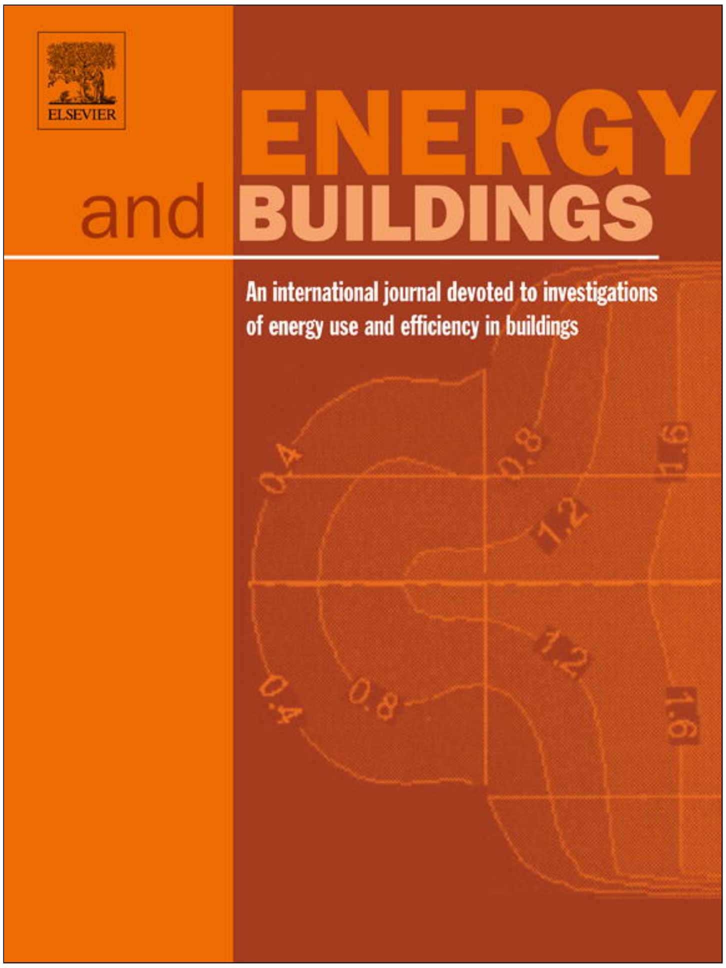
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Financial crisis and energy consumption: A household survey in Greece

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ABSTRACT

This research aims to investigate, analyze and characterize the relation between the economic crisis and energy consumption in Greece. A survey held in the spring and summer of 2012 collected data of the heating energy consumption for 2010–2011 and 2011–2012, from 598 households via a questionnaire. Comparing the 2010–11 winter to the harsher winter of 2011–12 showed that inhabitants consumed less energy during the winter of 2011–12 because of the rapid economic degradation. Important conclusions were drawn regarding the energy consumption of the households which during the harsh winter 2011–12 was 37% less than expected. Cluster analysis rendered two distinct clusters: three fourths of the households belonged to the lower income group that lived in a smaller space, had half the income and consumed more specific energy compared to the high income group, although much less than expected based on the degree hours of the second winter. One out of three higher-income and one out of four lower-income households adopted some conservation measures after the first winter while 2% of the higher income households and 14% of the lower-income households were below the fuel poverty threshold. Directions for further research include monitoring of low income households with sensors.

1. Introduction

It has been asserted that one of the most eminent social problems of the 21st century is fuel poverty, which has been recognized as a distinct form of inequality and an unacceptable feature of the present time [1,2]. It affects the poor and its roots are detected in the quality of the housing stock and the cost of fuel, particularly high in these times of global financial crisis and peak oil. A sufficient standard of warmth is usually identified as 21 °C for the main living area, and 18 °C for other occupied rooms [3]. The fuel poverty ratio (FPR) is identified as

$$\text{Fuel poverty ratio} = \frac{\text{energy consumption} \times \text{price}}{\text{income}}$$

and if it is greater than 0.1, the household is considered to be fuel poor [4]. FPR compares the cost of energy consumption to the income of a household [5] and is an interaction of three factors: the energy efficiency of the household, the cost of energy and the household income [6]. Although FPR does not reflect underlying problems and causes, it is the only indicator that shows both the extent and the depth of fuel poverty.

The term fuel poverty has been used since the early 1980s [7] and was defined by in 1991 as the difficulty or even inability of a family to afford the funds for proper heating at home [2]. Fuel poverty was officially recognized as a problem when the United Kingdom (UK) Minister at the Department of the Environment, Transport and the Regions (DETR) stated that an integrated approach across government to tackle fuel poverty and energy efficiency would be taken and that coherent policies should be produced aiming to go to the heart of the problem [2]. When the Third Energy Package led to the integration of energy poverty, within Directives 2009/72/EC and 2009/73/EC of the European Parliament and of the Council, it was

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the first time energy poverty entered the vocabulary of European Union (EU) institutions [8].

Poverty and fuel poverty are linked, but not synonymous concepts [2]. A vulnerable household is defined as one that contains children, elderly people and persons that are disabled or have a long term illness [2,5]. In the UK, the fuel poor have been categorized into poor households, vulnerable households and households with high energy bills with payment difficulties. Unfortunately, it is difficult to identify fuel poor households because the information needed is never held by one single entity and often cannot be communicated for reasons of privacy [9]. The calculation of fuel poverty is based on annual fuel costs set against annual income. Fuel costs in winter are likely to be more difficult to be paid by poorer households that pay for their gas and electricity using pre-payment meters and quarterly standard credits (compared to those that pay a set monthly amount by direct utility bill). A recent EC Working Paper suggests that those in fuel poverty could be defined as "*households that spend more than a pre-defined threshold share of their overall consumption expenses on energy products*" with the threshold set at "*double of the national average ratio number*" [10,11].

In addition to space heating, fuel-related costs may include spending on energy for water heating, lights, appliances and cooking. Fuel poverty is therefore not based on what a household actually spends on energy. As fuel poverty is a measure of what a household needs to spend on energy rather than what it actually spends, total energy needs are modeled by various factors, including the size and energy efficiency of the property, household size and type and the type of heating [12]. Energy efficiency is very important as it affects the fuel requirement of a household and it is affected by energy efficiency measures [6].

Fuel poverty is primarily a determinant of three household factors: income, energy prices and energy efficiency of dwellings. In most cases the profile of fuel poor people are those who receive social security payments, work part time or are in debt. Unemployment rates, growing job insecurity (part time employment, short-term jobs) lead a lot of people to live below the poverty threshold [4]. Beyond building degradation, fuel poverty translates into physical and mental health issues, e.g. cold temperatures can affect the immune and the cardiovascular system while damp cold houses influence negatively people who suffer from respiratory problems and allergies. A survey conducted among five countries (Belgium, France, Italy, Spain and United Kingdom) analyzed causes and consequences of fuel poverty, helped realize the difficulties faced by the people living in such a situation, and gave the opportunity for reflection on an appropriate strategy to wipe out this phenomenon [13]. At the same time, this study revealed the lack of data and of relevant studies beyond the UK.

Only three out of the 27 EU member states have officially defined fuel poverty. All existing definitions stress the relationship between low income and energy efficiency [14]. According to its most widely accepted definition (UK), a fuel poor household is one that needs to spend more than 10% of its income to achieve adequate energy services in the home [15]. This threshold figure was adopted in an investigation of the problem of affordable warmth by the Energy Report of the 1991 English House Condition Survey (EHCS) [16], an annual survey, commissioned by the Department of Communities and Local Government (CLG), which involves physical inspection of properties by professional surveyors. In April 2008, EHCS merged with the Survey of English Housing (SHE) to create the English Housing Survey [6]. In the UK in particular, because of the prepayment systems, the problem of debt is not as great as in other countries although it is still estimated that around one billion British pounds of debt is owed to energy suppliers by consumers. Unfortunately, the recent rise of energy prices (and further rise expected) will make it more and more difficult for this category of people to pay energy bills [13]. In the UK, fuel poverty is seen as a rights-to-warmth issue and it has become a matter of justice and entitlement to healthy living [17]. In fact, the UK appears to be the only country that has presented policies and scientific programs on fuel poverty, supporting vulnerable households that face inadequate heated homes and health problems [2].

Turning to European countries, the UK is a pioneer on fuel poverty surveys. Fuel poverty in England is researched with the English Housing Survey (EHS); in Scotland, by the Scottish House Condition Survey (SHCS); the Living-in-Wales Survey is used to estimate fuel poverty in Wales; finally, the Northern Ireland House Condition Survey is used to calculate the Northern Ireland fuel poverty levels [6]. There is also the National Ecosystem Assessment (NEA), which is the UK's leading fuel poverty charity campaigning for affordable warmth. Finally, a European project called European Fuel Poverty and Energy Efficiency (EPEE) aims to improve the knowledge of fuel poverty and identify operational mechanisms to fight against this phenomenon [6].

In a survey of energy efficient British households, it was shown that fuel poverty is a complex socio-technical problem that may be explained using a combination of physical, demographic and behavioral characteristics of a residence and its occupants [18]. A Structural Equation Model (SEM) was introduced to calculate the magnitude and significance of explanatory variables on dwelling energy consumption. Using the English House Condition Survey (EHCS) consisting of 2531 unique cases, the main drivers behind residential energy consumption were found to be: number of household occupants, floor area, household income, dwelling efficiency (determined by the Standard Assessment Procedure or SAP), household heating patterns and living room temperature. The number of occupants living in a dwelling was shown to have the largest magnitude of effect, floor area and household income while there is strong mediation between causal variables. Statistical analysis implied that homes with a propensity to consume more energy will be more expensive to decarbonize due to the law of diminishing returns, a finding of concern in the context of global climate change.

In another UK study, strategies of low-income households for coping with limited financial resources and cold homes in the winter months were investigated [19]. The sample of 699 households with an income below 60% of the national median income included in-depth interviews of a subsample of 50 households. Findings showed that the primary strategy adopted by low-income households to cope with financial pressure was to reduce spending, including spending on essentials such as food and fuel. Just below two out of every three (63%) of low-income households had cut their energy consumption in the previous winter and almost half (47%) had experienced cold homes. Very low income households could not afford any heating. For households surviving on very small domestic budgets, it is a sad truth that the extra cash-in-hand could be more attractive than a warmer home.

The Irish government defines fuel poverty as "the inability to afford adequate warmth in a home, or the inability to achieve adequate warmth because of the energy inefficiency of the home". A survey conducted in Ireland noted that existing households needed more fuel than others either because their circumstances imposed that they be heated for longer periods of time or because they were occupied by the elderly or those with very young children so they demanded higher temperatures [20]. Households were investigated based on demographic, educational and socioeconomic variables. A very strong relationship was found between the incidence of fuel poverty and social class. As expected, there was a very strong correlation between fuel poverty and income. Results regarding the severity of fuel poverty by income level were mixed, as they revealed both high- and low-income households suffering from high levels of chronic fuel poverty [21]. Many large families find it difficult to heat their home adequately over time, a troublesome result as health effects of cold and damp exposure are particularly intense among children. It was also found that housing tenure gave households varying levels of control over their home, heating systems and their energy consumption and was identified as an important dynamic of fuel poverty.

In France a person is considered fuel poor "if he/she encounters particular difficulties in his/her accommodation in terms of energy supply related to the satisfaction of elementary needs, this being due to the inadequacy of financial resources or housing conditions" [14]. The first measures targeting low-income fuel-poor households in France, were developed in the middle of 1980s [9]. However, it was only in 2010 that the current fuel poverty policy was instituted. Its basis is a program called *habiter mieux*, which supports the thermal renovation of low income households, which are located in rural areas. The aim was for 300 thousand households to be thermally renovated with financial support from a budget of 750 million euros managed by the National Agency for Habitat Improvement (ANAH). It is noted that a household may benefit from the program *habiter mieux*, if it has a project of thermal renovation that would result in an improvement of at least 25% of its energy efficiency.

A survey of 964 houses in Belgium compared insulated to non-insulated homes [22]. Calculation tools were found to predict heating energy consumption assuming typical dwelling use although this was subjected to physical restrictions and the average temperature in partially heated homes increased with higher insulation quality as expected. An average indoor temperature of 18 °C was considered usual.

In a German survey, Michelsen and Madlener [23] investigated the preferences of home owners for applying improved Residential Heating Systems (RHS) and found incentives for adopting RHS to vary among families. Homes that use gas and oil for heating were found to prefer energy savings whereas the ones using heat pumps or wood pellet fired boilers prefer to be independent of fossil fuels. Analysis of the data also showed that the grant from the Federal Office of Economics and Export Control (*Bundesamt für Wirtschaft und Ausfuhrkontrolle*, BAFA), which would be important for the adoption of RHS, does not play a role in the decision-making process. It was suggested that RHS manufacturers in Germany improve their marketing strategies in order for home owners to take the adoption decision, having in mind not only their behavior but also age, size etc. of their homes. In another German study, Schuler et al. [24] found both technical characteristics of buildings and utilization patterns of households to be essential factors of the demand of space heating of private West-German households. The paper considered that the energy consumption for space heating may vary broadly and depends not only on socio-economic developments but on political actions as well. Such considerations may motivate governments lower the barrier for energy investments and apply policies that provide incentives for insulation of dwellings. Energy consumption related behavior was also targeted by Braun [25] who investigated both East and West German households. Braun asserted that socio-economic characteristics together with building type and region are important determinants of the space heating technology applied. The paper focused on building features such as construction age that was found to play a more important role than home ownership.

In nearby Austria, the NELA project (German acronym for "Sustainable Energy Consumption and Lifestyles in Poor and at-Risk-of-Poverty Households") investigated energy consumption in households in Vienna, Austria [26]. NELA surveyed 50 Viennese households afflicted by poverty and compared them to ten better-off households. The interviews were conducted during the summer of 2009 and the spring of 2010.The results identified four distinct types of households: "the overcharged", "the modest fuel poor" (fuel poor), "the modest non-fuel poor", and the ones "on a low income" (non-fuel poor). Similar classifications were found by a survey conducted in France by Devaliere [27] as quoted by Brunner et al. [26]. It was confirmed that low income households try to cope by adopting various energy conservation measures.

Buzar [28] claims that fuel poverty is apparent in post socialist countries of Eastern and Central Europe and the Former Soviet Union. The author mentions to the "*hidden*" geography of poverty, referring to the lack of heating in the households of these countries. A survey held in FYROM and the Czech Republic showed that low income households are energy poor and areas of energy poverty (called "hidden") appear dull and messy due to specific circumstances of the post-socialist frame of these regions.

Turning to Southern Europe, in Italy, the E-SDOB (Statistical Distribution of Buildings) tried to address heating energy issues by defining the performance scale for energy certification of buildings, and evaluating the building volume falling in different classes [29]. E-SDOB has also been used to evaluate the energy saving potential of large scale retrofit actions on the building envelope. E-SDOB seems to be a useful tool for a better knowledge of the regional building stock as well as the adoption of coherent energy regulations. As the authors point out though, the global overview of the building stock energy performance provided by E-SDOB may provide further insight but it cannot replace specific analyses at a building level when retrofit actions have to be implemented.

In Spain, the Environmental Science Association (*Asociación de Ciencias Ambientales*, ACA) started a project named REPEX aiming to research the relationship between fuel poverty and unemployment. This project claims that fuel poverty in Spain is caused by unemployment and that the renovation of houses, in order to be efficiently heated, could offer employment to workers that lost their jobs because of the financial crisis. However, fuel poverty in Spain is not a first priority issue either to the Spanish Political Parties or to the media [30].

All in all, since fuel poverty lacks an official Europe-wide definition, comparing fuel poverty among European countries is not trivial [5].

A United States (US) survey conducted among families of equal economic status over a 15-year period (1987–2002) during the winter heating season in Seattle, Washington, USA (which has a climate similar to that of the eastern Mediterranean) showed that, regardless of life style, the space heating energy behavior of the tenants remained constant [31]. The results of the survey suggested that estimates of energy savings could be based upon envelope thermal resistance for moderate occupant behavior. For such behavior, space heating was well characterized by the difference between house temperature and outside air temperature. It is encouraging to note that over 15 years in which houses sustained considerable wear and tear as expected of rental properties, the space heating behavior did not change, i.e. the envelope tightness did not seem to degrade and the sensitivities remained constant.

A survey carried out in New Zealand, with houses poorly insulated and rental properties not required to have insulation or heating, showed the inability of many households to afford adequate heating [32]. Three of the main factors included: the poor quality of housing in terms of thermal efficiency; relatively high levels of income inequality compared to other Organization of Economic Cooperation and Development (OECD) countries [33]; and an increase in the real price of residential electricity, which occurred mainly after the deregulation of the industry in 1996 and 1998. Vulnerable population groups particularly those on low income, the old and the young (who are more likely to suffer health consequences) pressured the New Zealand governments to translate research into policy. The problem's antecedents were targeted, including inadequate standards for existing houses, rising income inequality and the need to protect low-income households from the rising price of heating fuels. A suggested policy to face fuel poverty in New

Zealand was prepayment metering as a method to pay for electricity, helping households that faced disconnection and wished to lower their expenditure [34]. As in many areas of Southeaster Europe and Greece, economic difficulties faced by the lower income clusters in New Zealand mean that as both unemployment and fuel poverty will intensify.

An energy conservation survey of 10 Japanese residential buildings, showed that energy-saving consciousness was raised and energy consumption reduced by energy saving activities of the household members [35]. An improved online tool for the registration of energy consumption information revealed that the power consumption of many appliances and the total energy consumption of the household were reduced by 18% and the total city-gas consumption decreased by 9%. Also, savings of 20% in space heating were achieved by residents that switched to more energy saving sources or reduced the duration of space heating.

During the winter of 2003–04, a questionnaire survey was undertaken of more than 200 residential households in the rural fringe of Xian City in China [36]. Fuel consumption, including the use of biomass for cooking and space heating, was investigated; stove types, stove use and characteristics of residents as well as residential houses were also reported and analyzed. The survey aimed to quantify energy consumption, emissions of greenhouse gases and air pollutants in rural areas of China. The survey showed that energy consumption in rural areas in China includes biomass fuel, in particular a mixture of agricultural waste and twigs commonly used for *kang* (a traditional cooking stove), coal and liquefied petroleum gas (LPG). It was proposed that there is a relationship between income level and priority of LPG use and that the energy consumption level of rural households in China remains a subject for further work.

In wrapping up this section, it is added that surveys on fuel poverty during the last decade in Europe have not come up with dramatic changes from year to year [37].

Nowadays, with the global financial crisis, it is suspected that fuel poverty is a substantial problem especially in areas of lower income such as southeastern Europe. Given the dearth of published research on fuel poverty in these areas, this research measures fuel poverty in Greece and investigates the impact of the global financial crisis on the energy consumption of households via a number of questions that look into how various socioeconomic, environmental and consumption variables relate to fuel poverty.

Literature review will be completed with a look into empirical research in Greece, carried out in the next section.

2. Energy consumption and economic situation in Greece: existing research

Turning to investigations in Greece about the specific energy consumption of households and its relation to the economic situation, a 2004 survey held in Athens, collected social, financial, energy and technical data from about 1110 households [38]. These households were divided into seven income groups and a detailed analysis showed that there was an almost direct relationship between income and household area. It was also found that higher income was associated with newer buildings and that almost 64% of the families in the lower income group lived in apartments (the corresponding number for the more affluent group was 48%). Low income families lived mostly in the lower part of multistory buildings while high income households live mainly in the higher part of the buildings. Only 28% of people in the poorest group dwelled in insulated buildings, with the corresponding figure for the richest group being close to 70%. High income families paid almost 160% higher annual costs than the low income ones. Low income households paid nearly 67% higher electricity cost per person and square meter than high income households. Furthermore 1.63% of the households suffered from fuel poverty and 0.35% from severe fuel poverty (2004 values). Fuel poverty in low income groups, was in the region of 16%. Severe fuel poverty, in the low income group, was calculated close to 4%. Concerning energy poverty, the average percentage of the households spending more than 10% of their income for energy was close to 11.3%, while 2% spent more than 20%. Almost 40% of the low income group, called the energy poor, spent more than 10% of their income for energy while almost one fifth of the poor households, called the severely energy poor, spent more than 20% of their income for energy. Fuel and energy poverty reached quite high levels in the low income groups, with a dramatic increase attributed to the fuel prices. It was concluded that energy policies addressed to the dwelling sector should set as a priority the improvement of the envelope quality of residents where low income people are living.

In another study referring mainly to the summer conditions, [39], it was found that low income population in Athens, lives in areas where the heat island is well developed. Recent studies have shown that temperature increase in high density areas suffering from heat island may reach 5–7 K, depending on the local climatic conditions, [40,41]. Higher urban temperatures increase considerably the necessary energy consumption for cooling purposes [42,43], affect thermal comfort conditions, [44] and increase pollution levels [45]. Monitoring of a high number of low income households in Athens during the heat waves of 2007 [46], shown that indoor temperatures as high as 40 °C occurred while the average indoor minimum temperature was always above 28 °C.

A study of a typical multi-family Greek building in 2007 compared commonly used heating sources (including oil), natural gas and autonomous systems [47]. The cost distribution of central heating was determined to favor penthouses over apartments in intermediate floors, possibly failing to motivate some occupants to promote energy conservation while at the same time not providing motivation for superior insulation of the roof of a building. The authors asserted that the use of electrically driven heat pumps can be a very good solution for heating Greek buildings, since (at the time of writing) they were in some cases equally expensive to other fuels. It was also suggested that the increased potential of renewable energy sources in electricity generation (mainly wind power) might also be improved. The authors expected the rationalization of electricity tariffs to enable the installation and use of heat pumps as central heating systems, increasing in turn their market infiltration.

Sardianou [48] highlighted the use of statistical models in determining domestic consumption of Greek households. The results of the survey held in 2003 in Greece, unveiled that various characteristics such as the number of persons in a household, the type of the building and the ownership status, influence the domestic demand for heating. Findings confirmed that there is a relationship between household annual income and annual fuel consumption while there were already (back then) households that had decreased their heating consumption in view of increasing oil prices.

Finally, according to the most recent opinion survey of fuel poverty in Greece [49], the median specific energy consumption of buildings in Athens was found to equal 29 kWh per cubic meter, greater (the author asserted) than that of other countries with more adverse weather conditions such as Denmark, Germany and the Netherlands. Fuel poverty was calculated with three different methods based on (a) the proportion of energy expenditures of a household, (b) the opinion of residents on their energy coverage and (c) the condition and conveniences of the household. From 1988 to 1997 Greece was found to have a seasonal rate of mortality of 18%, which ranked it at a position higher than that of other countries with heavier winters. Panas refers to the relation between the inadequate heating of households and the increased mortality rate during the winter season. However, through a recent questionnaire survey in northern Greece conducted in November of 2012, 814 people were asked whether they paid more than 10% of their annual income for heating (it is noted that this is a subjective method of documenting fuel poverty). According to the survey, respondents declared their inability to pay the heating bills and their fear for consequences of the current economic crisis in the future, supporting the notion that Greek households are not presently energy efficient.

Important research has been carried out to develop and propose proper mitigation and adaptation techniques to improve the environmental performance of low income households [50,51]. Applications in real scale projects showed that it is possible to improve considerably the environmental quality of buildings and open spaces, decrease the energy consumption and improve the quality of life of low income citizens [52].

3. Methodology

3.1. Research questions

A number of key research questions are gleaned from the literature and are listed below:

1. How do building characteristics and socioeconomic data relate to fuel poverty?
2. In particular, how does family income impact fuel poverty?
3. How do different heating sources relate to fuel poverty? Fuel poor cannot afford relatively expensive high fuel such as electricity, natural gas and liquid petroleum.
4. How are heating hours and other measures of energy use related to fuel poverty? Fuel poor households try to curb energy consumption by reducing their heating hours oftentimes irrespective of climatic conditions.
5. What conservation measures are usually taken by households in order to combat energy consumption and fuel poverty in a time of falling incomes? Such measures may depend on factors such as household size, heating sources and energy efficiency.
6. What are typical values of specific energy consumption measured in kWh per m^2? It is noted that electricity prices for household consumers should not exceed 0.10 euros per kWh in order to be considered affordable [53].
7. Are households typically clustered into groups that indicate social class? How big a role is played by annual family income and the type of family, i.e. number of children, senior citizens, members or with disabilities? What percentage of each cluster is fuel poor?
8. What policies and measures have been adopted especially in Southern East Europe and the Mediterranean? This question will be partially addressed as results are synthesized into conclusions.

To answer many of these questions, a survey was carried out in this work as explained below.

3.2. Survey

This survey focused on Greece, covering a wide variety of bioclimatic types. The survey was done in the spring and summer of 2012. A total of 598 households were polled with a questionnaire and data were gathered for the winter of 2010–11 (milder) and the winter of 2011–12 (harsher). The climatic conditions that prevailed over Greece during the two successive winters of 2010–2011 and 2001–2012 were remarkably different. Winter 2010–2011 ranks among the warmest winters on record in Greece according to the historical archives of the National Observatory of Athens, dating back to 19th century. In particular, winter 2010–2011 was the 3rd warmest on record with a maximum temperature averaging 16.6 °C from November to February, 2 °C above normal (with respect to the 1961–1990 period) for the 4-month period. It is notable that November 2010 was the second warmest recorded ever. On the contrary, winter 2011–2012 ranks among the 15% of coldest winters on record, with maximum and minimum temperatures averaging 13.5 °C and 6.6 °C respectively from November to February, approximately 3 °C lower than the corresponding temperatures of winter 2010–2011. It is also remarkable that November 2011 ranks among the 5 coldest on record.

The data were collected either by live interview of members of the household (adhering completely to the questionnaire) or by e-mailing the questionnaire. A follow-up by telephone of the households was carried out in order to confirm that collected data were correct; these households were selected from the sample systematically so as to cover both data collection modes and all personnel that collected data in the field.

Data were inspected for outliers; some rather large income values were located but none so large as to warrant exclusion from the data set. For buildings that were renovated, the renovation year was used to estimate the age of the buildings. As regards insulation, it is noted that buildings constructed: prior to 1980 lack insulation; from 1980 to 1990 have some ("flexible") insulation; and after 1990 are properly insulated.

A question relates to the energy consumption of apartments (as opposed to that of detached houses): does the reported energy consumption of households that live in apartments represent the energy consumption of the apartment or the entire apartment building? In many cases energy consumption was reported in monetary terms and, thus, represented correctly the energy consumption of the household.

4. Results

Variable names and selected descriptive statistics are shown in Table 1.

The sample comprised 598 households that were located in a wide variety of geographical regions and bioclimatic types of Greece, including: Attica, Crete, parts of Peloponnese and the Cyclades islands (intense thermo-Mediterranean); Mainland Greece (weak to intense Thermo-Mediterranean); Thessaly (weak to intense meso-Mediterranean); Macedonia (i.e. northern Greece, sub-Mediterranean); and other local bioclimatic types in Peloponnese (weak to intense meso-Mediterranean, intense thermo-Mediterranean).

Most households were located in Athens and Attica (78.4%) with a 10.2% in Crete and a 9.7% in Peloponnese. Greek Macedonia and the rest of Northern Greece were underrepresented, something that may be addressed in a future work.

4.1. Descriptive analysis

Of the 598 households that were surveyed, three-fourths (452, i.e. 75.6% if the total) lived in apartments with the rest one-fourth (146, i.e. 24.4% of the total) living in detached houses. Buildings were constructed (or renovated) from 1900 to 2010, i.e. building age varied from 2 to 112 years with an average value of 28.6 years; age distribution is shown in Fig. 1 and shows two peaks corresponding to periods of pronounced building activity fueled by economic growth (circa 1980 and 2000).

On the average, detached houses (31.3 years of age) were a little older than apartments (27.8 years). Surface area varied from 25 to 252 m^2 for apartments and from 50 to 400 for detached houses. The average surface area of apartments equaled 88.7 m^2; for detached

Table 1
Basic statistics for quantitative variables.

Variable name		Min	Max	Mean	Mode
DEGRDAYRATIO	Degree days ratio of area of household	1.26473	1.40310	1.35606	1.34897 (n = 469)
Q3MEMBERS	Number of persons in household	1	8	2.99497	4 (n = 180)
Q4M2	Household surface area (m^2)	25	400	96.4573	120 (n = 56)
Q5RENAGE	Building age since construction of last renovation (years)	2	112	28.6173	32 (n = 53)
Q7FLOOR	Household floor (if apartment)	−0.5	12	–	1 (n = 136)
Q9SALAR09	2009 income (euros)	0	200,000	26,221	30,000 (n = 38)
Q10SALAR10	2010 income (euros)	0	200,000	24,900.2	
Q11SALAR11	2011 income (euros)	0	200,000	22,497.8	10,000 (n = 34)
Q12OIL	Heating oil dummy variable	0 (n = 131)	1 (n = 465)		1
Q13GAS	Natural gas dummy variable	0 (n = 519)	1 (n = 63)		0
Q14AC	Air conditioning dummy variable	0 (n = 193)	1 (n = 405)		1
Q16BTU	Installed air conditioning (BTUs)	6000	84,000	25,390.1	9000.0 (n = 52)
Q18HOUR	Hours of operation of air conditioning	0.140	24	3.89724	2 (n = 61)
Q31CONSERV	Conservation measures dummy	0 (n = 386)	1 (n = 196)		0 (n = 386)
FUELPOVRAT1	Fuel poverty ratio (winter 2010–11)	0.0015	0.6	0.051171	0.05
FUELPOOR1	Fuel poor dummy (winter 2010–11)	0 (n = 415, 88.9%)	1 (n = 52, 11.1%)		0
FUELPOVRAT2	Fuel poverty ratio (winter 2011–12)	0.001	0.666667	0.0550866	0.0333333
FUELPOOR2	Fuel poor dummy(winter 2011–12)	0 (n = 399, 88.3%)	1 (n = 53, 11.7%)		0
Q48HEATHRS1	Hours of heating (winter 2010–11)	0.570	24	6.90073	4 (n = 83)
Q49HEATHRS2	Hours of heating (winter 2011–12)	0.570	24	5.92486	4 (n = 86)
KWHM2TOTAL1	Actual specific energy consumption (kWh/m^2, winter 2010–11)	0.0351695	882.793	134.034	82.1642 (n = 8)
KWHM2TOTAL2	Actual specific energy consumption (kWh/m^2, winter 2011–12)	0.0351695	676.798	114.172	90.1362 (n = 7)
KWHM2DEGRD	Specific energy consumption based on degree days (kWh/m^2, winter 2010–11)	0.0474425	1190.86	182.404	110.837 (n = 6)

houses it equaled 120.5 m^2. The mode (i.e. most frequent value) of surface area was equal to 120 m^2 for both subsets i.e. apartments and detached houses (and was valid for a total of 56 households). The median floor for apartments was 2 with a mode of one (valid for 136 apartments). Households had one to 8 members, with an average household size of 3.5 (and mode of 4) in the case of detached houses and an average of 2.8 (with a mode of 2) in the case of apartments. These figures corresponded to an average of 37 m^2 per household member (and a mode of 30 m^2 which was valid for 50 households) with no difference between apartments and detached houses.

The effect of the global financial crisis and resulting austerity measures in Greece is depicted in the average household income that was reduced from 26,221 euros (2009), to 24,900 euros (2010) and 22,498 euros (2011), a total reduction of 14%. Changes in the distribution of annual household income are shown in Fig. 2.

Household income changes were different across income classes as shown in Table 2.

Interestingly, the lowest income class gained about a fourth of its 2009 income probably because more household members joined the work force due to the worsening economic conditions. All other classes lost 12.7–31% of their 2009 income.

Looking at heating sources for the (colder) winter of 2011–12, it was found that: 18 households (3.1% of the total) did not use oil, natural gas or air conditioning; 141 households (24.3%, i.e. about one in four) were heated with oil alone; 29 households (5%, i.e. one in twenty) used only natural gas; and 51 households (8.8%) employed only air conditioning. Turning to mixtures of energy sources, it was found that: 309 households (53.2% of the total) were heated with oil and air conditioning; natural gas with air conditioning was by

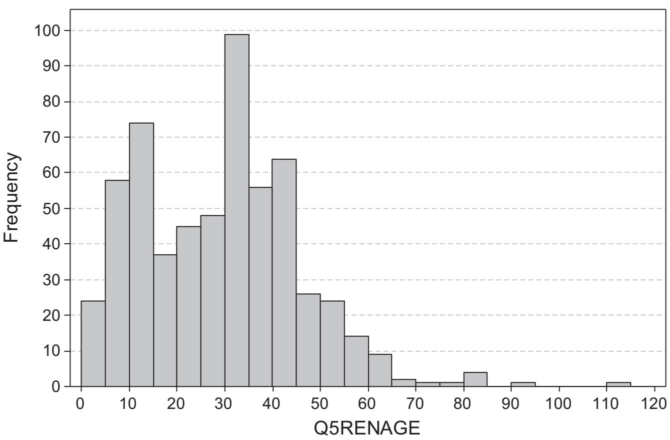

Fig. 1. Building age (since construction or last renovation).

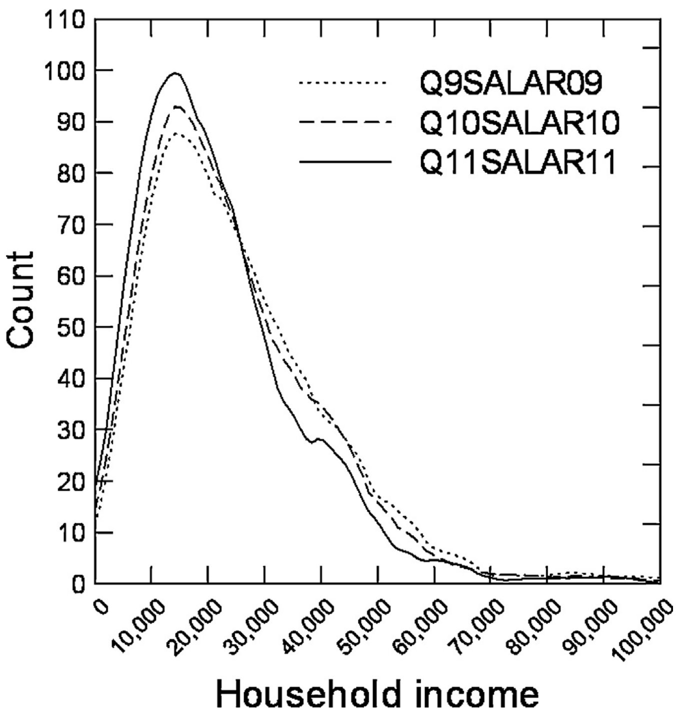

Fig. 2. Annual household income distribution (2009–2011).

Table 2
Household income changes across income classes.

2009 income (thousands of euros)	Income change until 2012 (euros)	% change relative to average 2009 income in class
0–10	+1682	+26.1
10–20	−1778	−12.7
20–30	−3539	−15.1
30–40	−5056	−15.4
40–50	−5545	−13.2
50–60	−9496	−18.5
60–70	−8615	−14.2
70–80	−21,667	−31.0
80–90	−19,400	−23.4

used by 32 households (5.5%); finally, only one household apparently had the opportunity to use all three heating sources (oil, gas and air conditioning). In the previous winter, 2010–11 (that was warmer), only 40 households (6.7% of the total) declared a different heating source; of these, 17 (2.8%) changed from oil to natural gas. In the 405 households (67.7% of the total or three out of four) that had air conditioning, the number of units varied from one to 7 with 9000 BTUs (2.64 kW) being the most prevalent unit type; three-fourths (74.4%) of the households had up to two units with 2 units being the mode (valid for 131 households). On the average, households with air conditioning turned on their unit(s) for 3.8 h daily and when the temperature fell below 17.3 °C. Finally, 280 households (71.6% of the 391 that had air conditioning) did not use their units at night.

Based on the consumption of the first (milder) winter and degree hours of the second (colder) winter, specific energy consumption in the second winter should have an average of 182.40 kWh/m^2 and a median of 138.40 kWh/m^2. Yet, the average specific consumption of the second winter equaled 114.17 kWh/m^2 (with a median of 88.052) so it more than a third (37.4%) smaller than expected. Breaking specific energy consumption by income class, shown in Table 3, shows that specific energy consumption in the second winter (2011–12) was up to 20.9% smaller than the first (2009–10) and up to 72.1% smaller than what was expected been based on degree hours.

Energy consumption in the first (milder) winter (2010–11) varied from 0 to 883 kWh/m^2 with an average of 134 and a median of 102 kWh/m^2; 12 large values varying from 514 to 883 were retained in the analysis because they appeared to be correct. Energy consumption in the second (colder) winter (2011–12) varied from 0 to 676 kWh/m^2 with an average of 109.6 and a median of 88 kWh/m^2; again, 5 large values (567 to 677) were nevertheless correct and were retained in the analysis. Households used an average of 20.1 kWh/m^2 less energy in the second winter (a 15% reduction) despite the fact that it was colder.

As mentioned in the literature review section, if the Fuel Poverty Ratio (FPR) is greater than 0.1, the household is considered to be fuel poor [4]. Two FPRs were calculated, based on fuel expenses for the winters of 2009–10 and 2010–11 and the household income of the years 2010 and 2011. Average FPR was 0.05 for the 2009–10 winter and 0.055 for the 2010–11 winter, with the second value being bigger than the first at a significance level higher than 99.99% (t-test for paired samples: $t = 2.620$; $p = 0.0045$). It is concluded that the fuel poverty of households deteriorated very significantly during the duration of the study. The ratio of fuel poor households was 11.1% (52 cases) for the first winter and 11.7% for the second (53 cases). These figures underline the importance of fuel poverty in Greece during this time of global financial uncertainty.

In the 452 apartments (75.6% of the total) that had an average age of 27.8 years and an average surface area of 88.69 m^2, dwelled an average of 2.82 persons, with an average three-year (2010, 2011 and 2012) household income of 23,034 euros and an average energy consumption of 124.8 kWh/m^2 in the first winter (2010–11) and 103.4 kWh/m^2 in the second winter (2011–12), i.e. a reduction of 17%. In comparison, in the 146 detached houses (24.4% of total households) that had an average age of 31.3 years and an average surface of 120.5 m^2, dwelled an average of 3.5 persons, with an average three-year household income of 27,126 euros and an average energy consumption of 163.1 kWh/m^2 for the first winter and 148 kWh/m^2 for the second winter (a reduction of 9.3%). It is worth noting that the bigger reduction that is observed in apartments may be (in part) due to the more accurate measurement of energy consumption in detached houses.

More interesting comparisons are presented in the next section that documents the clustering of households into a low and a high income group.

4.2. Cluster analysis

To achieve a distinct clustering of cases, a relatively small number of variables (representing salient features of households) should be included in the analysis. Of the many variables available, those (a) holding data considered to be of high quality and (b) having only a handful of missing values were considered for cluster analysis (so that a listwise deletion of cases with missing data would not result in a dramatic reduction of cases available for clustering). Data quality and missing data consideration along with a priori expectations as to which variables should characterize the profile of a household, lead to the following variables being selected for possible inclusion in cluster analysis:

- socioeconomic (Q9SALAR09/Q10SALAR10/Q11SALAR11, Q3MEMBERS);
- building related (property type, i.e. apartment/house, Q5RENAGE, Q4M2);
- energy consumption related (Q12OIL, Q13GAS, Q14AC, Q31CONSERV, Q48HEATHRS1/Q49HEATHRS2, KWHM2TOTAL1/KWHM2TOTAL2);
- environmental (DEGRDAYRATIO) variables.

Fuel poverty ratio information, in particular, could not be included in the analysis due to more than 150 missing values.

Prior to the analysis it was noted that some quantitative variables measured the same quantity at different times and were thus highly collinear. Retaining all such variables in the analysis would result in their overrepresentation [54]. On the other hand, extracting factors from such variables (via factor analysis) may result in several problems and is advised against by Dolnicar and Grun [55] with arguments that are valid in the case of principal component analysis as well. Based on these recommendations, it was decided that:

- only the 2011 income (Q11SALAR11) with the 2011–2009 income reduction (DIFFSALARY) be retained in the analysis, as the smallest number of income variables that still convey a measure of (a) income size and (b) income reduction due to the financial crisis;
- only the difference in heating hours (DIFFHEATHOURS) between the two winters be selected for inclusion in the analysis;
- energy consumption be represented by (a) the specific energy consumption of the second (harsher) winter (KWHM2TOTAL2) and (b) its difference from the specific consumption (of the same winter) expected from degree hours (DIFFKWHM2DEGRD).

Trying different two-step clustering schemes (carried out with IBM SPSS version 21) with the categorical variables (such as property type, Q12OIL and Q31CONSERV) included, showed that no stable number of clusters could be reached at. Dummy variables

Table 3
Specific energy consumption per income class.

2009 income (thousand euros)	Median consumption 2010–11 (kWh/m²)	Median consumption 2011–12 (kWh/m²)	Was reduced by (%)	Expected consumption 2011–12 (kWh/m²)	Should be bigger by (%)
0–10	115.06	102.41	−11.0	156.84	53.1
10–20	127.57	110.06	−13.7	173.53	57.7
20–30	140.52	118.25	−15.8	191.24	61.7
30–40	165.41	130.88	−20.9	225.29	72.1
40–50	127.33	109.47	−14.0	173.61	58.6
50–60	123.85	115.01	−7.1	168.26	46.3
60–70	160.78	134.70	−16.2	217.19	61.2
70–80	202.25	166.41	−17.7	272.83	64.0
80–90	184.13	177.49	−3.6	248.99	40.3

were found to exert an undue amount of influence in shaping the number and size of the clusters; when one relatively unimportant dummy variable (such as Q13GAS) was taken out, an entirely different number of clusters of different size resulted. Much stabler clustering schemes were obtained when only quantitative variables were included in the analysis and hierarchical clustering was used.

On the issue of sample size, Formann [56] as quoted by Mooi and Sarstedt [54] recommends a sample of at least 2^m cases, where m equals the number of clustering variables. Although these are just recommendations, it follows that it would be good to not exceed 8 (sample size of 256) to 9 (sample size of 512) variables in order to cluster analyze the available 598 cases (not all of which will be complete).

The final list of 8 variables included in hierarchical cluster analysis along with complete cases is shown in Table 4.

It was decided that hierarchical cluster analysis be carried out with Ward's linkage method and the squared Euclidean as the appropriate distance measure [57]. On the number of clusters, some exploratory graphs (Figs. 1 and 2) had previously indicated the presence of two clusters [58], a scheme that was confirmed by the analysis. The presence of two clusters was validated by rerunning the analysis on randomly sorted data [54] and is shown in Table 5.

The 508 complete cases were classified into two clusters:

1. The first cluster included about three-fourths (76.6%) of the cases and evidently represented lower-income households. These had a 2011 income of 18,006 euros, 4355 euros lower than their 2009 income; had 2.8 members per household; lived in an apartment of a house with an area of 83.2 m², in a building that was 30.5 years old (or last renovated); and had a specific energy consumption of 131.5 kWh/m² for the second (harsher) winter, a full 76.6 kWh/m² lower than expected from climatic conditions (degree hours);
2. The second cluster included the rest one-fourth (23.4%) of the cases, that represented higher-income households. These had a 2011 income of 39,744 euros (more than twice the income of the first cluster), that was only 2174 euros lower than their 2009 income; had 3.7 members per household, one more than the previous cluster; lived in an apartment of a house with an larger area of 136.3 m², in a building that was only 21.8 years old (or last renovated); and had a lower specific energy consumption of 102.4 kWh/m² for the second winter, 54.6 kWh/m² lower than expected from climatic conditions.

As noted by the t-tests for independent samples (with equal or unequal sample variances assumed as indicated by Levene's test) in the rightmost column of Table 5, all variable values at the cluster centroids were significantly different between the two clusters at a confidence level of 97% or higher. This provides an initial confirmation of the validity of the classification of households in two distinct clusters. Further validation is provided by comparing the values of other criterion variables at the cluster centroids – these are provided in Table 6, the last column of which tests indicates the results of independent sample t-tests or proportion z-tests (as appropriate).

It is seen that:

- the income of Cluster 2 (higher income) is twice that of Cluster 1 (lower income) and that even the per capita income is different between the two clusters at a confidence level higher than 99.99%;
- twice (i.e. 39.5%) the number of households of Cluster 2 live in houses compared to those of Cluster 1 (i.e. 19.54%) and this also reflects on the value of Q7FLOOR;
- more Cluster 2 households (15.97%) are heated with natural gas and have more installed air conditioning power (30,410 BTU) compared to those of Cluster 1 (9.95% and 23,953 BTU respectively);
- one out of three Cluster 1 households (i.e. 35.6%) adopted some conservation measures after the first winter, compared to one out of four for Cluster 2 (24.79%);
- only 2.06% of the households of Cluster 2 households were above the fuel poverty line, compared to 13.87% for Cluster 1;
- finally, Cluster 2 households consumed less specific energy in the first winter as well (115.4 kWh/m² compared to 145.1 for Cluster 1).

Table 4
Variables used in cluster analysis.

	Variable	Complete cases	Range
1	Q11SALAR11	585	0 to 200,000
2	DIFFSALARY (=Q11SALAR11 – Q11SALAR9)	579	−80,000 to 40,000
3	Q3MEMBERS	596	1–8
4	Q5RENAGE	588	2–112
5	Q4M2	597	25–400
6	DIFFHEATHOURS (=Q49HEATHRS2 – Q49HEATHRS1)	563	−22.5 to 20.0
7	KWHM2TOTAL2	560	0.0352–676.798
8	DIFFKWHM2DEGRD (=KWHM2TOTAL2 – KWHM2DEGRD)	558	−757.463 to 364.833

Complete cases after listwise deletion of missing data: 508.

Table 5
Cluster centroids (eq. var., equal variances *t*-test; uneq. var., unequal variances *t*-test).

	Variable	Cluster 1 ("low income")	Cluster 2 ("high income")	*t*-test H_0: $\mu_1 = \mu_2$ H_a: $\mu_1 \neq \mu_2$
1	Q11SALAR11	18,006	39,744	$t = -9.18$; $p = 0.0000$ (uneq. var.)
2	DIFFSALARY	−4355	−2174	$t = -2.52$; $p = 0.0120$ (eq. var.)
3	Q3MEMBERS	2.8	3.7	$t = -7.16$; $p = 0.0000$ (eq. var.)
4	Q5RENAGE	30.5	21.8	$t = 6.32$; $p = 0.0000$ (uneq. var.)
5	Q4M2	83.2	136.3	$t = -13.82$; $p = 0.0000$ (uneq. var.)
6	DIFFHEATHOURS	−1.3	−0.3	$t = -3.29$; $p = 0.0010$ (eq. var.)
7	KWHM2TOTAL2	120.7	102.4	$t = 2.28$; $p = 0.0234$ (uneq. var.)
8	DIFFKWHM2DEGRD	−76.6	−54.6	$t = -3.22$; $p = 0.0014$ (uneq. var.)
	Cases in cluster	389 (76.57%)	119 (23.43%)	

Table 6
Values of selected criterion variables at cluster centroids (eq. var.: equal variances *t*-test; uneq. var.: unequal variances *t*-test;.

Variable	Cluster 1 ("low income")	Cluster 2 ("high income")	*t*- or *z*-test: H_0: $\mu_1 = \mu_2$ H_a: $\mu_1 \neq \mu_2$
Q9SALAR09	22,361	41,918	$t = -7.96$; $p = 0.0000$ (uneq. var.)
Q10SALAR10	20,707	41,865	$t = -8.38$; $p = 0.0000$ (uneq. var.)
Income per household member (SAL11PCAP)	7638.69	12,590.8	$t = -5.42$; $p = 0.0000$ (uneq. var.)
% of households dwelling in house	19.54%	39.50%	$z = -4.45$; $p = 0.0000$
% of households dwelling in apartment	80.46%	60.50%	$z = 4.45$; $p = 0.0000$
Q7FLOOR	1.8	1.5	$t = 1.70$; $p = 0.0906$ (eq. var.)
Q13GAS	9.95%	15.97%	$z = -1.81$; $p = 0.0710$
Q16BTU	23,953	30,410	$t = -3.14$; $p = 0.0022$ (uneq. var.)
Q17TEMP	17	18.4	$t = -1.56$; $p = 0.1200$ (eq. var.)
Q18HOUR	4.01	3.46	$t = 1.49$; $p = 0.1398$ (uneq. var.)
% of households that took conservation measures (Q31CONSERV)	35.60%	24.79%	$z = 2.17$; $p = 0.0297$
DIFFTEMPIN	−0.54	−0.4	$t = -1.05$; $p = 0.2943$ (uneq. var.)
DIFFTEMPOUT	−0.69	−0.59	$t = -0.55$; $p = 0.5836$ (uneq. var.)
FUELPOVRAT1	0.055	0.033	$t = 5.02$; $p = 0.0000$ (uneq. var.)
% of households above fuel poverty line (2010–11) (FUELPOOR1)	13.87%	2.06%	$z = 3.24$; $p = 0.0012$
FUELPOVRAT2	0.061	0.040	$t = 4.18$; $p = 0.0000$ (uneq. var.)
% of households above fuel poverty line (2011–12) (FUELPOOR2)	14.71%	3.06%	$z = 3.10$; $p = 0.0019$
Q48HEATHRS1	6.9	7.1	$t = -0.33$; $p = 0.7408$ (eq. var.)
Q49HEATHRS2	5.6	6.8	$t = -2.27$; $p = 0.0244$ (uneq. var.)
KWHM2TOTAL1	145.1	115.4	$t = 3.22$; $p = 0.0014$ (uneq. var.)

Many of these findings are in agreement with Santamouris et al. [38].

Cluster analysis is thus brought to conclusion, having obtained a clear picture of the classification of households: one out of four household is of higher income that suffered a smaller loss since 2009; has more members; lives in a newer and larger house or apartment; and consumes less specific energy. It is the other three in four households that fuel poverty policies should target so that the 13.9% fuel poor proportion of this group is controlled even if the economic crisis in Greece deepens.

5. Conclusions

The survey presented in this paper focused on Greece and analyzed the energy consumption of households located in a wide variety of geographical regions and bioclimatic types. Many of the findings are in agreement with Santamouris et al. [38]. Clearly, the lower-income three out of four households are the ones that fuel poverty policies should target, so that the 13.87% fuel poor proportion of this group is controlled as best as possible, given the financial crisis in Greece. Energy policies should take into account social consequences so as to avoid causing further human misery [7]. Energy counseling together with energy saving packages for emergency relief (e.g. energy saving bulbs, radiator reflectors), pointed out by the French survey reviewer earlier, would help in this direction.

As regards the means, in Ireland, fuel allowance does reduce the severity of experience of fuel poverty among the low-income households. As pointed out by Kelly [18], homes with a propensity to consume more energy should be targeted using behavioral strategies combined with economic penalties and incentives; homes with low Standard Assessment Procedure (SAP) rates should be targeted for whole home efficiency upgrades in order to break through the energy efficiency barrier. The (SAP) is the methodology used by the Department of Energy & Climate Change (DECC) in UK which assesses and compares the energy and environmental performance of dwellings. In Greece, Santamouris et al. [38] concluded that energy policies addressed to the dwelling sector should set as a priority the improvement of the envelope quality of residents where low income people are living.

One should be beware of the economic means though, especially at this time of great financial crisis and hardship in Greece. The consequences of a liberal energy market without any regulations regarding the prevention of energy debts may be seen in Austria [26]. All the measures suggested should be integrated into a national strategy for the reduction of fuel poverty. The Austrian study suggests all proposed measures not be applied singularly but instead be integrated into a national strategy for the reduction of fuel poverty.

The UK Department of Energy (DOE) has claimed that the achievement of energy conservation together with affordable warmth are the two central aims of efficiency policies and even the slightest improvement in energy efficiency would help in providing affordable warmth to the poorest households [16]. The importance of this study is further underscored by the fact that the building sector in Greece represents 36% of total energy consumption and consumes around 450 million euros per year [49].

Turning to directions for further study, an important task that complements the present study is the monitoring of low income households with sensors in order to investigate temperature levels for the case of families that can barely purchase heating energy. This research is underway by some of the authors of this paper and its results are expected to shed more light on the relationship between energy and poverty and how these affect survivability at this time of a global financial crisis. Other tasks that would be beneficial to carry out in a future investigation include: collection and analyses of more household data from Northern Greece, an in-depth comparison of apartments versus detached houses, the impact of specific energy conservation measures adopted by households, and an examination of alternative policies designed to address fuel poverty in Greece and Southeastern Europe.

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