highest percentages of natural gas with values equal to 92.1% and 89.3% respectively. The percentages concerning the use of electricity for heating systems were higher in the hottest regions of Italy such as Sardinia (19.77%), Calabria (11.53%) and Sicily (9.26%) than the other regions.A limitation of the HBS data used in our analysis is that the expenditures for various fuels are not distinguished according to the final energy use. In order to account for the amount spent for space heating purposes we applied the breakdown of domestic fuel consumption by major end-use(distinguished in space heating, water heating, cooking, electricity for lighting and appliances) in Italy provided by ENEA in 1999. By using the percentage of usage for space heating for the various fuels (equal to 79.5% for natural gas, 91.7% for oil, 81.2% for Coal, 100% for wood, 23.3% for LPG and 2.2% for electricity) we can state that Italian households spent on average about 64 Euros for natural gas which represented 2.7% of total household expenses in 2009. Compared to natural gas, households using oil for space-heating purposes showed a higher monthly expenditurewhile lower level of expenses were registered for families using coal-wood, LPG gas cylinders and electricity.However it is important to note that there is a high heterogeneity in the amount spent for heating purposes among the various regionswhich reflects the incidence on the expenses of various factors (geographical location,offer, climate conditions and dwelling characteristics in terms of energy-efficiency). For example, Campania was the region with the lowest amount of expenses for natural gas equal to 40 Euros per month (and a weight on the total expenses equal to 2.1%) while Veneto in the North-Eastern part of Italy has the highest average expenses equal to 79 Euros per month which represents 3% of total expenses. The HBS contains data on the *characteristics of the dwellings*, such as age, number of rooms, heating system type, type of property(meaning both detached and isolated)and ownership status.In our study the dwellings were divided into seven categories according to the year of construction *(Year 1920 - Year2009*) as it is expected that families living in old houses are more likely to use oil or solid fuels such as coal for heating purposes, given that technologies relying on these fuels were mostly applied in the past (Davis and Kilian, 2008; Bernardini and Di Marzio, 2001). This is particularly true in Italy where historical buildings, which represent a large part of our cultural heritage, may need specific technologies due to restricted storage space which may exclude the use of oil heating or LPG gas cylinders and gas in external apparels. As an example, only 2% of medieval buildings use oil and liquid fuels as heating technology against a percentage of the total sample equal to 8%. This is also the case for those dwellings of historical importance which are obliged to respect landscape constraints. Since it is generally found that the energy efficiency of a detached house is much lower than that of a flat, a dummy variable (*Detached*) was introduced to account for this aspect concerning about 30% of Italian dwellings. We also introduced a variable referring to the number of rooms (*Size*) in order to take into consideration the size of the dwelling.

The choice of fuel and its intensity of use in Italy can be affected by the fact that more than 6% of the households live in isolated areas where natural gas from gas networks is difficult to find. Therefore we introduced a dummy variable (*Isolated*) which accounts for the fact that families in these areas are more prone to choose other types of fuel (Meier and Rehdanz, 2010). Concerning the type of heating system used, 77.7% of the Italian households rely on autonomous heating systems or on single appliances while 22.3% on central heating systems. On one hand, autonomous systems facilitate a careful consideration of heating needs and, therefore, encourage an energy efficient behavior of households. On the other hand, centralized systems, characterized by better combustion efficiency combined with the individual metering of the heat used would be more efficient. Therefore this aspect was included in the analysis by introducing a dummy variable (*Central heating*). Another important factor considered for explaining the choice of fuel and the amount of energy consumption is whether the households own the property or not (*Owner*). In Italy there is a high percentage of owner-occupied dwellings (75%) even if the effect of ownership on both the choice of fuel and heating consumption is very much debated (Baker *et al.*, 1989; Vaage, 2000; Berkhout *et al.*, 2004,Redhanz, 2007). Concerning the information provided by HBS on the*socio-economic and demographic characteristics of the households,* we selected the type of family (*single person; couple without children; couple with children; other type of families*), the level of education and the age (34 year or less; 35-64; 65+) of the head of the family, the number of family members (*Nc*) and the total monthly expenditure. We introduced four different levels of education in our analyses (*Degree, Diploma, Middle school and Primary school*). Nesbakken (2001) found that the older the household head is, the higher the level of energy consumption will be. This may be due to the fact that the elderly spend more time at home than the young and they often need higher indoor temperatures. We considered this aspect in our analyses since more than a third (33.6%) of the household members interviewed for the ISTAT survey were 65 years of age or older. Income also plays an important role concerninghousehold behaviour in general although its influence on environmental quality (Castellano *et al.*, 2011), fuel choice andenergy consumption is quite controversial (Vaage, 2000; Braun, 2010). In order to examine this aspect for the Italian households more deeply we referred to the total monthly expenses as a proxy of the net income (*Income*). The total average household expense is about 2,340 Euros per month with a large standard deviation (1606.16), as expected. Concerning the variable *retrofit* it is worth noting that the average value of 0.43% is the result of heterogeneous values at regional level. In fact, the regional number of retrofits for improving energy efficiency of existing buildings in the year 2009 relative to the population living in that region, varies from the lowest value of 0.09% recorded for Campania and Calabria to the highest value of 0.88% recorded for Friuli-Venezia Giulia.

MATERIALS & METHODS

In order to examine the determinants of the choice of heating type by households we use a multinomial logit model since it allows usto disentangle the influence of the various factors on the probability of applying one of the heating modes. Unordered choice models can be motivated by a random utility model (Greene, 2000). For the household*i*(i=1,…n)faced with J choices, the utility from choosing alternative j is:

$$u_{ij}^{*} = \boldsymbol{\gamma}'\mathbf{z}_{ij} + \varepsilon_{ij} \qquad j = 1,\ldots,k,..,J \tag{1}$$

If the household makes choice j then we assume that u_{ij}^{*} is the maximum among the J utilities. Therefore, the statistical model is driven by the probability that choice j is made, which is $P\left(u_{ij}^{*} > u_{ih}^{*}\right)$ for all other $h \neq j$.

Denoting u_i the random variable which indicates the choice made, so that takes on a value in , following McFadden (1973) we assume that the *J*error terms in [1], , are independent and identically distributed with Weibull distribution. This specification implies that the probability of choosing fuel*j* takes the multinomial logit form given by:

$$\mathrm{P}\left(u_i = j \middle| \mathbf{z}_i\right) = \frac{\exp\left(\boldsymbol{\gamma}'\mathbf{z}_{ij}\right)}{\sum_{j=1}^{J}\exp\left(\boldsymbol{\gamma}'\mathbf{z}_{ij}\right)} \tag{2}$$

where $\mathbf{z}_{ij}$ is a $1\times M$ vectorwhich represents a set of observable exogenous factors related to the socio-demographic characteristics of the households, the attributes of the various choices and the socio-economic variables concerning the geographic area where the households live,while $\boldsymbol{\gamma}$ is the vector of unknown coefficients. On the basis of expression [2], consistent maximum likelihood estimates of $\boldsymbol{\gamma}$ can be easily obtained. However the estimates resulting from a multinomial model must be interpreted carefully. Since the multinomial model is non-linear in the parameters the magnitude as well as the sign of a coefficient cannot be interpreted directly as the effect produced by a variable z_j on the dependent variable. Dropping the subscript and differentiating [2], marginal effects (ME) are given by:

$$\frac{\partial p_j(\mathbf{z})}{\partial z_{jm}} = p_j(\mathbf{z})\left[1 - p_j(\mathbf{z})\right]\gamma_m \qquad j = 1,\mathrm{K},J \;\; m = 1,\ldots,M \tag{3a}$$

$$\frac{\partial p_j(\mathbf{z})}{\partial z_{jm}} = -p_j(\mathbf{z})\,p_h(\mathbf{z})\gamma_m \qquad j \neq h \;\; m = 1,\ldots,M \tag{3b}$$

where $p_j(\mathbf{z})$ is the response probability in equation [2] and γ_m is the *m*th element of $\boldsymbol{\gamma}$.

In order to obtain unbiased and consistent estimates of the factors influencing fuel consumption for home heating, we must bear in mind the possible influence of the heating choice on energy consumption. In fact the choice of space heating equipment and its intensity of use may be related decisions made by the households. Observable and unobservable characteristics related to the household may influence both the choice of heating technologies and the consumption of energy for home heating purposes. For example, households who prefer warm homes may be prone to choose natural gas heating systems as well as being prone to consume more natural gas. An environmentally concerned household may choose the technology which is supposed to give the lowest CO2 emissions, and therefore the household will be also prone to low-energy consumption. *The* *consumption of fuel k, y_k, is observed only if category j=k is observed, which occurs when a household chooses fuel k. This happens when the utility from fuel k is the highest of all the available fuels such that*

$$u_{ik}^* > \max_{j \neq k}\left(u_{ij}^*\right) \quad (4)$$

Therefore the model to be estimated is a system composed of a demand equation and a selection equation:

$$y_{ik} = \boldsymbol{\beta}'\mathbf{x}_{ik} + w_{ik} \quad (5a)$$

$$u_{ij}^* = \boldsymbol{\gamma}'\mathbf{z}_{ij} + \varepsilon_{ij} \qquad j = 1,...,k,..,J \quad (5b)$$

where (5a) is the equation describing energy consumption conditioned by the choice of fuel *j* while [5b] models the selection process with latent variable u_{ij}^* representing the indirect utility level of the *i*th household associated with category *j* which determine the choice of fuel.Assuming that the error terms ε_{ij} are i.i.d. according to a Weibull distribution, the probability for household *i* for choosing fuel *k* takes the multinomial logit form [2]. The vector ***x***in equation [5a]contains all determinants of fuel *k* consumption for space heating such as the socio-economic characteristics of the households and of the area in which the household lives while the disturbance term w_{ik} verifies $E\left(w_{ik}\left|\mathbf{x},\mathbf{z}\right.\right) = 0$ and $V\left(w_{ik}\left|\mathbf{x},\mathbf{z}\right.\right) = \sigma^2$.

The problem is to estimate the parameter vector $\boldsymbol{\beta}$ while taking into account that the disturbance term w_{ik} may not be independent of ε_{ij}. This would introduce some correlation between the explanatory variables and the disturbance term in the energy consumption equation [5a]. For this reason, least squares estimates of $\boldsymbol{\beta}$ would not be consistent.

To overcome this problem we use the method suggested by Bourguignon et al. (2007) thus estimating the following model:

$$y_{ik} = \boldsymbol{\beta}'\mathbf{x}_{ik} + \lambda + \eta_{ik} \quad (6)$$

where η_{ik} is a residual that is mean-independent of the regressors and λ represents the selection bias correction term[1] given by:

$$\lambda = \sigma\left[r_k^* m\left(P_k\right) + \sum_{j \neq k} r_j^* m\left(P_j\right)\frac{P_j}{\left(P_j - 1\right)}\right] \quad (7)$$

where P_k represent the probability that any alternative *k* is preferred, r_j^* is the correlation between w_{ij} and $\varepsilon_{ij}^* = \Phi^{-1}\left(G\left(\varepsilon_{ij}\right)\right) \qquad j = 1,...,J$.

DISCUSION & RESULTS

By assuming that a household faces a set of unordered alternatives, represented by the heating fuels classified into five categories - oil, gas networks, LPG gas cylinders and gas in external appliances, coal and wood, electricity and solar panels - we estimated a multinomial logit model for Italian households as a whole, testing various specifications with different sets of variables.

Estimation results are reported in Table 1 where the explanatory variables are classified into three groups: *household socio-economic characteristics, dwelling characteristics and contextual variables.* Referring to the householdsocio-economic characteristics, we found that income significantly influences the choice of gas, coal and wood as heating fuels. More specifically, households with higher incomes are more likely to choose gas (M.E. 0.0054) and less likely to choose wood or coal (M.E. -0.0042) as also obtained by Carraro et al (2011). We found that couples without children are more likely to choose gas than single people (M.E. 0.0219). The results confirm that education is a relevant socio-economic factor that influences the choice of space heating. People with a lower level of education than diploma are less likely to choose gas for heating purposes (M.E. equal to -0.0664 and -0.1015 for middle school and primary school, respectively) and are more likely to choose coal and electricity (M.E. equal to 0.0035 and 0.0030 for middle and primary school, respectively). Braun (2011) in explaining similar results for his study referred to the household production theory in which the fairly high propensity for gas among the well-educated households is due to the relative ease for using these technologies.

Modern lifestyles, fewer inspections and long-term contracts with suppliers, which characterize the distribution of gas from networks, make the management of this type of fuel less time-intensive than other modes of residential space heating fuels. Moreover, a highly educated household head may have more consideration for the environment and more environmental awareness (Pirani and Secondi, 2011; Cordente-Rodríguez *et al.*, 2010). A similar explanation of this evidence can be found in Carraro et al. (2011) who stated that highly educated household heads are more likely to choose natural gas since it is cleaner than the other types of energy. Families in which the household head has a low level of education (middle school or primary school) are more prone to choose solid fuels such as coal or wood as space heating modes which can be time consuming to manage. In reference to *dwelling attributes* we agree with Carraro et al. (2011) since we found that families living in an isolated house are more likely to choose oil, coal-wood and gas cylinders (M.E. equal to 0.091, 0.2189 and 0.1070 respectively) while their probability of choosing gas is 0.41 lower than people living in dwellings located in urban areas. This may be due to the difficulty of linking up to the gas network and to the fact that they may have more space available for external storage of fuels. Home owners have a probability of 0.0318 higher of choosing natural gas than families living in rented dwellings while home owners were less prone to choose gas cylinders (M.E. -0.0248) and electricity (M.E. -0.0063). As expected the year of construction of the dwelling is one of the most important variables determining the choice of fuel. The estimations obtained confirm our assumptions. The more recent the year of construction of the dwelling, the more likely the probability of choosing natural gas as fuel (M.E. goes from 0.0234 for the dwellings built between 1920 e 1945 to a value equal to 0.0845 for the dwellings built in 2000 or later).

On the subject of the *contextual variables*, we found that having more green areas in the regions in which families live increases the probability of using gas as heating fuel in their dwellings rather than other types of fuels.

The number of retrofits carried out for improving the energy efficiency of existing buildings is found to significantly affect the probability for almost all fuel types.

Specifically the greatest positive effect was found for natural gas (M.E. 0.0340) while the probability of choosing gas cylinders and coal-wood was lower.

In order to take into account the high level of heterogeneity among the Italian regions concerning the choice and consumption of fuels and the differences in climate, economic development and in energy policies we divided Italy into the following five macro-regions:North East (which includes Trentino Alto Adige, Veneto, Friuli Venezia Giulia and Emilia Romagna), North West (Piedmont, Aosta Valley, Lombardy and Liguria), Central Regions (Tuscany, Umbria, Marche and Lazio), South (Abruzzo, Molise, Campania, Apulia, Basilicata, Calabria) and the Islands (Sicily and Sardinia). Localization variables were introduced to offer a clear picture of the choice of Italian households since families living in the Central, Southern and Insular regions are more likely to choose solid fuels or electricity than households living in the Northern part of Italy. Therefore firstly we included dummy variables in the global models and secondly we carried out separate analyses for each macro-area.

The heterogeneity among the regions concerning the use of fuels is still present at macro-area level. In the Northern and Central regions of Italy over 80% of Italian households choose natural gas as fuel for heating purposes with the highest percentages registered in the North-Western regions (88.09%) while in the Southern and Insular regions these percentages are equal to 65.01% and 38.75%, respectively. In these two macro-areas many households use electricity (or solar panels) for heating purposes (5.47% in the Southern regions and 12.1% in the Islands). Therefore, in order to analyze in depth household behavior when choosing the type of fuel for heating purposes, we estimated separate multinomial logit models for each macro area (North East, North West, Centre, South and Islands) bearing in mind the differences in the energy and planning policies, in solar irradiation and the possibility to latch on to the gas network.Due to limited space we report here only the results of the multinomial logit model for Southern regions (Table 2) while the results for the other areascan be obtained upon request. Concerning *socio-economic characteristics*, income has a more noticeable influence in the macro-areas than in the model estimated considering the overall sample. In fact the effects that the variable has on each single macro-area are particularly interesting. With an increase of a family's income, the probability of choosing gas for heating purposes increases significantly only in the North East while the probability of choosing coal or wood decreases. With an increase of income in Southern Italy the probability of using coal or wood decreases (M.E. -0.0258).Households living in these regions are also less prone to choose electricity and solar panels when income increases. On the other hand, the Islands represent the macro-area in which an increase in income has a positive effect on the probability of choosing oil.

As for *dwelling characteristics*, ownership status did not seem to influence the choice of any specific type of fuel in the Northern regions, while it significantly influences the choice in Central and Southern Italy and above all in the Islands. Moreover in the Centre as in the general model for Italy, the probability of choosing gas increases while the use of gas cylinders decreases. Home owners living in the Southern part of Italy are less likely to choose electricity while they are more likely to choose gas and coal-wood in the Islands (M.E. 0.1359 and 0.0267, respectively) and they are less prone to choose gas cylinders and electricity. Finally, significant marginal

Table 1. Marginal Effects on probability of the choice of heating fuel

	OIL			GAS			LPG GAS CYLINDERS			COAL - WOOD			ELECTRICITY & SOLAR PANELS		
	M.E.	St.error		M.E.	St.error		M.E.	St.error		M.E.	St.error		M.E.	St.error	
Household characteristics															
Income	-0.0004	0.0011		0.0054	0.0022	**	0.0001	0.0014		-0.0042	0.0011	***	-0.0009	0.0007	
Single person	ref.														
Couple without children	-0.0068	0.0045		0.0219	0.0082	***	-0.0104	0.0049	**	0.0005	0.0039		-0.0052	0.0017	***
Couple with children	-0.0107	0.0046	**	0.0012	0.0084		0.0024	0.0050		0.0141	0.0040	***	-0.0070	0.0019	***
Other households	-0.0088	0.0051	*	-0.0049	0.0099		0.0072	0.0061		0.0082	0.0049	*	-0.0017	0.0019	
Degree	0.0042	0.0063		0.0159	0.011		-0.0143	0.0063	**	-0.0111	0.0054	**	0.0053	0.0031	*
Diploma	ref.														
Middle School	0.0010	0.0043		-0.0664	0.0084	***	0.0259	0.005	***	0.036	0.0048	***	0.0035	0.0019	*
Elementary School	0.0049	0.0049		-0.1015	0.01	***	0.0322	0.0059	***	0.0614	0.0065	***	0.0030	0.0021	
Owner	0.0019	0.0040		0.0318	0.0073	***	-0.0248	0.0046	***	-0.0027	0.0033		-0.0063	0.0019	***
Dwelling characteristics															
Size	0.0050	0.0011	***	-0.0005	0.0021		-0.0034	0.0013	***	0.0022	0.0009	**	-0.0033	0.0006	***
Year 1920	ref.														
Year 1945	-0.0201	0.0070	***	0.0234	0.0137	*	0.0060	0.0091		-0.015	0.004	***	0.0057	0.0045	
Year 1960	0.0040	0.0074		0.0396	0.0112	***	-0.0171	0.0064	***	-0.0266	0.0033	***	0.0003	0.0031	
Year 1982	0.0171	0.0068	**	0.0374	0.011	***	-0.0201	0.0065	***	-0.0331	0.0039	***	-0.0014	0.0029	
Year 1991	0.0146	0.0087	*	0.0303	0.0123	**	-0.0162	0.0066	**	-0.0264	0.0032	***	-0.0023	0.003	
Year 2000	-0.0055	0.0073		0.0414	0.0121	***	-0.0041	0.0077		-0.0289	0.0031	***	-0.003	0.0031	
Year 2009	-0.0343	0.0055	***	0.0845	0.0113	***	-0.0164	0.0078	**	-0.0301	0.0033	***	-0.0038	0.0032	
Isolated	0.0906	0.0108	***	-0.4143	0.0156	***	0.2189	0.0139	***	0.107	0.0095	***	-0.0021	0.0031	
Detached	0.0100	0.0039	**	-0.0894	0.0071	***	0.0348	0.0043	***	0.043	0.0038	***	0.0015	0.0015	
Contextual variables															
North-West	ref.														
North-East	0.0055	0.0132		-0.2934	0.0314	***	0.1179	0.0252	***	0.1477	0.0267	***	0.0223	0.0131	*
Centre	0.0776	0.1416		-0.8759	0.0282	***	-0.0679	0.0192	***	0.86	0.1631	***	0.0062	0.0383	
South	0.0253	0.0862		-0.8885	0.0428	***	-0.0987	0.0425	**	0.5345	1.0998		0.4274	1.1554	
Islands	0.0068	0.1011		-0.8906	0.0148	***	-0.0648	0.0129	***	0.5308	1.2857		0.4179	1.3442	
Green space	-0.0408	0.0087	***	0.1065	0.0151	***	-0.0075	0.0098		-0.0416	0.0072	***	-0.0166	0.0062	***
Renewable Energy	0.0001	0.0001		-0.0011	0.0002	***	0.0004	0.0001	***	0.0004	0.0001	***	0.0002	0.0001	***
HDD	0.00056	0.00001	***	-0.0002	0.00002	***	0.00007	0.00001	***	0.00006	0.00001	***	-0.00009	0.00001	
Retrofit	0.0153	0.0044	***	0.034	0.0074	***	-0.0351	0.0044	***	-0.0137	0.0033	***	-0.0005	0.0037	
Price of fuels															
Gas price (per TOE)	0.0053	0.0006	***	-0.0124	0.001	***	0.0007	0.0005		0.0053	0.0004	***	0.0011	0.0003	***
Coal-Wood price (per TOE)	-0.0070	0.0027	**	0.0177	0.0049	***	-0.0165	0.0023	***	-0.0046	0.0022	**	0.0103	0.0035	***
Gas cylinders price (per TOE)	0.0006	0.0001	***	-0.0013	0.0002	***	0.0007	0.0001	***	-0.0001	0.0001		0.00013	0.00004	
Oil price (per TOE)	0.0004	0.0083		0.0084	0.0012	***	-0.0073	0.0007	***	-0.001	0.0006	*	-0.0005	0.0003	
Electricity price (per TOE)	-0.2144	0.0675	***	0.425	0.1119	***	0.1315	0.0703	*	-0.2595	0.052	***	-0.0826	0.0445	
Number of Observation	*20492*														

NOTES: * Significant at the 10% level. ** Significant at the 5% level *** Significant at the 1% level effects for Central regions reflect those displayed in the overall model.

The size of the dwelling has a significant effect on the choice of a specific fuel in all the macro-areas except for the North-East. On the contrary to the global model, with an increase in the size of their property, families living in the North East are less likely to choose natural gas while families in the South are more prone to choose oil and less likely to choose gas, electricity and solar panels. With an increase in the size of the property, families living in the Islands are more likely to choose oil or coal and wood and less likely to choose gas cylinders and electricity.

Families living in isolated homes in Southern Italy and in the Islands are less likely to use electricity or solar panels.

Concerning the age of the building, families living in Southern Italy in recently built houses are less prone to use electricity and solar panels compared to the global model even if solar panels could produce profits and benefits due to the larger amount of sunshine which is typical of these regions. It is important to note that there may be a compensation effect due to the fact that electricity is classified together with solar panels in the HBS survey.

We estimated five energy consumption regression models, testing various specifications with different variables,-regarding each type of fuel used by households according to the choice made - by using weighted least squares to account for the heteroskedasticity present in the model due to selectivity[1] (Bourguignon *et al.*, 2007).

Table 3 summarizes the results of the model estimated for describing the determinants of gas consumption while the results for the remaining four fuels[2]are shown in Table 4.

The results obtained overall support *dwelling attributes* as important determinants of energy expenses. In particular, gas consumption for heating purposes is found to increase with the age of the house. Dwellings built before 1920 differ significantly compared to more recent building. Families living in dwellings built 10 years ago (or less) spent less for gas than older houses (constructed before 1920). The age of the house is also significant for LPG and gas cylinder expenses and we found that recently built houses spend more. Other studies have found that energy consumption for space heating increases with the age of the house (Nesbakken, 2001; Carraro *et al.*, 2011). This effect may be due to better thermal insulation in newly-built houses leading to lower levels of energy consumption (Schuler *et al.*, 2000).

Heating expenditures for gas, oil and gas cylinders increase with the number of rooms (Size). Families living in detached houses and those living in isolated dwellings spend more for gas and gas cylinders compared to other types of dwellings.

In reference to the consumption of gas, families living in dwellings with centralized heating systems spend less than households with single heating systems. However it is important to note that households with centralized heating systems generally live in apartment blocks and therefore they do not require as much energy for heating as households living in detached houses (Nesbakken, 2001).

Concerning the socio-economic characteristics of the household we found that the age of the householder has a significant impact on gas and oil consumption for space heating. Our estimation results confirm the hypothesis that elderly household heads spend more for gas consumption while they tend to spend less for oil. *The lower the level of education of the household head, the more he/she spends on gas.* The estimated coefficients for household income are positive for all fuel types, i.e. the higher the household income, the more the household will spend for heating. This result agrees with the evidence shown that households with higher incomes use more energy (Moll *et al.*, 2005; Vringer and Blok, 1995 Abrahamse and Steg, 2011). Although it has been found that higher income consumers tend to be more environmentally conscious, this concern for the environment may not translate into personal energy use consciousness (Heslop *et al.*, 1981).

The type of family affects the consumption of gas, oil, electricity - solar panels since single householder are found to consume less energy than families while couples with children tend to spend more.It is interesting to note that ownership status does not necessarily have a significant effect on final energy consumption for all types of fuel. In fact,being a home owner or a renter is not a critical factor according to our results for all types of fuels considered in the study, but, as already mentioned, it is significant in determining the choice of fuel for space heating. The evidence on the role of tenure type on energy demand is ambiguous across countries and technologiesalthough Italy differs from other countries since about three quarters of families live in their own properties.

Carraro et al. (2011), who only analysed gas consumption in Italy treating the fuel expenditures as expenditures for the purpose of space and water heating, found a similar result. Rehdanz (2007) showed in his study for Germany that home owners have lower heating expenditures. For the US, ownership is not a

Table 2 . Marginal Effects on probability of the choice of heating fuel – Southern Italy

	OIL			NATURAL GAS			GAS CYLINDER			COAL-WOOD			ELECTRICITY AND SOLAR PANELS		
Household characteristics															
Total Expenses	-0.0039	0.0028		0.0035	0.0033		-0.0001	0.0015		-0.0258	0.0046	***	-0.0110	0.0031	***
Degree	0.0028	0.0151		0.0185	0.0178		-0.0185	0.0063	***	-0.0349	0.0162	**	0.0096	0.0122	
Diploma	ref.														
Middle school	-0.0159	0.0103		-0.0104	0.0132		0.0061	0.006		0.0338	0.0128	***	0.0034	0.0069	
Elementary school	-0.0009	0.0115		-0.0281	0.0156	*	-0.0047	0.0065		0.07	0.0146	***	0.0028	0.007	
Isolated	0.0154	0.0233		-0.1794	0.0329	***	0.0848	0.0214	***	0.1447	0.0194	***	-0.003	0.0091	
Size (rooms)	0.0066	0.0031	**	-0.006	0.0037	*	-0.0008	0.0017		0.001	0.003		-0.0082	0.0022	***
Single person	ref.														
Couple without children	0.0024	0.0113		0.0062	0.0134		-0.0101	0.0058	*	0.0216	0.0135	*	-0.0145	0.0056	***
Couple with children	-0.0186	0.0114	*	0.0239	0.0136	*	-0.0091	0.0062		0.0452	0.0122	***	-0.0046	0.0066	
Other households	-0.0106	0.0133		0.0148	0.016		-0.0039	0.0073		0.0104	0.0152		-0.0026	0.007	
Characteristics of the dwelling															
Size	0.0066	0.0031	**	-0.006	0.0037	*	-0.0008	0.0017		0.001	0.003		-0.0082	0.0022	***
Year1920	ref.														
Year1945	-0.0197	0.0196		0.0289	0.0222		-0.0022	0.0106		-0.0124	0.0166		0.0033	0.0119	
Year1960	0.052	0.0211	**	-0.0369	0.0224	*	-0.002	0.0089		-0.0341	0.0136	***	-0.0018	0.0098	
Year1982	0.071	0.0188	***	-0.0482	0.0202	***	-0.0032	0.0081		-0.0407	0.0147	***	-0.0085	0.0094	
Year1991	0.0641	0.0278	**	-0.0569	0.0292	**	0.0061	0.0118		-0.0353	0.0141	***	-0.0215	0.0074	***
Year2000	-0.0175	0.0195		0.0115	0.0236		0.0232	0.0144	*	-0.0304	0.0153	**	-0.0157	0.0085	*
Year2009	-0.0585	0.0163	***	0.0685	0.0212	***	0.0132	0.014		-0.0345	0.0173	**	-0.0212	0.0085	***
Owner	-0.0137	0.0102		0.0156	0.0122		0.0024	0.0057		0.0026	0.0094		-0.0212	0.0063	***
Isolated	0.0154	0.0233		-0.1794	0.0329	***	0.0848	0.0214	***	0.1447	0.0194	***	-0.0030	0.0091	
Detached	-0.0057	0.0100		-0.0657	0.0134	***	0.0318	0.0074	***	0.0905	0.0094	***	-0.0069	0.0048	
Number of Observations	5785														

NOTES: * Significant at the 10% level. ** Significant at the 5% level *** Significant at the 1% level

Table 3. Estimation results for gas consumption

	Coef.	St.error	
Household characteristics			
Income	0.61	0.06	***
Single person	ref.		
Couple without children	1.72	1.58	
Couple with children	8.05	1.83	***
Other type of households	10.89	1.66	***
Degree	-2.38	1.81	
Diploma	ref.		
Middle School	5.74	1.73	***
Elementary school	8.87	2.13	***
Owner	-0.73	1.42	
Age 34 year or less	ref.		
Age 35-64	2.404	1.81	
Age 65+	4.66	2.12	**
Dwelling characteristics			
Size	7.07	0.49	***
Year1920	ref.		
Year1945	-7.98	2.77	***
Year1960	-11.58	2.75	***
Year1982	-8.89	2.66	***
Year1991	-8.56	2.75	***
Year2000	-8.77	3.16	***
Year2009	-17.68	3.14	***
Isolated	22.63	6.32	***
Detached	19.34	2.24	***
Central Heating	-25.12	1.38	***
Contextual variables			
North West	ref.		
North East	6.83	-4.19	
Centre	-6.43	3.42	*
South	-20.14	7.05	***
Islands	-17.79	7.41	**
Green space	0.01	0.66	
Renewable Energy	0.14	0.04	***
HDD	-0.0015	0.010	
Retrofit	-2.21	1.88	
Gas price (*per* TOE)	-0.01	0.46	
Select (Oil)	39.16	20.93	*
Select (Gas)	5.18	9.53	
Select (Gas cylinder)	52.98	16.95	***
Select (Coal-wood)	71.16	22.46	***
Select (Electricity)	-30.91	27.19	
Constant	44.44	52.31	

NOTES: * Significant at the 10% level. **Significant at the 5% level *** Significant at the 1% level

significant determinant in Liao and Chang (2002), but Davis and Kilian (2008) found that home owners used much more gas than renters in a more recent study. Meier and Rehdanz (2010) found that UK home owners react differently to changes in income levels than renters.

Concerning the expenditure for natural gas, our results confirm the assumption that energy consumption significantly changes according to the geographical location of the house with lower expenses found in Central, Southern Italy and the Islands. Among the *contextual factors*, the heating degree days directly influence the energy consumption expenses too. As discussed in Carraro et al. (2011) this evidence can provide regional and local bodies with useful information in order to identify households with high consumption of gas which can be encouraged to employ energy conservation measures or technologies.

Table 4. Estimation results for fuel consumption: coal-wood,oil, electricity-solar panels and LPG gas cylinders

	COAL – WOOD			OIL			ELECTRICITY SOLAR PANELS			LPG GAS CYLINDERS		
	Coef	St. error		Coef	St.error		Coef	St.error		Coef	St.error	
Household characteristics												
Income	1.2152	0.448	***	0.4365	0.0794	***	0.02067	0.00564	***	1.4375	0.2376	***
Single person - Couple without children	ref.			ref.			ref.			ref.		
Couple with children	0.9692	13.2922		12.6713	2.6012	***	0.34658	0.12185	***	0.9861	5.932	
Other households	-4.324	11.9335		9.9362	2.8834	***	0.21928	0.11836	*	4.0913	6.4688	
Degree	42.7679	37.8693		-1.2789	3.6264		0.04725	0.17477		5.2293	11.3092	
Diploma	ref.			ref.			ref.			ref.		
Middle School	-2.7562	18.313		-3.1643	2.3584		-0.05292	0.12097		-0.462	5.5986	
Primary school	-16.6448	24.924		-1.8875	3.0959		-0.02101	0.14846		4.5759	7.1706	
Age 34-65	ref.			ref.			ref.			ref.		
Age 65+	-2.5119	13.6425		-4.4644	2.1564	**	-0.07119	0.09652		1.1454	5.9036	
Dwelling characteristics												
Size	3.6428	4.2300		3.626	0.9844	***	0.08734	0.05775		5.6239	2.5114	**
Year1960	ref.			ref.			ref.			ref.		
Year1991	20.2374	12.4041	*	-5.1899	2.8608		-0.06701	0.11187		3.7466	4.8696	
Year2009	9.6349	16.8977		-4.6089	3.4276		0.11399	0.13336		21.024	6.9628	***
Isolated	2.4893	24.7187		-0.0184	3.8867		-0.16316	0.3257		48.8661	12.4265	***
Detached	-11.6043	12.0722		0.4295	2.9604		0.04826	0.12693		16.5476	5.6193	***
Owner	4.5566	10.5203		-0.58	2.1523		0.10071	0.09218		3.2619	5.0456	
Contextual Variables												
North-Centrum	ref.			ref.			ref.			ref.		
South-Islands	-54.4186	31.4491	*	-6.7388	7.5011		-0.7089	0.32231	**	-20.1397	14.1815	
Green space	-5.174	3.2322	*	-0.7391	1.5045		0.08345	0.08912		0.8602	2.9742	
Renewable Energy	0.0553	0.2615		-0.0741	0.0392	**	-0.00123	0.0017		0.088	0.1637	
Heating Degree Days	-0.031	0.026		0.0086	0.006		-0.00017	0.00027		-0.0141	0.0197	
Retrofit	-3.4608	6.5359		-6.2586	1.6224	***	-0.00239	0.08776		3.2258	4.526	
Fuel price (per TOE)	-3.9483	4.6467		-0.4222	0.4		0.37354	0.26832		0.0453	0.1367	
Select (Oil)	158.1724	123.118		-19.5824	6.4989	***	-1.21805	1.40576		-29.1873	74.4546	
Select (Gas)	3.2758	52.6251		-28.1043	14.9065	*	-1.13811	0.51891	**	-60.0176	32.0626	**
Select (Gas Cylinder)	37.5336	66.45		-34.6905	26.7905		-0.96939	0.5716	*	31.4058	10.4673	***
Select (Coal-wood)	-38.7299	20.5804	*	-5.8037	28.2279		-1.11001	1.09823		-15.6405	32.5808	
Select (Electricity)	76.4981	121.9741		-27.2059	45.1366		-0.34977	0.24966		-28.4475	66.3084	
Constant	398.7097	189.5287	**	82.6257	32.8312	**	-8.82001	6.71305		-73.7616	45.5071	*

NOTES: * Significant at the 10% level. **Significant at the 5% level *** Significant at the 1% level

There are two measures for which the Italian government has set targets: energy consumption and energy efficiency. Improving energy efficiency contributes to the ultimate goal of reducing energy consumption[1].Among the wide range of programmes aimed at influencing energy efficiency, tax incentives for energy efficiency improvements to existing buildings have been established in Italy since 2007. The program provides tax credits to households and companies for single retrofit measures, such as thermal insulation, installation of solar panels, and replacement of old heating and air-conditioning systems, or for comprehensive retrofit work. The tax credit covers 55% of the energy-related cost, but cannot exceed a maximum value that depends on the type of measure taken. Tax credits are reimbursed over 10 years, starting after the completion of work.

The program proved to be an effective tool for improving energy efficiency since it boosted a large number of retrofit investments in the residential sector between 2007 and 2009 thus reducing energy consumption and CO2 emissions. In particular, in 2007 there were 106,000 interventions/operations with an estimate of primary energy savings of 880 GWh/y and CO2 emissions avoided by 193,000 t/y. The number of interventions more than doubled in 2008 (over 240,000 interventions) leading to an estimated quantity of CO2 emissions not emitted of about 418,000 t/y. In 2009 the number of interventions was confirmed at about 237,000 with an estimated saving of about 320,000 t/y in terms of C02 emissions avoided (ENEA, 2010). However, it is worth noting that over 60% of these interventions of energy-efficiency requalification were concentrated in four regions (Lombardy, Piedmont, Veneto and Emilia-Romagna).

Considering the effectiveness of these measures in reducing energy consumption, our aim in this study was to examine if an increase in the share of energy efficiency improvements in existing homes may lead to switching to less polluting fuels. Therefore, we constructed a scenario characterized by an increased number of retrofits compared to the population in all Italian regions and characterized by a reduced heterogeneity among the regions. In particular, we assumed the greatest increase in the share of energy efficiency improvements in Calabria, Sicily, Campania and Apulia (for these regions we doubled the percentage of people who have taken advantage of tax incentives for thermal retrofits) which were the regions with the lowest observed values in 2009 (Enea, 2010). For Molise, Abruzzo, Lazio, Basilicata and Sardinia we assumed a growth rate equal to 75%; for Liguria, Lombardy, Tuscany, Marche and Umbria we assumed a growth rate equal to 50%; for Friuli Venezia Giulia, Trentino Alto Adige, Piedmont-Aosta Valley, Veneto and Emilia Romagna we assumed a growth rate equal to 25%. In this way the average number of retrofits became equal to 0.61 thus obtaining a coefficient of variation equal to 0.45.

By considering the simulated values of retrofits we estimated different multinomial logit models for Italy as a whole and for the various macro-areas. The results obtained indicate that a greater response to this type of tax incentives can influence the choice of fuel used for heating purposes even if the differences are slight. At national level we found an increase in the probability of choosing gas as fuel for heating purposes. The predicted probability with the observed number of retrofits provided by Enea was equal to 80.78% while in our scenario this probability increased up to 80.84% (Table 5).

Notes: "Base" refers to the predicted probabilities obtained from the multinomial logit models estimated by considering the values of the variable "*Retrofit*" provided by Enea; "Scenario" refers to the predicted probabilities obtained by using simulated values of the variable concerning the incidence of number of thermal retrofits on citizens living in a certain region as specified above.

Moreover the probability of using gas as fuel for heating space increased in almost all the geographical areas with the percentage of growth ranging from 0.03% in North-Western regions to 0.61% in the Islands. At the same time, there is a decrease in the probability of using other types of fuel: the greatest variations can be seen for coal and wood in North-Western Italy, for gas cylinder in Central Italy and for electricity in the North-East regions.

Table 5. Predicted probabilities concerning the choice of fuel: impact of an increase in thermal retrofits

	NORTH-WEST		NORTH-EAST		CENTRE		SOUTH		ISLANDS		ITALY	
	Base	*Scenario*	*Base*	*Scenario*	*Base*	*Scenario*	*Base*	*Scenario*	*Base*	*Scenario*	*Base*	*Scenario*
Pr(j=Oil):	8.75	8.76	9.33	9.31	3.64	3.65	3.33	3.32	6.39	6.36	6.21	6.20
Pr(j=Natural Gas):	85.97	86.00	81.09	81.02	88.44	88.53	72.63	72.69	32.55	32.75	80.78	80.84
Pr(j= LPG Gas Cylinders):	2.68	2.66	3.69	3.75	5.21	5.13	11.65	11.58	37.17	37.05	6.86	6.83
Pr(j=Coal-Wood):	1.83	1.81	4.26	4.28	2.49	2.47	8.52	8.52	9.26	9.26	4.53	4.52
Pr(j=Electricity-Solar Panels)	0.77	0.77	1.64	1.63	0.22	0.23	3.88	3.88	14.62	14.58	1.61	1.62

CONCLUSION

This study investigated the determinants of fuel choice and fuel consumption in Italy by carrying out an analysis at household level taking into account that the behaviour of households concerning space heating is not only influenced by the socio-economic characteristics of the families but also by external factors which are not controlled by the household and depend on the national and local energy supply.

This paper fills an important research gap in analysingwhether there are geographic differences in the determinants of fuel choice bearing in mind the heterogeneity of households and behavioural aspects among the Italian regions.Many of the variables concerning the socio-economic characteristics of households and the characteristics of the dwellings proved to be important determinants of the choice of space heating technologies and of energy consumption.Regarding the choice of a space heating system, the level of income positively affects the probability of choosing gas while it negatively affects the probability of choosing coal and wood. Concerning the type of family living in a house, a single householder is less likely to use a gas-based heating system, while he/she is more likely to use LPG gas cylinders, oil, electricity and solar panels. Households living in newly built homes are more likely to opt for gas while households living in older buildings are more likely to choose coal and wood.

Significant differences in the determinants of fuel choice are found among the Italian regions thus proving the influence of the socio-economic context. By analyzing energy consumption, we found that heating expenditures for gas and oil increase with household size, age of householder and the number of family members. Moreover, families living in isolated areas and in detached homes have higher heating expenditures.

These results can help us to improve our understanding of household energy behavior and contribute to the careful design of policies aimed at curbing residential energy consumption or lowering its carbon intensity by paying special attention to the heterogeneity of households at regional level. For this purpose focusing on elderly people is in line with reducing overall heating expenses and supporting families with children could be a means of improving the residential energy performance.

Moreover, our results also indicate that properties built before 2009 are more expensive to heat than more recently built homes. By increasing the energy efficiency of these properties, i.e. through tax incentives, would therefore also contribute to lowering carbon emissions.The availability of data referring specifically to energy used for heating purposes and especially solar panels, or information on the management of heating of private homes as well as information on thermal retrofits at household level would be required in order to carry out further research which would enable us to study other important aspects concerning households' behaviour towards energy conservation.

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