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# Analysing Energy-Saving Behaviours in Italian Households

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**ABSTRACT**

In the European context of moving to a low-carbon economy, knowledge regarding household decisions surrounding residential heating systems is crucial for policymakers in order to design effective policies both to reduce non-renewable energy consumption and to enhance energy efficiency in the residential sector. The choices made by households concerning decisions on how to heat their homes can significantly influence the related environmental impacts. This research examines two aspects of decision making with respect to heating system upgrades in Italian households using, for the first time, data from the 2013 Italian Households Energy Consumption survey: the choice of using renewable energies for space heating and decision to invest in energy efficient retrofits. Our findings show that household socio-economic characteristics and contextual factors are critical for good decision-making regarding heating system. We also find that previous cash retrofit investments and dwelling characteristics are important determining factors both for the choice of heating system based on renewable sources and for the subsequent decision regarding the adoption of energy efficient retrofit measures.

**Keywords:** Household energy consumption, Retrofit investment, Renewable energy sources.

**JEL Classification:** D1, Q2, R21

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# Análisis de los Comportamientos de Ahorro de Energía en los Hogares Italianos

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**RESUMEN**

En el contexto europeo de transición hacia una economía baja en carbono, el conocimiento de las decisiones de los hogares en lo que a los sistemas de calefacción residencial se refiere es crucial para los responsables políticos a la hora de diseñar políticas efectivas tanto para reducir el consumo de energía no renovable como para mejorar la eficiencia energética en el sector residencial. Las elecciones hechas por los hogares con respecto a las decisiones sobre cómo calentar sus hogares pueden influir significativamente en los impactos ambientales relacionados. Esta investigación examina dos aspectos de la toma de decisiones con respecto a la modernización del sistema de calefacción en los hogares italianos utilizando, por primera vez, datos de la encuesta de consumo de energía de los hogares italianos de 2013: la elección de usar energías renovables para la calefacción de espacios y la decisión de invertir en modernización con energía eficiente. Nuestros resultados muestran que las características socioeconómicas del hogar y los factores contextuales son fundamentales para una buena toma de decisiones con respecto al sistema de calefacción. También encontramos que las inversiones previas en modernización de eficiencia energética y las características de la vivienda son factores determinantes importantes tanto para la elección del sistema de calefacción basado en fuentes renovables como para la posterior decisión con respecto a la adopción de medidas de modernización de eficiencia energética.

**Palabras clave:** Consumo de energía en los hogares; Inversión en modernización, Fuentes de energía renovable.

**Clasificación JEL:** D1, Q2, R21

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## 1. Introduction

The Italian National Energy Strategy aims at ensuring the widest possible use of instruments that help in enhancing energy security, environmental protection and affordability of energy, thus following a decarbonisation dimension and contributing to European objectives relating to energy and environment. Indeed, the European Clean Energy for All Package, implemented during the period 2018-2019, is composed of eight legislative acts focusing on energy efficiency, energy performance of buildings, renewable energy, electricity market design, governance rules for the Energy Union as well as energy security and eco-design.

In this framework, understanding household energy consumption and energy-saving behaviours may play a crucial role in informing policy makers in order to design effective policies both to enhance energy efficiency and to reduce energy poverty which is subject to increasing policy attention within the European Union (EU). The Energy Efficiency Directive demands EU member states to orient energy efficiency efforts towards households affected by energy poverty whose definition may include income levels, the share of energy expenditure of disposable income, the energy efficiency of homes, critical dependence on electrical equipment for health reasons, age or other criteria.

To this respect, the importance of retrofitting and improvement of apartment buildings to reduce household energy consumption and to address energy poverty is widely acknowledged among the EU countries (Trotta, 2018b; Bouzarovski et al. 2020). In 2018 households represented 26.1% of final energy consumption in the EU. The main use of energy by households is for heating their homes (63.6% of final energy consumption in the residential sector) while energy used for lighting and most electrical appliances, excluding the electricity use for powering the main heating, cooling or cooking systems, represents 14.1% and the proportion used for water heating represents 14.8%. Consequently, heating of space and water represents 78.4% of the final energy consumed by households (Eurostat, 2018).

The choices made by individuals concerning decisions on how to heat their homes can significantly influence the related environmental impacts (Eurostat, 2018). Although the environmental impact of each household is relatively small compared with that of production activities, household energy consumption in buildings for space heating largely contributes to the environmental pressure at country-scale (Besagni and Borgarello, 2018).

According to the Paris Agreement adopted in December 2015, EU member states have set ambitious targets for the energy transition towards 2030, focusing on increasing renewable energy penetration (at least 32% share), improving energy efficiency (at least 32.5%) and lowering greenhouse gas emissions (at least 40% cuts from 1990 levels). In this context it is essential to note that the residential building sector has higher energy and pollution reduction potentials than any other sector (IPCC, 2007; Ghaffarian et al., 2013). The share of non-renewable sources is still high in the EU since natural gas is the dominant source of energy for households heating with a rather stable share (45% in 2018). In contrast, oil is slowly being phased out by wood (-10 points) but remains significant in island countries. Interestingly, the share of wood increased by 13.3% points since 2000 to 21.3% in 2018.

In order to promote a more sustainable and efficient use of energy in the residential sector, national governments can adopt a range of policies and programs, including economic incentives for improving energy efficiency of homes through insulation, adopting sustainable heating systems and more efficient heating appliances. Indeed, increasing energy performances in the residential building sector while reducing household energy expenditure could encourage cost-effective saving behaviours, thus decreasing greenhouse gas emissions (Gatto and Busato, 2019; Guo et al., 2019).

In 2018, space heating accounted for 66.6% of Italian final energy consumption in the residential sector. Italy is one of the EU countries with the highest proportion of gas used for space heating (58.4 %). In 2016 energy consumption for air conditioning (space heating and air cooling) took almost 70% of the total consumption. The share of renewable sources is continuously increasing reaching 16.8% of consumption in 2016: one third of renewables consumption was solid biomass, followed by geothermal energy with 20.8% and hydroelectricity with 14.9% (ENEA, 2018). The improvement of the energy efficiency of residential buildings is a critical issue in Italy, where 55% of the building stock is over 40 years old. Moreover, more than 60% of buildings in Italy are over 45 years old, meaning before the law n. 373 of 1976, the first national law on energy saving (Carrosio, 2015).

The Italian National Strategy – a centrepiece of the Energy and Climate Plan – set out measures to achieve sustainable growth and environmental targets by 2030, contributing to a low-carbon economy and to the fight against climate change. Renewables and energy efficiency will contribute not only to environmental protection, but also to reduce final energy consumption and cost-effectiveness.

Italy has recently introduced new regulatory legislation to boost the share of renewables in heating in the Italian residential sector (*Ecobonus, Conto Termico*). In this context there is an increasing need for understanding which factors may influence the adoption of more efficient and innovative residential heating systems (RHS), primarily based on renewable energy sources in existing homes, and for analysing the dwelling-related and household characteristics influencing energy efficient retrofit investments (RI), typically involving changes or upgrades to the building envelope and to the heating systems.

Despite the policy interest in residential energy demand for space heating, few studies have examined household decisions around heating systems in Italy (Laureti and Secondi, 2012; Carraro et al., 2011; Besagni and Borgarello, 2018).

Therefore, this research aims at improving comprehension surrounding fuel choice for residential heating, with a particular focus on renewable sources and concerning the factors influencing household intention to adopt energy upgrading measures. An analysis of the determinants of heating technology at the micro-level can improve our understanding of Italian household energy behaviour and contribute to carefully design policies aimed at curbing residential energy consumption or lowering its carbon intensity.

To the best of our knowledge, empirical studies have not yet analysed whether and to what extent household socio-economic context, building characteristics and behavioural factors affect household propensity to adopt RI in Italy. This study is also unique since it uses, for the first time, data from the 2013 survey on Household Energy Consumption (HEC) carried out by ISTAT in collaboration with the National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA) and the Ministry of Economic Development. This dataset is particularly suitable for the purpose of the analysis since it provides detailed information to quantify residential sector space heating consumption according to different uses and energy sources.

The remainder of the paper is structured as follows: Section 2 provides a literature review of the factor influencing household energy demand for space heating and household propensity to adopt RI for energy saving. Section 3 describes the data used and provides information regarding the Italian household energy consumption. Section 4 describes methodological approach and model specification. Section 5 reports our estimation results while in Section 6 some concluding remarks are drawn.

## 2. Literature review on household energy-saving behaviours

Household energy consumption behaviours and energy efficiency investment decisions are complex and shaped by many factors, both individual and contextual (Trotta, 2018b). Due to this complexity, they are usually studied by adopting different methodological approaches and data sources.

Over the last few years, the analysis of energy consumption at microeconomic level associating energy expenditure with household characteristics, socio-economic factors and dwelling features has received a growing interest, generating a considerable number of studies (Cayla et al., 2011; Wyatt, 2013; Besagni and Borgarello, 2018; Levy and Belaid, 2018; Kostakis 2020).

Regarding residential energy demand for space heating, several researchers focused on the analysis of energy consumption/expenditure treating the stock of heating appliances as given. Empirical findings demonstrated the important role played by household socio-demographic and economic characteristics (Meier and Rehdanz, 2010; Sardianou, 2008; Arabatzis and Malesios, 2011) as well as by building characteristics (Rehdanz, 2007).

An increasing amount of research is focused on understanding the determinants of the household choice of heating system which is increasingly important in any country from a policy-maker perspective. Martinopoulos et al (2018) provided a review of the different technological solutions available for space and water heating and compared the most used heating systems in the residential building sector in EU countries. Several recent studies have investigated factors influencing household adoption of building-scale renewable energy technologies in various countries (for a review see Heiskanen and Matschoss, 2017). Numerous studies, including the pioneering article by Dubin and McFadden (1984) employed a two-stage modeling approach for the choice of energy appliances by households and the resulting energy consumption (i.e. discrete-continuous choice approach). For the appliance choice, these studies apply logit and multinomial logit models mostly on data from large household surveys on the national level (e.g. Vaage, 2000; Mills and Schleich (2009). Other studies focused on the residential heating system (RHS) choice only (e.g. Curtis et al., 2020).

Findings revealed that the choice relies on household-specific data, such as socio-demographic characteristics, including age of the household head, education, household income, number of household members, attributes of the home, such as vintage class, type, size or energy standard and spatial variables, described by location in a certain geographic area, administrative unit, rural region and climate zone. More specifically, Michelsen and Madlener (2016) analysed the drivers behind the homeowners' decisions to switch from a fossil fuel to a renewable RHS in Germany founding that environmental protection, a lower dependency on fossil fuels and a higher degree of RHS-related knowledge are key drivers.

Curtis et al. (2020) examined fuel choice for residential heating using Ireland as a case study. The authors focused on switching to natural gas from carbon intensive alternatives and found that a range of building attributes and household characteristics are associated with fuel choice in addition to a substantial distance decay effects with respect to gas network connection within relatively proximity to the network.

However, for Italy, empirical analyses on this topic are relatively few (Laureti and Secondi, 2012; Carraro et al., 2011; Besagni and Borgarello, 2018).

Besagni and Borgarello (2018) analysed the relationships between the residential energy expenditure and the building factors, socio-demographic variables and appliances using data from the Italian Household Budget Survey (HBS). Laureti and Secondi (2012) identified the factors which have a strong effect on the choice of a specific fuel by using a multinomial logit model considering the heterogeneity of households in the Italian regions. The authors then focused 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 Laureti and Secondi (2012) examined the implications of a simulated scenario concerning tax incentives for energy efficiency improvement.

Indeed, retrofitting is one of the most important policy measures for timely decarbonization of the residential sector due to slow turnover of the housing stock. The term 'energy efficient RI include structural improvements to a house (Dixon and Eames, 2013). They typically involve changes or upgrades to the building envelope, such as the installation of insulation systems or double glazing the replacement, or changes to the heating and hot water systems, such as the installation heat pumps, condensing boilers, and solar water heating (Dietz et al., 2009).

Investments in energy efficiency measures such as improved heating systems are driven not only by financial and economic reasons, but also by behavioural and psychological factors such as attitudes, motivations, expectations and trust (Aravena et al., 2016). There is also extensive literature examining the effect of non-economic elements such as comfort and convenience (e.g. Zundel and Stieß, 2011).

Nair et al. (2010) investigate the role of personal and contextual factors in influencing energy-saving behaviours by making energy efficient RI, in particular education, income, age, and gender. As expected, younger homeowners were more likely to adopt such a measure. Respondents who had only primary education were less likely to adopt a building envelope energy efficiency measure.

As energy efficiency retrofits raise the possibility of reducing pollution, various studies examined the role of environmental concerns on energy efficiency investments (Qiu and Kahn, 2019; Lindenberg and Steg, 2007; Oikonomou et al. 2009; Discher et al., 2010; Hills, 2011). Ramos et al. (2016) analysed whether pro-environmental households are more likely to invest in energy efficiency with two conflicting findings. On one hand, stated environmental attitudes do not indicate any effect on energy efficiency investments while environmental concerns seem to be less important for high-cost investments with less frequent substitution. On the other hand, homeowners engaging in pro-environmental practices, such as recycling or participating in environmental policy activism, are more likely than others to invest energy efficiency. The authors concluded that environmental attitudes are not necessarily translated into real actions.

Stieß and Dunkelberg (2013) found that the decision to install energy efficient refurbishment by private household is a result of a combination of personal and contextual factors including comfort, convenience, social status and belonging.

Concerning policy measures, building regulation and certification are important factors affecting the decision to invest in energy efficient retrofits. Knowledge from energy audits for the renovation of their house reveals that aesthetics, identity and convenience may be viewed as relevant as energy savings (Gram-Hanssen et al., 2007). Indeed, the added value due to energy performance depends on the willingness to pay more for having an energy efficient building (Popescu et al., 2012).

Moreover, among technical factors – building characteristics, type of ownership and building obsolescence are found to be positively associated with RI. Hamilton et al. (2014) and Trotta (2018b) investigate the role of dwelling-related and household characteristics on adopting energy efficient RI in the English residential sector.

Other aspects related to the households' well-being are examined in the literature. Mortensen et al. (2014) found that financial aspect of an energy retrofit have a great weight for the homeowners and is often the reason why energy retrofits are not carried out. Nevertheless, improvements in comfort, indoor environment and architecture proved to be motivating for the homeowners thus increasing the budget for retrofit. An energy efficiency retrofit can have beneficial effects on the indoor climate and health of all occupants (Weber and Wolff, 2018)

Concerning economic factors, income and expenditures on household energy use are key drivers in influencing household propensity to adopt more efficient energy systems (Liu et al. 2020; Pachauri and Jiang, 2008; Wang, et al., 2019).

Curtis et al. (2018) examined four aspects of decision making with respect to heating system upgrades: home-owner decisions on whether to upgrade the heating system, decisions on fuel choice, fuel switching patterns and an examination of the reasons why homeowners make these decisions. Maruejols and Young (2011) indicated that households not paying heating bills directly chose higher temperature settings. Gamtessa (2013) examined the response of household to the government program on financial incentives in energy efficient retrofit measures in Canada. They found that energy cost savings, financial incentives and costs of retrofits are important factors behind retrofit.

This study contributes to advancing the existing literature by examining two aspects of decision making with respect to heating system upgrades in Italian households: the choice of using renewable energies for space heating and decision to invest in energy efficient retrofits. To this aim we will adopt logit and multinomial models and use, for the first time, data obtained from a specific survey carried out by the Italian National Statistical Institute (ISTAT).

## 3. Household energy consumption for space heating in Italy

The HEC survey, carried out in 2013, collected detailed information on dwelling and technical characteristics, household characteristics, equipment of power plants available to households (home heating, water heating, cooling), fuel consumption and costs for biomass, lighting, appliances, expenses for energy use and previous cash investments on energy efficiency retrofits. This survey, based on a sample of 20,000 households, representative of all Italian households, allow us to analyse household energy consumption for space heating by type of fuel (gas, electricity, diesel, renewable energy source, etc.) and to examine the determinants of household choice to adopt energy saving retrofits.

Household energy behaviour and fuel choice greatly vary across the Italian regions. Most of the households, about 65.0%, use natural gas for heating purpose[1], with the highest incidence in Lombardia and Emilia Romagna (with percentages respectively equal to 86.13% and 86.09%). Renewable energy source for space heating is used by 20.43% of the Italian households, with high variability across regions. As illustrated in Table A.1 in the Appendix, the highest percentage is observed in Sardegna (42.96%) while the lowest incidence is recorded for Lombardia (7.85%).

In the HEC survey, the choice of the type of fuel refers to the main source used by household. Given that households could use various types of fuel sources for heating, it is interesting to study the choice of the main fuel type given the use of other sources. Indeed, from the last rows of Table A.1 in the Appendix it is possible to note different combinations of heating systems. The combination gas and renewable energy source is the most frequent and is chosen by 29.4% of Italian households.

Concerning household intention to adopt energy efficient RI, the HEC survey examined whether the household intend to invest in energy efficient retrofits without distinguishing the different types of RI measures. The question included in the HEC survey is the following: "*Do you intend to make retrofit investments in order to reduce home heating expenditure*?" There three modalities of reply: "*Householder will surely make RI*"; "*Householder is almost certain to make RI"; "Householder will not make RI*".

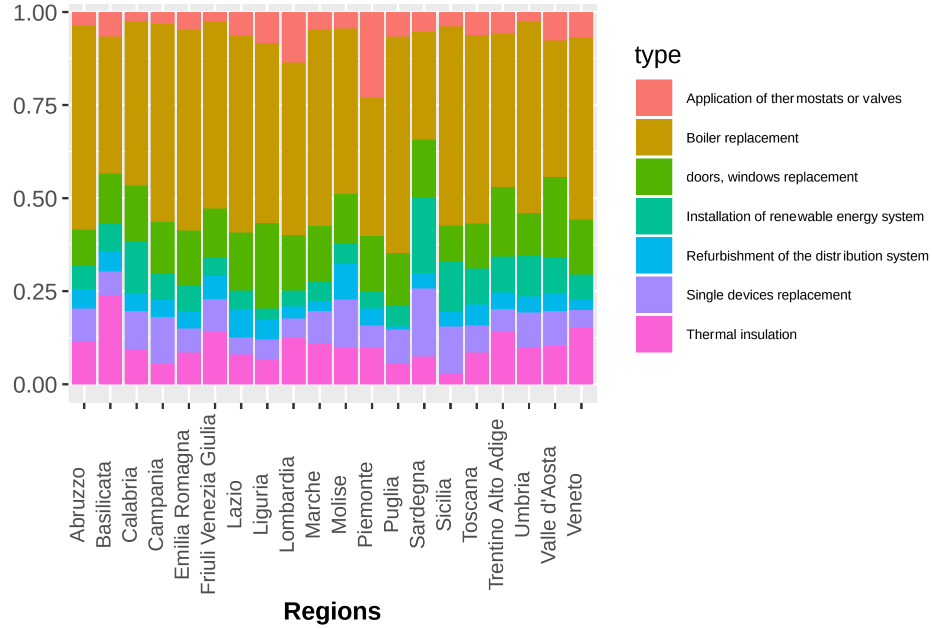
From Table 1.C in the Appendix, it is interesting to note that on average 67.61% of households will not make RI, 24.66% will almost certainly make RI and only 7.73% will surely make RI. These results are characterized by a high territorial heterogeneity. Indeed, the association observed between region of residence and intention to make RI is statistically significant (Pearson $\chi^2(38)$) = 102.115, p-value = 0.000). The highest percentage of households surely adopting energy efficient RI is observed for Valle d'Aosta (11.25%) followed by Piemonte (8.92%), while the lowest percentage is observed in Calabria and Basilicata (4.33% and 4.71% respectively).

In the same Table 1.C, we analysed whether households have previously made cash energy saving RI by region of residence. At national level, households who already made RI are equal to 21.39% with a higher incidence in the Northern regions than in the South. Previous cash investments on energy efficiency seem to be strongly associated with the intention to make future RI. Indeed, the association between the intention to make RI and investment in cash incurred over the past five years to reduce costs of heating home is significant (Pearson $\chi^2(2)$=123.135, P-value = 0.000). Regarding the previous cash energy efficient RI adopted by households, at national level, only 23.65% of Italians declared they have already adopted sustainable heating system and energy upgrading measures in order to reduce heating expenditure. Among all the possible type of investments, 42.77% of households declared that they adopted doors, windows, fixtures replacement, 31.84% of households declared that they replaced boiler, and approximately 7.20% of households stated they adopted a thermal insulation system. However, there is a high heterogeneity across the Italian regions. As shown in Figure 1, the highest percentages of households who implemented doors, windows, fixtures replacement resides in Liguria (53.42%) and Valle d'Aosta (52.02%). Contrastingly, the percentage of households who adopted

[1] Sardegna is the only Italian region without a Gas distribution network.

a replaced boiler is higher in Abruzzo (39.49%) and Friuli Venezia Giulia (37.33%). Concerning thermal insulation, the highest percentages of households reside in Basilicata (15.49%) and Veneto (10.74%).

**Figure 1.** Previous cash investments adopted by Italian households at regional level




*Source: Authors elaboration on Household energy consumption survey 2013.*

It is worth noting that the growing attention paid by the European Commission has been translated at national level into a series of legislative measures directed to promote energy efficiency of buildings. The Italian Directive 2010/31/EU and DL.63/2013 are aimed at developing the transformation of the buildings in "Nearly Zero Energy Building", requiring minimum energy performance for new and existing buildings, ensuring the energy certification and disciplinary controls on the implants. Concerning measures to economically support energy efficiency investments in the residential sector, Italy introduced two specific measures: *Conto Termico*, which is an incentive for renewable energies, regulated with the Ministry Decree of 28/12/2012 and *Ecobonus*, that is tax deductions on the Italian Personal Income Tax (IRPEF). These measures are also important to reduce household energy expenditure. Indeed, energy expenditure share for heating purpose represents a substantial financial burden for Italian households especially for low-income family units (Faiella and Lavecchia, 2018).

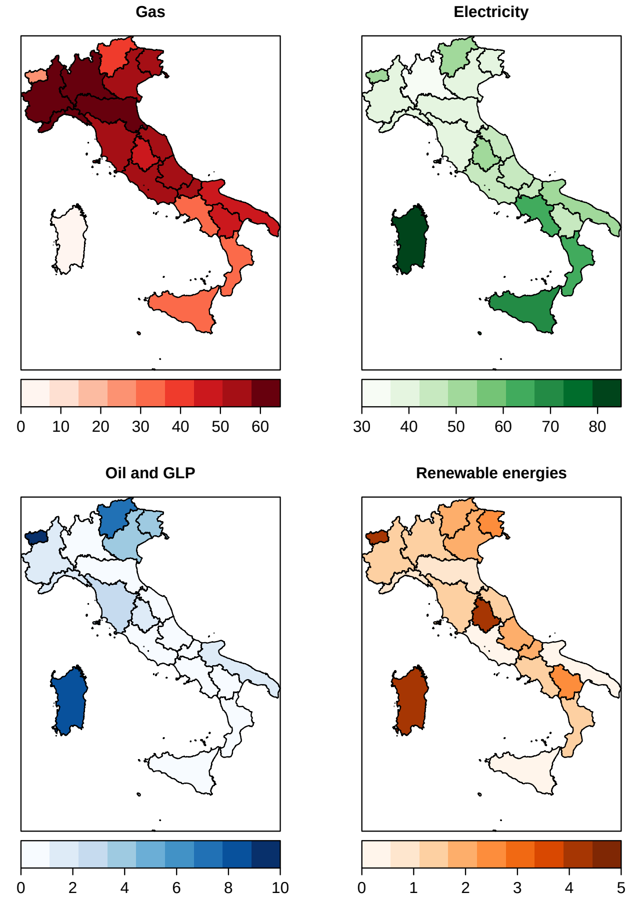
More specifically, energy consumption accounts for 5.8% of the total household expenditure in Italy; this percentage increases for households below the poverty threshold (8.6%) and shows a high territorial heterogeneity. Annual average energy expenditure varies considerably in different areas of the country, in relation to climatic conditions and the consequent use of the heating and air conditioning functions.

Figure 2 reports the shares of each heating fuel expenditure on total energy household expenditure. As expected, household energy expenditure is heterogeneously distributed across the Italian territory and by type of fuel. On average household energy expenditure is higher in Northern regions compared to the South of Italy. This aspect could reflect both the difference in weather conditions, with the temperature increasing from the North to the South of the peninsula and lower disposable income in Southern regions. These descriptive statistics suggest that some households are more vulnerable than others to get access to sustainable heating systems and energy upgrading measures. Indeed, the relationship between the intention to make RI and annual energy expenditure[2]

[2] In the absence of direct measurement, we used proxy indicators of income based on household expenditure. The level of household energy expenditure is divided into 4 groups, or 'quartiles. The first quartile is the lowest or 25%, the second quartile is the next lowest, and so on. For these data, the average expenditure is 678€ for the lowest quartile, 1323€ for the quartile 2, 1828 € for the quartile 3, 2792€ for the highest quartile.

was significant and confirmed by the $\chi^2$ test of independence (Pearson $\chi^2$ (6) =101.512, p-value = 0.000). Considering the type of fuel, it is interesting to note that the highest share of energy expenditure on renewable energy source is observed in Sardegna, Umbria and Valle d'Aosta, while the highest incidence of electricity expenditure on total energy expenditure is observed in the Insular regions, thus confirming similar results obtained by Besagni and Borgarello (2018).

**Figure 2.** Share of fuels in the final energy consumption in the residential sector for space heating




*Source: Authors elaboration on HEC survey 2013.*

## 4. Methods and models specification

By using data from the ISTAT HEC survey, providing detailed information regarding energy consumption in the residential sector for different energy uses and sources, we adopt a two-step empirical strategy. In the first step we analyse the factors influencing household propensity to adopt renewable heating technologies; in the second step, we examine the drivers of household intention to adopt energy upgrading measures.

Considering that a household could choice various fuel sources for space heating (gas, LPG and oil, renewable sources, electricity) we estimated the probability of adopting as the main fuel a renewable source (wood, biomass, pellets, solar thermal technologies) using a logit model for Italian households. The decision of whether to adopt renewable sources is modelled as a latent choice in the random utility framework: $y^* = \boldsymbol{z}'\boldsymbol{\gamma} + \boldsymbol{v}$ where $y = 1\ if\ \ y^* > 0$ (whether renewable energy is adopted), $\boldsymbol{z}$ is a row vector of variable influencing the choice of renewable energy source for heating, $\boldsymbol{\gamma}$ is a vector of estimated parameters and $\boldsymbol{v}$ is the error component.

Based on the literature review, the explanatory variables are classified into four groups:

i) Socio-economic characteristics of households: gender of the householder, age in classes (15-34, 35-44, 45-54, 55-64, 65 and over), occupational status (Employee, Self-employee, Job seeker, Not in labour force, level of education (primary, secondary and tertiary education), household size, number of children (0, 1, 2 or more);

ii) Technical factors – building characteristics: dwelling type (apartment or detached dwelling type), thermal insulation of the dwelling (well insulate, rather insulate, few insulate and presence of draughts), year property built; number of rooms; type of heating system (autonomous; centralized), use of heating system during winter season (every day, about once a week), number of hours heating on in a winter day, type of construction material (concrete, stone, bricks, wood);

iii) Contextual factors: regions and area of residence (metropolitan area, urban area, mountain and no-mountain municipalities);

iv) Behavioural factors: previous cash investments for energy saving.

The results from the estimated model for identifying the determinants of household propensity to adopt renewable source for space heating are then used to control for potential observed and unobserved heterogeneity in the subsequent estimation of household intention to adopt energy upgrading measures[3].

Turning on the second step, in order to investigate the determinants of household intention to adopt energy RI a multinomial logit model (MNL) is used (Hosmer et al., 2013). Our outcome variable represents household intention to make RI in order to reduce energy expenditure, as already mentioned in Section 3, where the base outcome "*Householder will not make RI*" is used in model specification.

According to the above literature review, in addition to the set of determinants used in the logit model we included other economic factors, such as annual expenditure on different type of heating, change of energy supplier due to cost reduction (yes; no), and additional variables measuring household behaviour, such as the knowledge of certification on energy efficiency (yes, no) and presence of thermostat or valves for heating control (yes, no).

The decision to adopt a RI is modelled within a random utility modelling framework. A household *i* (*i*=1, 2, …, *I*) selects out of a finite set of alternatives J *(j=1, 2, …, J).* Therefore, the utility of a certain alternative *j* is: $U_{ij} = \boldsymbol{\beta}'\boldsymbol{x}_{ij} + \varepsilon_{ij}$.

$U_{ij}$ represents the utility of householder *i* of RI *j*, $\boldsymbol{x}_{ij}$ represent explanatory variables (Socio-economic and dwelling characteristics, behavioural and economic factors), $\boldsymbol{\beta}$ unknown coefficients and $\varepsilon_{i,j}$ the error term assumed as independently and identically distributed according to the type I extreme value distribution (Gumbel distribution). We observe householder *i* to adopt RI *j*, if the utility from surely make RI is the highest compared to all other RI in the choice set (intend to make it and do not make it). Let $Y_i$ be a random variable that indicates the choice made. The MNL model specifies the following choice probability of a householder *i* for RI of type *j (j*=1, 2, …, *J):*

$$Prob(Y_i = \mathrm{j}) = \frac{exp(\boldsymbol{\beta}'\boldsymbol{x}_{ij})}{1 + \sum_{\mathrm{j}=1}^{J} exp(\boldsymbol{\beta}'\boldsymbol{x}_{ij})}\ for\ j = 1,2,3 \tag{1}$$

From the point of view of the estimation, it is useful that the odds ratio $P_j/P_k$ does not depend on the other choices, which follows from the independence of disturbances in the original model. The

[3] Since the Italian household choice of type of fuel (electricity, fuel oil, gas, renewable energy system) for heating purpose can influence the probability to adopt RI, we check the potential (endogeneity) bias resulting from unobserved factors determining both the fuel choice and RI intention, by implementing the Heckman two-step correction procedure (Heckman, 1979). Using different logit models, for each heating type, we estimated the probability of a household to make RI, and then corrected the selection bias in the estimation of RI investment probability. Results suggest that the impact of Mills ratio is not significant for the various type of fuels. Therefore, our analysis does not suffer from selection bias. Estimation results for all the type of fuel are reported in Table A.4 of the Appendix.

Relative Risk Ratio (RRR), obtained by exponentiating the multinomial logit coefficients, gives the proportionate change in the relative risk of choosing alternative *j* rather than the base alternative when $x_i$ changes by one unit. For a categorical variable the slope coefficient, or logit difference, is the difference between the log of the odds when x = 1 and the log of the odds when *x = 0*. For covariate with more than two levels, we expand the number of odds ratios to include comparisons of each level of the covariate to a reference level for each possible logit function. The exponentiated coefficients are commonly interpreted as odds ratio (OR).

## 5. Results and discussion

### 5.1. Factors influencing Italian household choice to adopt renewable energy source for space heating.

Estimation results, expressed in terms of OR, for choosing a renewable energy source for space heating are reported in Table 1.

Referring to the household socio-economic characteristics, we found that having made previous RI significantly influence the choice of renewable energy sources as main heating fuel. As expected, households who installed renewable energy system are more likely to choose renewable energy sources (OR equal to 3.54).

Focussing on the occupational status, we found that self-employed individuals are more likely to choose renewable energy sources (OR equal to 1.26). Considering dwelling characteristics, our results show that having an autonomous heating system increase the probability to choose renewable energy sources (OR equal to 2.49) compared to centralized heating system. The dwelling year of construction is one of the most important variables determining the choice of fuel. The more recent the year of construction of the dwelling, the more likely the probability of choosing renewable energy sources as the main heating fuel (OR goes from 1.233 for the dwellings built between 1980-1989 to a value equal to 1.297 for the dwellings built in 1990-1999).

**Table 1.** Results for choosing a renewable source based on a binary logit model

| | OR | s.e. | | | OR | s.e. | |
|---|---|---|---|---|---|---|---|
| ***Previous cash investments (ref.no)*** | | | | ***Regions (Ref. Lazio)*** | | | |
| Boiler replacement | 0.63 | 0.063 | *** | Piemonte | 0.518 | 0.071 | *** |
| Replacement of single devices | 2.17 | 0.368 | *** | Valle d'Aosta | 0.265 | 0.04 | *** |
| Installation of renewable energy system | 3.541 | 0.593 | *** | Lombardia | 0.217 | 0.031 | *** |
| Refurbishment of the distribution system | 1.569 | 0.4 | * | Trentino Alto Adige | 0.768 | 0.097 | ** |
| Application of thermostats or valves | 0.614 | 0.163 | * | Veneto | 0.504 | 0.068 | *** |
| Thermal insulation | 0.98 | 0.163 | | Friuli Venezia Giulia | 0.624 | 0.091 | *** |
| Replacement of doors, windows, fixtures | 1.087 | 0.083 | | Liguria | 0.578 | 0.096 | *** |
| ***Dwelling type (ref. Detached, single Household)*** | | | | Emilia Romagna | 0.211 | 0.034 | *** |
| Detached, multi households | 0.741 | 0.044 | *** | Toscana | 0.447 | 0.067 | *** |
| Apartments (Less than 10 apartments) | 0.275 | 0.017 | *** | Umbria | 1.105 | 0.157 | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Apartments (10 or more apartments) | 0.089 | 0.009 | *** | Marche | 0.66 | 0.1 | *** |
| ***Type of heating system (ref. Centralized)*** | | | | Abruzzo | 0.756 | 0.11 | * |
| Autonomous | 2.499 | 0.164 | *** | Molise | 0.611 | 0.091 | *** |
| ***Maintenance of equipment (ref. Planned)*** | | | | Campania | 0.937 | 0.129 | |
| Occasionally | 2.268 | 0.143 | *** | Puglia | 0.449 | 0.071 | *** |
| No maintenance | 2.805 | 0.21 | *** | Basilicata | 0.754 | 0.111 | * |
| ***N.ro of hours heating on in a winter day*** | 1.171 | 0.006 | *** | Calabria | 1.178 | 0.166 | |
| ***Type of construction material (ref. Concrete)*** | | | | Sicilia | 0.216 | 0.036 | *** |
| Stone | 1.415 | 0.1 | *** | Sardegna | 1.351 | 0.184 | ** |
| Briks | 1.148 | 0.065 | ** | ***Age (ref. 15-34)*** | | | |
| Wood | 1.019 | 0.149 | | 35-44 | 0.879 | 0.068 | * |
| ***N.ro of rooms*** | 0.961 | 0.018 | ** | 45-54 | 0.708 | 0.06 | *** |
| ***Thermal insulation (ref. Well insulate)*** | | | | 55-64 | 0.541 | 0.054 | *** |
| Rather insulates | 1.055 | 0.057 | | 65 + | 0.371 | 0.042 | *** |
| Few insulate | 1.018 | 0.072 | | ***Household size*** (***ref. 1)*** | 1.172 | 0.031 | *** |
| Presence of draught | 1.024 | 0.086 | | ***Number of children (ref. 0)*** | | | |
| ***Year property built (ref. 2000 to 2013)*** | | | | 1 | 0.908 | 0.076 | |
| From 1990 to 1999 | 1.233 | 0.139 | * | 2+ | 0.891 | 0.092 | |
| From 1980 to 1989 | 1.297 | 0.138 | * | ***Educational level (ref. Primary education)*** | | | |
| From 1970 to 1979 | 1.109 | 0.117 | | Secondary education | 0.643 | 0.042 | *** |
| From 1960 to 1969 | 1.016 | 0.112 | | Tertiary education | 0.408 | 0.038 | *** |
| From 1950 to 1959 | 0.873 | 0.106 | | **Gender** | | | |
| From 1900 to 1949 | 1.004 | 0.118 | | Male | 0.96 | 0.046 | |
| Before 1900 | 1.445 | 0.19 | *** | ***Occupational Status (ref. Employed)*** | | | |
| ***Area of residence (ref. Metropolitan area)*** | | | | Self-employed | 1.268 | 0.114 | ** |
| Urban area | 1.079 | 0.12 | | Not in labour force | 1.072 | 0.115 | |
| Mountain municipalities | 3.763 | 0.352 | *** | Job seekers | 1.261 | 0.087 | *** |
| No Mountain municipalities | 2.273 | 0.217 | *** | Constant | 0.024 | 0.005 | *** |

*Source: Authors elaboration from HEC 2013 Survey*
*Notes: * Indicates significant at 10% level, ** Indicates significant at 5% level, *** Indicates significant at 1% level*

Results confirm that the area of residence is a relevant contextual factor that influences the choice of space heating. Moreover, households living in mountain municipalities are more likely to choose renewable energy sources for heating purposes (OR equal to 3.76).

### 5.2. Factors influencing energy efficiency RI in the Italian residential sector

With the aim of identifying the factors that increase the probability of making RI, we estimated the MNL model specified by Eq. (1). A stringent assumption of MNL model is that outcome categories for the model have the property of independence of irrelevant alternatives (IIA). This assumption requires that the inclusion or exclusion of categories does not affect the relative risks associated with the regressors in the remaining categories. In order to test if the assumption of IIA is violated, we carried out the Hausman-Mc Fadden (HM) test (Hausman and McFadden, 1984). The estimated $\chi^2$ and p-values ($\chi^2 = 0.18\ and\ p - value = 1.000$; $\chi^2 = 15.52$ and $p -$ value $= 1.000$) results reveal strong evidence that we cannot reject the null hypothesis. Table 2 reports the estimation results of the MNL model which shows a good overall fit (McKelvey and Zavoina's $R^2$: 0.107; Count $R^2$: 0.241; Hosmer–Lemeshow Goodness-of-Fit Test: v2(16) = 23.03; p = 0.113). The estimates, obtained by using STATA 14, are presented referring to the RRR that is, $e^{\boldsymbol{\beta}_{jr}}$ which gives the proportional change in the relative risk of choosing alternative j rather than alternative 1 when $x_{ir}$ change by one unit (Cameron and Trivedi, 2009). We account for potential endogeneity of energy expenditures by conducting the Smith and Blundell (1986) and Baum et al. (2003) statistical tests for limited dependent variable models. The Chi-squared=2.05 with p-value=0.152 suggests to accept the null hypothesis in which the model is appropriately specified with all explanatory variables as exogenous.

As reported in Section 2, the demographic and socio-economic household characteristics proved to be strictly related to the Italian household propensity to make RI. Among household socio-economic characteristics, as shown by Nair et al. (2010) respondents' age and education are found to significantly influence the likelihood of making RI. Our results suggest that families with 35–44 year old householder have higher RRR to "surely make RI" compared to younger generations. On the contrary older people (65+) show a lower RRR. Moreover, a significant positive association is observed for educational level: householder who obtained tertiary education are more likely to surely make RI than householder who obtained primary education level (RRR=1.785). Higher education may be associated with higher environmental awareness and energy saving measures (Mills and Schleich, 2009). The higher number of family members the higher the probability of almost certainly make RI compared to households who do not make RI (RRR=1.247).

Among behavioural factors, householder who know the certification on energy efficiency are more likely to make RI (RRR=1.9653 and RRR=1.163). This finding suggests that householder may be motivated to adopt RI to increase the market value of the dwelling (Gram-Hanssen et al., 2007, Popescu et al., 2013).

**Table 2.** Results for adopting a RI measures based on MLP model

| | ***Householder will surely make RI*** | | | ***Householder is almost certain to make RI*** | | |
|---|---|---|---|---|---|---|
| | RRR | Se | sig | RRR | Se | sig |
| ***Previous cash investments (ref.no)*** | | | | | | |
| Boiler replacement | 1.677 | 0.189 | *** | 1.165 | 0.09 | ** |
| Replacement of single devices | 1.896 | 0.565 | ** | 0.894 | 0.178 | |
| Installation of renewable energy system | 1.523 | 0.473 | | 0.766 | 0.162 | |
| Refurbishment of the distribution system | 1.929 | 0.555 | ** | 1.2 | 0.261 | |
| Application of thermostats or valves | 1.404 | 0.344 | | 1.819 | 0.289 | *** |
| Thermal insulation | 2.145 | 0.407 | *** | 1.208 | 0.176 | |
| Replacement of doors, windows, fixtures | 1.597 | 0.139 | *** | 1.106 | 0.071 | |
| ***Dwelling type (ref. Detached, single Household)*** | | | | | | |
| Detached, multi households | 1.362 | 0.167 | ** | 1.115 | 0.091 | |
| Apartments (Less than 10) | 1.663 | 0.397 | ** | 1.011 | 0.159 | |
| Apartments (10 or more) | 1.863 | 0.48 | ** | 0.999 | 0.17 | |

| | | | | | | |
|---|---|---|---|---|---|---|
| ***Type of heating system (ref. Centralized)*** | | | | | | |
| Autonomous | 0.477 | 0.115 | *** | 1.239 | 0.198 | |
| ***Use of heating system during winter season (ref. Every days)*** | | | | | | |
| Once a week | 1.28 | 0.164 | * | 1.021 | 0.083 | |
| ***N.ro of rooms*** | 1.106 | 0.027 | *** | 0.995 | 0.017 | |
| ***Type of construction material (ref. Concrete)*** | | | | | | |
| Stone | 1.041 | 0.1 | | 1.044 | 0.063 | |
| Briks | 1.113 | 0.077 | | 1.047 | 0.046 | |
| Wood | 0.665 | 0.159 | * | 0.915 | 0.104 | |
| ***N.ro of rooms*** | 1.049 | 0.028 | * | 0.974 | 0.018 | |
| ***Thermal insulation (ref. Well insulate)*** | | | | | | |
| Rather insulates | 1.804 | 0.134 | *** | 1.889 | 0.089 | *** |
| Few insulate | 3.521 | 0.314 | *** | 3.96 | 0.225 | *** |
| Presence of draught | 4.327 | 0.466 | *** | 4.908 | 0.323 | *** |
| ***Year property built (ref. 2000 to 2013)*** | | | | | | |
| From 1990 to 1999 | 1.093 | 0.221 | | 1.657 | 0.22 | *** |
| From 1980 to 1989 | 1.408 | 0.294 | | 1.703 | 0.236 | *** |
| From 1970 to 1979 | 1.321 | 0.256 | | 1.886 | 0.239 | *** |
| From 1960 to 1969 | 1.452 | 0.285 | * | 1.794 | 0.23 | *** |
| From 1950 to 1959 | 1.557 | 0.286 | ** | 1.744 | 0.205 | *** |
| From 1900 to 1949 | 1.29 | 0.242 | | 1.512 | 0.181 | *** |
| Before 1900 | 1.453 | 0.311 | * | 1.796 | 0.251 | *** |
| ***Area of residence (ref. Metropolitan area)*** | | | | | | |
| Urban area | 1.076 | 0.114 | | 0.936 | 0.062 | |
| Mountain municipalities | 0.654 | 0.099 | *** | 0.996 | 0.098 | |
| No Mountain municipalities | 0.81 | 0.092 | * | 0.995 | 0.071 | |

| | RRR | Se | sig | RRR | Se | sig |
|---|---|---|---|---|---|---|
| ***Regions (Ref. Lazio)*** | | | | | | |
| Piemonte | 1.012 | 0.173 | | 0.946 | 0.104 | |
| Valle d'Aosta | 0.139 | 0.084 | *** | 1.06 | 0.426 | |
| Lombardia | 1.552 | 0.331 | ** | 0.825 | 0.116 | |
| Trentino Alto Adige | 0.517 | 0.121 | *** | 0.904 | 0.141 | |
| Veneto | 0.77 | 0.137 | | 1.065 | 0.116 | |
| Friuli Venezia Giulia | 0.863 | 0.162 | | 1.003 | 0.122 | |
| Liguria | 0.717 | 0.138 | * | 0.838 | 0.101 | |
| Emilia Romagna | 1.458 | 0.346 | | 0.795 | 0.124 | |
| Toscana | 0.985 | 0.173 | | 0.983 | 0.109 | |
| Umbria | 1.185 | 0.243 | | 1.026 | 0.135 | |
| Marche | 0.951 | 0.227 | | 1.042 | 0.147 | |
| Abruzzo | 3.779 | 1.532 | *** | 0.981 | 0.266 | |
| Molise | 2.768 | 1.174 | ** | 0.928 | 0.258 | |
| Campania | 0.43 | 0.105 | *** | 1.051 | 0.162 | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Puglia | 0.997 | 0.204 | | 0.786 | 0.101 | |
| Basilicata | 2.831 | 1.238 | ** | 1.011 | 0.287 | |
| Calabria | 0.845 | 0.169 | | 0.956 | 0.118 | |
| Sicilia | 0.704 | 0.134 | * | 0.781 | 0.099 | ** |
| Sardegna | 0.138 | 0.079 | *** | 1.295 | 0.491 | |
| ***Age (ref. 15-34)*** | | | | | | |
| ***35-44*** | 0.918 | 0.095 | | 1.209 | 0.088 | *** |
| 45-54 | 0.731 | 0.093 | ** | 1.163 | 0.102 | * |
| 55-64 | 0.698 | 0.095 | *** | 1.181 | 0.106 | * |
| 65 + | 0.386 | 0.067 | *** | 0.963 | 0.101 | |
| ***Household size*** | 1.247 | 0.155 | * | 1.139 | 0.088 | * |
| ***Number of children (ref. 0)*** | | | | | | |
| 1 | 0.945 | 0.103 | | 1.023 | 0.079 | |
| 2 + | 0.751 | 0.123 | * | 1.006 | 0.117 | |
| ***Educational level (ref. Primary education)*** | | | | | | |
| Secondary education | 1.522 | 0.189 | *** | 1.025 | 0.064 | |
| Tertiary education | 1.785 | 0.249 | *** | 0.838 | 0.066 | ** |
| ***Gender*** | | | | | | |
| Male | 1.104 | 0.071 | | 0.912 | 0.038 | * |
| ***Occupational Status (ref. Employed)*** | | | | | | |
| Self-employed | 0.977 | 0.101 | | 1.058 | 0.082 | |
| Not in labour force | 0.691 | 0.104 | ** | 1.092 | 0.098 | |
| Job seekers | 0.819 | 0.072 | ** | 0.946 | 0.055 | |
| ***Knowledge of certification on energy efficiency*** | 1.965 | 0.123 | *** | 1.163 | 0.046 | *** |
| ***Change of supplier due to cost reduction*** | 0.785 | 0.050 | *** | 0.801 | 0.033 | *** |
| ***Thermostats or valves (ref. no)*** | 0.953 | 0.066 | | 0.859 | 0.037 | *** |
| ***Wood and biomass expenditure*** | 1.001 | 0.022 | | 1.005 | 0.027 | |
| ***Oil and GLP expenditure*** | 1.002 | 0.015 | *** | 1.007 | 0.015 | * |
| ***Gas expenditure (ref. 1st quartile)*** | | | | | | |
| 2nd quartile | 0.799 | 0.081 | ** | 0.886 | 0.055 | * |
| 3rd quartile | 0.901 | 0.084 | | 1.022 | 0.060 | |
| 4th quartile | 1.168 | 0.115 | | 1.179 | 0.077 | * |
| ***Electricity expenditure*** | | | | | | |
| 2nd quartile | 0.991 | 0.086 | | 1.013 | 0.052 | |
| 3rd quartile | 1.004 | 0.092 | | 0.978 | 0.055 | |
| 4th quartile | 1.058 | 0.090 | * | 1.031 | 0.060 | |
| ***Constant*** | 2.371 | 3.462 | | 0.09 | 0.088 | ** |

*Source: Authors elaboration from HEC 2013 Survey*
*Notes: * Indicates significant at 10% level, ** Indicates significant at 5% level, *** Indicates significant at 1% level*

Regarding dwelling characteristics, having an autonomous heating system positively influence the likelihood of almost certainly making RI compared to households with a centralized heating system (RRR=1.239). Moreover, who lives in detached or semi-detached dwellings are more likely to almost certainly make RI; in this case, an obstacle for people who lives in apartment is the need for agreement on retrofit among the condominium residents. The disagreement may be caused by the different socio-economic conditions of the condominium residents.

Turning to the building characteristics, the period of construction and number of rooms are found to significantly affect the probability to surely and almost certainly make RI. Regarding the age of the building, families living in dwellings built from the year 2000 onward, are less likely to almost certainly make RI. Indeed, the older the building are, the probability to almost certainly make RI increase. Regarding thermal insulation, the lower is the level of insulation the higher is the probability to make RI thus confirming the results obtained by Stieß and Dunkelberg (2013). A higher probability is observed for the presence of draughts (RRR=4.327 and RRR=4.908). Among economic factors, households with gas expenditure in the fourth expenditure quartile are more likely to adopt RI (RRR=1.179). Similar results are obtained for oil and GLP expenditure.

## 6. Conclusion and Policy Implications

The reduction of green gas emissions from residential heating plays a crucial role in the transition towards a more sustainable energy system. Besides lowering the energy needs of existing homes by improving their energy efficiency, the adoption of renewable-based RHS and the household propensity to retrofitting offer the potential to reduce residential CO2 emissions while allowing a reduction of household energy expenditure. Therefore, understanding the determinants of the householders' RHS and retrofit adoption decision becomes increasingly important.

This paper contributes to the literature on the analysis of these two aspects of decision making with respect to heating system upgrades in Italian households using for the first time the 2013 Italian HEC survey data: the choice of using renewable energies for space heating and decision to invest in energy RI.

By using detailed information regarding energy consumption in the residential sector for different energy uses and sources, we adopt a two-step empirical strategy. In the first step we analyse the factors affecting household propensity to adopt renewable heating technologies; in the second step, we examine the drivers influencing household intention to adopt energy upgrading measures. Many of the variables concerning the socio-economic characteristics of households and the characteristics of the dwellings proved to be important determinants of both the probability to adopt a renewable energy source and the probability of making RI.

Firstly, our research shows that there are different drivers behind the householder decision to adopt a renewable-based RHS. We show that educational level, having done previous investments, the heating system intensity of use and its maintenance are key drivers to switching to a renewable RHS.

Secondly, our findings demonstrate that higher education level and younger age positively affects the probability of surely make RI. Among behavioural factors, the knowledge of certification on energy efficiency positively affects the probability of surely making RI thus confirming that energy RI are perceived by households as a long-term advantage. Regarding the dwelling characteristics, there is evidence that households living in detached houses are more likely to invest in RI than household living in apartments. A high level of heterogeneity is found across the Italian regions, thus confirming previous findings.

Our findings may have several policy implications for local governments which may use this information for designing targeted policy instruments such as information and awareness campaigns on renewable sources. Policies aimed at reducing energy consumption or promoting RI should be more tailored to suit the heterogeneity of households especially at regional level. An effective tool for motivating the adoption of RI may be to promote the knowledge of certification among consumers and households to increase conscious awareness in consumer behaviour.

In order to improve energy performance of existing buildings, a significant number of policies has been carried out in Italy, including *Ecobonus* and *Conto Termico*, which are very useful to help consumers saving energy using renewable sources. Unfortunately, the design and implementation of buildings energy requalification policies are complex processes involving many decision variables and actors, including factors mainly related to socio-economic characteristics of the household, buildings' characteristics and economic factors. An effective long-term policy could be an upgrading of residential buildings built before 1970 in the absence of specific regulations regarding energy efficiency. Most low-income households reside in poor quality homes, often not owned, so they do not have the opportunity to directly adopt energy efficiency retrofits. Moreover, most households could not effort these kinds of investments and may do not have access to credit, which constitutes a strong barrier for adopting renewable-based and energy saving RHS. Further research is needed to disentangle the source of regional variability by also considering household income level.

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## Appendix

**Table A1.** Fuel choice by region

| Regions | Gas | Oil and GLP[4] | Electricity | Renewable energy sources | Total |
|---|---|---|---|---|---|
| Piemonte | 71.38 | 8.46 | 1.31 | 18.85 | 100 |
| Valle d'Aosta | 32.16 | 43.61 | 1.47 | 22.76 | 100 |
| Lombardia | 86.13 | 4.96 | 1.06 | 7.85 | 100 |
| Trentino Alto Adige | 51.25 | 16.99 | 1.67 | 30.08 | 100 |
| Veneto | 72.32 | 8.01 | 1.31 | 18.36 | 100 |
| Friuli Venezia Giulia | 68.5 | 9.12 | 0.5 | 21.88 | 100 |
| Liguria | 77.36 | 8.87 | 1.98 | 11.79 | 100 |
| Emilia Romagna | 86.09 | 4.49 | 0.7 | 8.71 | 100 |
| Toscana | 77.16 | 7.99 | 1.52 | 13.32 | 100 |
| Umbria | 59.58 | 8.72 | 0.79 | 30.91 | 100 |
| Marche | 76.25 | 5.88 | 1.22 | 16.65 | 100 |
| Lazio | 70.09 | 9.29 | 3.5 | 17.11 | 100 |
| Abruzzo | 71.98 | 2.39 | 1.26 | 24.37 | 100 |
| Molise | 68.48 | 3.15 | 1.29 | 27.08 | 100 |
| Campania | 52.78 | 15.48 | 8.3 | 23.44 | 100 |
| Puglia | 76.62 | 7.18 | 3.3 | 12.9 | 100 |
| Basilicata | 66.48 | 2.91 | 2.22 | 28.39 | 100 |
| Calabria | 44.85 | 11.01 | 8.9 | 35.25 | 100 |
| Sicilia | 51.05 | 13.94 | 18.38 | 16.64 | 100 |
| Sardegna | 0 | 41.28 | 15.76 | 42.96 | 100 |
| Total | 64.52 | 11.2 | 3.85 | 20.43 | 100 |
| **Use of Renewable energy sources** | **Gas** | **Oil and GLP** | **Electricity** | **Renewable energy sources** | **Total** |
| Yes | 29.4 | 10.78 | 1.54 | 58.28 | 100 |
| No | 83.48 | 11.43 | 5.1 | 0 | 100 |
| Total | 64.52 | 11.2 | 3.85 | 20.43 | 100 |

Source: Authors elaboration on HEC survey 2013

[4] Gas Liquid Petroleum.

**Table A.2.** Households Energy saving behavior by region

| | household's intentions on energy efficient retrofit investments | | | | household's previous cash energy efficient retrofit investments | | |
|---|---|---|---|---|---|---|---|
| Region | He/She surely will make RI | He/She almost certainly make RI | He/She does not make RI | Total | No | Yes | Total |
| Piemonte | 8.92 | 23.9 | 67.18 | 100 | 73.82 | 26.18 | 100 |
| Valle d'Aosta | 11.25 | 25.75 | 63 | 100 | 73.17 | 26.83 | 100 |
| Lombardia | 7.45 | 22.19 | 70.36 | 100 | 74.62 | 25.38 | 100 |
| Trentino Alto Adige | 8.53 | 21.12 | 70.35 | 100 | 72.81 | 27.19 | 100 |
| Veneto | 6.46 | 25.83 | 67.71 | 100 | 77.81 | 22.19 | 100 |
| Friuli Venezia Giulia | 8.61 | 23.12 | 68.27 | 100 | 76.88 | 23.12 | 100 |
| Liguria | 7.23 | 20.56 | 72.2 | 100 | 73.91 | 26.09 | 100 |
| Emilia Romagna | 6.47 | 21.83 | 71.7 | 100 | 77.07 | 22.93 | 100 |
| Toscana | 8.28 | 27.61 | 64.11 | 100 | 78.6 | 21.4 | 100 |
| Umbria | 8.11 | 24.22 | 67.67 | 100 | 78.79 | 21.21 | 100 |
| Marche | 5.63 | 25.2 | 69.17 | 100 | 79.09 | 20.91 | 100 |
| Lazio | 7.73 | 21.7 | 70.57 | 100 | 79.56 | 20.44 | 100 |
| Abruzzo | 8.48 | 25.41 | 66.11 | 100 | 82.07 | 17.93 | 100 |
| Molise | 4.82 | 26.58 | 68.6 | 100 | 81.93 | 18.07 | 100 |
| Campania | 6.15 | 26.09 | 67.76 | 100 | 83.08 | 16.92 | 100 |
| Puglia | 4.99 | 21.12 | 73.9 | 100 | 83.59 | 16.41 | 100 |
| Basilicata | 4.71 | 31.34 | 63.95 | 100 | 81.62 | 18.38 | 100 |
| Calabria | 4.33 | 25.84 | 69.83 | 100 | 82.18 | 17.82 | 100 |
| Sicilia | 6.05 | 23.8 | 70.15 | 100 | 86.6 | 13.4 | 100 |
| Sardegna | 6.51 | 32.86 | 60.63 | 100 | 78.08 | 21.92 | 100 |
| Total | 7.73 | 24.66 | 67.61 | 100 | 78.61 | 21.39 | 100 |

Source: Authors elaboration on HEC survey 2013

**Table A.3**. Household decision to invest in energy efficiency by region

| | Household's intentions on energy efficient retrofit investments | | | | Household's previous cash energy efficient retrofit investments | | |
|---|---|---|---|---|---|---|---|
| Region | He/She surely will makes RI | He/She almost certainly makes RI | He/She does not make RI | Total | No | Yes | Total |
| Piemonte | 8.92 | 23.9 | 67.18 | 100 | 73.82 | 26.18 | 100 |
| Valle d'Aosta | 11.25 | 25.75 | 63 | 100 | 73.17 | 26.83 | 100 |
| Lombardia | 7.45 | 22.19 | 70.36 | 100 | 74.62 | 25.38 | 100 |
| Trentino Alto Adige | 8.53 | 21.12 | 70.35 | 100 | 72.81 | 27.19 | 100 |
| Veneto | 6.46 | 25.83 | 67.71 | 100 | 77.81 | 22.19 | 100 |
| Friuli Venezia Giulia | 8.61 | 23.12 | 68.27 | 100 | 76.88 | 23.12 | 100 |
| Liguria | 7.23 | 20.56 | 72.2 | 100 | 73.91 | 26.09 | 100 |
| Emilia Romagna | 6.47 | 21.83 | 71.7 | 100 | 77.07 | 22.93 | 100 |
| Toscana | 8.28 | 27.61 | 64.11 | 100 | 78.6 | 21.4 | 100 |
| Umbria | 8.11 | 24.22 | 67.67 | 100 | 78.79 | 21.21 | 100 |
| Marche | 5.63 | 25.2 | 69.17 | 100 | 79.09 | 20.91 | 100 |
| Lazio | 7.73 | 21.7 | 70.57 | 100 | 79.56 | 20.44 | 100 |
| Abruzzo | 8.48 | 25.41 | 66.11 | 100 | 82.07 | 17.93 | 100 |
| Molise | 4.82 | 26.58 | 68.6 | 100 | 81.93 | 18.07 | 100 |
| Campania | 6.15 | 26.09 | 67.76 | 100 | 83.08 | 16.92 | 100 |
| Puglia | 4.99 | 21.12 | 73.9 | 100 | 83.59 | 16.41 | 100 |
| Basilicata | 4.71 | 31.34 | 63.95 | 100 | 81.62 | 18.38 | 100 |
| Calabria | 4.33 | 25.84 | 69.83 | 100 | 82.18 | 17.82 | 100 |
| Sicilia | 6.05 | 23.8 | 70.15 | 100 | 86.6 | 13.4 | 100 |
| Sardegna | 6.51 | 32.86 | 60.63 | 100 | 78.08 | 21.92 | 100 |
| Total | 7.73 | 24.66 | 67.61 | 100 | 78.61 | 21.39 | 100 |

Source: Authors elaboration on HEC survey 2013

**Table A.4.** Estimation results for fuel consumption: Renewable energy sources, Gas, Oil and GLP, Electricity

| | Renewable energy sources | | | Gas | | | Oil and GLP | | | Electricity | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | OR | s.e. | | OR | s.e. | | OR | s.e. | | OR | s.e. | |
| ***Previous cash investments (ref.no)*** | | | | | | | | | | | | |
| Boiler replacement | 0.630 | 0.063 | *** | 1.656 | 0.137 | *** | 0.898 | 0.091 | | 0.453 | 0.149 | ** |
| Replacement of single devices | 2.170 | 0.368 | *** | 0.475 | 0.082 | *** | 0.601 | 0.145 | ** | 2.452 | 0.666 | *** |
| Installation of renewable energy system | 3.541 | 0.593 | *** | 0.277 | 0.051 | *** | 0.578 | 0.140 | ** | 3.227 | 1.072 | *** |
| Refurbishment of the distribution system | 1.569 | 0.400 | * | 0.908 | 0.206 | | 0.783 | 0.250 | | 0.905 | 0.584 | |
| Application of thermostats or valves | 0.614 | 0.163 | * | 1.597 | 0.315 | ** | 1.172 | 0.272 | | 0.770 | 0.461 | |
| Thermal insulation | 0.980 | 0.163 | | 0.959 | 0.141 | | 0.897 | 0.180 | | 2.505 | 0.872 | *** |
| Replacement of doors, windows, fixtures | 1.087 | 0.083 | | 0.971 | 0.065 | | 1.104 | 0.090 | | 0.807 | 0.141 | |
| ***Dwelling type (ref. Detached, single Household)*** | | | | | | | | | | | | |
| Detached, multi households | 0.741 | 0.044 | *** | 1.514 | 0.083 | *** | 0.811 | 0.059 | *** | | | |
| Apartments (Less than 10 apartments) | 0.275 | 0.017 | *** | 4.230 | 0.235 | *** | 0.573 | 0.039 | *** | 1.072 | 0.125 | |
| Apartments (10 or more apartments) | 0.089 | 0.009 | *** | 9.291 | 0.699 | *** | 0.536 | 0.043 | *** | 0.806 | 0.111 | |
| ***Type of heating system (ref. Centralized)*** | | | | | | | | | | | | |
| Autonomous | 2.499 | 0.164 | *** | 0.188 | 0.012 | *** | 1.528 | 0.099 | *** | 7.344 | 0.807 | *** |
| ***Maintenance of equipment (ref. Planned)*** | | | | | | | | | | | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Occasionally | 2.268 | 0.143 | *** | 0.375 | 0.022 | *** | 1.253 | 0.087 | *** | 2.222 | 0.250 | *** |
| No maintenance | 2.805 | 0.210 | *** | 0.264 | 0.019 | *** | 1.222 | 0.098 | ** | 2.090 | 0.254 | *** |
| ***N.ro of hours heating on in a winter day*** | 1.171 | 0.006 | *** | 0.934 | 0.004 | *** | 0.939 | 0.006 | *** | 0.825 | 0.010 | *** |
| ***Type of construction material (ref. Concrete)*** | | | | | | | | | | | | |
| Stone | 1.415 | 0.100 | *** | 0.747 | 0.047 | *** | 0.968 | 0.076 | | 1.124 | 0.150 | |
| Briks | 1.148 | 0.065 | ** | 0.917 | 0.044 | * | 0.977 | 0.057 | | 1.032 | 0.108 | |
| Wood | 1.019 | 0.149 | | 1.071 | 0.130 | | 0.803 | 0.120 | | 1.180 | 0.264 | |
| ***N.ro of rooms*** | 0.961 | 0.018 | ** | 0.985 | 0.017 | | 1.090 | 0.023 | *** | 1.014 | 0.040 | |
| ***Thermal insulation (ref. Well insulate)*** | | | | | | | | | | | | |
| Rather insulates | 1.055 | 0.057 | | 0.988 | 0.046 | | 1.033 | 0.060 | | 0.889 | 0.092 | |
| Few insulate | 1.018 | 0.072 | | 1.016 | 0.063 | | 1.011 | 0.078 | | 0.905 | 0.122 | |
| Presence of draught | 1.024 | 0.086 | | 1.050 | 0.079 | | 0.980 | 0.090 | | 0.803 | 0.119 | |
| ***Year property built (ref. 2000 to 2013)*** | | | | | | | | | | | | |
| From 1990 to 1999 | 1.233 | 0.139 | * | 0.662 | 0.065 | *** | 1.484 | 0.191 | *** | 0.888 | 0.210 | |
| From 1980 to 1989 | 1.297 | 0.138 | * | 0.677 | 0.064 | *** | 1.544 | 0.190 | *** | 0.609 | 0.136 | ** |
| From 1970 to 1979 | 1.109 | 0.117 | | 0.818 | 0.075 | * | 1.428 | 0.174 | *** | 0.603 | 0.130 | * |
| From 1960 to 1969 | 1.016 | 0.112 | | 0.877 | 0.084 | | 1.436 | 0.181 | *** | 0.676 | 0.149 | * |
| From 1950 to 1959 | 0.873 | 0.106 | | 0.960 | 0.100 | | 1.240 | 0.169 | | 0.967 | 0.222 | |
| From 1900 to 1949 | 1.004 | 0.118 | | 0.789 | 0.081 | ** | 1.204 | 0.165 | | 1.196 | 0.275 | |
| Before 1900 | 1.445 | 0.190 | *** | 0.617 | 0.073 | *** | 1.275 | 0.201 | | 0.802 | 0.236 | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Area of residence (ref. Metropolitan area)*** | | | | | | | | | | | | |
| Urban area | 1.079 | 0.120 | | 1.014 | 0.083 | | 0.989 | 0.093 | *** | | | |
| Mountain municipalities | 3.763 | 0.352 | *** | 0.323 | 0.024 | *** | 1.411 | 0.121 | *** | 0.781 | 0.111 | * |
| No Mountain municipalities | 2.273 | 0.217 | *** | 0.534 | 0.040 | *** | 1.199 | 0.102 | ** | 0.873 | 0.113 | |
| ***Regions (Ref. Lazio)*** | | | | | | | | | | | | |
| Piemonte | 0.518 | 0.071 | *** | 1.918 | 0.215 | *** | 0.945 | 0.144 | | 0.484 | 0.153 | * |
| Valle d'Aosta | 0.265 | 0.040 | *** | 0.655 | 0.084 | *** | 6.728 | 0.956 | *** | 0.438 | 0.182 | * |
| Lombardia | 0.217 | 0.031 | *** | 4.102 | 0.462 | *** | 0.561 | 0.087 | *** | 0.407 | 0.121 | *** |
| Trentino Alto Adige | 0.768 | 0.097 | ** | 1.017 | 0.110 | | 1.755 | 0.236 | *** | 0.500 | 0.147 | ** |
| Veneto | 0.504 | 0.068 | *** | 1.704 | 0.193 | *** | 0.887 | 0.137 | | 0.677 | 0.237 | |
| Friuli Venezia Giulia | 0.624 | 0.091 | *** | 1.596 | 0.197 | *** | 0.941 | 0.157 | | 0.231 | 0.125 | ** |
| Liguria | 0.578 | 0.096 | *** | 1.446 | 0.183 | *** | 1.088 | 0.177 | | 0.720 | 0.219 | |
| Emilia Romagna | 0.211 | 0.034 | *** | 4.085 | 0.529 | *** | 0.510 | 0.094 | *** | 0.403 | 0.163 | ** |
| Toscana | 0.447 | 0.067 | *** | 1.919 | 0.231 | *** | 0.862 | 0.136 | | 0.773 | 0.242 | |
| Umbria | 1.105 | 0.157 | | 1.028 | 0.128 | | 0.778 | 0.137 | | 0.374 | 0.185 | ** |
| Marche | 0.660 | 0.100 | *** | 1.560 | 0.200 | *** | 0.636 | 0.118 | ** | 0.774 | 0.292 | |
| Abruzzo | 0.756 | 0.110 | * | 1.789 | 0.228 | *** | 0.236 | 0.061 | *** | 0.918 | 0.344 | |
| Molise | 0.611 | 0.091 | *** | 2.194 | 0.291 | *** | 0.269 | 0.068 | *** | 0.583 | 0.242 | |
| Campania | 0.937 | 0.129 | | 0.501 | 0.056 | *** | 1.590 | 0.214 | *** | 2.132 | 0.446 | *** |
| Puglia | 0.449 | 0.071 | *** | 1.798 | 0.225 | *** | 0.680 | 0.112 | ** | 1.227 | 0.319 | |
| Basilicata | 0.754 | 0.111 | * | 1.703 | 0.223 | *** | 0.257 | 0.066 | *** | 1.202 | 0.392 | |
| Calabria | 1.178 | 0.166 | | 0.600 | 0.075 | *** | 0.929 | 0.147 | | 2.189 | 0.507 | *** |
| Sicilia | 0.216 | 0.036 | *** | 0.812 | 0.093 | * | 1.222 | 0.169 | | 3.878 | 0.771 | *** |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sardegna | 1.351 | 0.184 | ** | - | - | | 5.068 | 0.658 | *** | 2.589 | 0.538 | *** |
| ***Age (ref. 15-34)*** | | | | | | | | | | | | |
| 35-44 | 0.879 | 0.068 | * | 1.004 | 0.069 | | 1.153 | 0.103 | | | | |
| 45-54 | 0.708 | 0.060 | *** | 1.166 | 0.089 | ** | 1.269 | 0.123 | ** | 0.942 | 0.156 | |
| 55-64 | 0.541 | 0.054 | *** | 1.514 | 0.134 | *** | 1.141 | 0.129 | | 0.986 | 0.189 | |
| 65 + | 0.371 | 0.042 | *** | 1.925 | 0.189 | *** | 1.314 | 0.161 | ** | 0.881 | 0.185 | |
| ***Household size** (**ref. 1)*** | 1.172 | 0.031 | *** | 0.929 | 0.022 | *** | 0.945 | 0.027 | * | | | |
| ***Number of children (ref. 0)*** | | | | | | | | | | 0.914 | 0.047 | * |
| 1 | 0.908 | 0.076 | | 1.014 | 0.076 | | 1.119 | 0.107 | | | | |
| 2+ | 0.891 | 0.092 | | 0.916 | 0.085 | | 1.378 | 0.160 | *** | 1.021 | 0.228 | |
| ***Educational level (ref. Primary education)*** | | | | | | | | | | | | |
| Secondary education | 0.643 | 0.042 | *** | 1.375 | 0.079 | *** | 1.164 | 0.085 | ** | | | |
| Tertiary education | 0.408 | 0.038 | *** | 1.997 | 0.157 | *** | 1.130 | 0.109 | | 1.131 | 0.184 | |
| **Gender** | | | | | | | | | | | | |
| Male | 0.960 | 0.046 | | 0.978 | 0.040 | | 1.048 | 0.054 | | 1.109 | 0.102 | |
| ***Occupational Status (ref. Employed)*** | | | | | | | | | | | | |
| Self-employed | 1.268 | 0.114 | ** | 0.820 | 0.065 | * | 0.960 | 0.098 | | 1.216 | 0.264 | |
| Not in labour force | 1.072 | 0.115 | | 0.901 | 0.088 | | 0.879 | 0.110 | | 1.188 | 0.223 | |
| Job seekers | 1.261 | 0.087 | *** | 0.834 | 0.051 | *** | 0.943 | 0.072 | | 1.000 | 0.136 | |
| Constant | 0.024 | 0.005 | *** | 27.219 | 4.979 | *** | 0.052 | 0.012 | *** | 0.008 | 0.003 | *** |

Source: Authors elaboration from HEC 2013 Survey

Notes: * Indicates significant at 10% level, ** Indicates significant at 5% level, *** Indicates significant at 1% level